Freedom To Originate:

Developing Fin Plug and Fins for Jetboards

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MASTER THESIS

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Developing Fin Plug and Fins for Jetboards

Master Thesis

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Abstract

This master thesis generates a concept for the means of attaching fins onto jetboards without infringing on existing patents. The resulting concept establishes freedom to operate (FTO) and enables production of fins with original designs. FTO meaning the possibility of producing and selling a product without legal liability to any patent holders. The thesis further presents and discusses user needs for fins, theoretical fluid mechanics data, physical validation data as well as two fin concepts for future guidance.

The project followed a product development process which began with studies regarding computational fluid dynamics (CFD), existing patents and surf mechanics, seeing as the currently used fins were designed for surfboards. This was followed up by further research about materials, ways of manufacturing and assembling, as well as market opportunities.

The main part of the thesis regarded the product development of the fin plug, i.e., the means of fin attachment. Key aspects during this process were concept generation, patent analysis, prototyping and user testing.

The secondary objective, i.e., exploring the product segment of jetboard fins, was reached by conducting interviews and gathering of user needs. The resultant mapping of said needs composed the foundation for concept generation, 3D-modelling of fin concepts, CFD-analysis and physical testing.

Following the processes of developing concepts for fin plugs and fins, one final fin plug and two different fin setups were presented. The fin plug, with the concept name Tongue, showcased a solution that enabled freedom to operate, product features desirable according to test users and a recommended material for the mentioned features. The material also enables injection moulding and two different ways of assembling. The two final fin concepts, Stable Understeer and Stable Oversteer, utilise contrasting dynamics to generate different desired jetboarding experiences. Together with data from both theoretical and physical testing, they demonstrate different directions for future development.

Keywords: Fin plug, fins, jetboard, CFD, user testing, concept generation

Sammanfattning

Det här examensarbetet utvecklar ett koncept för infästning av fenor på jetboards som inte inträger på befintliga patent. Det resulterande konceptet medför handlingsfrihet (FTO) och följaktligen tillåter produktion av fenor med originell design. FTO innebär möjligheten till att producera och sälja en produkt utan rättsligt ansvar gentemot ägare av patent. Examensarbetet presenterar och diskuterar användarbehov för fenor, data på teoretisk strömningsteknik, data på fysisk validering samt två fenkoncept för framtida vägledning.

Projektet följde en produktutvecklingsprocess som började med studier angående beräkningsströmningsdynamik (CFD), befintliga patent och surfmekanik, då de fenor som används idag designades för surfing. Detta följdes upp med ytterligare undersökning av material, tillverknings- och hopsättningssätt samt marknadsmöjligheter.

Den huvudsakliga delen av examensarbetet handlade om produktutvecklingen av fenkassetten, d.v.s. feninfästningen. Nyckelaspekter under processen var konceptgenerering, patentanalys, framställning av prototyper och användartestning.

Den sekundära målsättningen att utforska produktsegmentet jetboardfenor uppnåddes genom att genomföra intervjuer och insamling av användarbehov. Den resulterande kartläggningen av de nämnda behoven skapade grunden för konceptgenerering, 3D-modellering av fenkoncept, CFD-analys och fysisk testning.

Efter utvecklingen av koncept för fenkassett och fenor presenterades ett slutgilitgt fenkassettskoncept och två olika fenuppsättningskoncept. Fenkassetten, med konceptnamnet Tongue, uppvisade en lösning som tillåter handlingsfrihet, önskvärda produktegenskaper enligt användartester och ett rekommenderat material för de nämnda egenskaperna. Dessutom tillåter materialet formsprutning samt två olika hopsättningssätt. De två slutgiltiga fenkoncepten, Stable Understeer och Stable Oversteer, utnyttjar kontrasterande dynamik för att generera olika önskvärda jetboardupplevelser. Tillsammans med data från både teoretisk och fysisk testning, demonstrerar de olika tillvägagångssätt för framtida utveckling.

Nyckelord: Fenkassett, fenor, jetboard, CFD, användartestning, konceptutveckling

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Acronyms

3D - three-dimensional
ASTM - American Society for Testing and Materials
CFD - computational fluid dynamics
CNC - computer numerical control
CoG - center of gravity
FDM - fused deposition modelling
FEM - finite element method
FTO - freedom to operate
GPS - global positioning system
P.M. - Performer Medium
RTM - resin transfer moulding
STL - stereolithography
VARTM - vacuum assisted resin transfer moulding

Materials

ASA - acrylonitrile styrene acrylate
CFRP - carbon fibre reinforced polyester
FRP - fibre reinforced polyester
GFRP - glass fibre reinforced polyester
POM - polyoxymethylene

Concept Screening Categories

AoP - amount of parts
Dur - durability
EoA - ease of attachment
EoD - ease of detachment
EoM - ease of manufacturing
Fail S - fail-safe
RelG - reliable grip
RoT - risk of turbulence

Lists from Physical Testing

C.1 etc. - Combination
O.1 etc - Overall
S.1 etc - Spoiler
TH.1 etc - Tail Handling

1 Introduction

This chapter covers a description of the problem, the scope and goals as well as mission statement and key people. It will enlighten the reader with the given conditions and under which circumstances this thesis was conducted.

1.1 Problem Description

Radinn are a widely renowned jetboard company, distributing their products all across the globe. They are consistent with developing new and improved solutions for their products and thus providing a greater experience for their customers. Included in the product catalogue are boards, jetpacks, batteries and accessories. Moreover, Radinn are a company who would like to increase their customer base, which provides this thesis's incentive. Their main approach towards a broader customer base in this project is to decrease the cost as well as providing improved jetboarding capabilities.

Together with Radinn, a development process was conducted to decrease the cost of their jetboard models. Radinn currently order their fin plugs and fins from another company and have identified the need to produce their own fins in an attempt to reduce cost. The other company currently has a patent on their fin fastening design, preventing Radinn from using the same system. To acquire freedom to operate (FTO), developing a new fin fastening design was central and thus the main objective of this thesis. Being able to produce their own fins, Radinn have also looked into the opportunity of designing fins specifically for jetboarding. Up to this point, the majority of jetboard companies order fins optimised for surfboards which leaves a product segment to be explored and a possibility for Radinn to offer an original jetboarding experience.

1.2 Scope and Goals

The primary goal of this master thesis was to develop a new fastening system concept for Radinn's jetboard fins that does not infringe on existing patents, but presents desired qualities such as tool-less attachment and detachment using only one hand. The secondary goal was to develop new fin designs that are optimised for jetboarding. The concept development was thus divided into two different phases, the first one being for the fin attachment and the latter one for the fin designs. The goal for Radinn is to reduce overall costs and to utilise the opportunity of developing fins of their own.

To change the current bought-in fin system into one produced by Radinn, patent studies had to be performed to eliminate the chance of possible infringement on intellectual property. The focus was otherwise put on adapting theories and prior art to develop new concepts, both for fastening mechanisms and for fin designs that generate desired jetboarding capabilities. Furthermore, seeing as jetboard fins is a new product segment, user needs were collected to define what said capabilities would entail.

The scope of this master thesis was limited to the time frame of approximately five months. The project was based on theories in product development but did not include activities regarding production ramp-up or sales plans. The new fin system was developed to fit Radinn jetboards and focus was not put on developing a product that could be sold separately and integrated into other watercraft systems by external parties.

1.2.1 Limitations

The main part of this project was focused on developing a concept for a new fin fastening system. Given the limited time frame and available resources, the development of the fin design focused on a fixed set of parameters determined by team members. These parameters were decided based on their hypothesised effects on jetboarding properties, overall jetboard interface and development capability.

Seeing as this thesis' goal was to develop a viable concept for a fin plug to Radinn, but not prepare for production ramp-up, finishing structural analyses were not conducted. This is due to the fact that they possibly will be redundant in further development when Radinn make decisions to change dimensions or other acting parameters.
Since Radinn already have examined the market and determined a market opportunity, limitations regarding the market analysis were predetermined. The analysis instead presented Radinn's arguments for this product opportunity. Moreover, the project brief given by Radinn also directed the project's approach regarding product platform and architecture.

1.3 Mission Statement

The mission statement for the project is presented in Table 1.1.

Table 1.1 Mission Statement for this Master Thesis.

Mission Statement: Fin plug with corresponding jetboard fin	
Product Description	- New cost reducing fin plug that entails easy attachment and detachment of fins - New fin designs specifically made to improve jetboarding capabilities
Benefit Proposition	- Cost reducing to produce own fin plugs and fins - Easily remove fins with the use of only one hand and no tools - Designed to optimise the experience of using a jetboard
Key Business Goals	- Developed to launch with future versions - Competitive pricing lowering the total cost of a jetboard - Competitive jetboard riding properties
Primary markets	- Customer base of Radinn. Beginners in jetboarding as well as experienced riders.
Assumptions & Constraints	- Lower cost of fins when producing rather than buying - Patents of current solutions - Affordance to help the user - Manufacturable for mass production
Stakeholders	- Radinn - Major retailers - Marketing and sales - New and existing customers - Manufacturing and assembly department

1.4 Key People

In Table 1.2 below, the key people are presented. These people have in one way or another contributed, with their knowledge or guidance, to help this project progress.

Table 1.2 Key People in this Master Thesis.

Name	Position	Role in this Project
Axel Nordin	Associate Senior Lecturer at Product Development, Faculty of Engineering, Lund University	Supervisor
Robert-Zoltán Szász	Researcher at Fluid Mechanics, Faculty of Engineering, Lund University	Supervisor
Martin Pråme Malmqvist	Chief Product Officer, Radinn AB	Supervisor
Philip Sveningsson	Product Manager, Radinn AB	Supervisor

2 Background

This chapter presents the different background aspects where the foundation for this thesis is established. It is presented to give the reader an insight in why this thesis was conducted and what knowledge was already known in the beginning. The latter part of the chapter introduces scientific backgrounds and theories used for reasoning in the development process.

2.1 Team Background

This master thesis was performed by Albin Johnsson Jähnke and Alex Mauritzson who are Master of Science students in Engineering, Mechanical Engineering with Industrial Design. The project was performed to generate new knowledge within computational fluid dynamics and to improve the students' skill set within product development.

2.2 Company Background

Radinn AB is a world-leading jetboard company. Their journey began in 2013 when Philip Werner and Alexander Lind, the founders, worked with a small team to develop their first series of prototypes. Looking for excitement and extremes in surfing, through radical innovation, Radinn launched the very first electrical jetboard. A new perspective in a combustion-overshadowed industry. The year was 2015 when finally, a finished generation of jetboards was ready for shipping. Since then, they have iterated on their design and produced a wide product line to fit all different types of users; from the beginner Radinn FreeRider to advanced Radinn Carver.

Radinn AB are dedicated to continuously further develop their product to introduce new features for users and optimise performance. In the future they hope to make jetboards available for a larger part of the worlds population. This is why they constantly work with cost reduction and trying to minimise the price tag on their products for their users. The research and development take place at their main office in Malmö, Sweden and their manufacturing facility is located in Gdańsk, Poland.

2.3 Project Background

The goal of this project was to develop a new fin system for Radinn jetboards. Developing such a system requires three major needs to be taken into account, the need for easy attachment and detachment, as well as providing improved jetboard riding properties. However, the currently used fin system on Radinn jetboards already provides tool-less attachment and detachment as well as changed jetboard riding properties, compared to riding without fins. The reason for Radinn to initiate this product development is therefore not entirely based on the said aspects, but instead, mainly to lower the overall cost of the jetboard as well as introducing new riding properties. Radinn have thus concluded that a fin system produced by themselves generates a cheaper end product than what a bought-in fin system does.

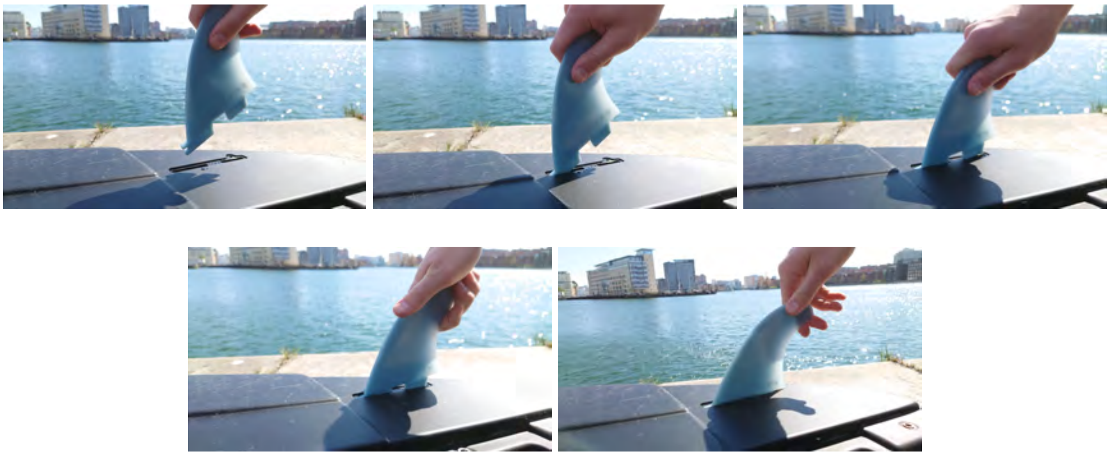


Figure 2.1: The currently used fin system entails attachment by inserting the nose of the fin first and then locking it into place by pushing down the rear part.

The currently used fin system, seen in Figure 2.1, is bought in by Radinn and costs approximately 100 € per board. The majority of the cost is the fin, not the fin plug which connects the fin to the board. Unfortunately there have been poor possibilities to reach a concord in previous attempts of collaboration between Radinn and the company currently producing the fin system. The proposition of producing fins compatible with their fin plug would allow Radinn to reduce the cost of buying fins whilst still keeping the relatively cheap fastening solution already in store. However, such a collaboration did not occur and Radinn, therefore, started looking into developing an entirely new fin system to produce on their own. To ensure that no infringements on active intellectual property occurs, the project also includes performing a patent analysis.

The patent, on which several analyses are conducted, is the one regarding the fastening of the fin. The solution is the most sold surfboard fin fastening solution in the world. A big part of its success is granted to the fact that it allows fins to attach and detach without the use of tools or extra equipment. The patent covers the attachment means that exist on both the fin plug and the fin, and hinders a combination of design choices regarding functions, geometry and material.

Taking advantage of acquiring FTO, Radinn wants to explore the opportunity to create fins specifically designed for jetboard riding. Previous fin systems rely on user data from surfboarding, a product segment that has existed since the first surfboards with fins were developed. Thus, developing fins for jetboard riding would generate a new segment, something that Radinn identifies as a possible compelling feature for a product in a competitive jetboard market.

Radinn had already identified the needs for the fin fastening system, meaning the product development project had predefined constraints. Regarding the product development of the fin design, that was not the case. The interpretation of the goal, that is providing jetboard riding properties, can yield different answers and therefore researching what that goal would mean for this project became a major part of the fin designs' product development process.

2.4 Methodological Background

This thesis is based on scientific theories laid out in the fields of product development and computational fluid dynamics.

In the scope of product development, several theories were compared when deciding on which processes to apply to the project. The broad theories created by Ulrich and Eppinger [1] describes the outlines of how such a process could be set. Both team members possessed previous experiences in the theories and opted for the scientific theory on the grounds that it is a structured process that allows for interpretation and adaptation to several types of product development projects.

When planning on how to explore different concepts and how to generate new ones, the team members acknowledged computational fluid dynamics as a technological resource that could aid in the exploration as well as the validation of different hypotheses. Computational fluid dynamics (CFD) was previously limited to only a few engineering areas, such as astronautics and aeronautics. Since then, CFD has developed into a popular field of study for both academic research as well as industrial applications and has now even been implemented in the development of some surfboard fins [2]. The team members recognised this aspect and wanted to utilise the available technology and generate knowledge to Radinn regarding how their products can perform hydrodynamically. To use CFD, several software programs are available, however, given constraints regarding licensing and computational power, the choice of software program fell to Simcenter Star-CCM+.

As mentioned in section 2.3, Radinn desired a certain product development based on their already conceptualised user needs. Hence, the development of the fin fastening system had clear constraints when starting the project. However, the development of the fin design was given the general goal of adapting the product for jetboard riding and thereby improving the riding properties. This goal was deemed rather unclear and open for interpretation, as the field of jetboard riding is relatively unexplored. Seeing as jetboard riding is different from surfboarding, from a hydrodynamical point of view, sciences and theories in surfboarding were not considered to be directly applicable to this project. Nevertheless, such sciences and theories were still used to generate concepts and benchmark different parameters which could affect the jetboard riding properties.

2.5 Surf Science and Culture

2.5.1 Surf History and Culture

The earliest evidence of surfing taking place is traced back to Polynesia in the 12th century. Carvings of people standing on wooden boards, riding waves, have been located in caves. It is then said to have been brought to Hawaii amongst other things from their culture. When it comes to hard evidence the earliest documented mention of the surfing lifestyle is from James Cook's diary from the 18th century. Describing it as a lifestyle is not only because of the common trends in which we find surfing today. Dating from ancient Hawaiian and Polynesian history, surfing differentiated upper and lower class. Rules determined which waves were allowed to be surfed and how long the surfboards could be. [3]

The first surfboards, made during the rules of Kapu in Hawaii, had to follow the conventions to a sacred extent. The boards could weigh up to 80 kg, compared to the average of today being 7 kg. The first fin attached to a surfboard is said to be innovated by Tom Blake in 1934. Before this, the majority of surfing involved going straight with the board and gaining minimal manoeuvrability with weight, heels and toes. Later in the 20th century, 1970, the first tri-fin design was invented by the Campbell brothers and is still used widely today. [3][4]

The removable fin was launched in 1954, with the requirement of tools during the first decades.

This radically affected the production and handling of surfboards. It enabled easier shaping and travelling, it eradicated the worry of snapping off a glassed-in fin and it enabled a variety of materials to be used in fins [5]. The current fin system used by Radinn placed the milestone for tool-less installation when they introduced the first tool-less fin system in 2012. The innovation enabled attachment and detachment of fins in a couple of seconds [6].

2.5.2 Jetboards

Figure 2.2: The three different models of jetboards offered by Radinn. From left to right, Explorer, Freeride and Carve. [7]

A jetboard is shaped similarly to a surfboard and has an attached water jet. It is seen both with combustion motors as well as electric, where Radinn was the first company to launch the commercially sold electric one. Electric jetboarding allows users to ride a board during all seasons in every different condition, with lower noise pollution and without environmental pollution. It combines the freedom of movement over open water and the adrenaline rush of speed and extreme sports. The major difference when comparing a jetboard to an original surfboard is, aside from the water jet, the available conditions a user can ride in. There is no need to confirm whether the tide comes or goes during the day, it is always possible to ride a jetboard.

The jetboards Radinn develops are currently produced with two fin plugs, meaning that users have the option of attaching up to two fins. The company is looking into using four fin plugs and consequently allowing up to four fins to be attached onto the jetboards.

After Radinn launched the first electric jetboard, a variety came closely after. Today the market consists of hydrofoil boards jetting over the surface, stand-up paddleboards with an electric motor, motorised bodyboards as well as jetboards similar to Radinn's, but in all different shapes and sizes.

2.5.3 Surf Mechanics

Surf mechanics as an applied science was first introduced when the pioneer Terry Hendricks [8] released an article regarding the subject in 1969. During this early stage, all data was experimental with which Hendricks could describe the surfboard's drag, pressure, speed and the separated flow produced behind it. In his research, he also touches upon the fins and their impact, more on that in subsection 2.5.4. As in many sciences, the question Hendricks wanted to investigate was if there was anything to be done to optimise a surfboard's properties and determine the sections of a board that would be interesting to examine.

Areas of interest in surf mechanics can be condensed to the shape of the board, placement on a wave, direction of the board, and fin mechanics. Due to the scope of this project, fin mechanics will be discussed on a more profound level in the next section, subsection 2.5.4. Regarding the other areas, some are more interesting for surfing upon a wave and will only be touched upon briefly. [8]

The shape of the board is seen both as the overall geometry as well as the detailed roughness of the surface. An objective of the shape is to reduce different kinds of drag forces and increase or decrease the wetted area beneath the board as well as lowering the flow separation. Drag forces are forces acting opposite the direction of movement and in the case of surfing they are described as skin friction drag, pressure drag, wave-making drag and spray-making drag, all of which are affected by the board's shape, either detailed or overall. [8]

The shape of the board also induces flow separation usually happening at the end of the board. The phenomenon is created because of the deceleration of the passing fluid and the pressure difference in the boundary layer, which leads said boundary layer to detach, i.e., flow separate. This creates a wake behind the board. The deceleration and pressure created usually depends on the abrupt contraction of a shape, in this case, the board. These separated flows are commonly accompanied by a drag force in the opposite direction to the board's movement. [9]

Since jetboards do not ride waves in the same aspect as a surfboard, the angle of attack and trim angle will not contribute with the same proportions. When surfing a wave there are three main forces acting on the board; pressure, gravity and drag. The angle of attack will determine how much dynamic lift the rider will create, i.e., pressure from the passage of water beneath the board. It also alters the frictional drag since it will affect the wetted area; the area immersed into the water. To support the weight of the rider, a buoyant lift is created via Archimedes' principle, which also depends on the immersed volume of the board. Quite quickly the parameters increase and the results of a single variable change is harder to determine. Hendricks has in his assessment presented an optimal angle where the frictional drag together with the induced drag from dynamic lift achieves the lowest possible drag. [10]

The skin frictional drag is produced through the roughness of the board's surface. Because turbulent flow induces more frictional drag than laminar flow, the optimal solution would want the laminar flow to continue for as long as possible [8]. Unfortunately, the laminar flow length is not possible to enlarge, however, it is possible to delay the separation point when the turbulent flow starts to create a wake (something that can be seen in golf balls).

Hendricks also examined how different wave speeds act on a surfboard and where the optimal section on a wave gives the fastest velocity. This depends on a lot of factors such as weight, rails and fins. An interesting take-away presented was that the wetted area proportional to total weight achieves the same velocity. He also presents an indication of a maximum speed on a six-meter wave to be about 38km/h. [11]

When it comes to jetboards, the corresponding forces acting on the boards are the same but in different proportions. There is one addition as well; the force from the electric jet. The forces induced on the board due to the pressure, friction and rails when riding along a wave can still be translated into jetboards in their turning. When turning a jetboard one rail will create an entry point and angle of attack, something to be discussed further when developing a fin fitting for those occasions.

2.5.4 Fin Mechanics

As mentioned by Hendricks [10], an important aspect when analysing the dynamic characteristics of surfboards is the mechanics of the attached fins. The purpose of attaching fins to a watercraft is to obtain manoeuvrability, but doing so without sacrificing desirable speed. To generate said manoeuvrability, an object which can create lift force is required. In the case of a watercraft, the lift is a force generating momentum around the yaw axis. However, introducing lift forces will consequently also introduce drag forces. Subsequently, this means the speed will have to be compromised to generate control of the board. An interesting aspect of fin design thus becomes the ratio between lift and drag. Depending on various geometrical, topological and material property parameters, said ratio can be manipulated.

One key parameter which determines the flow of water around the fin is the cross-sectional shape of the fin parallel with the board. In fin and wing designs in various applications, this shape is referred to as a *foil*. A foil can be designed in many different shapes, but the purpose is to be able to generate a higher pressure on one side of the foil and a lower pressure on the opposite side of the foil, given a certain angle of attack. Should the foil be asymmetrically shaped it is referred to as a cambered foil [12]. The pressure difference will generate lift and force the foil towards the side with lower pressure. As previously mentioned, induced lift also means induced drag. Given the typical shape of a foil, the narrow side is the leading edge of the foil, which means the pressure drag acting on the edge of the fin will be relatively small, compared to the friction drag acting on all sides of the fin. The friction drag increases as the water flows along the sides of the foil, generating shear stresses in the material. The purpose of having an oblong shape such as a foil, other than its lift-generating properties, is the delayed flow separation. Thanks to the rounded oblong shape, the water will not separate from the foil until it reaches the trailing edge of the fin. Should an object generate a larger flow separation, this would subsequently generate larger eddies, that is turbulent flow with higher kinetic energy, which further increases drag and decreases lift.

An aspect Hendricks discussed was the generated surfboarding properties from varying *aspect ratios* of the fin. Figure 2.3 below showcases how Hendricks used the ratio between the chord length of the fin and the height of the fin to calculate said aspect ratio.

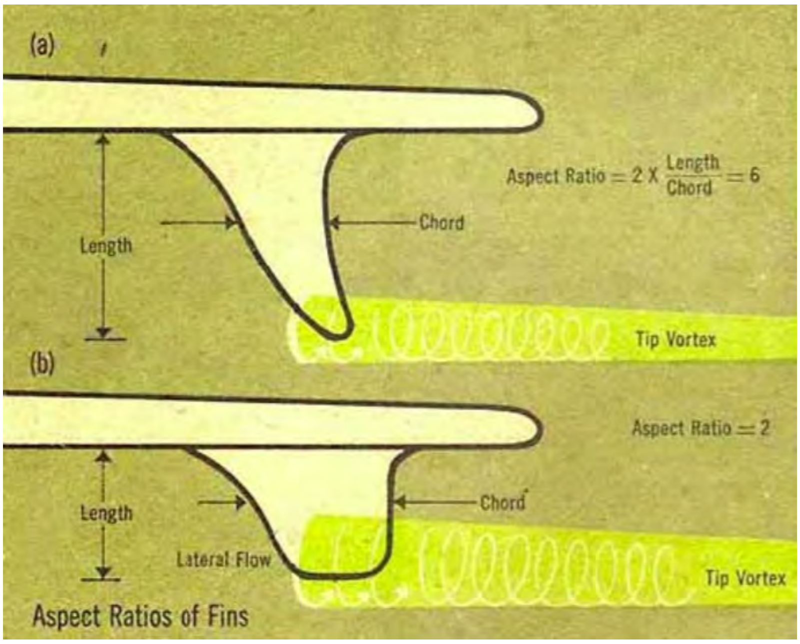


Figure 2.3: Aspect ratios of fins [9]. The reader should be informed that Hendricks uses "length" for what is otherwise described as "height" in this report.

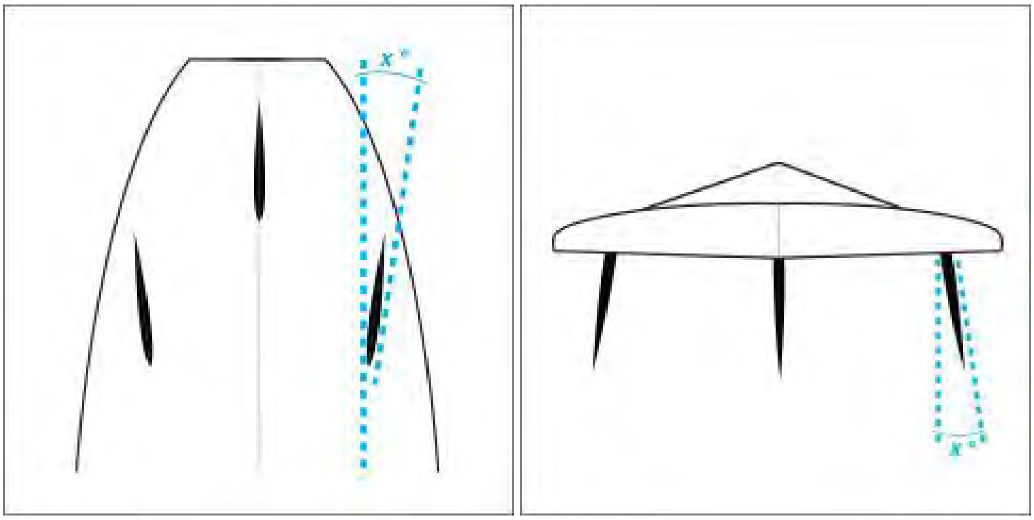
In Surfboard Hydrodynamics Part III: Separated Flow [9] it is explained how a fin with a high aspect ratio will generate more lift than one with a lower aspect ratio, given that the different fins have the same area. This is due to induced tip vortices, as seen in Figure 2.3 above. The flow of water will be forced off the side with higher pressure towards the side with lower pressure over the tip of the fin and generate a vortex. If the aspect ratio is low, meaning the fin has a longer chord length, a bigger vortex will be generated. What makes tip vortices a negative effect for surfboarding is the decrease of the lift-to-drag ratio. The generated vortex will even out some of the pressure differences between the two sides of the fin, thereby reducing the amount of lift that forces the fin from the high pressure zone to the low pressure zone, whilst simultaneously inducing drag.

Fins can be swept backwards at the tip, thereby generating a geometrical feature called *rake*. A longer rake creates bigger turning radii and a more stabilised board, whereas shorter rakes instead generate tighter turns and a more direct response from the board. [13]

Utilising the stiffness of certain materials can also generate different surfing properties. Using a material with high stiffness will generate a direct response from the fin onto the board. Fins with lower material stiffness provide *flex* when turning, meaning that the response from the fin will be delayed and generate an increased projection when the fin returns to its original position after being bent. [13]

How fins are positioned in relation to a watercraft can have a big effect on manoeuvrability and speed. The angle between the centerline of the board and the chord of the fin is referred to as *toe* angle, see Figure 2.4a. When altering the toe angle, the front of the fins used are commonly angled inwards, towards the center of the board. This generates a higher pressure on the fins and a more responsive feel when turning, compared to non-angled fins. [14]

Another angle commonly changed to manipulate the lift-to-drag ratio is *cant* angle, the angle between the fin and the bottom surface of the board, see Figure 2.4b. When using cant, fins are commonly angled towards the rails of the board. Using this angle can create a “looser feel” and give the surfer more control. Not using cant on the other hand maximises speed. [14]



(a) Illustation of toe angle. *(b) Illustration of cant angle.*

Figure 2.4: Angles describing the fin positioning on a board. [13]

The number of fins used on a surfboard can vary and will drastically affect the surfboarding properties accordingly. Typical surfboards usually have one up to five fins attached onto them, placed symmetrically around the center line of the board. The general effect of using more fins is both increased lift and increased drag. Placing the fins far from each other will generally create more control and bigger turning radii, whereas a placing of the fins closer to each other will generate a more direct and responsive feel from the board. [14]

3 Methodology

This chapter presents the chosen development process of Ulrich and Eppinger as well as how the process is applied to this thesis. The same concerns the computational fluid dynamics section, where it is introduced and its application to this project is presented. It will provide the reader with an understanding of the process and why certain tools have been used.

3.1 Ulrich & Eppinger Product Development

3.1.1 Introduction

The methodology chosen for the product development process was the recognised theories of Ulrich et al. [1], traditionally referred to as *Ulrich & Eppinger*. The theories outlined by the authors explain how multiple sets of activities make out a product development process, from an identified market opportunity leading up to a finished, producible product, ready to be sold. The goal of their theories are to clearly explain these different activities and methods, in order to encourage the development of products based on cross-functional expertise.

Ulrich et al. [1] describe how to approach every step of their development process, detailed and conclusive; a reason it has become renowned and utilised all over the world. The process is divided into six generic phases, shown in Figure 3.1, starting with planning. Each phase is in turn divided into what Ulrich et al. claim are the three most central functions of a company going through a development process; marketing, design and manufacturing. Since this project is not conducted by a company, alterations will be made and these will be stated in subsection 3.1.2.

The marketing function includes parts of the process regarding the product's place in the outside world. Comparing the product to competitors, analysing market segments and gathering information from the identified customer segments. The marketing function will be needed through all phases to keep the product relevant for its intended markets and customers. [1]

Design is the major function in the development process. This is where customer needs are regarded and met. Through engineering and industrial design, the optimal product form, material and interface are developed. Producing the visual and physical properties sought-after in the product. The design is throughout the phases concentrating into more detailed parts and functions as the process progresses. [1]

The last function is manufacturing. This function exists to make sure that the production system develops in accordance with the product. The choice of concept might be determined depending on the different methods and materials available, the designing of new tools or the cost for purchasing compared to producing in-house. Mentioned factors are all relevant to the manufacturing function and are utilised through all different phases. [1]

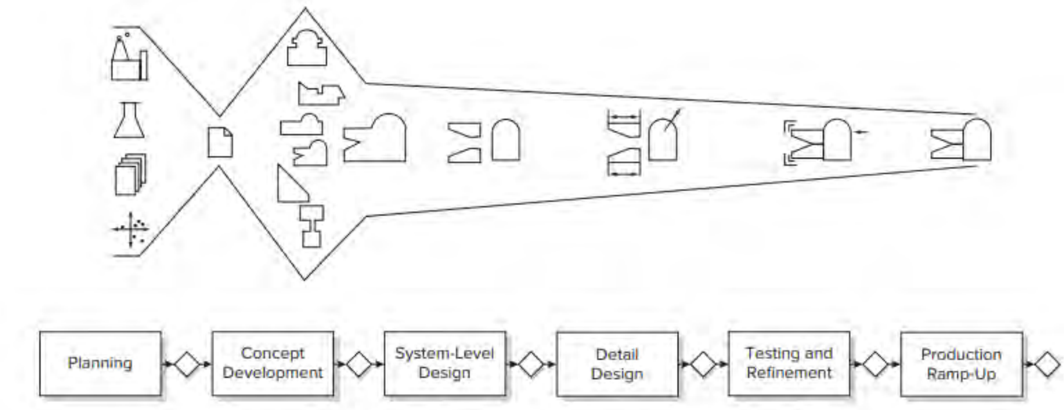


Figure 3.1: The generic product development process including its six phases [1, p.14].

The six phases of the Ulrich & Eppinger process are as shown in the figure above; *Planning*, *Concept Development*, *System-Level Design*, *Detail Design*, *Testing and Refinement* and *Production Ramp-Up*.

Beginning with *Planning*, this phase is usually not seen as a part of the project. This is because it includes analysing markets and determining opportunities, activities which are usually done to argue for approval of the project. Identification of constraints, product platform and new technologies are also activities for this first phase. [1]

Concept Development plays a major role in the process. This is where the customer needs are identified and translated into metrics. Metrics which later on will be met through form, functions or features, resulting in a concept. The concepts are then compared to each other as well as competitors' products. Analyses are made to determine the feasibility and prototypes to present a proof of concept. [1]

The two design phases, *System-Level Design* and *Detail Design*, are both focused on the product geometry, deviating on the overall size. System-level orients on a sub-system level, constructing interfaces and the interaction of the assembly. Where detail design concentrates on the different subsystems; assigning tolerances, materials and design tools. [1]

Testing and Refinement is all about reliability, durability and performance in regards to the design function. If needed, the testing leads to iteration of the design to better meet the needs. As opposed to marketing and manufacturing, this phase is mainly about preparing the world of what is to come. Production staff will need training and customers want the first notice. [1]

Production Ramp-up is the phase where the final product is thoroughly evaluated to correct any remaining flaws. The product is usually handed to favourable customers as an early-edition. After this phase, the production is meant to be independently ongoing. An assessment of the product and launch usually coincides with the ramp-up, both from commercial and technical perspectives. [1]

Analysing a performed product development, the profitability can be telling in how successful the process was. To be able to define the profitability of a performed product development, Ulrich et al. list a few parameters. These parameters regard the finished product, time spent developing, different costs as well as the effect on future product development. The factors referring to cost, called *Product Cost* and *Development Cost*, address different aspects. The formerly mentioned is associated with the cost of manufacturing and is thus affected by the sales volume, whereas the latter addresses the investment made to develop a product. Looking at the finished product, *Product Quality* is the parameter judging whether or not customer needs have been met and the robustness of said product. A fourth parameter considered is the *Development Capability* which describes how effectively a company will be able to develop future products as a result of the performed product development. [1]

3.1.2 Product Development Application

This master thesis was chiefly to help inspire and present concepts regarding fin plugs and fins whilst enhancing knowledge regarding fluid dynamics affected by fins, thus increasing Radinn's development capability. Therefore the parts of the product development process presented by Ulrich et al. from section subsection 3.1.1 needed to be re-evaluated. The majority of this project focused on the concept generation and validation. This includes the system-level design as well as detail design to a certain extent. Fin plug concepts were not able to be installed on the jetboards at disposal, instead the concepts were tested uninstalled. Physical testing and validation of different fin concepts on current jetboards are however presented and acted as a complement to the CFD-analysis.

The planning phase and determining of a market opportunity was already concluded by Radinn which made this master thesis possible. The planning phase which this project went through instead focused on how to solve the brief given from Radinn and a coarse explanation can be seen in Figure A.1 in Appendix A.

The situation affecting the world in the spring of 2021 altered the availability of customer needs validation and the concept generation methods offered in Ulrich & Eppinger. The methods used in this project will therefore act on Radinn and their personnel as a client and the customers regarded. To broaden the concept generation methods the project group was in contact with Elin Olander [15] who specialises in concept generating.

The concept generation phase was structurally inspired by Ulrich et al. regarding their method of searching for inspiration externally and internally, converging in a systematic exploration. This project made use of patents, corporate information and lead users externally for inspiration. The internal process included a variety of brainstorming sessions with different initial inspiration sources, some taken from Ulrich & Eppinger and some from Elin Olander.

The ramp-up phase was outside the scope of this thesis. The results achieved through this project will be given to Radinn and they can choose to continue with drafts and suggestions the results offer. This was why material and manufacturing methods were touched upon and taken into some consideration, but the product Radinn wants to go forth with will still need to be re-evaluated by a corporate team taking these kinds of decisions.

Finally since this thesis was made up of two separate development processes, the concept generation was conducted twice; once for the fin plug and once for the fins. Due to the preparations needed to be conducted to validate a fin concept, the project began with facing the fin plug generation. This could have altered how conducive the fin concept generation was and it should be noted that beginning with the fin concept could have given another outcome.

3.2 Computational Fluid Dynamics

3.2.1 Introduction

Computational fluid dynamics is a method combining fluid mechanics with mathematical equations and computer science. Fluid mechanics is the study of fluids in motion or at rest, dynamic or static. CFD as the name suggests focuses on the dynamic part of fluid mechanics. Moreover, the mathematical equations describe the physical characteristics of the fluid, typically in partial differential form. These equations govern a process of interests and are therefore referred to as governing equations. Lastly, computer science is the final discipline that combines fluid mechanics and the governing equations into a virtual simulation process. [16, pp. 1-10]

Today CFD is one of the basic methods to solve problems in fluid dynamics and heat transfer. The others being experimentally and analytically. These methods usually act in symbiosis to strengthen reliability. CFD has overtime become a practical tool in engineering practices because of its features and cost-effective process. It provides freedom regarding possible simulations, in comparison to physical testing, where it allows for the change of a single parameter and receive values otherwise hard to measure. A combination of CFD with experimental data is still a desired way to strengthen reliability. [16, pp. 1-10]

3.2.2 Construction of a CFD-Case

In practice, constructing a CFD-case requires iterations to generate a model which suits the specific case in question. The aim is to as accurately as possible describe the environment and model under investigation. Trade-offs are made regarding the processing capacity of the computer and the simulation resembling reality. The user needs to determine what factors are important in each different case and optimise the computing capacity towards the intended solution.

Set-up begins with constructing the geometry which is intended to resemble the model under investigation. Included in this construction is also the boundary geometry, and its boundary conditions, that limit the CFD-case. The boundary conditions are statements known from the beginning that enables the program to understand under which conditions the simulations are evaluated. Boundary conditions depend on the type of flow resulting from the applied physics model. Said conditions could be an inlet velocity from where the fluid flows, an outlet pressure where the fluid exits and different wall conditions depending on what surroundings the case wants to imitate.

Before simulating, a mesh needs to be generated. A mesh is a grid that covers the model to determine the elements over which the mathematical governing equations are to be solved. The generated finite amount of small elements are required to numerically solve the governing equations, resulting in an accurate representation of the flow. When choosing the size of this grid a couple of factors are to be considered. The number of elements determines how fast the solver will be, simultaneously, it determines the coarseness of the grid. A coarse grid might be more rapid to simulate but suffers in resolution. A narrow grid might be more detailed but suffer in the time to simulate. Moreover, there is another trade-off to consider coinciding with the size, namely the discretisation error contra round-off error. A round-off error happens when the accuracy of a computer will no longer account for the precision. However, with the development of computational power, this has become relatively small error which seldom dominates. A discretisation error envelops because of a coarse mesh, deriving from the approximations needed to be made in these cases. Discretisation errors will always be present since they are a result of converting the partial differential equations into algebraic ones.

The last general part of the set-up is to declare a physics model. This describes, as the name suggests, how the applied physics should act. Depending on the used computing power the model can differ in complexity and realism. The set-up consists of determining medium; gas, liquid or solid, solving equations and flow conditions. Solving equations determine how complex the computing will be and which variables should be a determining factor, time-step or iterating solutions. Moreover, flow conditions determine if the flow model will be a turbulent or laminar flow. If turbulence is chosen, extra equations describing the eddies also need to be determined.

3.2.3 Results and What to Decipher

After a solution has iterated and converged, the output from a CFD-program are the flow variables, such as velocity and pressure. These variables can be represented in the form of plots or a visualisation of streamlines and flow vectors. It is important to know what data one wants to examine before starting the simulation. Usually, when specific data is desired, a filtration method needs to be introduced to process the field variables into the specific data. Specific data could mean forces or momentum.

The filtration method, plots and visual graphics are intuitive to use and interpret. Streamlines describe the flow-movement around the part, pressure plots visualise underpressure and overpressure, plots can describe coefficients and forces acting in different directions. The hardest part of the results is declared to be determining the simulation's reliability.

The first indication of a result worth reviewing is, as previously mentioned if the residuals have converged. A contrasting diverging residuals plot is an indication of something wrong in the set-up. Another variable worth examining is the dimensionless y^+, which indicates if the mesh should be finer or more coarse closer to the wall. For a deeper explanation of the y^+-value and other variables, please see Appendix B. Since a simulation can fail because of the slightest irregularity in the mesh, usually a simplified geometry is to be preferred in simulations, another indirect trade-off.

This project will use a CFD-software called Star-CCM+ developed by Siemens. It is a widely known software used in all different kinds of simulating sectors. The set-up, validation and areas of interest for this project is presented in "Computational Fluid Dynamics Application", subsection 3.2.4. The results and post-processing is presented in "Initial CFD-Analysis", subsection 5.2.4.

3.2.4 Computational Fluid Dynamics Application

In this thesis, CFD is used as a validation tool, primarily for the fin section. Since the properties Radinn is striving towards come down to a subjective feeling of the rider, the CFD application will merely focus on optimising the properties measurable objectively. Properties such as drag, lift and z-forces, as well as vortex induction. Due to the subjectivity, this report will focus on connecting user feedback to physical values in CFD and draw conclusions on how desired jetboarding dynamic can be achieved.

To ensure that the results are viable depending on the used set-up, a sensitivity analysis is conducted and presented in Appendix B. Due to the different conditions a board and fins experience during a riding session, every realistic turbulence model will not be possible to take into account. Therefore solely a couple of variables will be tested regarding turbulence and the rest following recommendations from an expert in the field. Other variables evaluated in the sensitivity analysis were domain size, mesh coarseness, placement of fin and wake refinement. Since there is no access to experimental data, the method used was to set-up the finest or largest case and refine the set-up to make the simulation show the same results as the extreme cases, but with as fast iteration time as possible.

Once the sensitivity analysis is done, simulations will be made on generated fin designs. The different fin designs will have theorised functions and to validate said functions before testing, the generated drag, lift and lateral forces will be examined.

4 Research

This chapter will showcase the research conducted prior to the synthesis. Before concepts were to be generated, studies regarding market, manufacturing, material and assembly was conducted. Lastly, this chapter presents the patent of the current fin fastening system supplied to Radinn as well as a list of interpreted needs from an introductory interview with Radinn. The chapter lets the reader take part of the same theory as was researched by the project group.

4.1 Market Analysis

This section presents how Radinn's current boards compare in relation to competitors. Thereafter a deeper analysis is conducted of the fins and fin plugs available on the market. The reader should be informed that Radinn already have established a market opportunity and this section is used to present their arguments and findings supporting the brief given prior in this project.

4.1.1 Radinn's Electric Jetboard

The jetboard market's boundaries are unspecified and therefore, this analysis will limit the boundaries to electric jetboards, stand-up paddleboards and bodyboards. The pricing span over those watercrafts begins at 3850 € and ends at 19900 €. In such a span, Radinn's boards are placed below average. Radinn is currently, like the majority of the board competitors, using one out of the two most commonly used surf fins and their corresponding fin plugs. These fins are designed for an ordinary surfboard, which is supposed to be riding waves and needs a different agility to move along a wave's topology. It is with precaution to errors the weight of the boards are compared. Some boards are weighed without a battery and some without a jetpack. With this in mind, according to Top Jet Surfing, Radinn's boards are in the heavier section of the available boards [17].

Radinn is a company that wants to broaden its segment to become accessible to more users. Their vision to accomplish such a goal is to lighten the weight and lower the price even more. At the same time they want to make sure every user is happy with their boards over a long period of time, even when the user transpires from beginner to experienced. To offer such a property, Radinn believes in giving the user a wide range of fins to choose from, allowing different styles of riding. Something this project focuses on, and Radinn has discovered a missing market segment arguing for this project, which will be presented in the section below, see subsection 4.1.2.

4.1.2 Market Segments

The market segments interesting for this project will be divided into a segment for jetboard fins and one for fin plugs.

Regarding fin plugs, the market is currently consisting of two major brands and a couple of smaller ones specialising in wakeboards, stand-up paddleboards and windsurf boards. Of these, there is only one that offers tool-less attachment and detachment, something Radinn describes as an important feature when it comes to jetboards, because of the weight and handling of such a board.

The fact that only the fins fitting to these tool-less plugs are sold by the same company transitions into the next market segment.

When it comes to which fins are available at market, there is only one company that claim they have developed a set of fins solely made for jetboards. These were made in collaboration with a company specialising in surfboard fins and produced with compatibility to one of the plugs which require tools. As previously mentioned the tool-less plugs are only compatible with surfboard fins made from the same company. Creating one's own fins with compatibility to the tool-less plug with a focus on jetboards would infringe on a patent filed by the company.

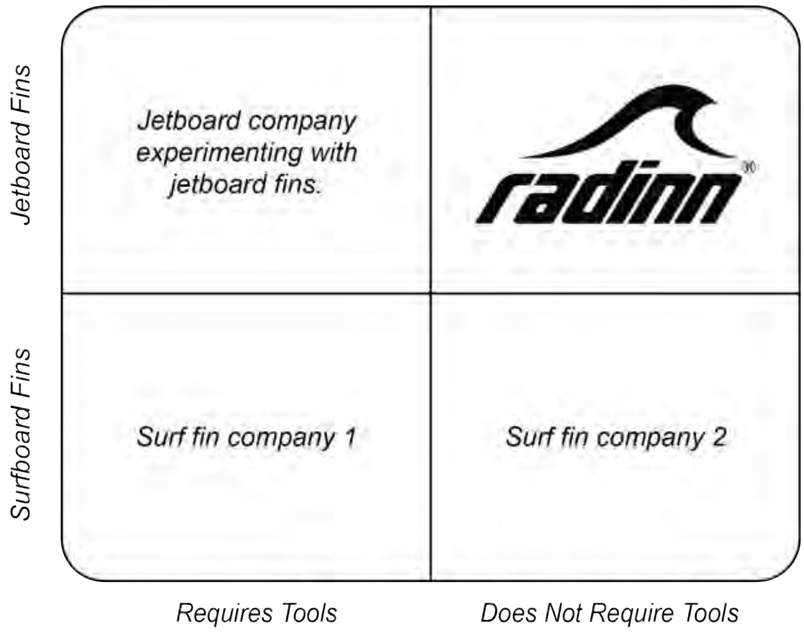


Figure 4.1: Market segment map showing what kind of companies currently in possession of said segment.

To concretise the opportunity and give reason to the research initialised, the available plugs and fins are shown above in a simple segment map, see Figure 4.1. Today the surfboard fins cost from 20 € (a replacement one) to 150 €. The fin plugs cost around 13 € depending on the retailer. This fact encourages Radinn to develop a fin plug of their own enabling custom made fins specialising towards jetboards. Not only lowering their production cost but also, offering their users a variety of properties to match their level of expertise and riding conditions.

4.2 Material Study

The following subsections describe different materials that were researched for use in fin plugs and fins.

4.2.1 Polycarbonate

Polycarbonate is a relatively flexible material found in varying applications. Its properties do not fluctuate compared to similar polymers which induce reliability. When a more rigid structure is needed the materials shift towards glass inforced polyester or epoxy. [18]

Polycarbonate's adaptation into surfing is both through actual surfboards as well as fins. Surfboards make use of the stronger, lighter, more durable properties while still maintaining the performance and flex pattern. Moreover, Pump Surfboards claims that it provides faster production and lead time, in comparison to other surfboard manufacturing methods and materials [19]. In regards to fins, there are a couple of brands producing polycarbonate fins, mainly for wakeboards and stand-up paddleboards. [20][21]

There are several possibilities for manufacturing fins when it comes to polycarbonate. By using the technology of today, it is possible to both make use of selective laser sintering (SLS) and fused deposition modelling (FDM). Both methods do require unusual measures in either after-treatment or during extrusion, but none extreme. Another method also available is to injection mould. [22][23]

4.2.2 Polyurethane - Elastomeric Grade

Polyurethane is a plastic material found in several consumer applications such as insulation, mattresses and rollerblade wheels. The polymer allows a wide variety of manufacturing ways and subsequently a wide variety of shapes [24]. In general, the material provides increased resistance to abrasion and tear as well as good fatigue resistance. Furthermore, in relation to other thermoplastic elastomers, polyurethane presents a high tensile strength [25].

Polyurethane can be used as an elastomeric polymer foam core, encapsulated by a layer of glass fibre. The material provides the overall product with a stiffness that matches that of a fin made solely from glass fibre, whilst minimising the overall weight. [26]

Polyurethane can be formed in several ways, where moulding is a popular choice. The material is suited for blow moulding, injection moulding as well as rotational moulding. Additionally, polyurethane allows extrusion and calendering as options of forming, but produces poor machinability [25], meaning milling is not recommended.

4.2.3 Polyoxymethylene (POM)

Polyoxymethylene, also referred to as polyformaldehyde and acetal plastic, is a semi-crystalline thermoplastic material. Its properties include high stiffness and strength as well as superb resilience, meaning it can withstand a high amount of elastic cycles. Additional characteristics are low moisture absorption and great sliding capabilities. [27]

POM allows for injection moulding and generates low warpage, i.e., will deliver high dimensional stability. An example of a POM material is the Tenac 4010, a thermoplastic often used in housings and fasteners. [28]

4.2.4 Fibre Reinforced Polymer (FRP)

A fibre reinforced polymer is a composite that, as the name suggests, consists of a polymer matrix that has been merged with fibres to change the material properties of the overall material. Fibres often used are glass and carbon, however new solutions with fibre from renewable material are also available. The polymer matrices frequently used in the different compounds are often made up out of epoxy, polyester or vinylester resin [29]. The general properties that make FRP a desired material, from a mechanical design point of view, are the high strength-to-weight ratio, its resistance towards corrosion and the fact that it is cost-competitive [30].

4.2.5 Glass Fibre Reinforced Polymer (GFRP)

In glass fibre products, the matrix transfers the shear load and the fibres resist the tensile and compressive loads. As mentioned in FRP, it is the lightweight property making GFRP desirable, from a mechanical design standpoint. The composite is typically less brittle, in comparison to carbon fibre reinforced polymer (CFRP), and the materials in use are less expensive. Together with its ease of forming, it rapidly becomes a common application in high-performance aircraft, boats and automobiles. [31]

From discussions with an expert in the field [28], two different GFRP materials were recommended. One material, called GVX-7H, is used in propellers and is a thermoplastic material, based on both semi-crystalline polyamide and partially aromatic copolyamide, reinforced with 70% glass fibre. The other recommended material is called Grilamid and is polyamide 12 reinforced with glass fibre. Both materials handle moisture well and generate superb stiffness and strength as well as high dimensional stability. Both materials are well suited for injection moulding, however one advantage with the Grilamid is that it allows the same mould setup for varying percentages of glass fibre in the part. This meaning that the same tools can be used for creating the same part, but with varying stiffness.

4.2.6 Carbon Fibre Reinforced Polymer (CFRP)

Carbon fibre consists of thin fibres about 1 µm in diameter. The fibres are made up of carbon atoms bonded together into parallel fibres. It is the crystal structure providing the composite with its strength. Carbon fibre can be combined with different materials such as both plastic resin and wood, enabling a variety of different weave patterns of the fibre. The ease of forming, similar to GFRP, as well as its strength, compels the application of carbon fibre in aerospace, motorsports and civil engineering. [31]

4.2.7 Glass Fibre vs Carbon Fibre

In Elanchezhian et al.'s article [31], carbon fibre is compared with glass fibre in material properties tests, in accordance with the standard of American Society of Testing and Materials (ASTM). They proved carbon fibre's superiority regarding tensile, impact and flexural strength. Glass fibre's percentage elongation during tensile testing proved greater than carbon fibre, promising to withstand more strain before breaking. In this case, the conclusion presented was that carbon fibre had better properties and therefore suited mechanical structures to a greater extent than glass fibre.

4.2.8 Natural Fibre Reinforced Polymer

Attempts to increase the market share of renewable materials in the polymer industry has increased in recent years. Producing a material with similar properties to that of synthetic glass fibre and carbon fibre, but doing so by using natural materials that generate sustainable societies[32]. The word natural can incorporate an extensive variety of renewable materials, consequently why more specific material properties cannot be defined in this subsection.

4.2.9 Matrix Variants

As previously mentioned, a binding polymer matrix is needed to manufacture FRP. Three of the more common resins used as matrices are epoxy, polyester and vinylester. Each of these resins generates close to no corrosive effects but present different structural properties. Polyester generally produces the lowest bonding strength and is prone to micro-scaled crack propagation due to its brittle properties [33]. Contrastingly, polyester has a low cost and a short cure time, resulting in the overall most cost-effective material of the three. Epoxy on the other hand presents a high bonding strength as well as a high impact strength, compared to the other resins. Its high resistance towards environmental degradation means it will not blister when in contact with water, as both polyester and vinylester are inclined to do. The third resin, vinylester, is a hybrid of the other two, meaning it is suitable for a wide range of applications. Combining the other resins means that both unsought and sought-after properties from both will be present in the vinylester. Sought-after properties are higher tolerance towards vibrations and being less prone to crack propagation, but also unsought properties such as poor repair abilities and a higher cost than polyester. [34]

4.2.10 Low Friction Coating

Low friction coating or anti-friction coating is mostly integrated into hull coatings for performance boats. There have been many studies trying to investigate the actual drag reduction properties of coatings and hull topology. Ahmadzadehtalatapeh and Mousavi [35] presented the conclusion that it is primarily the form of the hull which reduced drag, secondary properties were evaluated to fouling and air lubrication. Hence, the actual coating to act as a low friction one usually contributes to anti-fouling properties and in cases, also a micro-structured topology, mimicking sharks and lotus leaves. The hydrophobic structures included in coatings measured to reduce drag up to 10%.

4.3 Manufacturing Study

The following subsections describe various ways of manufacturing the fin assembly, i.e., shaping the materials mentioned in section 4.2.

4.3.1 Injection Moulding

Injection moulding requires molten polymer to be extruded through a nozzle into a cold mould. Once the entire mould has been filled and the polymer has solidified, the mould can be opened and the formed object removed. The dividing line where the cavities of the mould meet is called parting line. When removing the object, no permanent protrusions can exist in the moulds that would hinder the extraction. Therefore, to create recesses in an injection moulded object, cores are used. They move mechanically to create the recess and then gets pulled out before extracting the object, giving the process the name core pulling. Adding cores to a moulding tool is expensive and therefore usually circumvented. Considerations regarding shrinkage during cooling, as well as warpage, also have to be made in order to guarantee accurate dimensions within the set tolerances. The cost of tooling is high, but depending on the desired quality of the moulded object, the production cost will be exceedingly low. This process is thus mainly used for large-volume production. [25]

4.3.2 Blow Moulding

Blow moulding is a quick manufacturing method to produce plastic bottles or containers consisting of cavities. The principle is to blow air into a plastic parison which expands towards an outer mould to acquire the desired form. This describes the commonly used extrusion blow moulding, others being injection blow moulding and injection stretch blow moulding. In the latter ones, a plastic form is at first injection moulded to later be infused with air, either directly or while being stretched by a piston. [36]

Designing towards blow mould manufacturing needs consideration. The plastic used will be stretched and if the mould requires uneven stretching it is always the thinnest part which will expand the fastest, risking to burst and result in a failed part. Variables which determine the reliability of this process are deemed to be plastic quality, mould design, mould surface treatment, parison placement as well as blow velocity. Other variables are added depending on the chosen method. [37]

4.3.3 Compression Moulding

This process requires granulates or tablets of the desired polymer to be placed into an open, heated mould. By closing the mould, the polymer is pressurised which subsequently forces the material into existing cavities. Once enough pressure has been applied and the polymer has solidified, the mould can be opened and the object removed. The surface finish of the moulded part is generally quite poor, however in comparison to injection moulding and resin transfer moulding, the tolerance of wall thickness is relatively fine. Furthermore, compared to the two other mentioned manufacturing ways, compression moulding is more frequently used when shaping larger parts and its generated tooling cost is generally lower. [25]

4.3.4 Resin Transfer Moulding (RTM)

Resin transfer moulding is a process well suited for the shaping of composites. A reinforcing material, such as glass fibre or carbon fibre, is placed onto a mould. Depending on how the material is placed, the part that is about to be manufactured will yield varying structural properties. By closing the mould and applying pressure, a resin can be injected into the mould. The resin, acting as the matrix in the composite, will fill all cavities in the mould and impregnate the reinforcing material. Depending on which resin is used as the matrix, the part will yield different cure times. A vacuum can be applied to reduce the chance of voids in the composite, as well as increasing the flow rate of the resin when entering the mould. This process is called Vacuum Assisted Resin Transfer Moulding (VARTM). In an effort to shorten the cure time of this process, heat can be applied. [38]

4.3.5 3D Printing

Three-dimensional (3D) printing, also referred to as additive manufacturing, is a process that means successively adding material according to predefined geometry references. This process can be performed in different ways. The earliest versions of 3D printing were done through Fused Deposition Modelling (FDM), i.e., a process that extrudes a heated filament of desired material layer by layer. This method presents low costs and is widely used. In comparison to FDM, another process, referred to as powder bed fusion, delivers higher accuracy of printing, improved surface finish and enhanced structural stability. Selective Laser Sintering (SLS), is such a process. By using a laser beam, powder of the desired material can be fused according to predefined geometry references. Layer by layer, a part with finer tolerances can be produced. Both FDM and SLS can however create parts with varying part size, material, desired tolerance and surface finish. [39]

4.4 Assembly Study

The following subsections describe current and potential future assemblies of fin systems in Radinn jetboards.

4.4.1 Glassed-in

The fin plug is placed inside a cavity on the board with the same dimensions, making sure the plug does not protrude from the board surface. It is attached using a resin such as polyester or epoxy, mentioned in subsection 4.2.9, sometimes together with a residue thickener, which will make sure the plug is fastened to the board once the resin is cured. Afterwards, woven glass fibre and a layer of resin are placed on top of the fin plug, whilst its cavities are covered. This will provide extra bonding strength, preventing the entire assembly from snapping out of the board when a user tries to detach the fin. The final step in the process is to grind off the cured resin and glass fibre that lays on top of the plug cavities. [40]

4.4.2 Capture Moulding

This method, referred to as capture moulding by Radinn, presents different geometrical requirements on the fin plug, in comparison to a glassed-in assembly. By changing the geometry and introducing extrusions in the profile, which are able to absorb vertical forces, the fin plug can be assembled into the jetboard using vacuum. This is done by placing the fin plug on a metallic surface with the cavities for fin fastening facing downwards. A sheet of not hardened acrylonitrile styrene acrylate plastic (ASA), the size of the watercraft, is then placed on top of the plug. This sheet of plastic will act as the outer shell of the watercraft. On top of the plastic sheet, a plastic foam core is placed. The core has beforehand been prepared by shaping it according to the dimensions of the watercraft, as well as coating it with uncured GFRP. Furthermore, a cut-out has been made on the craft where the fin plug is supposed to be inserted. The last step of the process involves placing another sheet of ASA plastic on top of the foam core and subsequently enclosing the entire setup using a mould. Inside, a vacuum will be generated and the fin plug will be forced inside the cut-out on the core. Thanks to the extrusions in the geometry on the fin plug, the GFRP will be able to expand and fill the entire cavity, resulting in itself and the plastic layer to be pressed against the plug. Once cured and hardened, the capture mould will provide a fastening able to absorb forces in the normal direction from the top area of the fin plug. An example of capture moulding can be seen in Figure 4.2. The pink foam that is GFRP can be seen pressing the red layer of ASA plastic into the cavity on the profile of the black plastic insert.

Figure 4.2: Example of capture moulding.

4.5 The Current Patent

The following section describes the current patent on the fin fastening system.

The patent covers the design of both the fin plug and the fin tabs on the bottom of the fin, i.e., the parts being inserted into the fin plug. As seen in Figure 4.3, the fin plug consists of two cavities. The fin is attached by inserting the nose of the fin first and having a protruding geometry on the front end of the fin plug engage with a cavity in the front end of the fin. This is illustrated in Figure 4.4.

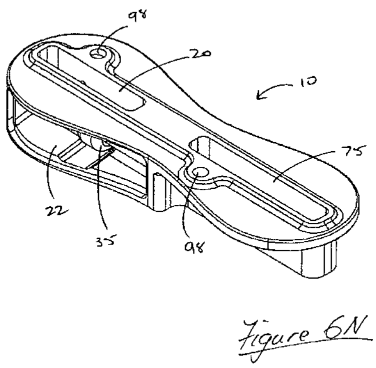


Figure 4.3: Illustration of the currently used fin plug. [41]

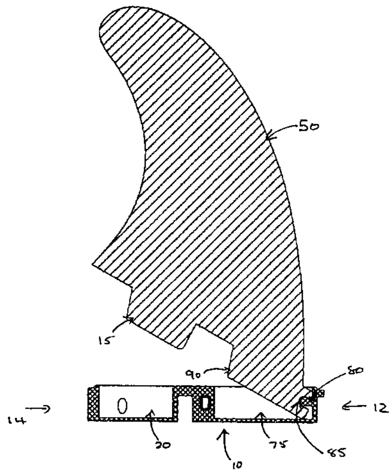


FIG 2A

Figure 4.4: Illustration of the currently used fin fastening system [41]. The fin is attached by inserting the front end first.

After having inserted the front end of the fin, the rear end is pushed downwards and is met by resistance from a ring-shaped member that is mounted on a resiliently flexing rod within the fin plug. The rear fin tab is shaped to abut said ring-shaped member, as seen in Figure 4.5. Applying enough force will push the fin tab downwards, surpassing the ring-shaped member and ultimately locking the fin into place by having the member and rod continuously pushing on the fin tab. The locked position is visualised in Figure 4.6. The shape of the fin tab can be seen protruding underneath the ring-shaped member, thereby preventing the fin from detaching unintentionally.

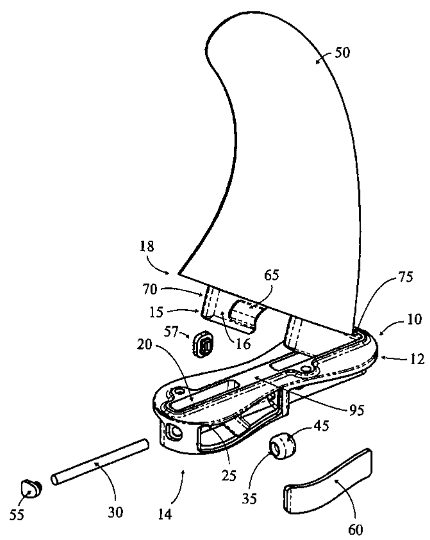


Fig 1B

Figure 4.5: Illustration of the currently used fin fastening system [41]. The ring-shaped member and the shape of the rear fin tab can be observed.

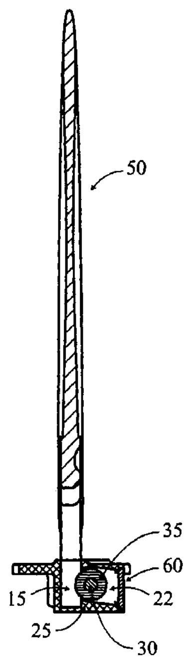


Fig 2C

Figure 4.6: Illustration of the currently used fin fastening system [41]. The fin is rigidly locked into place by the force from the ring-shaped member and the resiliently flexing rod.

4.6 Interpreted Needs

The following section displays the needs identified by Radinn prior to this project.

During an initial meeting with Radinn, desired qualities of fins and fin plugs were discussed. The meeting was the foundation of the interpreted needs. Said qualities related to the brand, the ergonomics as well as wants and needs. This gave the team members an understanding of where Radinn wanted to focus the development and how important the individual needs were in relation to each other.

The scope of this project attends to both the fin plug and the fins. With this in mind, the interpreted needs divide into corresponding categories seen in Table 4.1. Numbers 1 to 10 regard the fin plug and the entire fin assembly. Remaining numbers regard solely the fins. These needs will be revisited in each corresponding concept generation phase.

Table 4.1 Interpreted needs from Radinn. Importance ranges from 1 to 5, where 1 is of lowest importance and 5 is of highest importance.

No.		Need	Importance
1	The fin plug	allows easy removal of the fin	5
2	The fin plug	is rigid	5
3	The fin plug	allows the fin to be struck	4
4	The fin plug	allows for one-handed attachment and detachment	5
5	The fin assembly	entails easy manufacturing	4
6	The fin plug	entails easy assembly into jetboard	4
7	The fin plug	allows for backwards compatibility	1
8	The fin assembly	instills quality	3
9	The fin plug	does not erode in water	5
10	The fin assembly	prevents damaging forces to be transferred onto the board	4
11	The fin	demonstrates the qualities sought-after in a fin	4
12	The fin	demonstrates new qualities optimised for jetboards	5
13	The fin	entails good affordance	4
14	The fin	provides a wide range of handling	3
15	The fin	eliminates drag force	3
16	The fin	has similar graphical design to Radinn	2
17	The fin	is environmentally sustainable	4
18	The fin	recycles if lost in water	2
19	The fin	allows for comfortable riding	4

5 Synthesis

This chapter is divided into two parts. The first part regards the development of the fin plug and the latter regards the development of the fins. The sections each present a concept generation phase, concept selection phase, testing phase and result presentations. The fin section also displays a conducted computational fluid dynamic analysis generating knowledge about the selected concepts prior to physical testing. The chapter lets the reader take part of every action leading to the final concepts.

5.1 Fin Plug

The following subsection describes the synthesis of the product development of the fin plug.

5.1.1 Interpreted Needs

The Table 5.1 displays the needs for the fin plug, as presented by Radinn.

Table 5.1 Interpreted needs - Fin Plug. Importance ranges from 1 to 5, where 1 is of lowest importance and 5 is of highest importance.

No.		Need	Importance
1	The fin plug	allows easy removal of the fin	5
2	The fin plug	is rigid	5
3	The fin plug	allows the fin to be struck	4
4	The fin plug	allows for one-handed attachment and detachment	5
5	The fin assembly	entails easy manufacturing	4
6	The fin plug	entails easy assembly into jetboard	4
7	The fin plug	allows for backwards compatibility	1
8	The fin assembly	instills quality	3
9	The fin plug	does not erode in water	5
10	The fin assembly	prevents damaging forces to be transferred onto the board	4

5.1.2 Concept Generation

Based on the needs displayed in Table 5.1, concepts were generated. The process began with a brainstorming session [1, pp.131-132] to put pre-established ideas on paper and to generate new ones. Some of the sketches made during this process are shown in Figure 5.1 below.

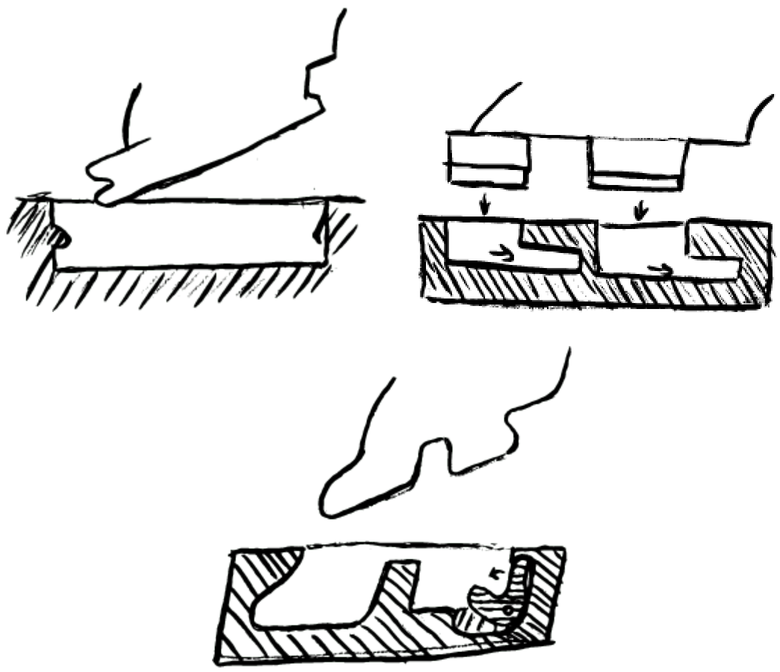
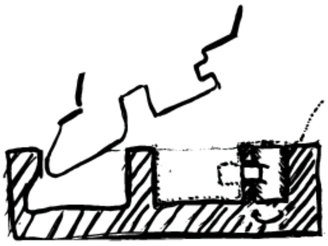


Figure 5.1: Sketches from the first session consisting of a fin part and a cross-section of a fin plug part.

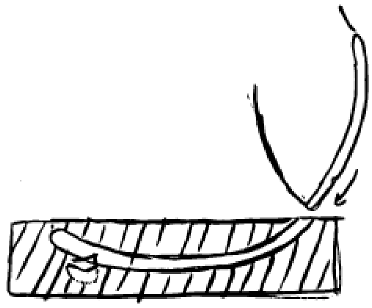
The sketches and ideas generated in the first step of the concept generation were used to create a concept combination table [1, pp.138-141]. Groups of different attachment functionalities, locking mechanisms, unlocking mechanisms and extra features, seen in Table 5.2 below, were identified from sketches. Having identified the mentioned groups, new concepts could be generated in a structured way by using a combination of two objects from two different groups. By sketching ten different combinations for 45 minutes each and analysing the results, the number of overall concepts was rapidly increased. See examples of combinations in Figure 5.2.

Table 5.2 Combination table of different functions

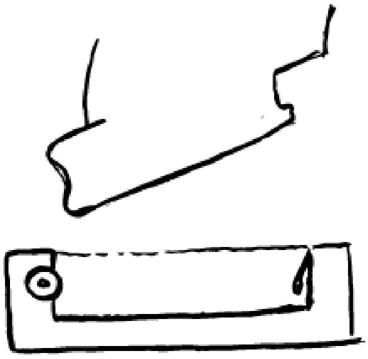
Attachment	**Locking**	**Unlocking**
Pivot	Bump	Torque
Uniform press	Flat flap	Force
Horizontal rotation	Friction	Button
Vertical rotation	Round flex	Slider
Slide	Ring-shaped member	Gravity
	Interlocking	Pressure
	Pressure	Multi-step



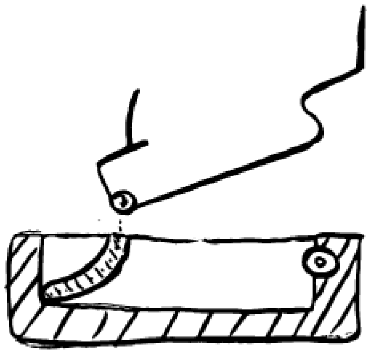
(a) Pivot - Interlocking - Slider.



(b) Slide - Interlocking - Force.



(c) Pivot - Flat flap - Multi-step.



(d) Pivot - Ring-shaped member - Torque

Figure 5.2: A couple of examples from the combination table concept generation.

To create new radical concepts, not limited by the conceived possibilities from the unstructured concept generation, two different methods recommended by Elin Olander [15] were used. The first method, presented by Michanek and Breiler as *Slumpordsassociationer* [42, p.111], required one verb or noun and one adverb or adjective that together would function as the main source of inspiration. The purpose of this method was not to sketch fin plugs, but to generate non-related ideas and afterwards applying them to the fastening of fins. Word combinations used were *Extreme Fastening* and *Extreme Stabilisation*.

The second method used to generate radical concepts was utilising an already established solution of some sorts that would serve as illogical or counterproductive if used for fin fastening. The solution was then changed and adapted to work as means for fin attachment. For example, concepts were sketched that used the function of a stapler as a fin fastening solution in different ways. This method is referred to as *The Dark Horse* by Wikberg Nilsson [43, p.143]. Like the theories of Michanek and Breiler [42], this method was brought from external sources, into the Ulrich & Eppinger development process.

5.1.3 Concept Screening

Having generated a quantity of concepts, quality now became the main focus. By screening the sketches and ideas, a narrowed scope of concepts could be generated. In order to produce a diverse selection, a limited number of concepts were chosen and given a rating. Each team member got to choose ten different concepts in this process. This method, called *Multivoting* [1, p.48], was used to efficiently move forward in the product development process and seeing as the specific field required knowledge regarding fins, fin plugs and jetboarding as a whole, only the team members performed the selection process. Additionally, the rating of chosen concepts ranged from 1, meaning that the idea will most likely be realisable and functional should it be produced, to 5, meaning that the idea presents the most radical way of pleasing the established needs.

Concepts with the rating of 1 or 2 were similar to the currently used solution, in either function and/or geometry, and were thus sent to intellectual property attorneys for infringement analysis. This was done to map problem areas of different designs and plan on how to avoid infringement in potential future concepts. Figure 5.3 shows a couple of concepts extracted from the document sent to intellectual property attorneys. See Appendix C for the whole document containing all concepts and explanatory text of their respective designs that were analysed for infringement.

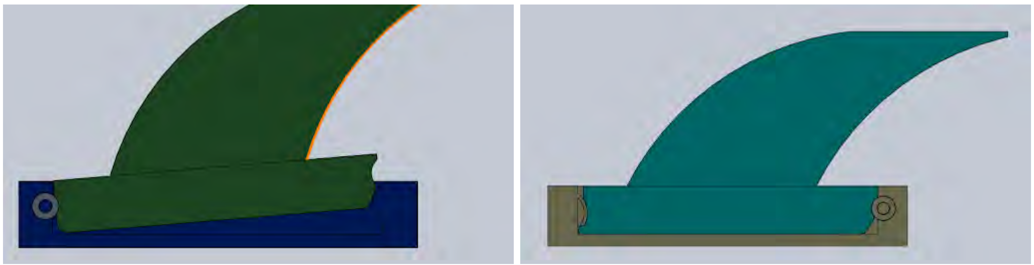


Figure 5.3: Two concepts sent for infringement analysis.

In preparation for upcoming prototyping and testing, the number of concepts had to be decreased further. The concepts previously chosen were presented in a table and were rated in relation to a reference concept in various categories, as can be seen in Table D.1. This general method is referred to as *Concept Screening* [1, pp.156-159] and was performed simultaneously as the patent analysis to create an objective basis for upcoming decisions.

Based on the interpreted needs presented by Radinn in subsection 5.1.1, the categories used for the comparison were *ease of attachment (EoA), ease of detachment (EoD), amount of parts (AoP), risk of turbulence (RoT), ease of manufacturing (EoM), reliable gripping (Rel G)* and *durability (Dur)*. The reference concept used in the table was the currently used solution by Radinn. Each concept was discussed in accordance with each category and was given a rating of -, 0 or +. A minus sign (-) meant the concept was considered to be worse than the reference concept in that particular category. A zero (0) meant the concept was considered to have similar qualities as the reference. Lastly, a plus sign (+) meant the concept was considered to present improved qualities in that category.

Based on their respective net ratings seen in Table D.1, several concepts could be discarded. Solutions presenting only a single, or a few, negative notations were discussed in order to identify possibilities of improving that single, or those few, categories. The possibilities of combining different solutions based on how they potentially could complement each other according to the concept screening table were also discussed.

5.1.4 Iteration of Concept

The iteration process of the first concept drafts were guided by the response of the patent attorney together with the concept screening conducted in subsection 5.1.3.

The reader should keep in mind that the concepts reviewed by the patent attorney were the ones given a rating of 1 or 2 in the similarity-to-radical-scale. This resulted in the attorney's initial

Table 5.3 Concept Screening of the first 15 chosen concepts. Illustrations and descriptions of the concepts can be found in Appendix D.

	Ref	Ring - bump	Round flex - bump	T-shape - Ring	Tracks - Round flex	Slide - hinge	Stapler	Slide - Ring	Pivot - Rear pressure	Pivot - Pie	Center pivot organic cav.	Air pressure	Water pressure	Scissor	Axe head	Thread-ed puck
EoA	0	0	0	0	0	-	-	0	0	-	0	+	+	-	-	-
EoD	0	0	0	0	0	-	0	0	0	-	0	0	+	-	0	-
AoP	0	0	0	0	+	-	-	0	+	-	0	+	+	-	-	-
RoT	0	0	0	0	0	-	-	0	0	-	0	-	-	-	-	-
EoM	0	0	0	0	0	0	-	0	+	-	0	+	+	-	-	-
Rel G	0	0	-	-	0	0	0	0	-	0	0	-	-	-	0	0
Dur	0	0	-	0	-	-	-	-	-	-	0	-	+	-	-	-
NET	0	0	-2	-1	0	-5	-5	-1	0	-6	0	0	+3	-7	-5	-6

response being that some of the presented concepts were too similar to the current patent as well as some other patents that they disclosed in their process. Similarities were the use of a resiliently flexible rod and the use of two cavities in the fin plug, among other aspects. In contrast, some concepts had more similarity to patents which were out-dated and hence referred to as prior art. A consultation with Radinn regarding the importance of a future possibility to obtain a patent led the iteration into a path where the use of prior art is a possible solution. In figures 5.4, 5.5 and 5.6 below, some of the now-expired patents found by the attorney is shown. Similarities were the tongue section on the rear end of the fin in Figure 5.4, as well as the sliding function in Figure 5.5 and the flexible attaching means in Figure 5.6.

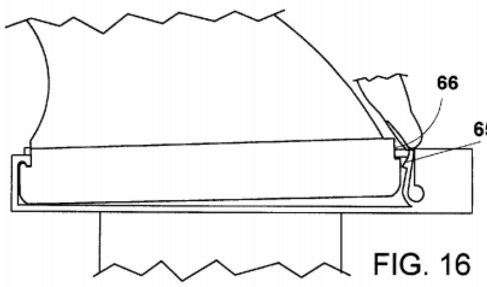


FIG. 16

Figure 5.4: A drawing explaining the design of expired patent US 6,695,662 B2 [44].

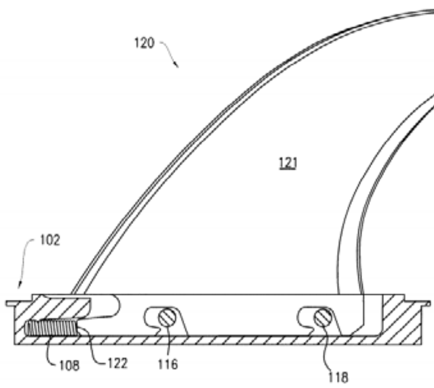


FIG. 4C

Figure 5.5: A drawing explaining the design of expired patent WO 2010/056706 A2 [45].

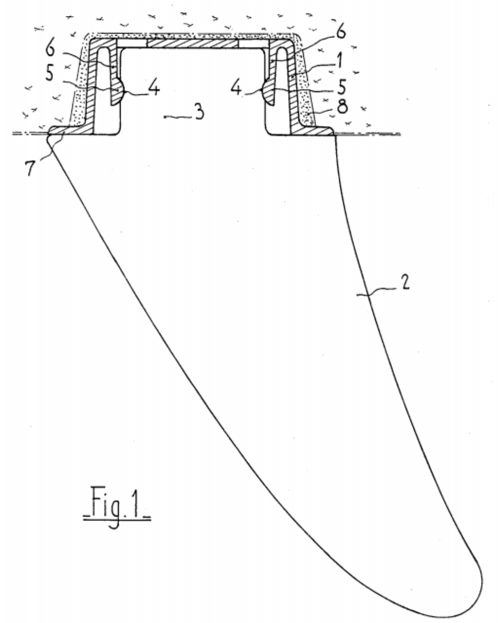


Figure 5.6: A drawing explaining the design of expired patent US 4,398,485 [46].

The concept screening seen in subsection 5.1.3 showed the concepts with the best net value. These were also some of the concepts sent to the attorney. With the feedback from the attorney together with the net values from the screening, a new set of combined concepts were created.

The possible solutions regarding fastening and pivoting are not usually constrained to each other. This results in a combination matrix where the different possible and desired front ends were combined with the possible and desired rear ends. The desirability was evaluated from the previous screening. For consistency, the same categories were used for comparison, only this time, the values were referenced to a competing concept instead of the currently used one. One addition was the last category, *fail-safe (Fail S)*, which was meant to determine how well the concept would satisfy the need of preventing damaging force to be transferred onto the jetboard, i.e., need no.10

in Table 5.1. The new screening can be seen in Table 5.4.

Table 5.4 Concept Screening of second iteration. "Tracks - Round Flex" from last iteration in Table D.1 was used as reference value.

Rear-end	Round Flex	Flex Up				Flex Down				Sphere			
Front-end	Tracks	Tongue	Ledge	Sphere	Bump	Tongue	Ledge	Sphere	Bump	Tongue	Ledge	Sphere	Bump
EoA	0	+	+	+	+	+	+	+	+	+	+	+	+
EoD	0	-	-	-	-	0	0	0	0	0	0	0	0
AoP	0	0	0	0	+	0	0	0	+	-	-	-	0
RoT	0	-	-	-	-	0	0	0	0	0	0	0	0
EoM	0	0	0	-	+	0	0	-	+	-	-	-	0
Rel G	0	0	0	0	0	0	0	0	0	0	0	0	0
Dur	0	0	0	0	0	0	0	0	0	0	0	0	0
Fail S	0	0	0	-	-	0	0	-	-	0	0	-	-
NET	0	-1	-1	-3	0	+1	+1	-1	+2	-1	-1	-2	0

To ensure the new concepts' infringement factor, a new document with combined concepts was sent to the attorney, see Appendix E. These concepts were also condensed into five different models in an attempt to touch upon the different front ends and rear ends with the highest screening value, while limiting the cost of prototyping. The models were thereby sent to be 3D printed for further evaluation and to ensure proof of concept. The prints were furthermore used for user testing to narrow down the amount of desired front- and rear ends based on users' input regarding feel and affordance.

The patent attorney's feedback from the second iteration added no prioritisation factor. All the concepts sent for reviewing were applicable solutions with a small degree of different certainties. Consequently the choice of concept mainly depended on the user testing presented in the next section, subsection 5.1.5.

5.1.5 User Testing

For the phase of user testing, five prototypes were 3D printed. The concepts chosen were combinations of the front ends and rear ends which received the best result in the second screening, touched upon in the previous section subsection 5.1.4. The chosen concepts are presented in this section, followed by a description of the test case, the results and a discussion.

Dual Bump

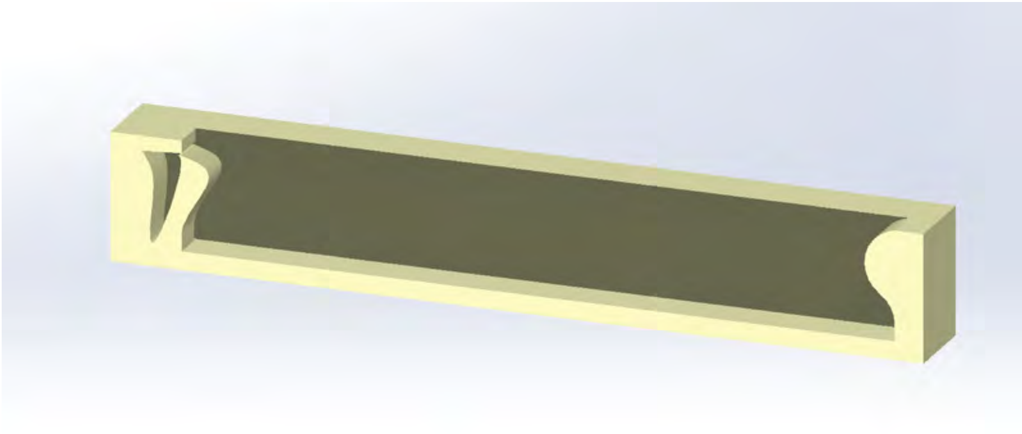


Figure 5.7: The Dual Bump concept corresponding to Flex Up - Bump.

Dual Bump consists of a front end that is supposed to flex enough to let the rear end pass over the rear bump. The cavity becomes symmetrical since the front flex has a small protrusion similar to a bump. This is why the concept is known as Dual Bump from here on.

Tongue

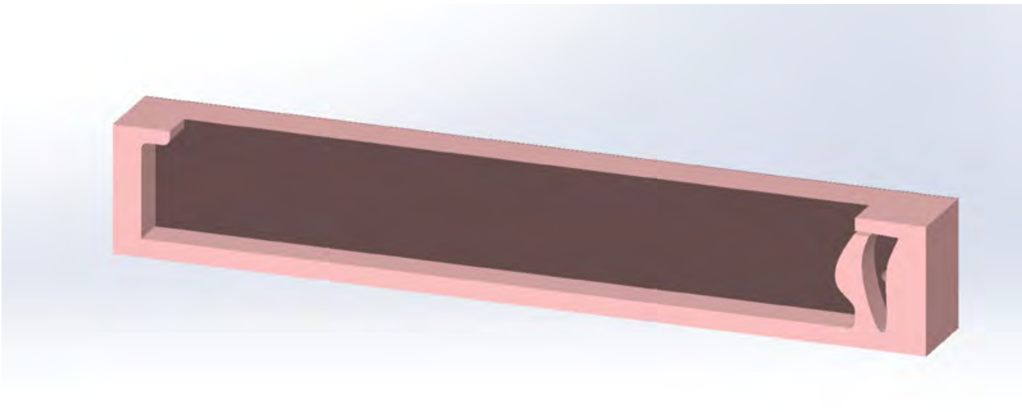


Figure 5.8: The Tongue concept corresponding to Flex Up - Tongue.

Tongue is constructed with inspiration from an expired patent which then becomes prior art. A small protruding ceiling creates a cavity where the front end of the fin is fitted. The rear end looks similar to the front of Dual Bump and is supposed to flex for a receiving rear end.

Flexing Ledge

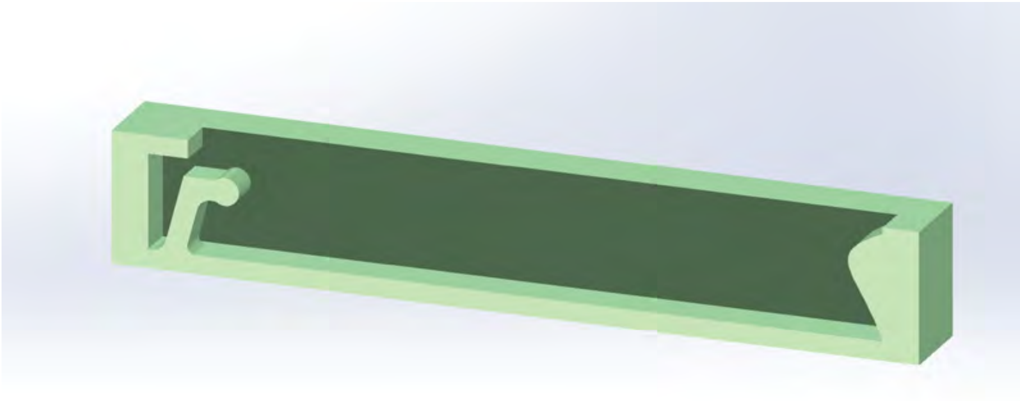


Figure 5.9: The Flexing Ledge concept corresponding to Flex Up - Bump with altercation on the flexing part.

The Flexing Ledge concept characterises through the front end pivot point placed upon a flexing member, becoming a flexing ledge-portion. The flexing action from the front end is supposed to enable the rear end of the fin to pass over the rear end bump, similar to the Dual Bump.

Tracks

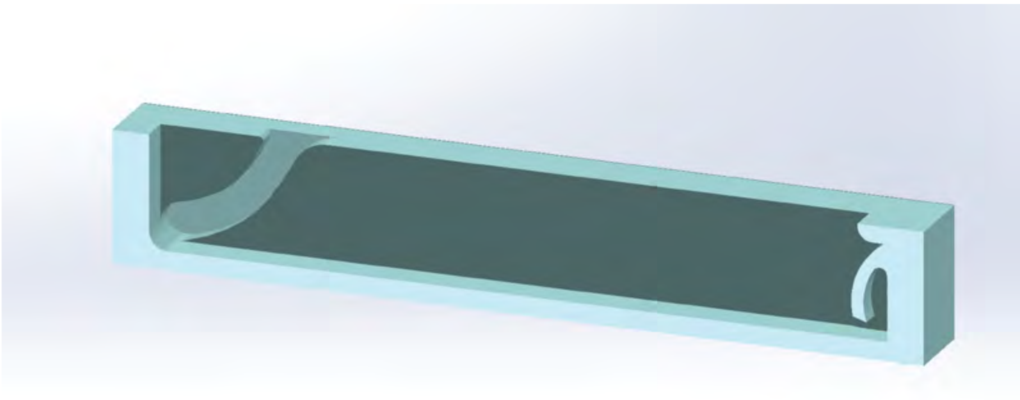


Figure 5.10: The Tracks concept corresponding to Tracks - Round Flex/Flex Down.

Tracks' front end consist of two tracks, alternatively referred to as trails, guiding an extruded fin-portion into the right position. The ability to rotate around said extruded fin portion enables the rear end to consist of a flexing agent. To test another feeling of a flexing agent the attaching part is for this concept fitted at the top of the fin plug.

Solid Ledge

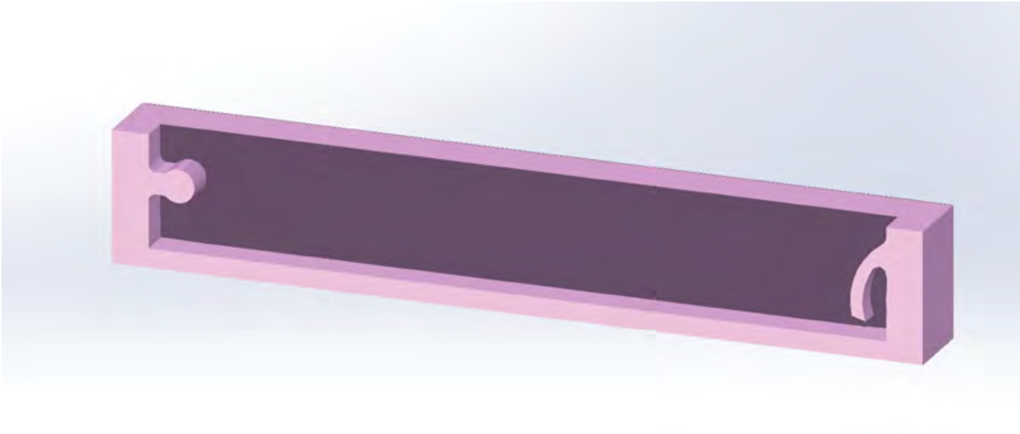


Figure 5.11: The Solid Ledge concept corresponding to Flex Down - Ledge.

Solid Ledge is similar to flexing ledge consisting of a front end pivot point where a ledge portion is protruding. The difference between the concepts is that the flex has moved to the rear end. Therefore this concept has a solid ledge in the front end, thereby the name; Solid Ledge. The rear flex is similar to Tracks', however, the detail design of this flex is experimented with to try different solutions of similar concepts.

Test Case

To receive feedback from users regarding the usability of the fin plug prototypes, user tests were conducted with both experienced and inexperienced fin users. In each test, the test user was asked to try the five different printed prototypes, attaching and detaching fins in their respective fin plugs. The printed prototypes can be seen in Figure 5.12. While trying them out, the users were asked to think aloud. For each prototype, the user then rated the fin tabs and fin plugs in different questions to extrapolate quantitative data from the test. This was followed up by asking the user which prototype was their favorite as well as which features were considered to be positive and which were considered to be negative.

Figure 5.12: Fin plugs with their corresponding attaching means. The protrusion on top of fin tabs makes it easier for users to grip the mechanism, which subsequently recreates how a fin could be attached or detached.

Test Results

The results of the quantitative part of the questionnaire is presented below in Figure 5.13. Each concept has one group of bars representing their ratings. Ratings ranged from 1, meaning the test user found it very difficult or that they were not confident that they used the prototype correctly, to 5, meaning the test user found it very easy or that they were very confident that they used the prototype correctly. Furthermore, each colour represents a different question that the users answered. The complete questionnaire and all results from the quantitative part of the user test can be seen in Appendix F.

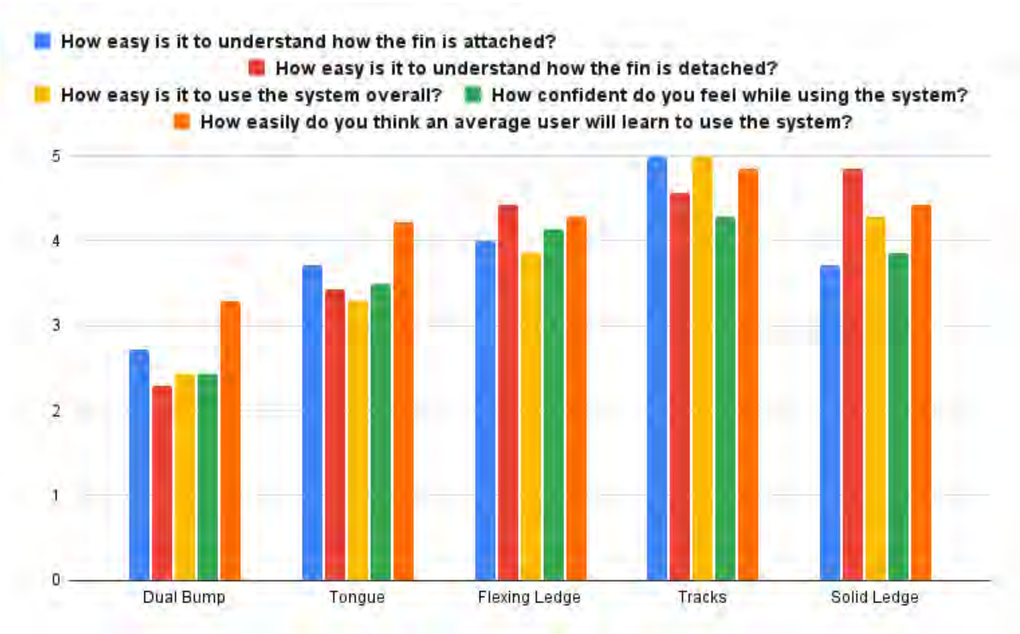


Figure 5.13: Compilation of the quantitative results from the user testing. Each group of bars represent one concept and the colours corresponds to different questions.

The qualitative results are presented in a summary below, see Table 5.5. Since the users differ in having previous experience and not, this was taken into consideration when evaluating different aspects. In the summary the key phrases from each question will be presented. These are gathered from different user tests with the similar previous experience.

Table 5.5 Summary of the qualitative part of the user tests. Divided into Inexperienced and Experienced users.

Question	Inexperienced Users	Experienced Users
What concept is your favourite?	Tracks Flexing Ledge	Tongue
Because of what reason?	Easy to understand	The feedback from attaching the fin. It lets the user know that the fin is secured.
	Satisfying snapping feel	Simple Design
		The nose part always ends up in the correct place.
		It does not require too much force to detach.
Which features do you consider to be positive?	When you get feedback that the fin is secured.	Sound Feedback
	When it is easy to tell the front end and rear end apart.	A constant pressure on the tab ensures that it is secured.
	When the rear end is conceptually understood.	
	When detaching does not require too much force.	
	Symmetry can be aesthetically pleasing.	
Which features do you consider to be negative?	Symmetry is confusing when attaching the fin.	Risk of dirt in the smaller cavities.
	When it is hard to understand how to detach the fin.	Symmetry is confusing.
	When the fin is fastened too tight.	If it is too easy to detach the fin.
	When the fin is fastened too loose.	
	If there is a wearing feeling of the motion	
	If there is a gap or play	
	Packaging difficulties with protruding parts	
If you could combine any front end with any rear end, what combination would you choose?	Front Tracks and rear Tongue x4	Front Solid Ledge and rear Tongue x1
	Front Flexing Ledge and rear Tongue x1	Front Tongue and the feeling of Flexing Ledge rear x1
	Tracks straight through x1	
	Small Ledge in front and the protruding heel from the rear of Tracks x1	
Other observations	Some users used Dual Bump in the wrong intended way.	The Dual Bump was used in the wrong intended way.
	One user did not notice the tongue section of that concept until the end of the session.	To use the ledge, the fin had to be placed in a specific angle according to one user.
	One user wanted a technique instead of force to be the locking/unlocking mechanism.	One user believes that the Flexing Ledge is not durable enough to be reliable.
	A window in some of the prototypes was used to understand the concepts' conceptual models.	A little play makes the user feel like the used technique is correct. However, play is maybe not that nice when it comes to riding.
		It was pointed out that small cavities might be problematic when it comes to sand and other dirt.

Discussion and Key Take-aways

The inexperienced users all seemed to appreciate the easy understanding of a specifically shaped front end to attach the fin. It is noted that all users did go through a learning curve and had usually a better understanding of the concepts picked up last. The order of the concepts altered from test to test to bypass this aspect. A sound feedback was always a positive property for the fin plug. It ensured the users that they used the concept correct, which seemed to be an important factor. However, a prototype fastened too hard instead made the users unsure if they tried to detach the fin the correct way.

Something to be noted is that the current solution needs an extra lever or tool to be detached even by experienced users when it is not inserted in a board. When the fin plug is inserted in a board, the board usually acts as a lever when detaching the fin. With this in mind, the input from the inexperienced users regarding how much force is required is weighted less than from the experienced ones. The focus therefore shifts towards how the user appreciated the feeling and affordance of the fin plug. How tight the fin plug is fastened is determined by tolerances, which can be altered before manufacturing to resemble the same amount of force.

The experienced users mainly focused on the simplicity, wear-factors, ease of maintenance and how the fin will act when hitting a stone or similar. They did however mention that some prototypes were too loosely fastened. Another aspect to be noted regarding the force is the contradicting opinion of the experienced users. The tightest fastened prototype, where most inexperienced users thought it was unpleasantly hard to detach, was by the experienced users described to be nice because it was secure but still easy to detach.

Regarding the affordance of the fin plugs, the experienced users had no confusion unless it was symmetrical. They also stated that the learning curve is almost immediate which suggests that designing a fin plug for first time users would be redundant. The fin plugs they currently use have had to be cleaned from sand and is something they took into consideration when discussing the presented prototypes.

5.1.6 Iteration of Tested Concepts

Going forth from the user testing and the five combined prototypes, two main concepts were chosen to re-iterate into new versions and hybrids of the two. The choice was made with the user input from the test phase. Since a difference in result was noted between experienced and inexperienced users, the chosen concepts considered both types of users to let the final concept be determined after the next iteration. To consider the easy affordance, Tracks was chosen. The second concept was Tongue because of the ensuring feedback and the tight fit.

There is a hypothesis that the same fit is possible to conceive on all of the different prototypes, but after taking time and scope into account, this option was discarded. The proof of concept from the already tested Tongue prototype weighted heavier in this process, being able to continue the development.

Focusing in on a detailed level design, the pros and cons from a manufacturing perspective is also included into the development. Regarding the concepts Tracks and Tongue, this mostly touches upon the fail-safe mechanism. There is a part of the assembly that is supposed to break before the other ones when an accidental force is thrust upon the fin. The concerning factors are the wear from the contact areas with said part as well as the manufacturability of the details.

The new batch of 3D prints, seen in figures 5.14 & 5.15, are designed to reflect a more finished product of the different concepts. Prototypes where the conceptual models are more apparent regarding the fail-safe mechanism, the attaching means and the manufacturability. The prototypes also express a possible outer shell for how the capture moulding will fasten the fin plug.

Figure 5.14: A final iteration of the Tracks concept with a fin plug designed for both possible assembly methods.

Figure 5.15: A final iteration of the Tongue concept with a fin plug designed for both possible assembly methods.

5.1.7 Final Concept

Having 3D printed the two previously mentioned fin plug concepts, with aspects regarding the new look and feel from the iterated geometries, as well as the needs listed in subsection 5.1.1, the choice of the final concept was made.

Looking at the results of the user test from subsection 5.1.5, differences between the concepts Tracks and Tongue can be identified. The main differences were that Tracks generates greater affordance for the first-time user, whereas Tongue generates a rigid feel and a satisfying feedback when the fin is locked in place. Having placed the flexible protrusion of the Tongue concept onto Tracks, the rigid feel and the satisfying snap became present on that concept as well. This left the debate of which concept was more desirable to if a high affordance should outweigh any other positives that could be found on the Tongue concept. The method used for determining said debate and choosing the final concept was *Pros and cons*, where team members list identified positives and negatives regarding the different concepts and based on that make the final decision internally [1, p.151].

Narrowing down the amount of concepts to only two, aspects regarding choice of material, manufacturing and assembly were taken into account. As stated by Radinn, a wide range of materials could be used, meaning any of the materials listed in section 4.2 could be utilised. However, given that the final concept of the fin plug would work as a concept for inspiration and not present exact dimensions, the choice of detail design would be decided by Radinn at a later stage. This thereby meant that no exact material properties could be sought-after without knowing the exact wear and thus reasoning was based on estimations regarding reliability and the cost the production would present.

When consulting Magnus Ullman [28], an expert in the field, he presented that basing on estimations is common practice when ordering plastic details. The discussion treated both materials for the fin plug as well as the fin with "Material Study" section 4.2 as a foundation. Regarding the fin plug, which is a stationary part that has to allow for recurring flexing, POM was suggested as a promising material. It allows for injection moulding, which was determined to be a profitable manufacturing method given the geometry of the plug. After evaluating the proposed moulds, parting lines and core pulls, seen in Figure 5.16, Ullman confirmed that injection moulding was the preferred option. The mould involves three cores but was preferred to the alternatives as it does not require any cores to be placed on the parting line and has easy to none post-processing, features that outweigh the disadvantage of using three cores. One section of the mould was considered to be sub-optimal regarding its thickness, but Ullman declared it as a possible solution still. Thereby the chosen material for the fin plug was Tenac 4010, a POM plastic, with injection moulding as the corresponding manufacturing method. The choice of assembly had not been established by Radinn for their future versions of jetboards and thus the final concept had to allow for both methods mentioned in section 4.4.

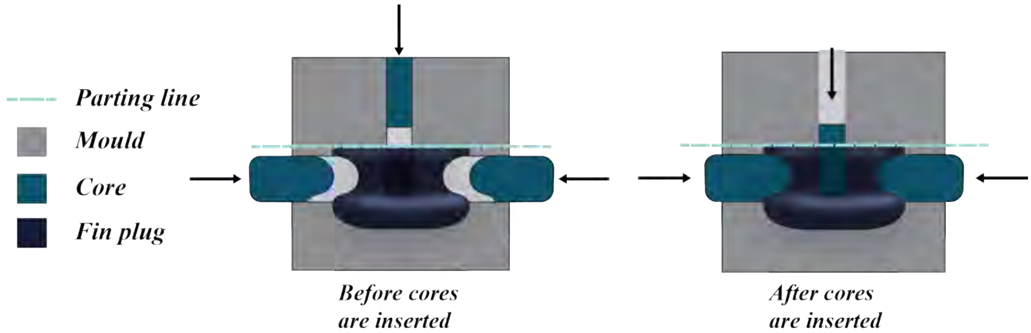
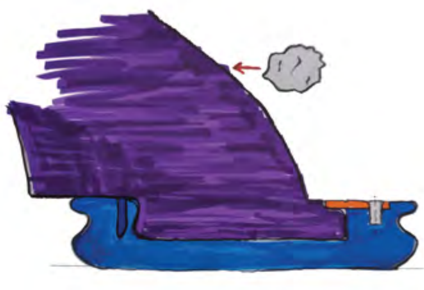


Figure 5.16: A proposal of injection moulds for manufacturing in a profile perspective. More perspectives of the mould can be seen in Appendix G.

Returning to the comparison between the concepts, one of the needs identified in subsection 5.1.1, is need no. 5, which states that the fin plug should be easy to manufacture. It was perceived that the Tongue concept entailed a simple geometry which would make for a less complicated manufacturing process than Tracks. The trails leading down to the bottom of the cavity were believed to add concern regarding draft angles when injection moulding the part. Tongue on the other hand was thought to require a simpler core pulling procedure since the travel distance of the cores is shorter. Furthermore, acknowledging that the Tongue concept generated good results in affordance as well, granted not as good as Tracks, the satisfaction of simplified manufacturing outweighed the high affordance. In addition, further comments regarding the ease of cleaning the Tongue concept, should sand or dirt enter the cavity, and the sleek finish when the fin is inserted, compared to the cavities and the protrusions on the Tracks concept, made the choice of the final concept fall on Tongue.

An additional aspect investigated was the fail-safe mechanism. However, this was not a strong deciding factor since the fail-safe concepts were still vague and highly dependent on further development. Nonetheless, the two different concepts had propositions on the fail-safe mechanism. In the Tracks concept, the protruding cylinder in the front end was suggested to contain two small cuts, dimensioned to break at a certain force. In the Tongue concept, the protrusion at the top of the front end was suggested to be a separate part, see Figure 5.17. This part is dimensioned to break at a certain force and is fastened with a screw. The manufacturing of a threaded part would add an additional segment of the production compared to a cylinder. However, since the fail-safe concepts still are hypothetical, the manufacturing of the fin plugs per se weigh heavier than of the fail-safes.



(a) The fin is fastened in the fin plug. The fail-safe part is fastened with a screw and has a small cut where it is designed to break.

(b) After hit by a stone, the orange fail-safe part breaks, keeping the fin plug and fin intact.

Figure 5.17: A section of a fin (purple) and fin plug (blue) with a fail-safe part (orange) designed to break.

Summary of Final Concept

The final concept came to be the Tongue concept, rendered in figures 5.18, 5.19 and 5.20, in colours based on the colour palette used by Radinn. It features a single cavity with a minor protruding tongue portion at the front end and a flexible protrusion at the rear end. The simple geometry enables affordance and generates a rigid feel with sound feedback telling the user when the fin is securely locked. It additionally creates a sleek finish, both attached and detached. The concept is made from POM and is manufactured using injection moulding. The concave shell enables assembly using either the method of Glassed-in or the method of Capture Moulding.

Figure 5.18: The top surface of the final fin plug concept.

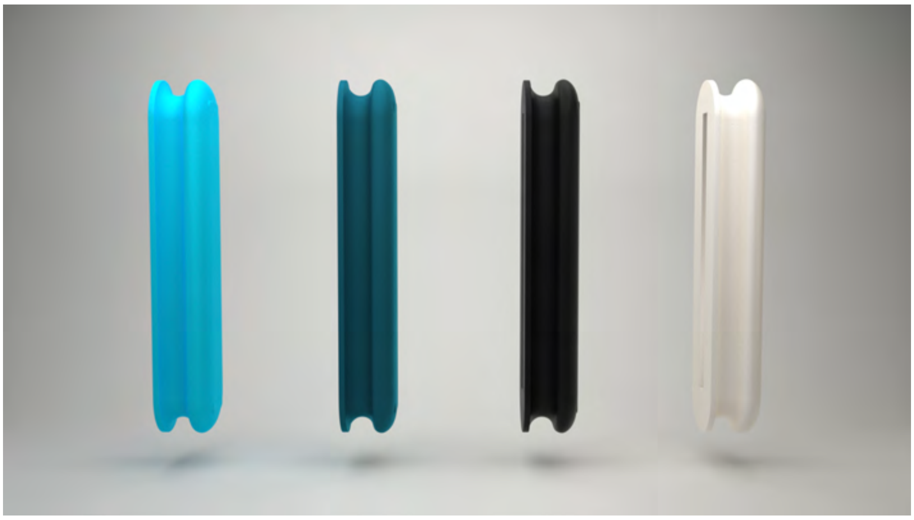


Figure 5.19: The side profile of the final fin plug concept.

Figure 5.20: The front end profile of the final fin plug concept.

The geometry inside the fin plug can be seen in figures 5.21 and **??**.

Figure 5.21: The cross-section of the final fin plug concept.

5.2 Fin

The following section describes the synthesis of the product development of the fin. The needs used for the concept development were the presented needs from Radinn, see subsection 5.2.2. Said needs described the company's point of view and in order to determine lead users' thoughts and opinions, interviews were conducted to interpret further needs. The section also describes the process of validation of the generated concepts through CFD-analysis together with physical testing, result interpretation and lastly showcase the final concepts.

5.2.1 Terminology

The following subsection explains the terminology used for describing fins.

The Height and Length of a Fin

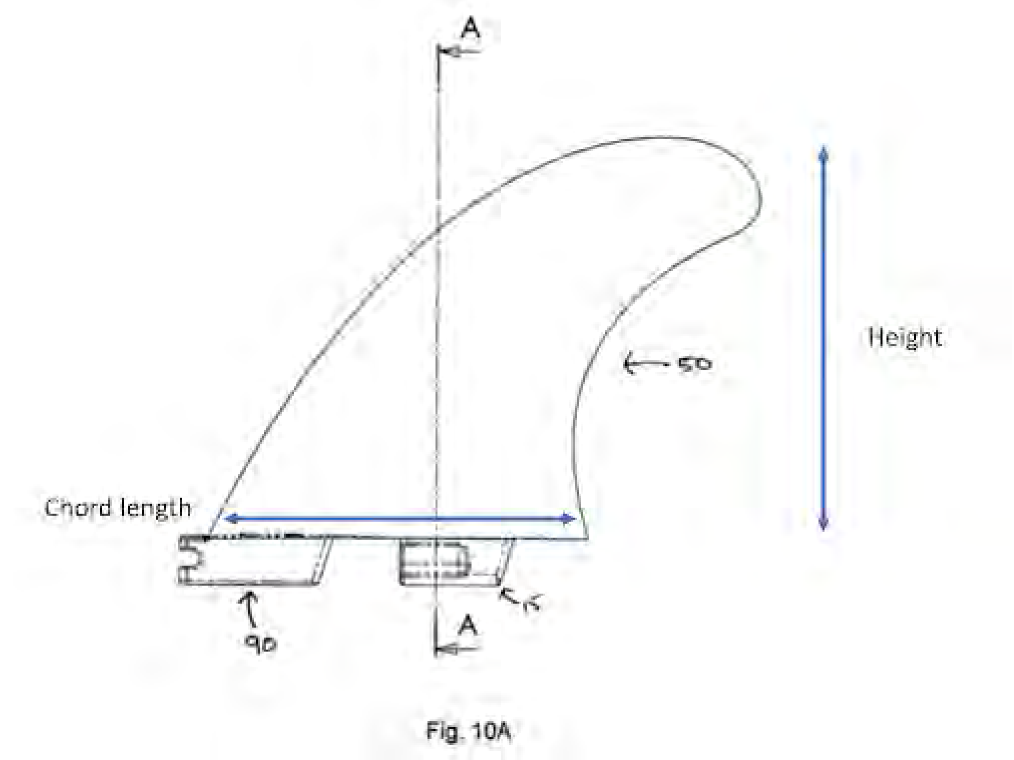


Figure 5.22: Illustration from current patent [41]. Height and chord length of the fin defined.

The Forces Acting on a Fin

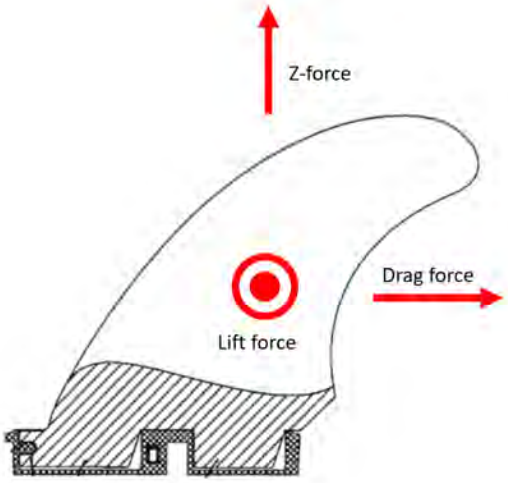


Figure 5.23: Illustration from current patent [41]. Lift, drag and z-forces defined.

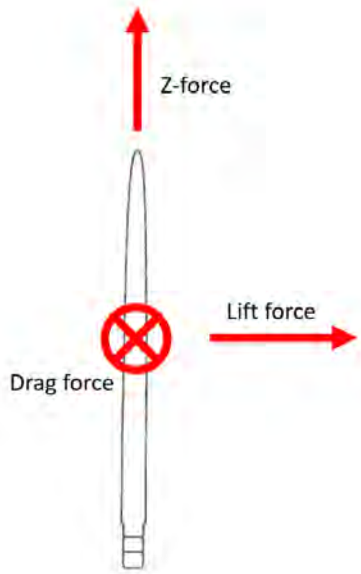


Figure 5.24: Illustration from current patent [41]. Lift, drag and z-forces defined.

5.2.2 Interpreted Needs

The following subsection showcases the needs for the fin development and how they were collected.

At the start of the project Radinn presented their needs regarding the development of new fins for their jetboards, see Table 5.6. These describe the necessities in a fin from the company's point of view, however not by the lead users'. To gather further needs, as well as helping to define needs 11, 12 and 19 in Table 5.6 below, interviews with lead users were conducted.

Table 5.6 Needs for fins, as presented by Radinn. Importance ranges from 1 to 5, where 1 is of lowest importance and 5 is of highest importance.

No.		Need	Importance
5	The fin assembly	entails easy manufacturing	4
8	The fin assembly	instills quality	3
10	The fin assembly	prevents damaging forces to be transferred onto the board	4
11	The fin	demonstrates the qualities sought-after in a fin	4
12	The fin	demonstrates new qualities optimised for jetboards	5
13	The fin	entails good affordance	4
14	The fin	provides a wide range of handling	3
15	The fin	eliminates drag force	3
16	The fin	has similar graphical design to Radinn	2
17	The fin	is environmentally sustainable	4
18	The fin	recycles if lost in water	2
19	The fin	allows for comfortable riding	4

Interviews

Interviews were conducted with four different lead users. Given that the field of jetboard fins is relatively unexplored by the market, a lot of latent needs and previously unthought of desired product features were presumed to exist. Thus, the interviews were conducted as open interviews, meaning both the interviewer and the interviewee can lead the discussion and there are no pre-established questions as well as no set time limit [47]. This was done in an attempt to gather a lot of information from only a limited amount of interviews.

A few noteworthy statements were:

"Call it what you want, but don't call it surfing."

"The jetboard should have more bite."

"I want the speed, but it can become too bumpy in choppy conditions."

"Usually I don't use fins to be able to slide and do tricks."

"I want the same sense of control over the whole speed range."

Full transcripts of the conducted interviews can be found in Appendix H.

From the transcripts of the interviews, statements were gathered that were considered to relate to jetboard riding or the overall user experience. These statements are found in Appendix I where they are also translated into individual needs. The method of translating statements into needs comes from the Ulrich & Eppinger process [1, pp.87-88], where the interpreted needs are expressed in terms of how a fin should perform, for example:

Statement: "I would like to be able to turn in higher speeds" $\rightarrow$ *Need: "The fins allow for better turning at high speeds"*

The needs were during the same process categorised depending on what they highlighted. This categorisation was merely a tool to more easily find similarities amongst the needs for further processing. The categorisation is seen together with the statements in Appendix I.

In the next step the needs were grouped together and put into a *Hierarchy* [1, pp.88-90]. During the process, needs that were found redundant or repetitive were eliminated. This resulted in a hierarchical list over the needs where they received a degree of importance depending on how extensive the problem was expressed by the interviewees or Radinn. The complete list is presented in Appendix J, but the needs with the highest rated importance is seen in Table 5.7. Furthermore, three needs were determined to be of a higher hierarchy. These needs had a wider perspective and acted as guidance for the process going forth.

Table 5.7 Interpreted needs with the highest rated importance. The rows in bold text are the three needs that acted as guidance in the overall concept generation.

There are different types of fins
The different types of fins offer different riding properties
The fins allow the rider to advance his/her riding style without the need to acquire a new board
The fins offer stability
The fins offer stability when riding against waves
The fins offer stability on still water
The fins offer stability in lower speeds
The fins reduce the bouncing of the board in wavy conditions
The fins offer different riding styles
The fins allow the rider to kneel when riding the board
The fins allow the rider to lay down when riding the board
The fins offer speed handling
The fins offer the rider control through the entire speed range of the board
The fins offer smooth acceleration of the board
The fins offer smooth deceleration of the board
The fins offer a sense of control when standing up
The fins help the board to act according to the riders intuition
The fins offer a unique riding feeling
The fins offer agility
The fins offer agility at lower speeds
The fins offer agility at higher speeds
The fins enable turns at different speeds
The fins initiate turns
The fins transfer rider interaction
The fins enable rider to interact through change of position
The fins offer sliding
The fins make use of the board's geometry
The fins enable riding in different conditions
The fins allow riding in lull
The fins allow riding in small waves
The fins allow riding in big waves
The fins allow riding in cold conditions
The fins are easy to handle

5.2.3 Concept Generation

From subsection 5.2.2, the three mentioned needs were considered to define the general concept development approach this project would take. These were: *There are different types of fins, The different types of fins offer different riding properties* and *The fins allow the rider to advance their riding style without the need to acquire a new board.*

Different fin concepts were thus generated from the remaining interpreted needs. The individual concepts were: *Tight turns, Smooth riding, Rookie, Long distance, Sliding/Tricks, Stand quickly and get going, Instigate turning, Easy turning and sliding, Max speed* and *Standard - Overall.* They encapsulated several needs from varying need groups and in that way the several fin solutions covered the majority of the remaining needs. Mentioned concepts and their corresponding needs can be seen in Appendix K. Dividing the entirety of the needs into smaller categories additionally made the concept generation phase more structured and allowed the team members to more easily focus on selected important needs.

The research conducted in "Surf Mechanics" subsection 2.5.3 and "Fin Mechanics" subsection 2.5.4 was used as a source of inspiration in hypothesising why certain interpreted needs existed and how these areas could potentially be improved. However, acknowledging that major differences between jetboarding and surfing exist, mentioned research could not be directly transferred into the context of this project. Ideas and concepts were also derived from other sources of inspiration, such as biomimicry and extreme sports.

Following are the different fin solutions with corresponding concept generation. Some sketches are shown below in Figure 5.25. For an extensive overview of sketches and ideas in relation to this subsection, see Appendix L.

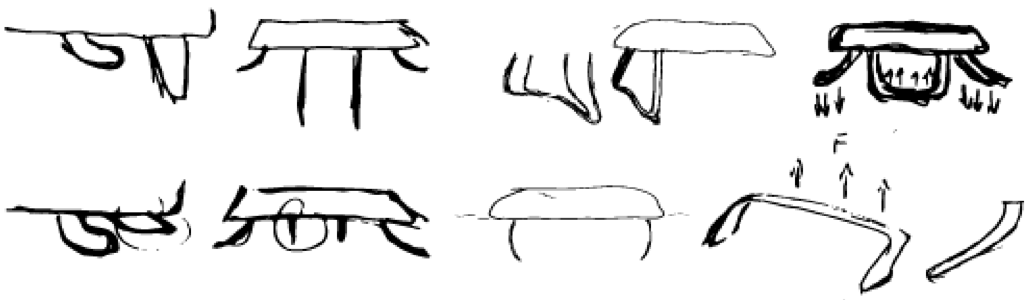


Figure 5.25: Extraction from the sketch session with focus on different concept groupings.

Given the scope and the time frame of this project, the number of categories of thought-of fin solutions were further narrowed down. Categories were combined where several solutions showed similarities in their function. The three final categories were *Tight Turns, Stability* and *Slide and Tricks*.

In an attempt to manipulate the dynamics of the jetboard, several hypotheses were made surrounding its handling. The jetboard is controlled by applying force to one of the sides and thereby pushing said side deeper into the water. According to the hypothesis laid out, greater pressure between rail and water surface generates improved control of the board. Thus, by assisting the rider in pushing down the desired side of the board, the rider will also be aided in making turns. Decreasing the effort needed to turn and staying in control of the jetboard also enables sharper turns and higher speeds, according to the hypothesis.

The mentioned hypothesis was applied in two different ways. Both approaches made use of the idea that when the rider wants to turn, one side will be pushed downwards and the opposite side will be pushed upwards. If the fin rises above the water surface, the non-wetted area will no longer provide lift or drag forces, meaning the net lift force will no longer equal 0 N, provided the fins used are symmetrical along the center plane of the jetboard. Thus, the first concept introduces a foil that generates lift force towards the water, as seen in Figure 5.26 below. The idea is to have the net force in lift pull the fin and jetboard towards the water surface. These fins also feature a rounded shape with the radius of a theoretical circle that centers in the roll axis. The theorised purpose of the shape is to decrease the resistance the outer fin will face when it is lifted out of the water when rolling the board. Furthermore, when the board is being tilted in roll, the outer fin will pull the tail of the fin outwards and the inner fin will pull the inside rail into the water and generate higher pressure. This concept was named Circular Fin.

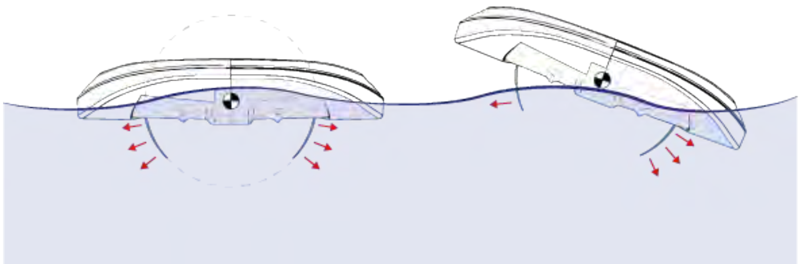


Figure 5.26: Illustration of the Circular Fins' hypothetical resulting forces in z-direction and lift when turning.

The second approach focused on the net momentum in roll. By applying forces pushing the fin and jetboard in the normal direction of the wetted underside, the jetboard should roll and push its rail further into the water. A fin with a cambered foil that pulls the jetboard downwards into the water was generated, as seen in Figure 5.27 below. This concept was named Side Fin.

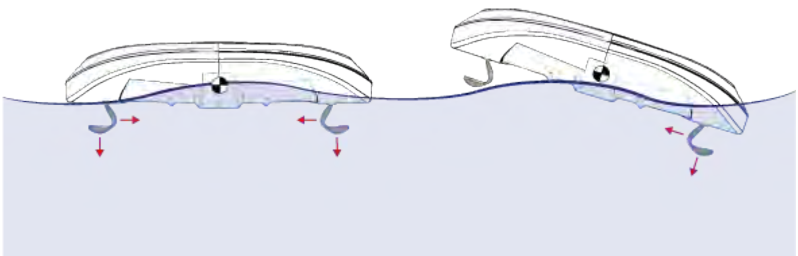


Figure 5.27: Illustration of the Side Fins' hypothetical resulting forces in z-direction and lift when turning.

Additionally, another hypothesis regarding the jetboard's dynamics was made. Considering the center of gravity (CoG), applying momentum in yaw could generate what in vehicle dynamics is known as understeer or oversteer. It was hypothesised that applying momentum in yaw, that forces the tail of the board away from the turn and the nose into the turn, would result in the rider taking a tighter turn. Potentially having the tail slide could also generate a more playful feel and a rush of adrenaline, something that would suit the jetboarding image. However, should the momentum in yaw show no effect in rotating the board around CoG, this could instead keep the jetboard from generating pressure against the water, resulting in inefficient turning. Two different concepts were developed, where one would generate positive momentum in yaw, i.e., oversteer, and the other one would generate a negative momentum, i.e., understeer. This can be seen in Figure 5.28. The hypothesis was tested to investigate the different turning abilities yielding from different tail handling. The analogy to vehicle dynamics is, as can be noted, to chiefly visualise the tail handling of the board. No direct comparison is drawn between steering theories in vehicle and jetboard dynamics.

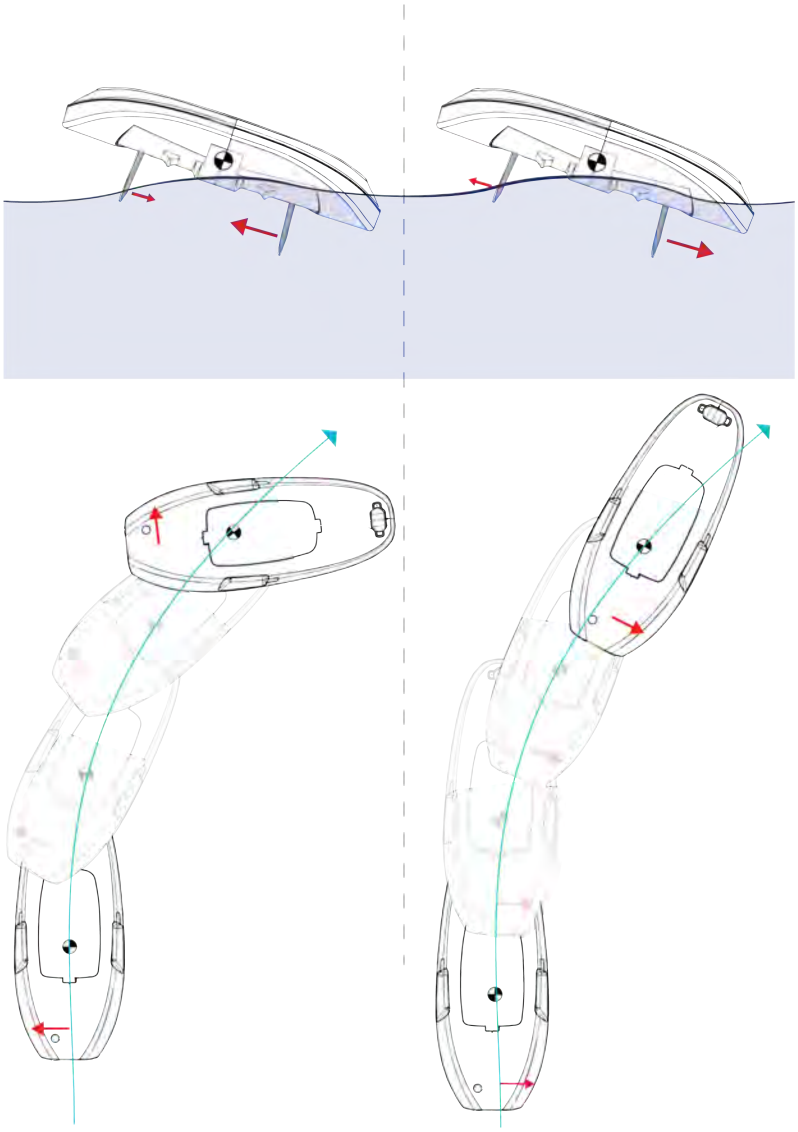
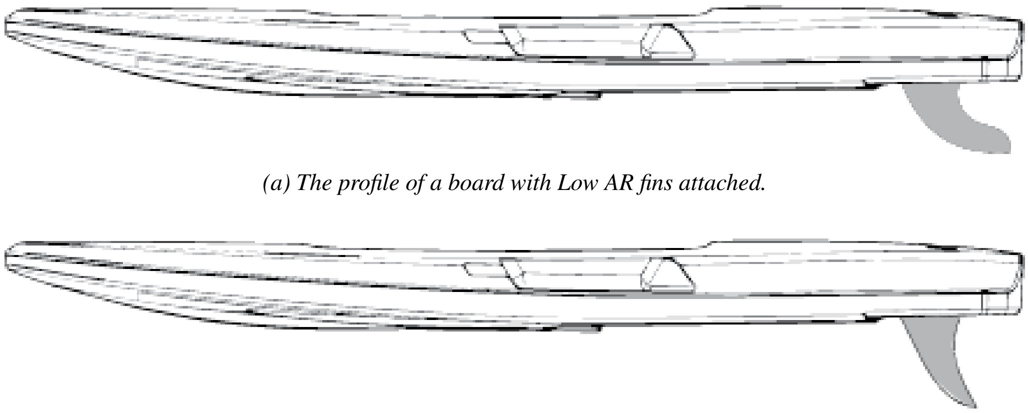


Figure 5.28: Illustration of the difference between the momentum and force hypotheses. The left section illustrates the momentum hypothesis referred to as oversteer. The right one illustrates the force hypothesis referred to as understeer.

The mentioned fins generating positive momentum in yaw, i.e., pushing the tail away from the turn, was further divided into two different designs. The fin in Figure 5.29a has a design with a relatively low aspect ratio, that is the ratio between chord length and height, as well as an extended rake. According to theories laid out in "Fin Mechanics" subsection 2.5.4, this should generate longer, smoother turns. This concept was named Low AR. In comparison, the fin in Figure 5.29b has a design with a relatively high aspect ratio, which according to the same theory should generate a more direct and responsive riding experience. This concept was consequently named High AR. Seeing as the theory surrounds surfboarding, it was deemed interesting to investigate if said theory would be applicable on jetboards after a physical test session. The test could additionally convey which riding property is more desirable for the jetboard user.



(a) The profile of a board with Low AR fins attached.

(b) The profile of a board with High AR fins attached.

Figure 5.29: Illustrations of the difference regarding aspect ratio.

For the category *Slide and Tricks*, a fin was generated that would give the user a feeling of control, as well as the ability to perform sliding and tricks on the jetboard. The option of not using fins at all to enable sliding and tricks is a choice often taken by the interviewed users. Therefore, a fin that creates desired handling and makes the user want to attach said fins instead of discarding them, was the main need. A short fin with an elongated base, called Slide'N'Tricks, was developed to generate lift force in the direction creating oversteer. Decreasing the size of the fin was intended to make the jetboard less stable and enable more tail sliding, as illustrated in Figure 5.30.

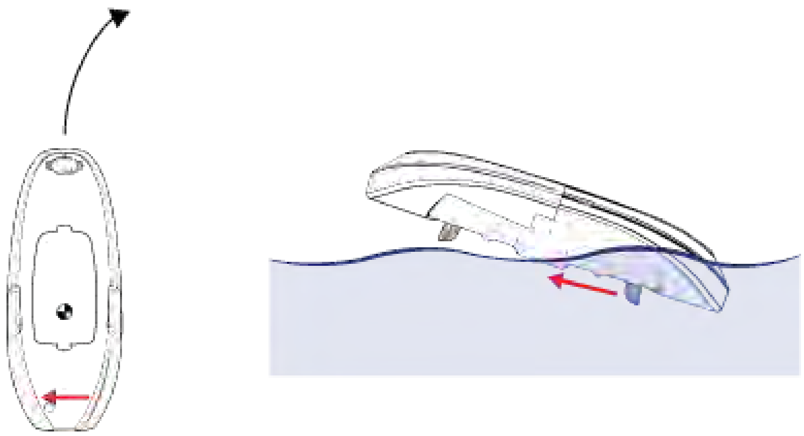


Figure 5.30: Illustration of a short fin generating oversteer.

The last category, *Stability*, had the purpose of dampening the effect of riding over a wave, i.e., the nose of the jetboard being pushed upwards by the water and the rider losing the feeling of control. To confront this issue, the CoG was again hypothesised to be the center of rotation when the nose of the board is being pushed upwards. In comparison to the theory regarding generating momentum in yaw around CoG, these concepts were designed to generate momentum in pitch. Seeing as the nose of the board is being pushed upwards when riding over waves, adding a force pushing the tail of the jetboard upwards would counteract the generated momentum from the waves. A spoiler that is supposed to be fastened on both the left and the right side was developed, called Full Spoiler, and is seen in Figure 5.31 below. The sections of the spoiler that are normal to the underside of the board were designed to generate relatively low lift in an attempt to only have the jetboard being affected by forces in the z-direction and make for an easier analysis when physically testing. The section that is parallel to the board has a cambered foil which, thanks to its angle of attack, theoretically should generate a force pushing the tail upwards and generate a counteracting momentum. The mentioned angle of attack was discussed and how an even greater force could be generated if the nose is being pushed upwards, thereby changing the direction of flow against the foil.

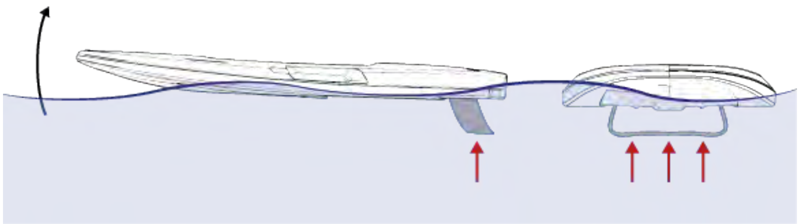


Figure 5.31: Illustration of the Full Spoiler attached and its hypothetical pitch reducing impact.

Next fin setup generated was named Side Spoiler. The fin pair generate relatively high momentum in yaw, roll and pitch. To effectively do so, a design that fastens to the two fin plugs on the same side was created. This design contains a unique foil that has been swept in an organic shape, with the main purpose of stabilising the board in pitch as well as pulling the jetboard towards the water when turning and thereby generating increased control when doing so. The side spoiler can be seen in Figure 5.32.

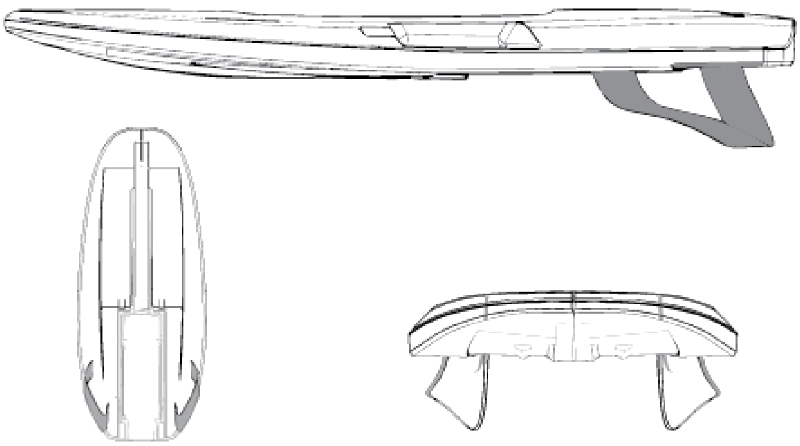


Figure 5.32: Illustration of the Side Spoiler from different views

Another design with intentions of stabilising the jetboard in pitch, when riding in choppy conditions, was the design called Slingshot, seen in Figure 5.33 below. Its extended rake with a flat surface at the end is theorised to dampen any potential pitch rate. The extension of the flat surface makes for an elongated lever, that thanks to the thin, flexible material should act similarly to a scuba diving fin. Furthermore, using a rake will hypothetically generate longer, drawn out turns, which should strengthen the feel of stability.

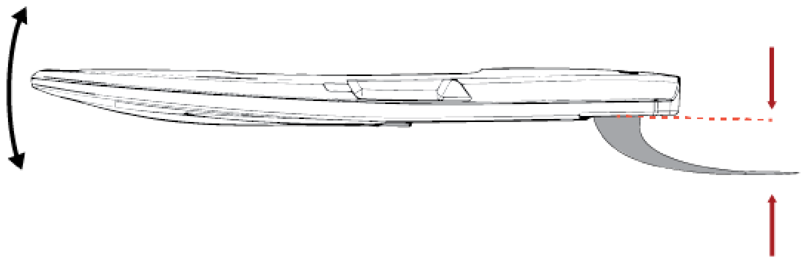


Figure 5.33: Illustration of the Slingshot concept with the hypothetical pitch reducing effect of using a lever to enhance its inertia.

5.2.4 Initial CFD-Analysis

Having hypothesised the dynamics of the different fin concepts, validation of their theoretical impact was conducted in CFD. The concepts were modelled in a 3D environment in order to go forth with the simulation study. Minor changes were made to the models in an iterative matter to reach the sought-after qualities. The theoretical data gathered below are results from the final iterations of the models. To generate reliable results from simulations with varying fin designs that would be directly comparable to each other, a sensitivity analysis was made. The purpose of this analysis was to define a computationally efficient domain in CFD with settings regarding specified size, physics model and mesh. This meaning that the settings should construct said efficient analysis but still yield results only marginally different from simulations with high definition settings. Assumptions regarding turbulence had to be made seeing as no prior knowledge could be applied on the fluid dynamic that is induced by the geometry of the board or the jetpack's effects on the water flow. Furthermore, not taking into account the geometry of the entire board, as well as the introduction of aerodynamics from the other side of the water surface, allowed the project to stay within the set scope and generate fin concepts from a previously relatively unexplored field.

Iterations of the said analysis and the corresponding results can be seen in Appendix B. The main final set-up parameters regarded the domain, boundary conditions and mesh. The domain size was set to 1x1x2 (m) and utilises a symmetry plane boundary condition to simulate the effect of using two mirrored fins simultaneously in a computationally efficient way. Another boundary condition set was an inlet velocity of 7 m/s in the positive x-direction, which is approximately the average speed from users on Radinn jetboards. Additionally, a tetrahedral mesh was used on the domain and refinements were made on the fin object as well as the flow of water leading up to it and the wake generated behind it.

A snapshot from the graphical user interface in Star-CCM+ can be seen in Figure 5.34. It represents the final version of the domain that was used for the entirety of simulations performed in this project. The grey xy-plane in said figure represents the surface of the jetboard and the blue xz-plane represents the mentioned symmetry plane.

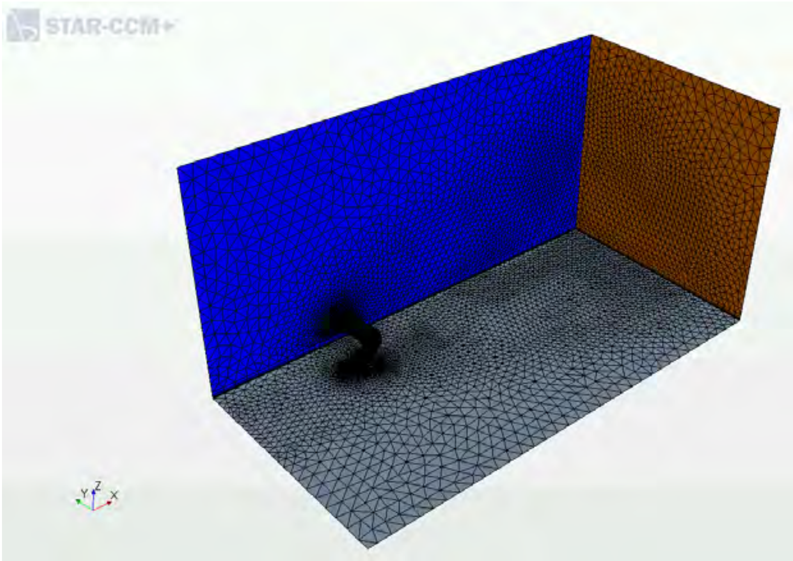


Figure 5.34: The final domain set-up. The blue plane in the figure is the mentioned symmetry plane which simulates having a mirrored fin on the opposite side of the plane. The grey plane represents the surface of the jetboard and the orange plane represents the outlet.

As stated formerly, assumptions regarding turbulence had to be made and therefore the accuracy of the generated scalar results could not be guaranteed. Using a reference point would therefore be more telling of the theoretical physical properties of the generated concepts. The set of fins that are currently shipped with Radinn jetboards were thus used as a reference point. However, mentioned fins were available in physical form but could not be acquired as a direct replica 3D model and instead had to be recreated in other ways. Granted the assistance of teacher Per Kristav at the Department of Design Sciences at Lund University, the physical fin was scanned using a 3D scanner and reconstructed as an stereolitography-file (STL) with a high mesh density that captured the geometrical details that the constructed CFD domain would allow for. For further information regarding the scan, see Appendix M.

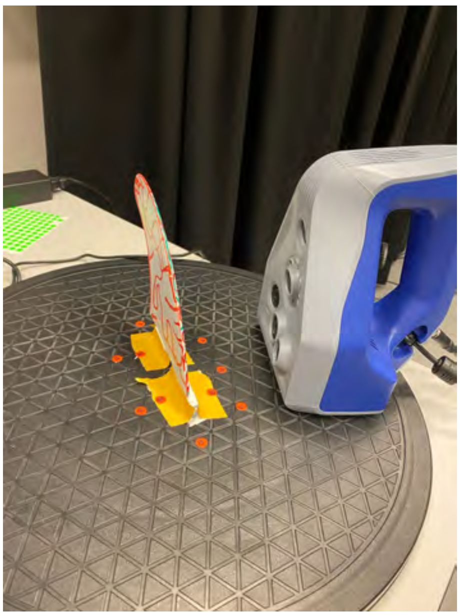


Figure 5.35: The fin that Radinn currently ships with their sold jetboards was scanned with a 3D scanner.

The currently used fin model, called Performer Medium (P.M.), was subsequently refined in remeshing software programs and afterwards placed in the generated CFD domain. Seeing as the toe-angle alternates between 0 degrees and approximately 3 degrees, depending on which Radinn jetboard is used, both angles were simulated and produced the following results:

Table 5.8 Results from simulation of the currently used fin by Radinn, at a toe-angle of 0 degrees.

Performer Medium	*toe-angle: 0 deg*	
Drag force	4,09	N
Lift force	47,8	N
Z-force	0,1	N
Roll momentum	5,61	Nm
Pitch momentum	0,37	Nm
Yaw momentum	-31,92	Nm
Fin nose momentum	0,14	Nm

Table 5.9 Results from simulation of the currently used fin by Radinn, at a toe-angle of 3 degrees.

Performer Medium	*toe-angle: 3 deg*	
Drag force	3,72	N
Lift force	12,2	N
Z-force	-0,4	N
Roll momentum	1,46	Nm
Pitch momentum	0,68	Nm
Yaw momentum	-8,49	Nm
Fin nose momentum	0,18	Nm

In figures 5.36 and 5.37 below, the difference in pressure distribution between the two toe-angles used can be seen. The colour mapped xy-planes represent the cross-section at a height of 8 cm.

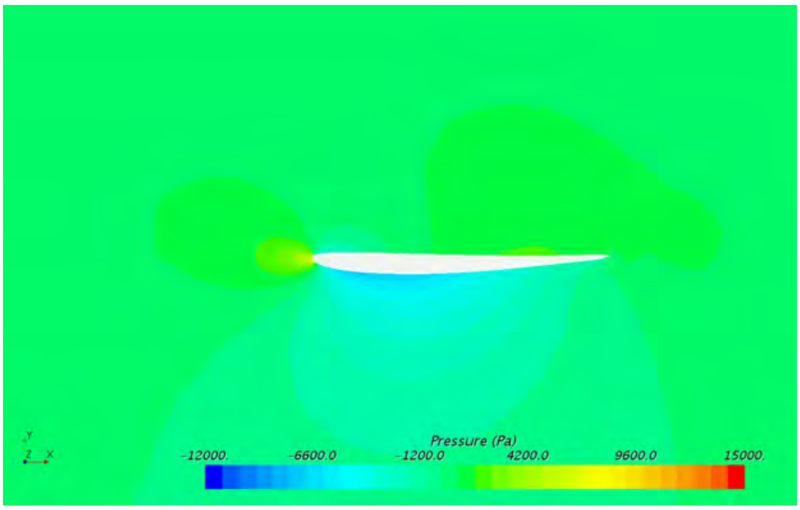


Figure 5.36: The pressure distribution at toe-angle of 0 degrees, viewed on an xy-plane.

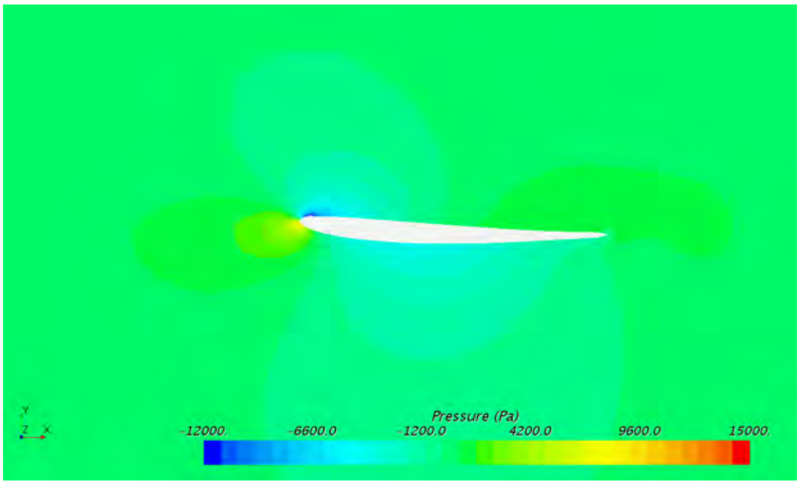


Figure 5.37: The pressure distribution at toe-angle of 3 degrees, viewed on an xy-plane.

From tables 5.8 and 5.9, a difference in the amount of generated lift can be seen. The amount of drag induced is however relatively similar, indicating that the lift-to-drag ratio is lower for the fin with 3 degrees of toe-angle. Figures 5.36 and 5.37 further indicate that the pressure difference between the different sides of the fin is larger on the fin with a 0 degree toe-angle. The blue zones, visualising a relatively low pressure compared to its surroundings, are clearly visible on both sides of the fin with a 3 degree toe-angle, whereas the 0 degree toe-angled fin shows a pressure decrease on mainly one side.

Having identified reference points, the previously mentioned concepts could be simulated and compared. All fin concepts simulated were placed on the same x- and z-coordinates in the CFD domain to limit potential sources of error. The positioning in the y-direction depended on the conceptualised position of the fin. Radinn had presented future attachment locations for a jetboard with 4 fins attached, meaning that the fin simulated in our domain was placed approximately 20 cm from the symmetry plane if a rear fin was simulated and approximately 30 cm if a side fin, more forwardly located, was simulated. Moreover, the fin concepts were iterated with minor geometrical changes, based on their simulated dynamic, to generate the desired properties. The following are the results of the initial simulations:

Mirror - Currently used fin, mirrored version

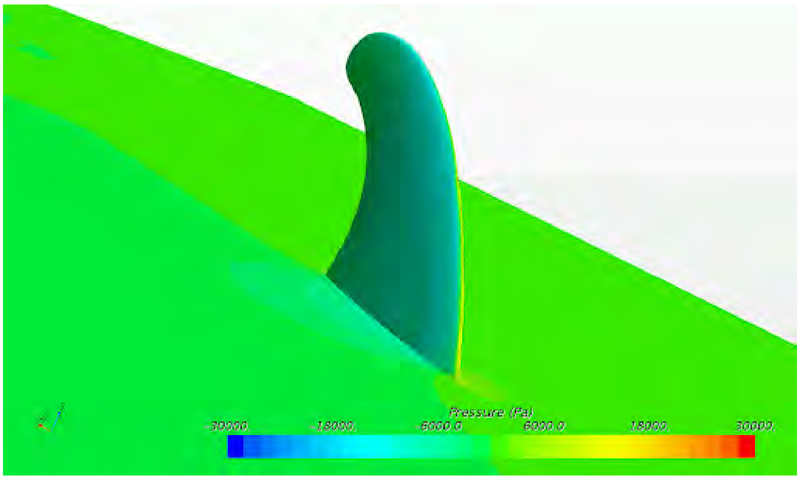


Figure 5.38: The pressure distribution on the Mirror concept.

Table 5.10 Results from simulation of the Mirror concept.

Mirror	*toe-angle: 3 deg*	
Drag force	6,73	N
Lift force	-85,12	N
Z-force	2,99	N
Roll momentum	-10,74	Nm
Pitch momentum	-1,29	Nm
Yaw momentum	58,66	Nm
Fin nose momentum	0,03	Nm

From Table 5.10, the results of mirroring the currently used fin by Radinn, and angling it 3 degrees in toe, can be seen. The purpose of simulating a mirrored fin of the currently used design is to clarify the effect of the foil by having all other geometrical parameters be identical. The idea of not angling the original fin -3 degrees in toe is to instead generate a positive momentum around the yaw-axis and test the hypothesis regarding oversteer and understeer. As seen in the mentioned table, the created lift and yaw momentums in absolute units are vastly higher than said momentums from the original fin, especially in comparison when angled 3 degrees in toe. The pressure distribution on the concept in 3D can be seen in Figure 5.38.

In Figure 5.39 below, a low pressure zone can be seen on the opposite side of the fin compared to that on the P.M. with a 0 degree toe-angle.

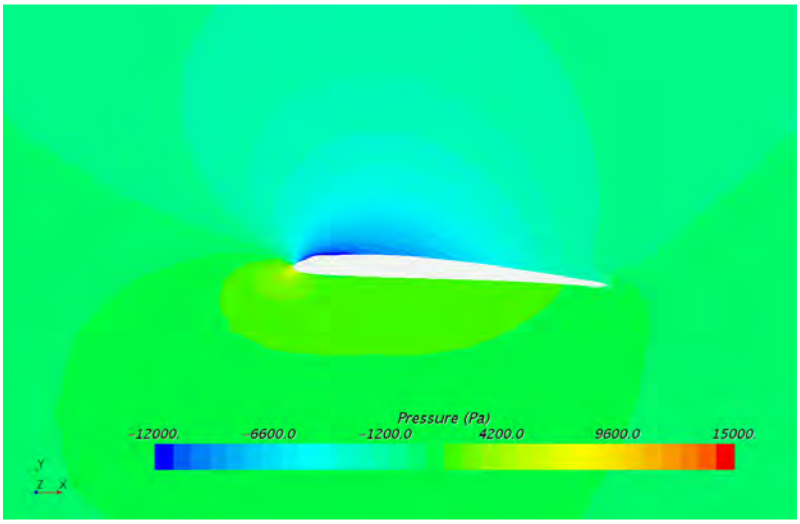


Figure 5.39: The pressure distribution around the foil on the Mirror concept, viewed on an xy-plane.

Circular Fin

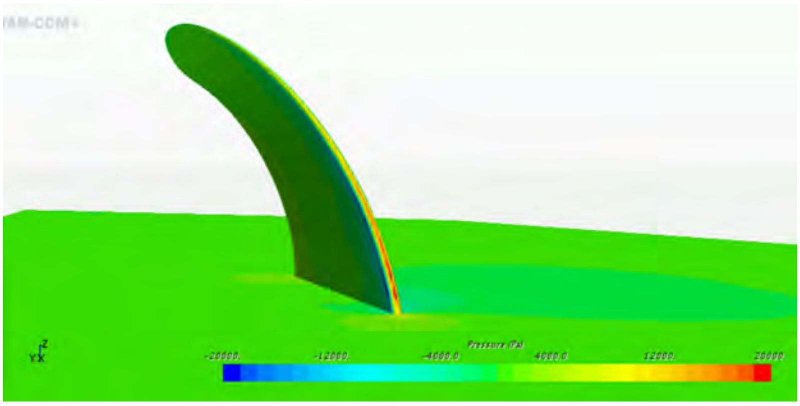


Figure 5.40: The pressure distribution on the Circular Fin concept.

Table 5.11 Results from simulation of the Circular Fin concept.

Circular Fin	*toe-angle: 0 deg*	
Drag force	4,81	N
Lift force	42,24	N
Z-force	19,64	N
Roll momentum	1,63	Nm
Pitch momentum	-12,87	Nm
Yaw momentum	-27,71	Nm
Fin nose momentum	-1,41	Nm
Fin chord momentum	2,6	Nm

Looking at Table 5.11, all parameters except z-force and consequently pitch momentum are similar to the P.M.'s. Hopefully this will highlight the effect of both z-force and the hypothesis drawn from Circular Fin, swept along a theoretical cylinder around the roll axis. The iterations of this concept mostly concerned the placement of CoG and how large the radius of sweep will be. The final model has a sweep corresponding to a fin plug placement in Radinn's third generation of boards. A visualisation of the pressure distribution can be seen in Figure 5.40.

In figure 5.41, the pressure plot can be compared with the P.M. at 0 degrees of toe. There is a slight difference located above the stagnation point, where the magnitude of the negative pressure is larger for the Circular Fin.

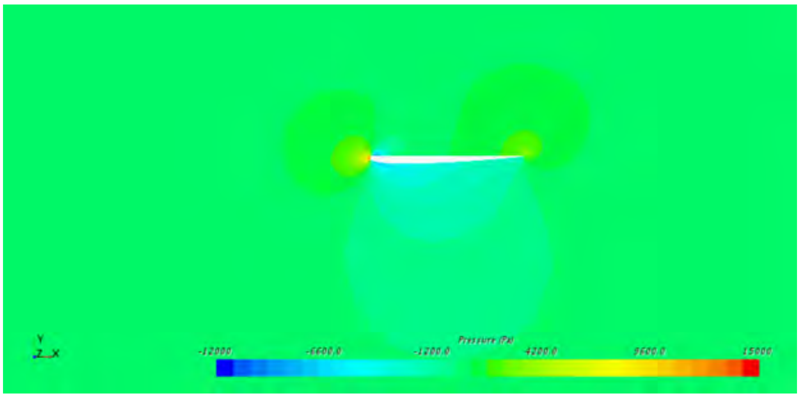


Figure 5.41: The pressure distribution around the foil on the Circular Fin concept, viewed on an xy-plane.

Side Fin

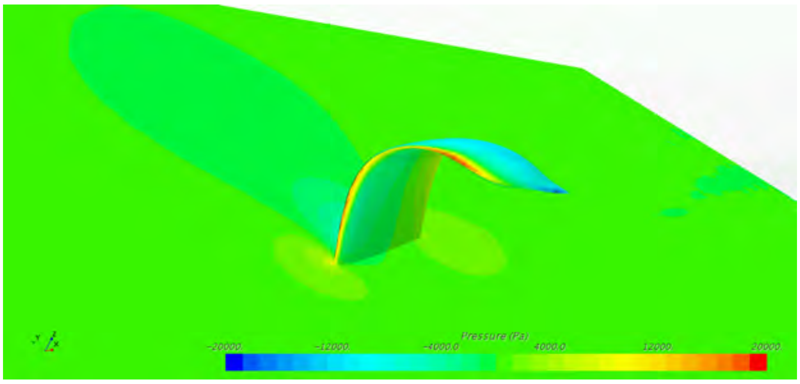


Figure 5.42: The pressure distribution on the Side Fin concept.

As seen in Table 5.12, out of the forces measured acting on the fin, the force acting in the z-direction has the largest absolute value. This comes as a result of the foil seen in figure 5.43. The foil uses a camber and an angle of attack that increases the lift-to-drag ratio, compared to a non-angled foil. The resulting low pressure zone in figure 5.42 can be seen on top of the foil, meaning the force acting on the fin will be pulling it towards the water.

Table 5.12 Results from simulation of the Side Fin concept.

Side Fin	*toe-angle: 0 deg*	
Drag force	8,63	N
Lift force	-31,93	N
Z-force	44,46	N
Roll momentum	-19,71	Nm
Pitch momentum	-19,62	Nm
Yaw momentum	16,13	Nm
Fin nose momentum	-4,88	Nm
Fin chord momentum	-4,14	Nm

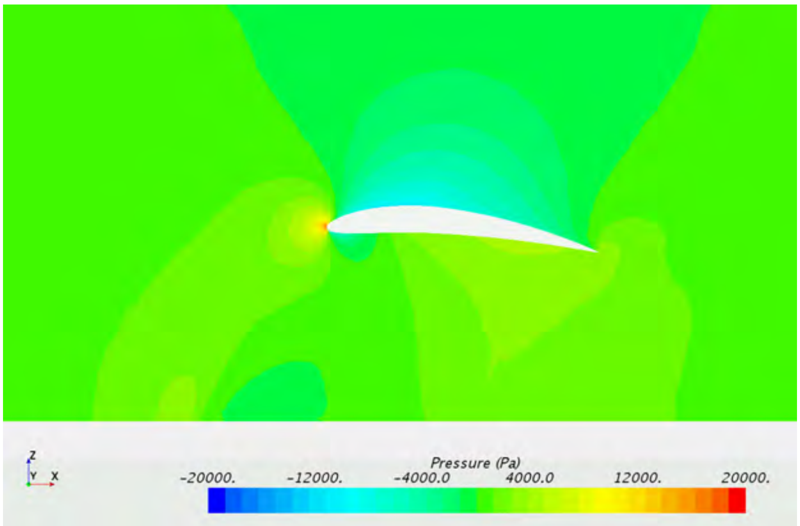


Figure 5.43: The pressure distribution around the foil on the Side Fin concept. Note that the cross-section is in the xz-plane, i.e., showing the foil on the top arc of the concept.

Low AR

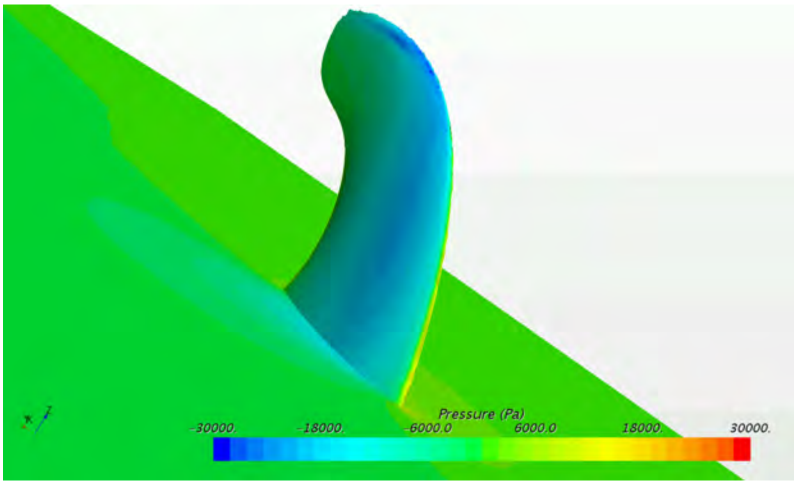


Figure 5.44: The pressure distribution on the Low AR concept.

Table 5.13 Results from simulation of the Low AR concept

Low AR	*toe-angle: 7 deg*	
Drag force	11,28	N
Lift force	-112,92	N
Z-force	11,56	N
Roll momentum	-15,69	Nm
Pitch momentum	-6,4	Nm
Yaw momentum	76,87	Nm
Fin nose momentum	-0,25	Nm
Fin chord momentum	-5,47	Nm

From Table 5.13, a lift force higher than that of the mirrored, currently used fin can be observed. The lift-to-drag ratio is approximately 10. Through figures 5.45, 5.46 and 5.47, the difference in foil is seen from the bottom of the fin to the tip of the fin. In all cross-sections, clear low and high pressure zones exist and theoretically verify the high lift generating effect that the entire fin supplies. A full, 3D view of the pressure acting on the fin can be seen in Figure 5.44.

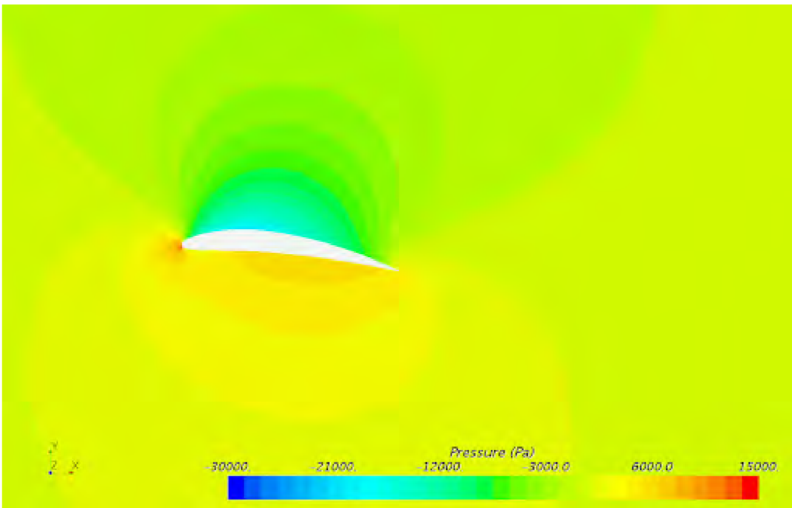


Figure 5.45: The pressure distribution around the foil on the Low AR concept close to the bottom of the fin, viewed on an xy-plane.

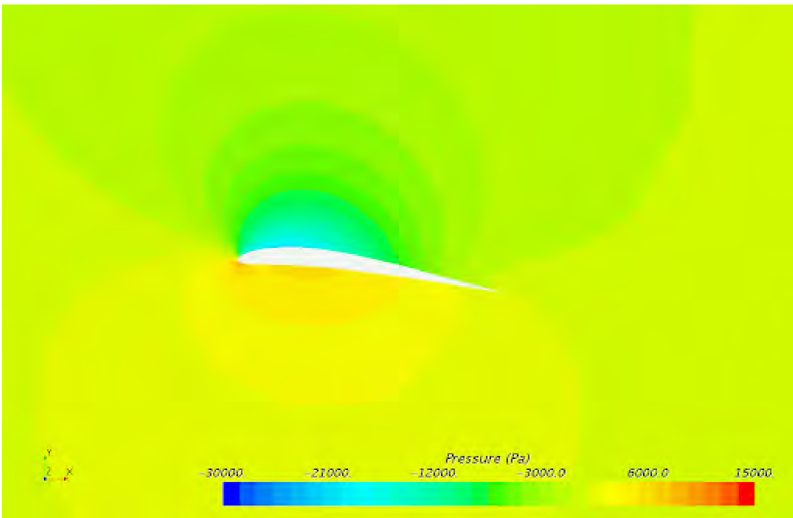


Figure 5.46: The pressure distribution around the foil on the Low AR concept at the middle of the fin, viewed on an xy-plane.

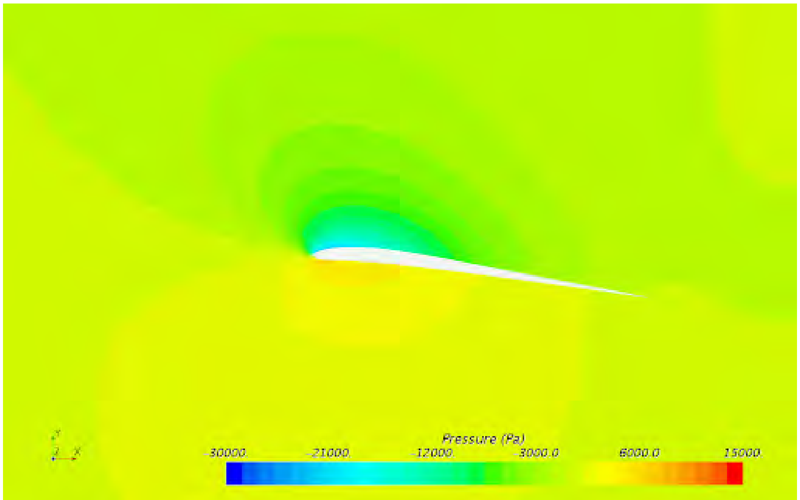


Figure 5.47: The pressure distribution around the foil on the Low AR concept at the tip of the fin, viewed on an xy-plane.

High AR

Results in lift and yaw momentum from table 5.14 can be compared to those from the simulation made on the concept Low AR as they are proportionately similar, with High AR generating marginally smaller forces in both lift and drag. As stated in subsection 2.5.4, a fin with high aspect ratio should generate an effective lift-to-drag ratio. Seeing as concepts Low AR and High AR have similar foils at the base, both in shape and chord length, their respective lift-to-drag ratios are arguably comparable for validating this theory. The ratio for Low AR is as mentioned approximately 10, whereas the ratio for High AR is approximately 13. A comparison between generated pressure plots, depending on the aspect ratio, can be seen in figures 5.44 and 5.48.

The change in foil over the fin and how it affects the dynamics is of high interest. In figures 5.49, 5.50 and 5.51, the change of the foil at different heights of the fin can be observed. Starting with figure 5.49, a low pressure zone is seen on one side of the fin and a high pressure zone on

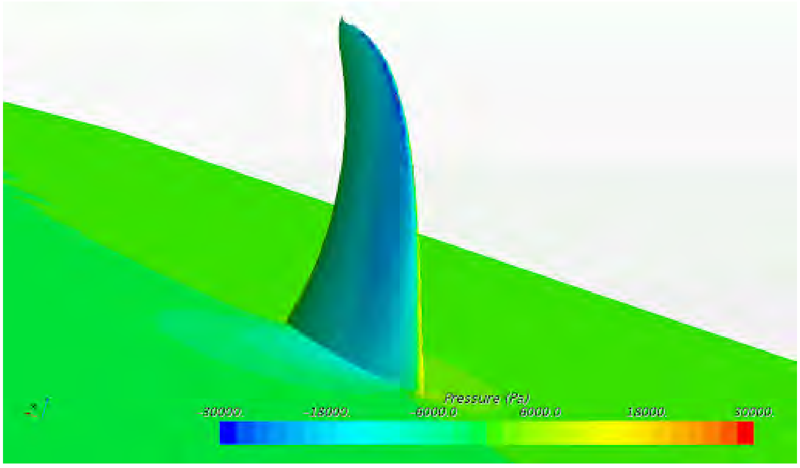


Figure 5.48: The pressure distribution on the High AR concept.

Table 5.14 Results from simulation of the High AR concept

High AR	*toe-angle: 5 deg*	
Drag force	7,64	N
Lift force	-98,39	N
Z-force	6,84	N
Roll momentum	-13,37	Nm
Pitch momentum	-3,52	Nm
Yaw momentum	65,42	Nm
Fin nose momentum	0,05	Nm
Fin chord momentum	-5,11	Nm

the other, which indicates the effect of the relatively aggressive camber angle. Moving up on the fin, the percentage of camber has been reduced. However, in Figure 5.50, areas with even lower pressure than in Figure 5.49 can be observed. Furthermore, the stagnation point, i.e., the point with the darkest red colour, has been moved slightly from the tip of the fin, down towards the high pressure side of the fin. Finally, Figure 5.51 shows a foil without camber that has a rather small, but clearly visible, low pressure zone. However, no clear high pressure zone can be observed. The idea of the concept was to utilise an aggressive camber at the bottom of the fin and have it transform into a so called 50/50 foil, generating no lift at 0 degrees angle of attack. When the fin is lifted out of the water, the bottom of the fin will be the first segment of the fin to be removed from the water, meaning ideally the segment generating the most amount of lift will be eliminated first. This would play on the need to have the fins initiate turning by applying the most amount of lift per degree of angle in roll when initially starting to tilt the jetboard. As seen in the mentioned figures, the difference in pressure between the two sides of the fin is the highest at the two lower cross-sections whereas the cross-section at the tip generates no clear high pressure zone.

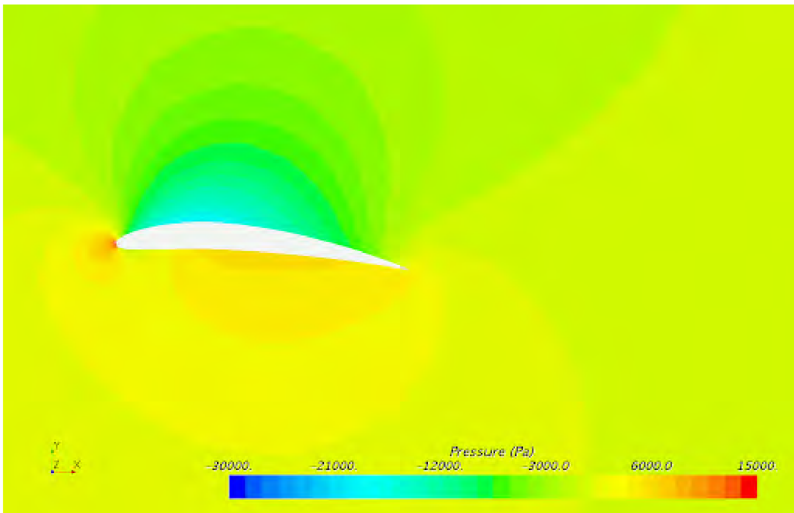


Figure 5.49: The pressure distribution around the foil on the High AR concept close to the bottom of the fin, viewed on an xy-plane.

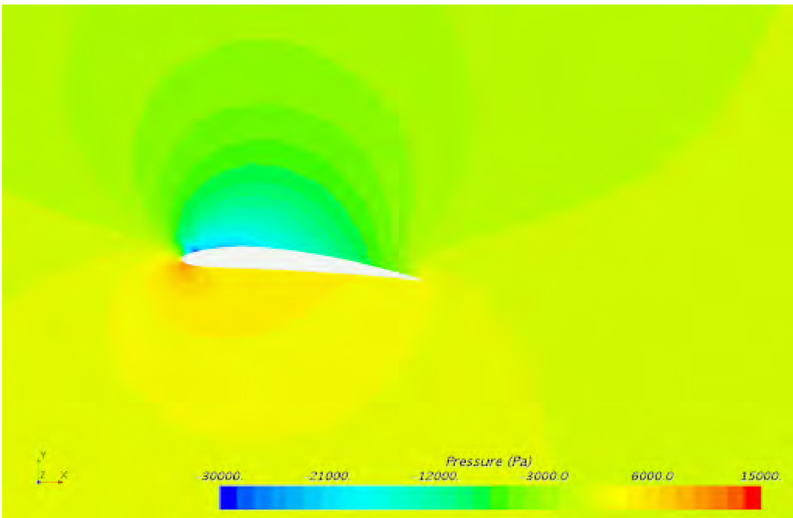


Figure 5.50: The pressure distribution around the foil on the High AR concept at the middle of the fin, viewed on an xy-plane.

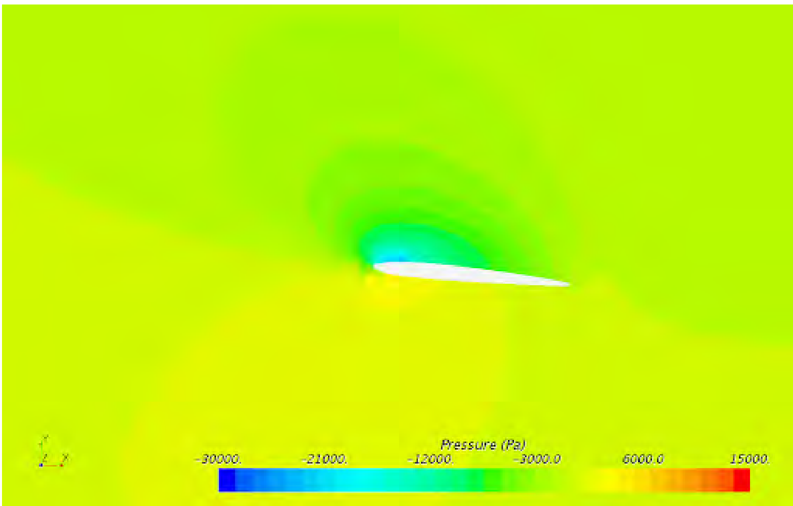


Figure 5.51: The pressure distribution around the foil on the High AR concept at the tip of the fin, viewed on an xy-plane.

Slide'N'Tricks

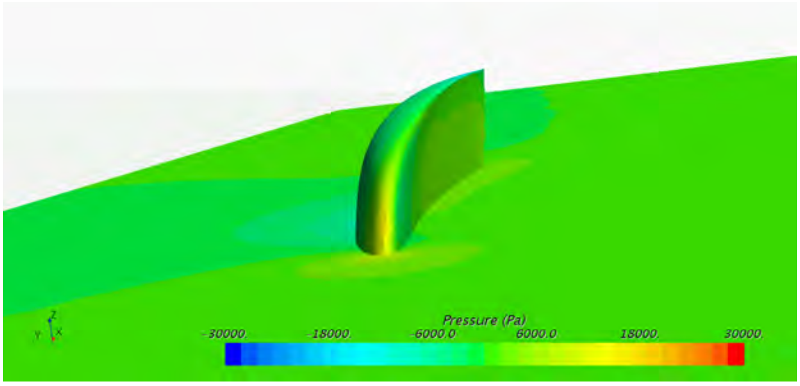


Figure 5.52: The pressure distribution on the Slide'N'Tricks concept.

Table 5.15 Results from simulation of the Slide'N'Tricks concept

Slide'N'Tricks	*toe-angle: 9 deg*	
Drag force	9,9	N
Lift force	-44,78	N
Z-force	17,76	N
Roll momentum	-7,72	Nm
Pitch momentum	-11,93	Nm
Yaw momentum	34,24	Nm
Fin nose momentum	-1,97	Nm
Fin chord momentum	-1,04	Nm

The purpose of the Slide'N'Tricks fin concept is to generate a lot of lift which should create a positive momentum in yaw. This means that when the jetboard is being tilted in roll, the outer fin is lifted out of the water, leaving the inner fin as the only contributor to lift forces, resulting in the tail of the board starting to slide and being pushed away from the turn. When sliding, the reduced resistance from a short fin, as seen in Figure 5.52, will hypothetically enable the sought-after playful feel. From table 5.15, a comparatively high lift force can be observed, which indicates promising dynamics for testing the concept physically. In comparison to the concepts High AR and Low AR, its generated lift is considered to be low, but as previously stated, the hypothesised resistance when sliding should be considerably smaller in theory, thanks to its short height. The relatively large low pressure zone, stretching over one entire side and generating mentioned lift, is seen in Figure 5.53.

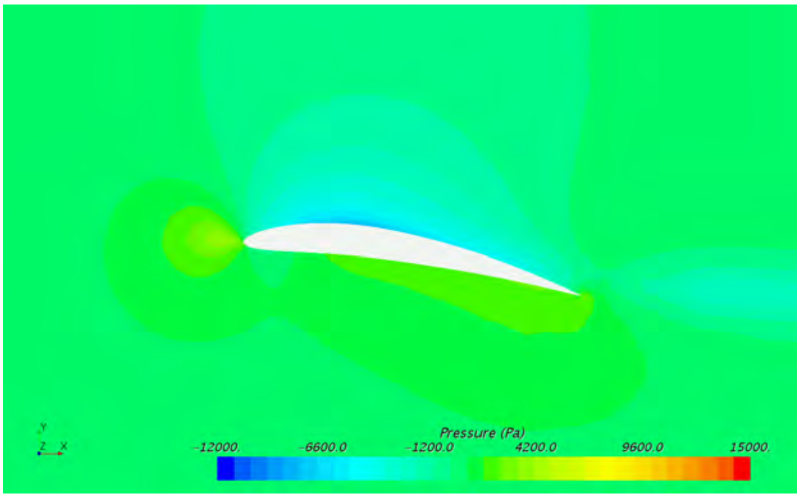


Figure 5.53: The pressure distribution around the foil on the Slide'N'Tricks concept, viewed on an xy-plane.

Full Spoiler

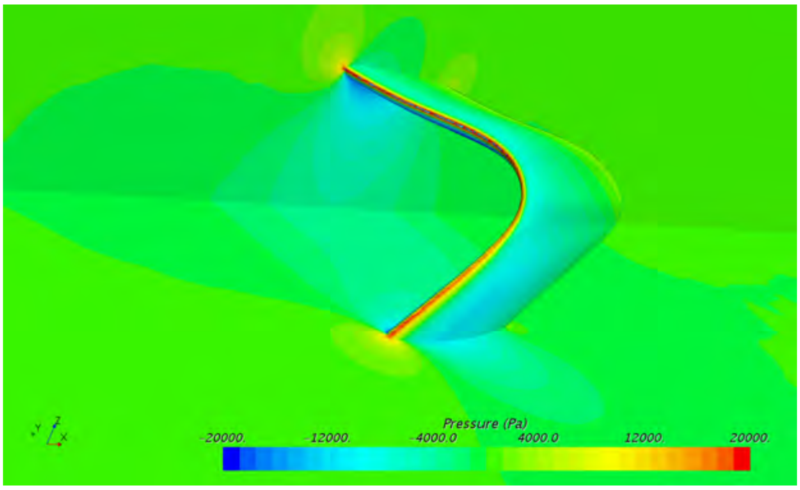


Figure 5.54: The pressure distribution on the Full Spoiler concept.

Table 5.16 Results from simulation of the Full Spoiler concept

Full Spoiler	*toe-angle: 3 deg*	
Drag force	14,99	N
Lift force	-21,28	N
Z-force	-204,49	N
Roll momentum	18,39	Nm
Pitch momentum	145,38	Nm
Yaw momentum	16,06	Nm
Fin nose momentum	21,64	Nm
Fin chord momentum	-21,02	Nm

As seen in table 5.16, the Full Spoiler concept generates a significant amount of force in the z-direction, i.e., pushing the board upwards. The reader should be informed that the data presented in said table only displays the effect of half of the Full Spoiler because of the use of a symmetry plane, as seen in Figure 5.54. The overall effect of the Full Spoiler is theoretically 410 N in the negative z-direction which consequently, together with the overall drag force, generates a pitch momentum of 290 Nm.

In figures 5.55 and 5.56 below, the difference between the foil used on the end plate of the spoiler and the foil used in the top section can be seen. The foil in figure 5.55 generates low pressure zones on both sides of the foil, meaning the lift force will be relatively small, as seen in table 5.16. This was considered desirable since the effect of generating pitch momentum should be the main focus when physically testing the spoiler and thus restricting the amount of lift will hypothetically decrease the effect of other factors. The foil in figure 5.56 however generates a relatively large low pressure zone and subsequently a relatively large z-force as seen in table 5.16. The purpose of using foils with a thicker base in relation to its chord length and camber was to increase the structural integrity of the overall object as it will endure high forces, according to the simulation.

A further observation from the simulation is the increased drag force, which compared to the currently used fin creates almost four times the amount of resistance when riding in 7 m/s.

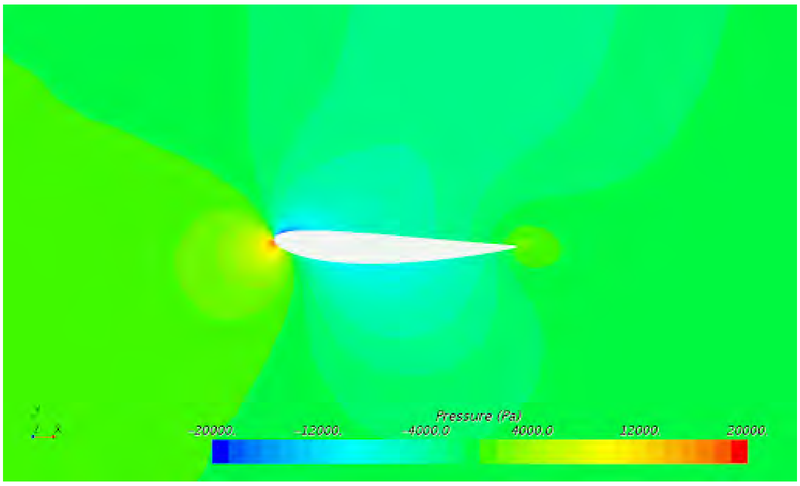


Figure 5.55: The pressure distribution around the foil on the end plate of the Full Spoiler concept, viewed on an xy-plane.

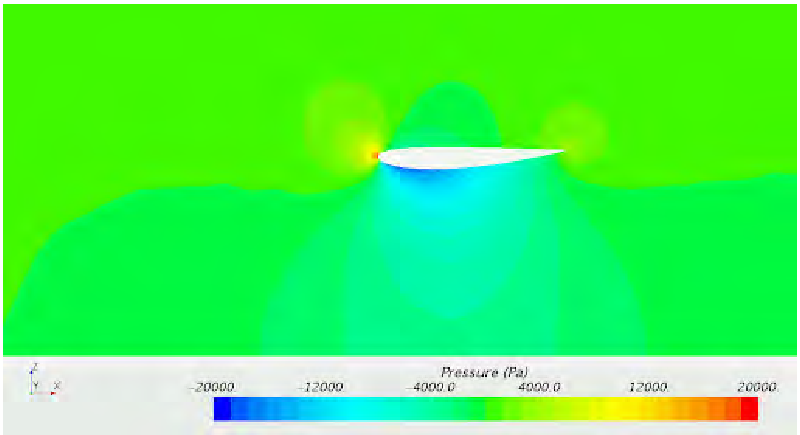


Figure 5.56: The pressure distribution around the foil on the top of the Full Spoiler concept, viewed on an xz-plane.

Side Spoiler

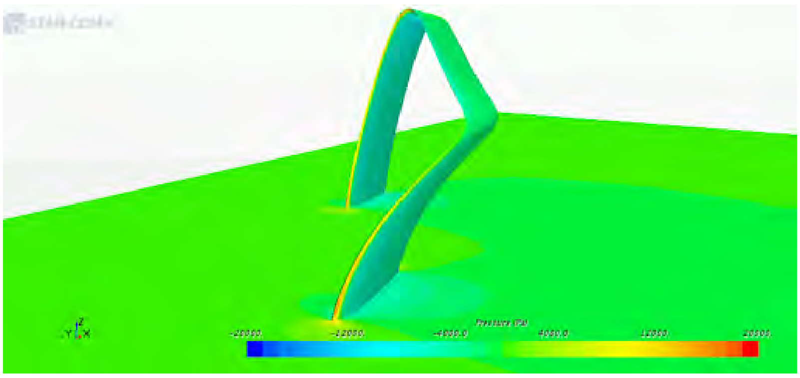


Figure 5.57: The pressure distribution on the Side Spoiler concept.

Table 5.17 Results from simulation of the Side Spoiler concept

Side Spoiler	*toe-angle: 0 deg*	
Drag force	16,87	N
Lift force	146,32	N
Z-force	-26,44	N
Roll momentum	28,77	Nm
Pitch momentum	20,66	Nm
Yaw momentum	-86,72	Nm
Fin nose momentum	3,61	Nm
Fin chord momentum	13,24	Nm

The Side Spoiler consists of two fin shaped bases with a bridge section, creating the spoiler. Since there are two fin portions in the same part when simulating, the forces will be above the average ones which can be seen in table 5.17. The spoiler has a upwards sweep which can be seen in figure 5.57. This will add forces in both z-direction and lift. Inspecting the fin portions and their pressure plots in figure 5.58, it can be noted that they have similarities with the P.M. at a 0 degree toe-angle.

The pitch moment is not of the same magnitude as the other spoiler concept, Full Spoiler. However, it is similar to the Side Fin but in the opposite direction. Hopefully, this will contribute to the understanding of what force in z-direction and subsequently pitch moment does for the user.

Regarding the spoiler, seen in figure 5.59, the pressure is slightly shifted to the rear end when compared to the Full Spoiler. Note that the interval of the pressures in the corresponding figures differ.

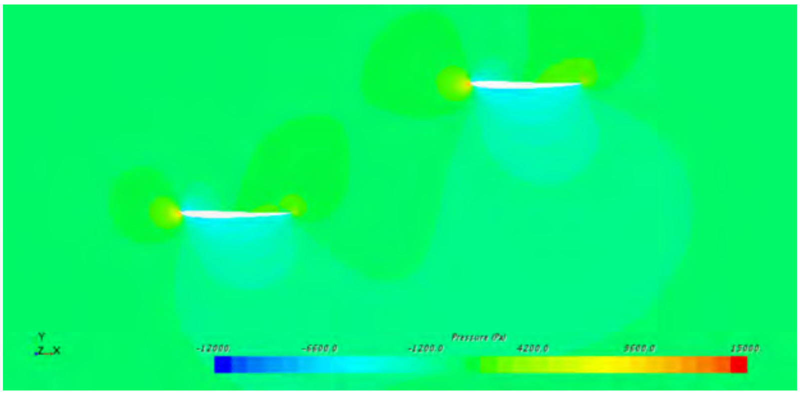


Figure 5.58: The pressure distribution around the foils on the end plates of the Side Spoiler concept, viewed on an xy-plane.

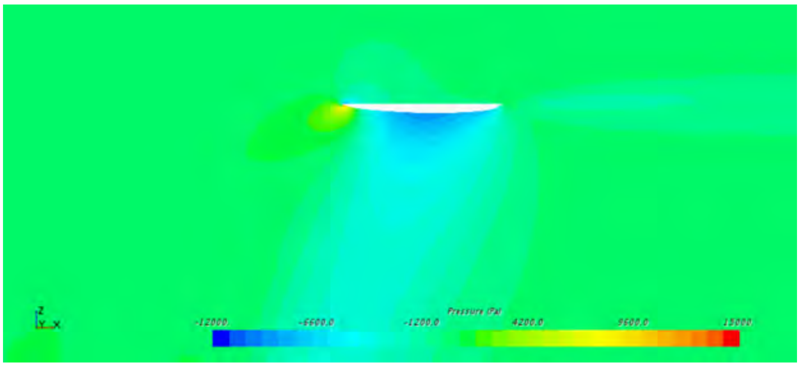


Figure 5.59: The pressure distribution around the top foil on the Side Spoiler concept, viewed the xz-plane.

Slingshot

Even though the foil is created with a slight inner camber seen in figure 5.61, the resulting lift is negative meaning it is directed towards the symmetry plane. The pressure has more presence closer to the base portion. In figure 5.60, the declining pressure can be seen towards the rake portion, unlike the other high rake concept Low AR. A slight difference in the pressure distribution can be seen around the flat surface portion. It should be noted that the pressure interval is drastically decreased in figure 5.62 where the difference can be seen. It is believed to exist because of the three degrees of rotation, making the water hitting one side harder than the other.

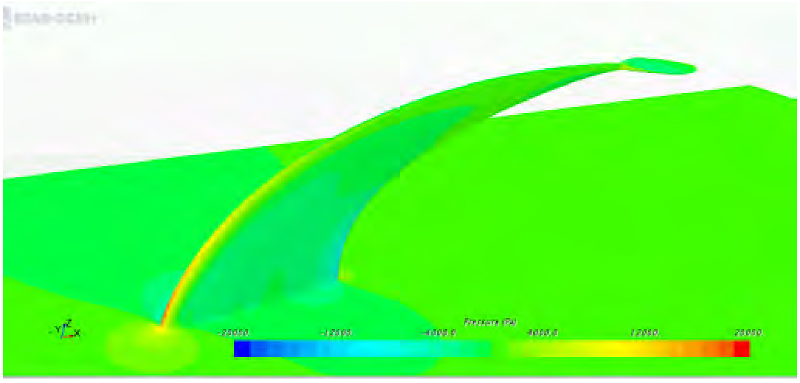


Figure 5.60: The pressure distribution on the Slingshot concept.

Table 5.18 Results from simulation of the Slingshot concept

Slingshot	*toe-angle: 3 deg*	
Drag force	5,45	N
Lift force	-23,19	N
Z-force	2,85	N
Roll momentum	-3,9	Nm
Pitch momentum	-1,48	Nm
Yaw momentum	16,22	Nm
Fin nose momentum	-0,16	Nm
Fin chord momentum	-1,71	Nm

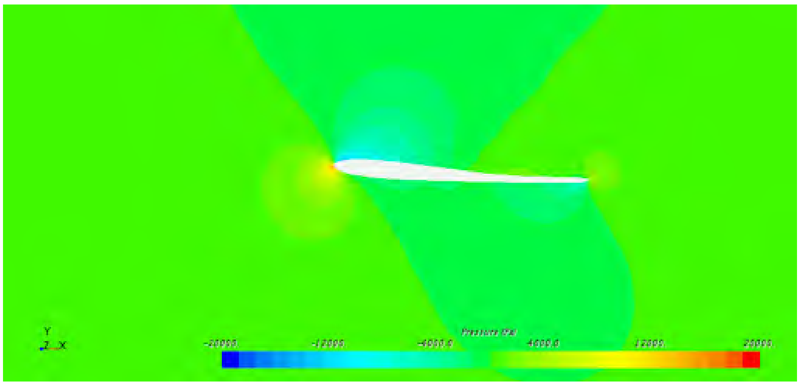


Figure 5.61: The pressure distribution around the foil on the Slingshot concept, viewed on an xy-plane.

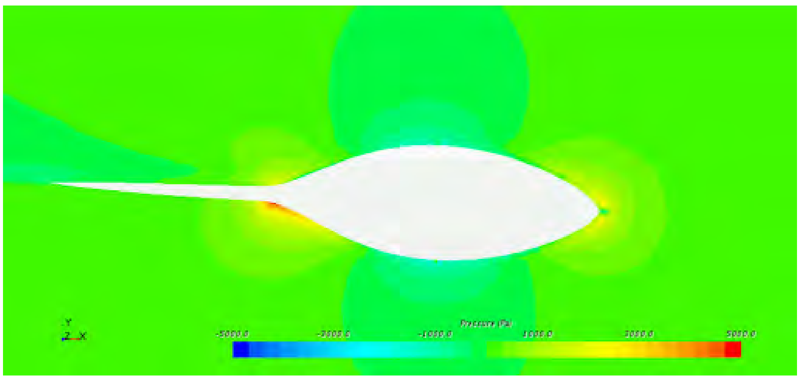


Figure 5.62: The pressure distribution around the flat surface portion of the Slingshot concept, viewed on an xy-plane.

Summary of the CFD-analysis

Table 5.19 The data summary of the analysis results.

	Drag force (N)	Lift force (N)	Z-force (N)	Roll momentum (Nm)	Pitch momentum (Nm)	Yaw momentum (Nm)
Performer Medium (0deg)	4,09	47,8	0,1	5,61	0,37	-31,92
Performer Medium (3deg)	3,72	12,2	-0,4	1,46	0,68	-8,49
Mirror	6,73	-85,12	2,99	-10,74	-1,29	58,66
Circular Fin	4,81	42,24	19,64	1,63	-12,87	-27,71
Side Fin	8,63	-31,93	44,46	-19,71	-19,62	16,13
Low AR	11,28	-112,92	11,56	-15,69	-6,4	76,87
High AR	7,64	-98,39	6,84	-13,37	-3,52	65,42
Slide'N'Tricks	9,9	-44,78	17,76	-7,72	-11,93	34,24
Full Spoiler	14,99	-21,28	-204,49	18,39	145,38	16,06
Side Spoiler	16,87	146,32	-26,44	28,77	20,66	-86,72
Slingshot	5,45	-23,19	2,85	-3,9	-1,48	16,22

The results from all simulations can be seen in Table 5.19. Notable values are the increased lift forces on Mirror, Low AR, High AR and especially Side Spoiler, as well as the z-force from the Full Spoiler concept. The concept generation focused on hypothesising desired functions of both lift forces and z-forces, leaving the desire to minimise drag forces to become secondary. As seen in the mentioned table, all concepts generate higher drag forces than the Performer Medium does at both 0 and 3 degrees of toe.

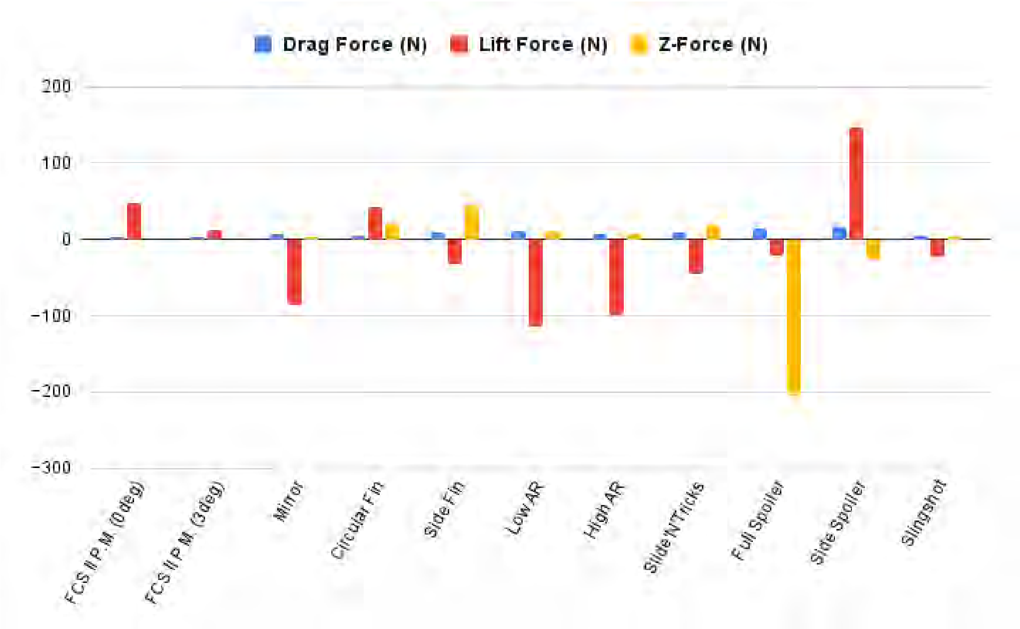


Figure 5.63: The generated force from the different concepts.

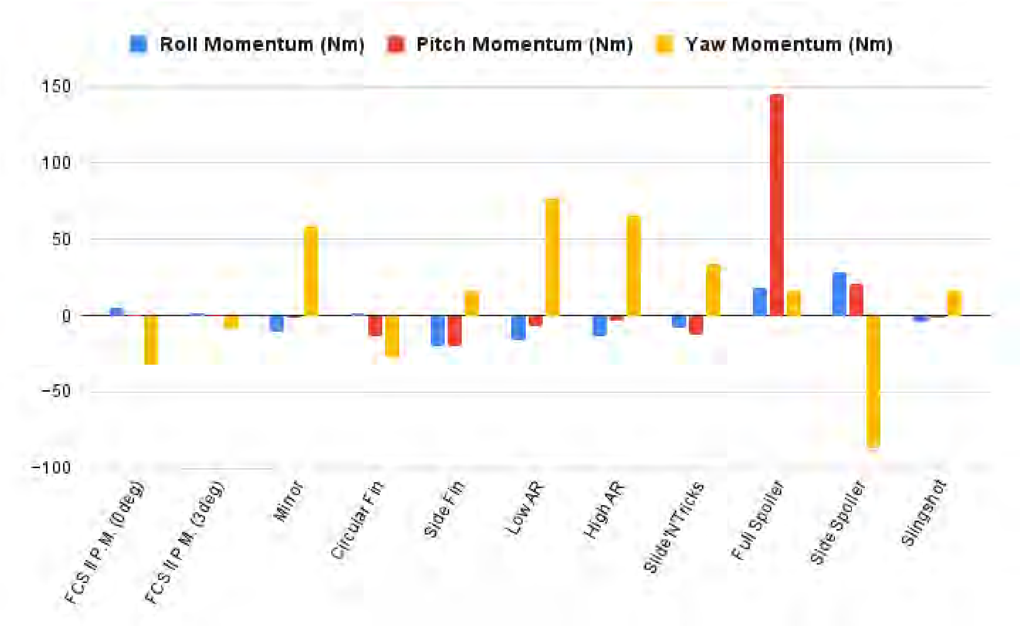


Figure 5.64: The generated momentum from the different concepts.

In Figure 5.63, the red bars indicate the amount of generated lift force. Noteworthy is that the currently used P.M. fin, as well as Circular Fin and Side Spoiler generate said force in the positive direction, whereas Low AR and High AR, among other concepts, generate lift force in the negative direction. The resulting momentum from the varying directions of lift forces can be noted in Figure 5.64, where concepts with relatively high lift forces generate high momentum in yaw in the opposite direction. This further showcases the difference between the mentioned fins and their design intent to research desired handling when turning in physical testing. Another notable observation is that Side Fin, but foremost Full Spoiler, generate comparatively high forces in the z-direction, be that in different directions. The purpose of the designs are however different, seeing as the Side Fin is intended to aid turning, and the Full Spoiler is intended to stabilise the jetboard around the pitch axis. This theorised function is also seen in Figure 5.64, where the Full Spoiler concept shows vastly higher generated momentum in pitch in relation to the other designs.

5.2.5 Physical Testing

The concepts presented in subsection 5.2.3, which later were simulated, all had a hypothesis to be confirmed or discarded. This was done through physical testing of the fins, after having them 3D printed with the currently used tab design to be able to attach them to the existing boards. The fins printed can be seen below in Figure 5.65. Due to budget constraints, not all fin concepts from subsection 5.2.4 were able to be printed. The prioritised concepts were reasoned to generate a foundation from which conclusions could be drawn regarding the potential functionality of the discarded concepts.

(a) Full Spoiler *(b) Side Spoilers* *(c) Circular Fins*

(d) Low AR Fins *(e) Low AR Fins together with Side Fins*

(f) High AR Fins *(g) High AR Fins together with Side Fins*

Figure 5.65: Fins printed for the physical testing.

For the physical testing, two test users with previous experience in riding jetboards participated. To get a reference and a reminder of how the currently shipped fins feel, the test users began the session using those and later progressed with using the 3D printed concepts. The users were asked to consider the experience of getting up on the board, accelerating from idle mode, doing both heel turns and toe turns at average speed as well as doing both heel turns and toe turns at higher speeds. After these tasks were performed, they reported to a secretary who noted their thoughts and responses on a prepared question sheet. The question templates can be seen below in lists *Overall (O)*, *Turn Handling (TH)*, *Combinations (C)* and *Spoilers (S)*.

O - Questions asked after all test runs.

O.1 Initial reaction, what is your opinion of the fin set?

O.2 What is the biggest difference compared to the original P.M. fin?

O.3 How easy was it to get control over the board, starting from standing/swimming in the water?

O.4 When reaching average speed, how did you perceive turning?

- (a) Compared to the original P.M.?
- (b) Any difference between heel and toe turns?
- (c) Did you have to adjust speed when turning?

O.5 When reaching average speed, how did you perceive stability/vibration/turbulence?

O.6 When reaching higher speeds, how did you perceive turning?

- (a) Compared to the original P.M.?
- (b) Any difference between heel and toe turns?
- (c) Did you have to adjust speed when turning?

O.7 When reaching higher speeds, how did you perceive stability/vibration/turbulence?

In list O are the questions listed that were asked in all test runs, to both test users. The reasoning of the questions is to have the test users reflect on their experience immediately after riding the jetboard. The first question is meant to allow the test user to answer openly, in order to extrapolate information potentially not considered beforehand. The remaining questions in list O were selected to generate feedback regarding stability and turning in different speeds, i.e., to map the physical feel of the hypothesised functions from the concept generation in subsection 5.2.3.

TH - Questions asked after test runs with Mirror, Low AR, High AR and Circular Fin.

TH.1 How do you perceive tail handling when turning?

- (a) Did you feel a clear difference in handling?
- (b) Did you feel aided in turning?
- (c) Did you prefer that type of handling (oversteer/understeer)?

TH.2 How do you perceive responsiveness? (responsive/delayed)

- (a) Did you feel a difference between the fins in responsiveness?
- (b) Which responsiveness is preferred?

TH.3 Were the turns tighter or longer?

The questions in list TH were only asked the test users after they had tested the concepts Mirror, Low AR, High AR and Circular Fin. The purpose of the questions was to actively get the test users to compare the concepts in terms of the tail handling, i.e., if or how hypotheses from subsection 5.2.3 regarding oversteer and understeer concur with physical testing. The questions also touched upon the responsiveness of using different aspect ratios, as well as the overall effect on how tight or drawn out the turns will be as a result of tail handling.

C - Questions asked after test runs with Side Fin, Low AR, High AR, the combination of Side Fin and Low AR, as well as the combination of Side Fin and High AR.

C.1 Did you feel a difference in turning?

C.2 Did you feel a difference in responsiveness

C.3 Did you feel a difference in top speed?

The purpose of Side Fin was to aid turning by applying momentum in roll when one fin is being lifted out of the water, whereas the purpose of Low AR and High AR was to affect responsiveness and oversteer. Testing the fin concepts separately, but also in a combination of Side Fin and Low AR or Side Fin and High AR, would therefore be telling if a combination would hinder or aid overall turning, responsiveness and speed. The questions in list C were thus asked after the tests on mentioned fin sets.

S - Questions asked after test runs with Full Spoiler and Side Spoiler.

S.1 Did you notice any difference in pitch?

S.2 How would you describe the difference between side and full spoiler?

S.3 Which do you prefer?

Two types of spoilers were used, with one providing force in the positive z-direction and the other in the negative direction. If and how the concepts affected the riding was then asked after tests with the said spoilers, as seen in list S.

Results From Testing

The testing, seen in Figure 5.66, resulted in a large amount of gathered data from only two test users. The condensed results from testing are seen in tables 5.20 - 5.29 below. The conditions during the testing was a smooth sea with wavelets alongshore. It was overcast with an air temperature of around 18°C and a water temperature around 10°C.

Figure 5.66: Test users trying different fin concepts and being asked questions afterwards.

Table 5.20 The results from testing High AR.

High AR	**Lasse**	**Philip**
Stability	Wobbles more than the current ones. They felt overall a bit more unstable. Vibrating at higher speeds.	Wobbly, almost like riding without fins, more unstable at higher speeds.
Turning	Could go into slightly tighter turns but stil wobble when pushing. They are still more unstable when turning than P.M..	Not great grip, wobbly in turns, less control than P.M., felt like the board randomly let go of control in turns.
Other comments	Similar to Low AR. A little more responsive.	Felt like the board was sliding a bit, the idea of oversteer was preferred over understeer, did not feel responsive, felt marginally aided in turning.

Table 5.21 The results from testing Low AR.

Low AR	**Lasse**	**Philip**
Stability	It was wobbly. Alright in the beginning but after a certain speed vibrations occured. You could feel that the fins had low stiffness.	Wobbly, almost like riding without fins, more unstable at higher speeds.
Turning	Not as comfortable to turn with. They felt more unstable in turns. They slide a bit as well when turning. Similar to Mirror but with a worse, more vibrating feeling.	Not great grip, wobbly in turns, less control than P.M., felt like the board randomly let go of control in turns.
Other comments	I probably like the shape still, but they are too soft I believe.	Felt like the board was sliding a bit, the idea of oversteer was preferred over understeer, did not feel responsive, felt marginally aided in turning. Very similar to High AR but generated marginally improved grip and stability.

Table 5.22 The results from testing Side Fin.

Side Fin	**Lasse**	**Philip**
Stability	Speed is the biggest difference but it has the same stability when going straight as the P.M.. When turning it felt more unstable.	Stability similar to using P.M..
Turning	It can start off with good grip but when really inside the turn you can feel it loose grip. Especially when pushing hard. Makes it unstable.	Smaller turns were OK, taking more aggressive turns felt weird.
Other comments	Bad acceleration, lot of drag and not so high top speed. It sucks the board to the surface, it feels weird and makes it slow.	More responsive than P.M..

Table 5.23 The results from testing a combination of High AR and Side Fin.

High AR + Side Fin	**Lasse**	**Philip**
Stability	The combination helps with the wobblyness of the High AR. It feels like the Side Fins grabs the water more compared to with only Side Fins. Grabbing and giving more traction instead of getting stuck to the surface and slowing down.	Feels stable, gripped well, could ride in very straight lines.
Turning	It was more stable than P.M.. Good traction, grabs the water and holds it around the board.	Good grip, reliable, extra support with two additional fins, felt better than using two P.M., the board did not randomly let go in turns.
Other comments	The combination takes the best of the fins. But there is still some vibrations when going in higher speeds.	Very similar to Low AR + Side Fin, generated marginally less control.

Table 5.24 The results from testing a combination of Low AR and Side Fin.

Low AR + Side Fin	**Lasse**	**Philip**
Stability	The combination help with the wobblyness of the Low AR. It feels like the side fins grabs the water more compared to with only Side Fins. Grabbing and giving more traction instead of getting stuck to the surface and slowing down.	Feels stable, gripped well, could ride in very straight lines.
Turning	It was more stable than P.M.. Good traction, grabs the water and holds it around the board.	Good grip, reliable, extra support with two additional fins, felt better than using two P.M., the board did not randomly let go in turns.
Other comments	Almost the same as the High AR + Side Fin, it was a little harder to take sharp turns. Could be user strength.	

Table 5.25 The results from testing Full Spoiler.

Full Spoiler	**Lasse**	**Philip**
Stability	It was okay. You really felt the drag.	More stable than P.M..
Turning	Loose, no traction. Rolling in the back end. The only fin set I felt I had to adjust speed when turning.	Felt slow in drawn out turns, had to adjust with more throttle and not let go of that speed.
Other comments	Almost worse than no fins.	Had to move backwards to balance out the force pushing the tail upwards, was easy to quickly get control of the board when starting to ride, the board levels out faster than when using P.M..

Table 5.26 The results from testing Side Spoiler.

Side Spoiler	**Lasse**	**Philip**
Stability	Super stable, but maybe the drag makes it so they do not reach the same top speed.	Felt good, more stable than P.M..
Turning	Really good in turns. Much traction and possibly tighter turns.	More grip and less sliding than using P.M., felt like it kept its track throughout the turn, felt easy and controlled.
Other comments	Biggest difference was traction and control. You feel the drag a bit, the top speed might not be the same. But that made it possible to have full throttle in turns. It is the favourable between the Full spoiler and Side Spoiler.	Felt like the force pushing the tail upwards was 50% to that from the Full Spoiler and that is preferred. Also preferred Side Spoiler because of its turning capabilities.

Table 5.27 The results from testing Mirror.

Mirror	**Lasse**	**Philip**
Stability	It felt alright. Not much difference from the P.M..	Stability felt improved compared with Low AR and High AR.
Turning	It felt like the board was slipping a bit more with the tail. Almost drifting. But compared to the Low and High AR these at least felt stable and more rigid. It felt a bit harder to turn compared to P.M., but it was also more fun to feel the board sliding slightly.	Felt similar to the turning of Low AR and High AR, but more grip. Turns were as tight/drawn out as when using P.M..
Other comments	I did not think that it would feel any different but it did.	Felt like the board was sliding a bit, the idea of oversteer was preferred over understeer. Did not feel responsive, felt marginally aided in turning.

Table 5.28 The results from testing Circular Fin.

Circular Fin	**Lasse**	**Philip**
Stability	It felt easier to get up and it is almost as if the nose goes up a little. I thought that was nice in these choppy conditions. The board feels more stable overall.	At lower speeds it felt stable, at higher speeds it felt wobbly but still OK.
Turning	Stable Turns, Good grip and initiating or maybe just more comfortable. Might be too soft when pushing a hard turn, you feel it loose grip a bit then.	In lower speeds turning felt really good, at higher speeds turning felt weird, felt like the board lost control randomly. Felt like less control than using P.M..
Other comments	Surprisingly good, More traction in the handling.	Felt special, felt like they were flexing when riding.

Table 5.29 The results from testing Circular Fin.

Overall	Lasse	Philip
Favourite and extra comments	My favourite fin set was the Circular Fin. Maybe it could be a bit stiffer because it lost a little grip in hard turns. Otherwise the Side Spoiler was nice as well. With less drag to get them to go at higher speeds would be nice. The size makes you worry a little when going at shallower depths.	Favourite was Low AR + Side Fin, because they felt stable and reliable in turning. Would have liked to try Side Spoiler in calmer, less choppy waters. Would like to know if less power is used when riding with Full Spoiler because of how it lifts up the board.

5.2.6 Interpretation of Test Results

A key point of discussion in the "Concept Generation", subsection 5.2.3, was which dynamic would be more preferred out of understeer and oversteer, i.e., keeping the tail of the jetboard firmly gripped against the inside of the turn or having it slide. Out of the concepts tested, the currently used P.M. and Circular Fin made use of understeer, whereas Low AR, High AR and Mirror made use of oversteer. From the corresponding test results, patterns between the different concepts can be seen. In tables 5.21 and 5.27, comments stating that the fin concepts Mirror and Low AR generate sliding can be observed. Another comment states that Mirror was harder to steer with than P.M., but also that the concept was considered more fun because of the sliding. Nonetheless, looking at comments made on the combination of Low AR + Side Fin in Table 5.24, positive statements can be observed regarding improved stability and grip, but no reflection was made on sliding. On the other end of the spectrum, comments regarding Circular Fin in Table 5.28 describe how it generated stable turns, good grip and increased traction compared to P.M.. The general reaction to Circular Fin was that it was good for turning, but that it lost its effect at higher speeds or harder turns. Other comments made on both Low AR and High AR also state that they felt wobbly. It could then be argued that these concepts could not withstand the largest loads present when riding and instead generated unsought qualities. Prototyping in a different material with higher stiffness could therefore be beneficial in ensuring consistent dynamic from the fin concepts.

Based on the outcome of the mentioned results, conclusions can be drawn in relation to the effect of understeer and oversteer. Given the positive feedback regarding the turning capabilities of Circular Fin and Side Spoiler, it can be concluded that the concept of understeer makes for improved grip, stability and traction, as well as less sliding. All aspects ultimately leading up to reliable turning with the sense of control. Regarding oversteer, varying remarks can be made given the feedback that the oversteer concepts physically generated sliding and a fun feel. One remark was that applying z-forces from Side Fins created a sense of stability and improved grip. It can therefore be concluded that oversteer generates sliding and a more playful feel, yet provide improved stability and grip in combination with z-forces.

Returning to the test result of Circular Fin, comments made regarding its improved performance compared to the currently used P.M. at 0 degree toe-angle are considered noteworthy. Looking at the results from the corresponding CFD-simulations in tables 5.11 and 5.36, the two fins show similar values in lift and drag, with the notable exception of the increased z-force in the positive direction from Circular Fin, meaning it is pulling the tail of the jetboard further into the water.

This means that the main difference between the two is the rounded shape and increased fin area of Circular Fin, as well as the z-force. It can then be speculated that the improved feel of Circular Fin, be that in low speeds or in soft turns, is generated because of these factors.

One aspect that was presented both in "Fin Mechanics" subsection 2.5.4 and "Concept Generation" subsection 5.2.3 was how responsiveness potentially could be affected by varying the aspect ratio of the fin. Testing said function was done with the two concepts High AR and Low AR, however, no clear difference in responsiveness could be established between the two when physically testing. Instead, comments about them feeling wobbly can be seen in test results from tables 5.20 and 5.21. Conclusions regarding the lack of material stiffness can thus be drawn and that it prevented any potential difference in responsiveness thereafter.

Regarding the stability concern of the jetboard that was mainly approached by concepts Full Spoiler and Side Spoiler, several remarks can be made. The concept Full Spoiler generated a high z-force, both in the CFD-simulation and in physical testing, as seen from comments in Table 5.25. Answers from said table construct a discourse regarding whether or not the function of applying increased z-force and momentum in pitch was desirable. One comment stated that it made the jetboard level out faster, something that made it easy to quickly gain control over the board. Contrastingly, Full Spoiler forced the test users to move further back on the board to adjust for the changed balance and find the desired riding style. Further comments added that the concept made the jetboard feel slow and that it complicated turning. Side Spoiler on the other hand produced positive reactions regarding both turning and stability, as seen in Table 5.26. The Side Spoiler concept presented z-forces pushing the tail of the jetboard upwards, approximately 13% of what Full Spoiler generated in simulation, but also relatively high lift forces in the positive direction. Seeing as the Full Spoiler concept showed low lift forces and poor turning ability, this organises the means for a discussion about the importance of supplying force in both lift and z-direction. The currently used P.M. supplies close to 0 N in z-force, as seen in Table 5.8 and Table 5.9, whereas the Side Spoiler supplies 26,44 N, according to the CFD-simulation results in Table 5.17, and is considered to be more stable and create more grip than the currently used. Looking at simulations of fin combinations High AR + Side Fin and Low AR + Side Fin in tables 5.23 and 5.24, both of these produce better turning and stability than using the fin concepts separately, as seen from comments in tables 5.20, 5.21 and 5.22. Concluding remarks can be made that applying force and stability in both lift and z-direction is desired and increases the feeling of control all over. The fact that the combination of Low AR + Side Fin, as well as High AR + Side Fin, present said forces in the opposite direction of Side Spoiler, that is using understeer and pushing the tail of the jetboard upwards, further strengthens that stability comes from applying both lift and z-forces and that the direction of the forces is secondary and a question of personal preference.

5.2.7 Final Concepts

From subsection 5.2.6, new fin concepts were generated to exemplify how the made conclusions could be put into design. The reader should be informed that neither CFD-analysis nor physical testing were performed for validation as these are concepts for inspiration.

Stable Understeer

The final concept Stable Understeer, seen in figures 5.67 and 5.68, utilises the Circular Fin design, but instead of using two fins, the final concept takes advantage of all four attachment points on the board. By doing so, both lift and z-forces were intended to be increased with the purpose of improving turning and stability. Looking at the quad setup, similarities can be seen between four Circular Fins and two Side Spoilers, with the main difference being the bridge section connecting the Side Spoiler as well as the direction of the z-force. Removing the bridge section is intended to reduce the drag force which was stated as a negative aspect from Side Spoiler. Furthermore, how the said z-force is directed could be a key point of discussion in further development and could potentially be researched through more extensive physical testing. In the final concept Stable Understeer, it is directed downwards. Moreover, it can be noted that the Circular Fin designs have been swept in different radii to adapt to the different positions in relation to the idealised center line of roll, meaning that the rearward fins that are fitted closer together use a smaller radius than the forwardly placed fins.

The fin concept utilises understeer tail handling as well as positive z-force, pulling the tail into the water. The purpose of the concept is to generate improved grip, stability and traction. By utilising a stiffer material, the fin setup is believed to offer reliable performance over the entire speed range. Looking back at the three final categories *Tight Turns*, *Stability* and *Slide and Tricks* from subsection 5.2.3, Stable Understeer is believed to combine *Tight Turns* and *Stability* to a large extent. Contrary to the stated stability generated from fin concepts using understeer and z-forces, no conclusions could be drawn regarding tighter or more drawn out turns from physical testing. However, the agility sought-after in *Tight Turns* is believed to be achieved through the grip, control and traction from Stable Understeer.

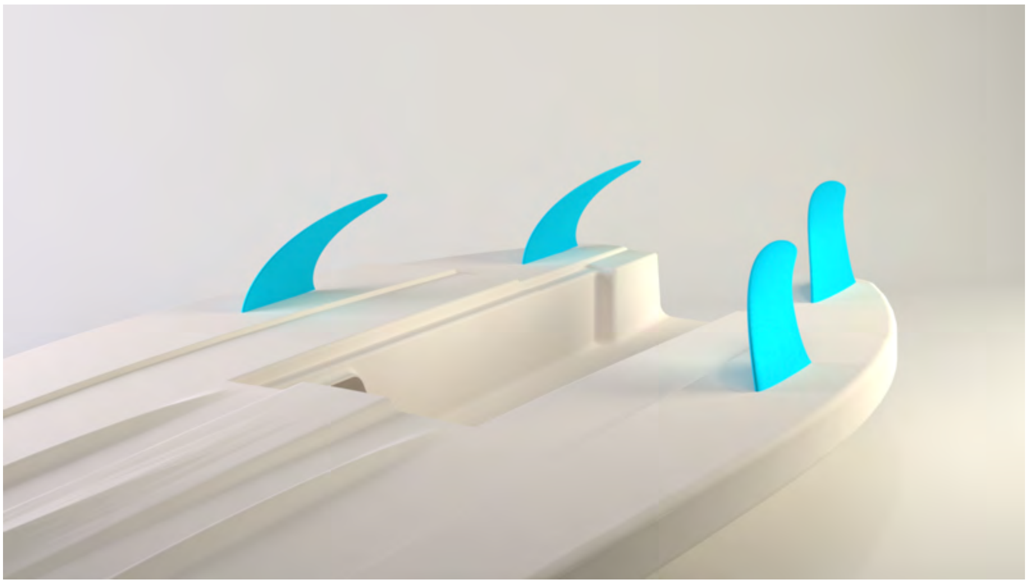


Figure 5.67: The final concept Stable Understeer attached to a jetboard.

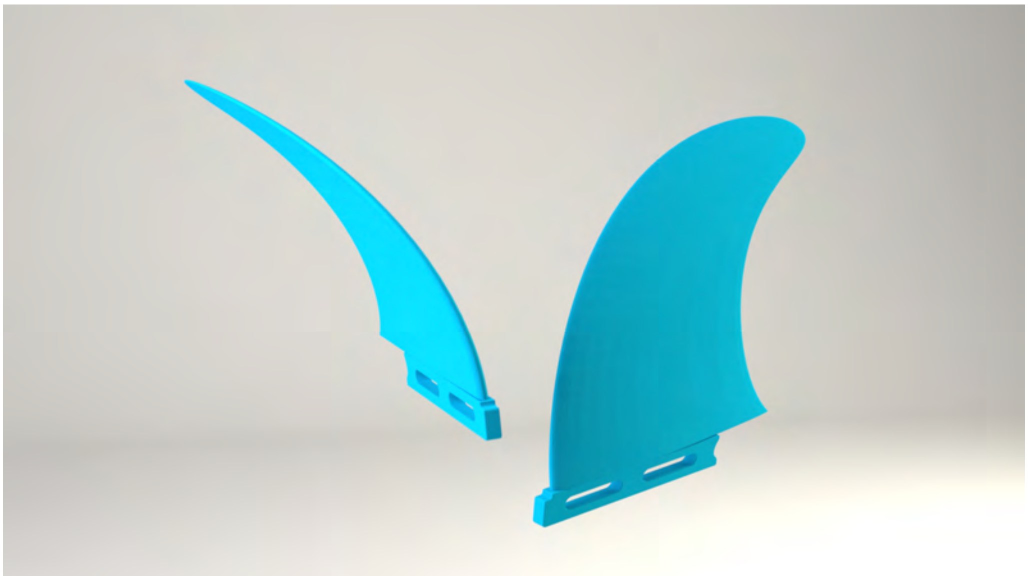


Figure 5.68: The final concept Stable Understeer.

Stable Oversteer

The final concept Stable Oversteer, seen in figures 5.69 and 5.70, utilises both the Low AR design as well as the Side Fin design. Contrastingly to the tested combination in physical testing, the fin setup on Stable Oversteer uses the Side Fin concept in the rear fin position, and the Low AR concept in the forward position. Seeing as the test result didn't point out a clear improvement of either turning or stability from applying excessive roll momentum from the Side Fins, the z-force is instead utilised in the rearward fin position to generate a bigger effect on pitch momentum and a smaller one on roll momentum. Looking at the new Side Fin design, changes to its geometry can be observed as it no longer contains a flat top arc. From the test session it was noted that the fin concept generated a strange feeling when turning, which was believed to occur when the flat top section was tilted out of the water and no longer induced z-force. To counteract this dynamic, a new front profile that is angled instead of flat was designed. Looking at the design of the new Low AR fin, the main difference compared to the previous version is that the new geometry is scaled up size wise to increase the amount of generated lift.

The fin concept utilises oversteer tail handling and positive z-forces. The purpose of the concept is to combine sliding and stability through an optimal balance of lift and z-forces, potentially resulting in a jetboard that gives the user a sense of control and a playful feel. Returning to the final categories in "Concept Generation" subsection 5.2.3, Stable Oversteer is believed to partially combine *Stability* and *Slide and Tricks* through its conceptualised controlled sliding.

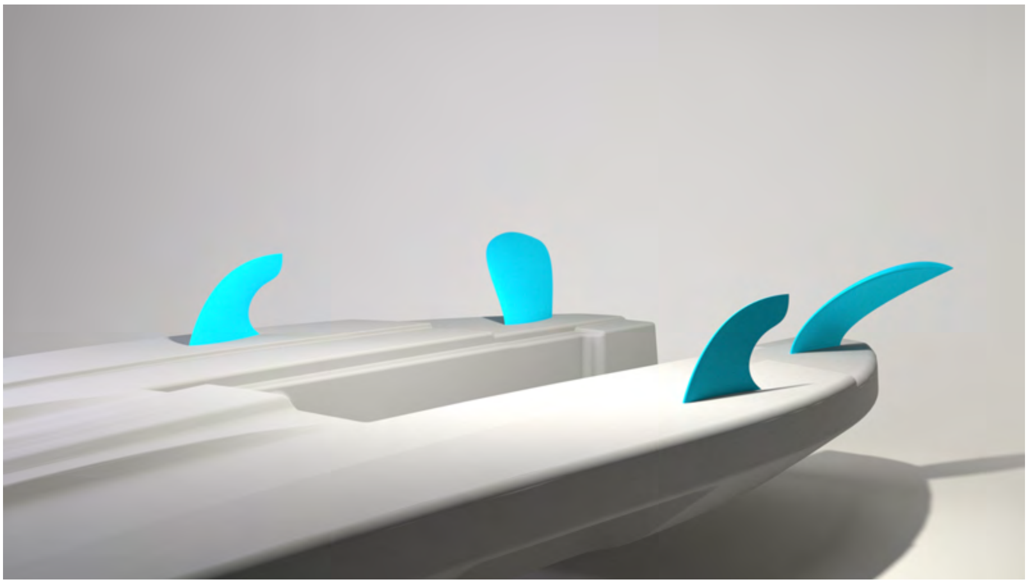


Figure 5.69: The final concept Stable Oversteer attached to a jetboard.

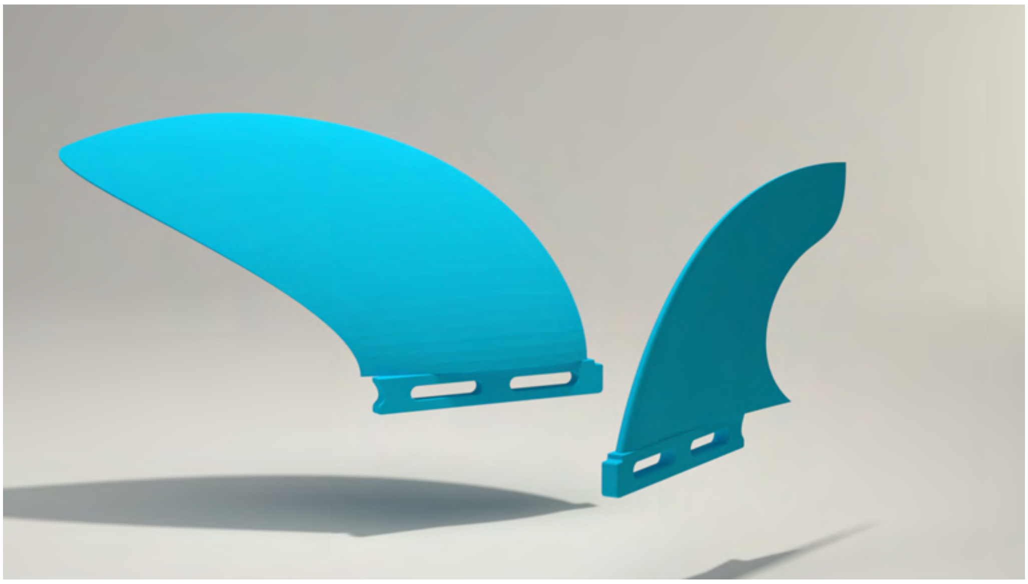


Figure 5.70: The final concept Stable Oversteer.

Overall Fin Choices

Consultations were conducted with both Radinn and Magnus Ullman [28] regarding the production of the fins. The knowledge gathered from Radinn answered the amount of fins planned to produce as well as possible manufacturing methods and materials available. After presenting the gathered knowledge to Ullman it was explicit that the favourable manufacturing method is injection moulding when production is going to be initiated. This was taken into account when discussing the possible materials.

The material has to be tough, meaning that it should withstand a constant force or iterative force cycles without permanent plastic deformation. GVX-7H is a tough material used for boat propellers, thereby also shown to withstand high magnitude forces underwater while maintaining a hydrodynamic shape. The other material taken into consideration is Grilamid, which is a GFRP consisting of polyamid 12 and glass fibres. Both materials handle moisture well and generate superb stiffness, strength as well as high dimensional stability. They are well suited for injection moulding, however one advantage with the Grilamid is that it allows the same mould setup for varying percentages of glass fibre in the part. This means that the same tools can be used for creating the same part, but with varying stiffness, an aspect interesting for Radinn to investigate further if the stiffness is a property they want to be able to alter when further developing fins. However, it could be concluded that jetboard riding is always superior when riding with a stiffer set of fins, a variable not determined by this thesis.

6 Summary of Results

This chapter showcases the summary of the final results from each section in the previous chapter. The closing section of this chapter additionally demonstrates the complete Fin Assembly by visually presenting the final fin plug concept together with one of the final fin concepts.

6.1 Fin Plug Results

The chosen concept became the one named Tongue. The name derives from its upper protrusion of the front end in the single cavity. It enables an alternative fail-safe design of a thin, exchangeable protrusion that breaks at a certain accidental force. The fin part is attached with a pivoting motion, placing the front end under the protrusion to then press the rear end past the flexing agent. To detach the fin part, it is rotated around the front end to generate a momentum, easing the detachment. The flexing agent is designed to give feedback in form of sound when attaching the fin as well as an ensuring feel for the user. Depending on the direction of the forces acting on the fin, the fin plug could either be fixated more tightly or be pulled out of its grip. The force required to detach the fin could therefore have to be adapted to the fin designs in future detail design.

The material suggested for the fin plug is Tenac 4010, a POM plastic. POM is a tough material that allows for iterative flexing of a part without permanent plastic deformation. Another important material property of POM is its capability to be injection moulded, leading to the next segment.

The suggested manufacturing method of the fin plug is injection moulding. The parts can be moulded in a couple of different ways, depending on placement of parting lines, amount of cores and consequently the ease of manufacturing of the tooling. A feasible version of injection moulding, reviewed by an expert in the field, can be seen in Appendix G.

If Radinn were to add the fail-safe feature to the fin plug, the concept would allow for the front end protrusion to be removable. Due to the manufacturing, the proposed means for attachment are a self-tapping screw or a self-drilling screw, both ease the assembly process and the required tolerances.

Following, in Figures 6.1, 6.2 and 6.3, are some renderings of the final fin plug concept suggested to Radinn.

Figure 6.1: The top surface of the final fin plug concept.

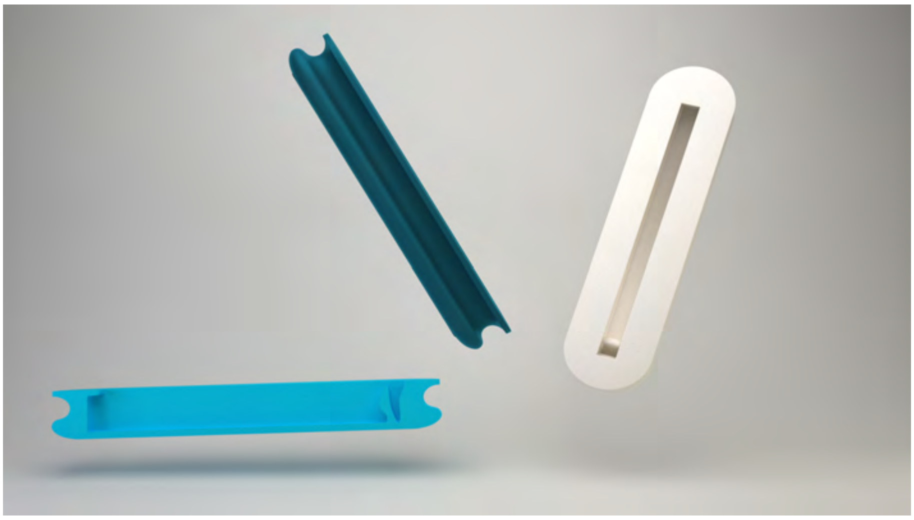


Figure 6.2: The final fin plug concept showing a section of the cavity, the profile of the outer shell and the top surface.

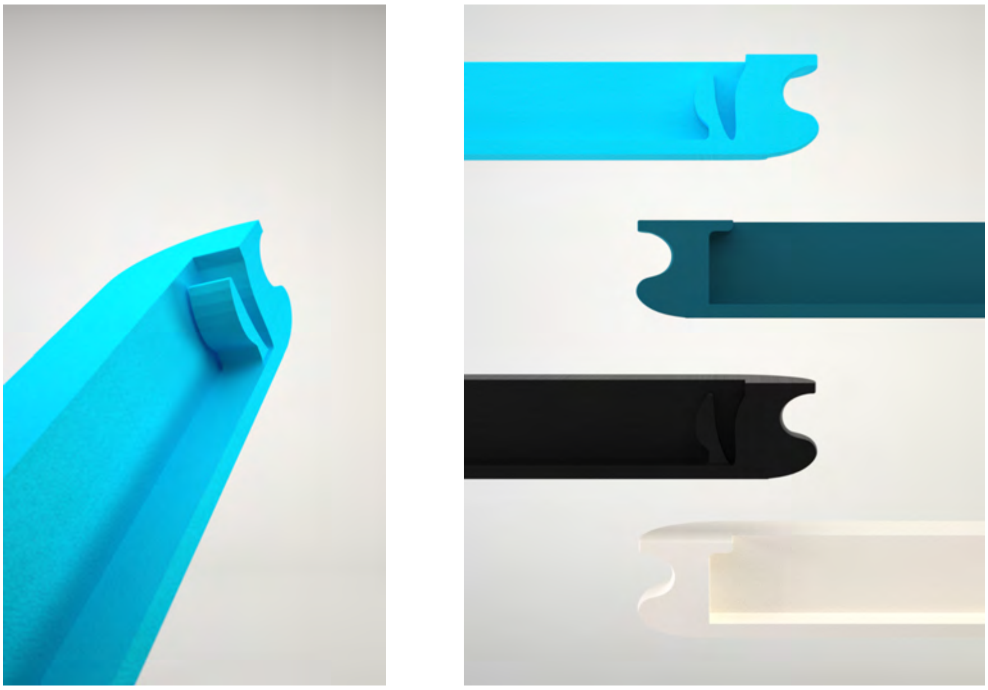


Figure 6.3: Different perspectives on the cavity of the final fin plug design.

6.2 Fin Results

The chosen fin concepts were results from the physical testing and the interpretation of the statements from said testing. It was concluded that two main qualities were possible to establish regarding the handling. The concepts were described from two different aspects, one from understeer to oversteer and the other from stable to unstable. Presented in this thesis are two potential concepts interesting for further development with the aspects of stable understeer and stable oversteer which also became the concepts' names. They are believed to be making use of the final categories in "Concept Generation" subsection 5.2.3. Stable Understeer, covering needs of *Stability* and *Tight*

Turns, is believed to present stability and agility through the presence of grip, traction and control. The Stable Oversteer concept is intended to cover needs of *Stability* and *Slide and Tricks* with its sliding and playful feel whilst supplying stability and grip. However, these concepts are merely ideas constructed from the results that give knowledge about jetboard fins' dynamics and have not been validated in CFD nor physically.

Thanks to CFD-simulations, hypotheses have been able to be stated with underlying presumptions. Some hypotheses have been confirmed and others discarded over the course of this project. The idea of creating a positive momentum around the yaw axis of the board did make the tail of the board shoot out and oversteer, although it did not necessarily create tighter turns. This contradicts the initial theory to some extent, but still confirms that it is the direction of the lift force that determines the users perception of the board's acting. This aspect is also confirmed with the contrary fin concepts that have lift force in the opposite direction. These concepts have been described by test users as giving more traction.

Regarding the force in z-direction, the results are ambiguous. Since both positive and negative z-directional forces have been stated to give a stable feeling and could be a part of an understeered as well as an oversteered concept. The z-directional force is therefore an interesting aspect to investigate further. The pitch of the board, which the z-force affects, is an aspect usually taken into account when evaluating different sea conditions. It is thus considered necessary to test future fins in different types of sea conditions and consequently draw further conclusions regarding its effect. The only practical aspects that could be noted, was that the positive z-force made the board level out quicker and that a negative force made the nose rise.

The materials suggested for the fins are GVX-7H and Grilamid. Two stiff plastic materials, one used for boat propellers and is known to withstand great forces, the other one is possible to alter with different amounts of fibre. The altering would allow Radinn to use the same mould whilst trying out different stiffnesses in the fins. Hence why both materials are suggested and the final choice depends on Radinn's decision about their fins. If they want to try different stiffnesses without having to invest in new moulds or if they want to use a material already found in propellers for watercrafts and shown to maintain hydrodynamic properties.

The manufacturing method relates to the choice of material. Both of the materials are applicable to injection moulding. Considering the amount of fins Radinn plan to produce, an injection mould is believed to be a cheap investment. If they then want to change the stiffness of a fin, depending on material, this could still be possible with the same mould. Hence, the suggested manufacturing method is injection moulding.

Depending on the fin plug design, the fail-safe feature could be moved to the fin. This would ease the manufacturing of the fin plug and would be quite easy to implement into the fin part. The disadvantage is that when the accident happens, the whole fin is no longer usable, unless another part is exchangeable which leads to the same assembly process as the fin plug. It should however be noted that the expert stance from a plastic production point of view, is that the fail-safe feature should be placed on the fin.

Following, in Figures 6.4 and 6.5, are renderings of the final fin concepts suggested to Radinn.

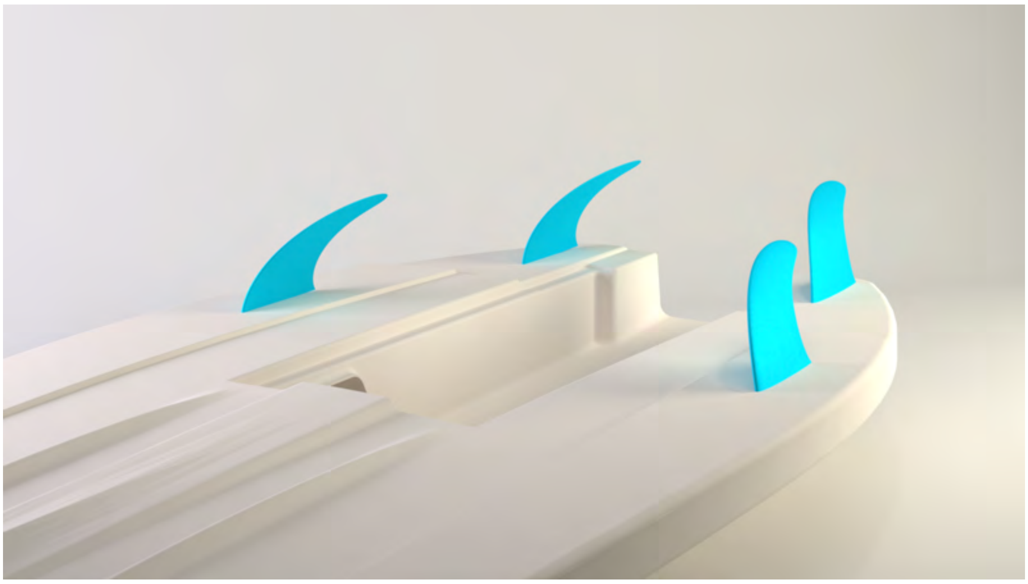


Figure 6.4: The final concept Stable Understeer attached to a jetboard.

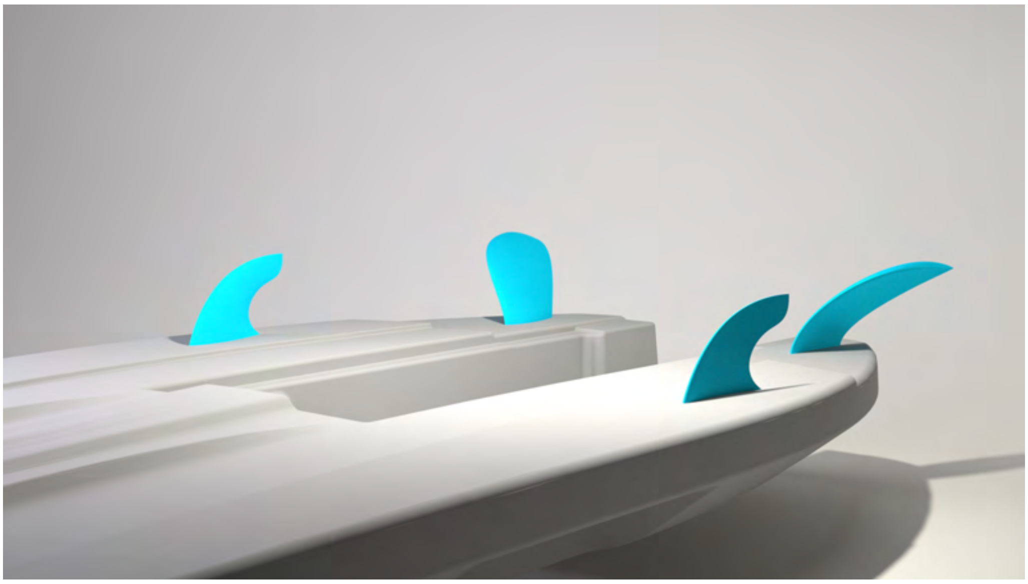


Figure 6.5: The final concept Stable Oversteer attached to a jetboard.

6.3 Fin Assembly Results

The fin and fin plug are designed to cooperate and fit together with a clicking sound. The responsive feedback pleases the user, ensuring them that the fin is attached. To assemble the fin into the fin plug, the front end of the fin is pushed towards the front end of the fin plug cavity. When reaching a stop it feels natural to start pressing the rear end down, into the cavity. Pushing down the rear end of the fin will engage the resiliently flexing agent of the fin plug which ends with creating a clicking sound to confirm that the attachment has been done correctly.

Detachment of the fin is done without any tools by pulling the rear end upwards. The shape of the fins creates a lever to grip and will aid the user to extract the fins. In the Figures 6.6, 6.7, 6.8 and 6.9, the interface between the parts can be seen.

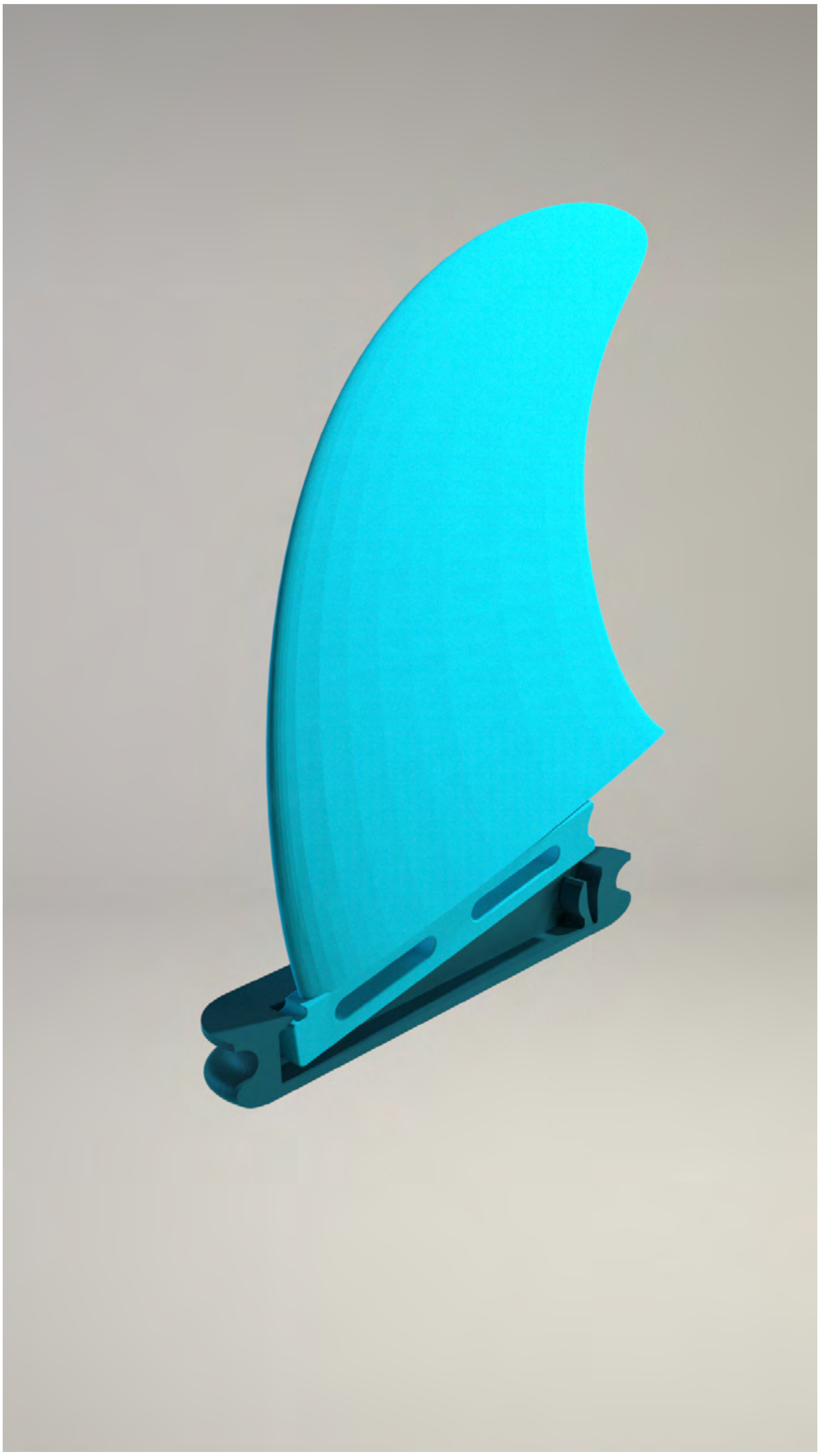


Figure 6.6: A fin from Stable Understeer concept being fastened in the final fin plug concept Tongue. Note the tab design on the fin.

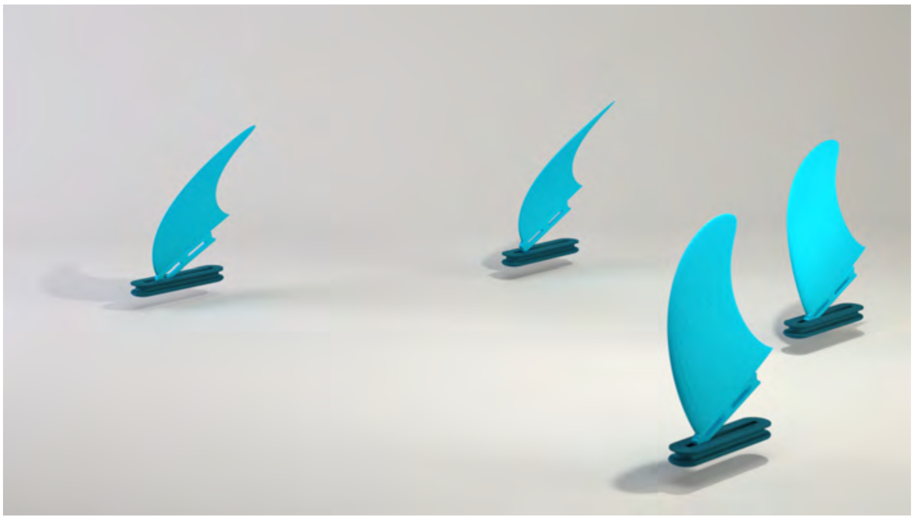


Figure 6.7: Stable Understeer concept being fastened in the final fin plug concept Tongue.

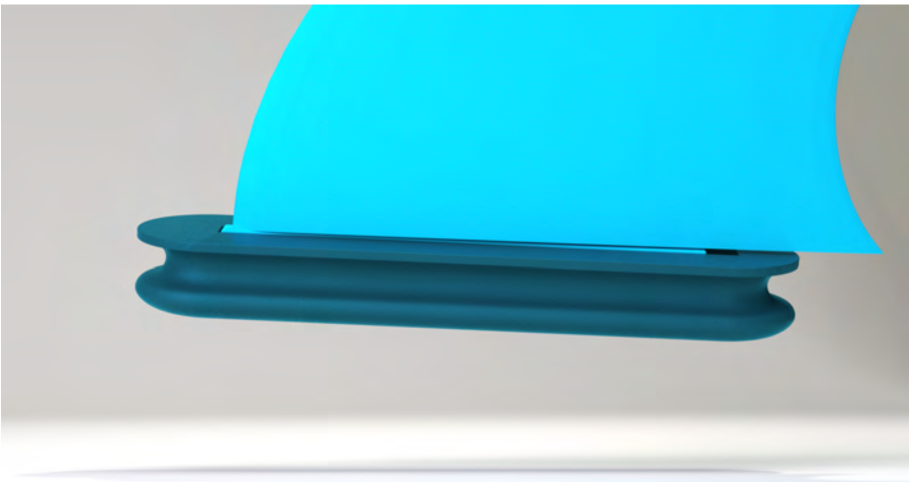


Figure 6.8: A fin from Stable Understeer concept fastened in the final fin plug concept Tongue.

Figure 6.9: A fin from Stable Understeer concept fastened in the final fin plug concept Tongue, viewed in a cross-section.

7 Discussion

In this chapter, both aspects chosen and aspects overlooked in the process are presented and discussed. This is to give the reader an understanding of the perspectives available if they were to recreate this process.

7.1 Fin Plug Discussion

The structure of this thesis complies with Radinn's primary goal to produce their own fin plugs. A goal that was meant to broaden Radinn's development capability, enabling them to design their own jetboard fins. To ensure that the thesis delivers what has been stated as the primary goal, the development process started by focusing on the fin plugs. However, by starting with the fin plugs, which will act as a fastening agent for the fins, this process might actually be hindering the full development capability. A concept generation focusing on the handling of a jetboard without restricting the concepts to be fastened in fin plugs could have led to completely different concepts.

There is a resemblance between jetboards and surfboards that easily leads to the conclusion that a jetboard should consist of similar parts as a surfboard underneath the board. A jetboard can just as easily find resemblances to a jetski. A potential winning concept of how the jetboards are supposed to be steered might not have anything to do with fins, an aspect overlooked by this thesis due to its structure. Such a development however, would have had to include a more extensive study regarding symbiosis with other sections of the board. A possible concept could change the entire architecture of the board which would have had to consider what the changes might do for the battery or jetpack.

The concept generation of the fin plug, which was the primary goal of the thesis, had a couple of leading objectives from the beginning. One being to not infringe on any patents, another being to enable detaching the fin without any tools. To not infringe on any patents, the new concept is either eligible to form its own patent or it makes use of expired patents, i.e., prior art. The choice of whether to be able to form a patent or not was made by Radinn. This could either enable or restrict possible solutions. The choice to not search for a patentable solution enabled the thesis to make use of the advice from a patent attorney. It was pointed out that some of the concepts designed had similarities which would infringe on a patent but some concepts had similarities with expired patents, thus able to go forth with due to Radinn's choice.

The discussion thereby continues into whether a patentable or non-patentable solution is to prefer. A patentable solution in this case would not contain the same amount of preferable qualities of a fin plug, according to the different concepts screened in this thesis. However, it could generate a market opportunity to be able to develop fins optimised for jetboards, a segment currently unsaturated or even undiscovered. With a non-patentable solution, it will be possible for every jetboard company to use the solution for their own development of fins and fin plugs. Hopefully, the predicted reduced cost of a non-patentable solution is enough to make up for the revenue a patentable solution would offer, considering that a patentable solution would probably add parts, seeing as existing patents and prior art are considered to cover most simple and usable concepts brought forward in this project. Adding said parts could consequently lead to increased costs from manufacturing and assembling.

In the two final concepts, a detail design has been touched upon. Both the geometry of the flexing agent has been investigated as well as the outer shell which is supposed to enable capture moulding and glassed-in assembly. Since the final concept needs to consider both possible methods, the process has not examined the possible detail designs any further. Another detail, which has been included in the process, is the fail-safe mechanism. The reason why it has been a part of the product development but not prioritised is because of the boards' possible future designs, varying in manufacturing, design, cost and quality. A couple of aspects need to be reviewed by Radinn before going forth with the fail-safe mechanism, such as if it is a valuable feature considering the extra costs.

7.2 Fin Discussion

The goal set by Radinn to start producing their own fins, specifically designed for jetboarding, was secondary to the development of the fin plug. This meant that the fin development had clear restrictions regarding possible geometry and positioning. As the project proceeded, several interviews were conducted to analyse users' experience of Radinn jetboards. Statements from said interviews and the interpreted needs thereafter gave a clear indication that a fin for jetboarding has vastly different requirements compared to a fin designed for surfboarding. This was something that was already considered in the research phase. However, after coming to the realisation of precisely how different the two watercrafts are, the synthesis phase of the project transformed from potentially looking into detail design of fin parameters, to instead researching the profound purpose of using fins on a jetboard. Without the mentioned restrictions, which emerged by developing the fin plug first, the final fin concepts could instead potentially have resulted in radically different designs and generated further knowledge, something also discussed in section 7.1 above.

The performed synthesis of the fin included concept generation through hypothesised desired fin functions, simulations in CFD to validate their functions theoretically and physical testing to validate their function in reality. Given the scope and time frame of the project, only one iteration of the mentioned steps was conducted. To be able to draw further conclusions, more iterations would have been required. This could have generated more knowledge for the company and potentially aided them further in making decisions regarding potential future fin development. Oppositely, not performing more than one iteration resulted in broader conclusions that reflect the overview of desired fin functions. This will supposedly allow Radinn to also make a broader decision on said potential future fin development. More iterations could have resulted in conclusions too specific and not relevant for the path yet to be chosen by the company.

Returning to the comparison between jetboards and surfboards, a similarity can be found in the stated conclusion from "Interpretation of Results" subsection 5.2.6 and the dynamic of surfing on a wave. The velocity of a surfboard comes from dropping down a wave and having the pressure from the water accelerate the board. That pressure, also addressed in one of the interviews in Appendix H, creates the feeling of control and connects the surfer to the surfcraft. That very same feeling of control was touched upon in test results, seen in "Physical Testing" subsection 5.2.5. By applying force in lift and in the z-direction simultaneously, a better connection between the rider and the jetboard was identified. This composes a discourse regarding whether or not it is desired to replicate the feeling of surfing. It could be argued that the feeling of control is sought-after, however, that does not necessarily equal to the feeling of control felt on a surfboard. Granted that a jetboard is not intended to ride on bigger waves, it could further be argued that the same feeling could never fully be reconstructed and thus any chosen jetboard fin will create a unique feel of riding, which automatically differs from surfboarding. What the comparison between jet- and surfboarding more specifically means to the design of jetboard fins could be that the fin mechanics, that are thoroughly researched for surfboards, can be transferred onto jetboards, to a large extent. Nonetheless, only relying on surfboard fin mechanics would be to ignore the need for generating z-forces, something that is not common practice in the world of surfing. Instead, combining said fin mechanics with other theories could result in fin designs that produce both desired lift and z-forces, ultimately generating improved jetboarding experiences. The other mentioned theories could be vehicle dynamics, such as understeer and oversteer, aircraft dynamics, e.g., stability derivatives, or other applicable theories.

8 Further Development

This chapter presents different aspects worth investigating when using this thesis as a foundation for further development. It regards aspects not in scope of this thesis or possible improvements of certain procedures conducted in the thesis.

8.1 Fin Plug

The final fin plug concept presented in this thesis is a design proposal for Radinn's approach to produce their own fin plug. The scope of the project involved presenting a concept viable for manufacturing and free from infringements. However, for Radinn to manufacture their own fin plug they will have another team to validate the detail design of the concept with calculations and simulations to ensure a durable product. Therefore, the project has not approached any simulations and calculations to measure safety-factors or load cycles, important aspects for further development.

Another aspect for further development is the detail design of the fail-safe mechanism and determining how valuable the feature is for the overall jetboard. It was said to be a desirable feature regarding the safety of the board's inner structure. However, an additional part in the manufacturing and assembly line will add to the cost of the product. An alternative could be to move the fail-safe feature to the fin instead which would ease the manufacturing of the fin plug. Since it will add to the fin's design and manufacturing, it is an aspect to approach in a further development.

Regarding different placements, the flexing agent should also be investigated to ensure its most optimal placement. The prior art disclosed in the thesis claims both a flexing agent on the fin and on the fin plug which allows for this investigation. The difference will change the perception of the product regarding quality and durability. It is also interesting to evaluate the different costs if the flexing agent was to break. The wearing factor also becomes present in this discussion. The question is if the fin wears on the plug or vice versa, and what the best alternative is.

The scope of the project did not include determining precise measurements and tolerances since the final concept presented will act as a design proposal. The tolerances of the models should however be investigated and determined in a further development. It will decide the cost of manufacturing and the fit of the fin into the fin plug. The fit should be considered a crucial part of the final product since it expresses the quality of the fin plug and gives the user a sense of security when using the product. The sound feedback, which was proven to be a desirable quality, will also change with the tolerances.

In a further development, a more realistic test rig could be an alternative improvement to the test cases. A tightly fitted fin in a fin plug with no lever available for when detaching it can alter the impression of that concept. In reality, a user often places a hand on the board further away from the fin plug to ease the detaching of the fin. Solely the weight of the board will act as a countering force to ease the detachment, an aspect overlooked in this project which could give a more precise test response.

In future versions, Radinn have the possibility to use both assembly methods presented in the assembly study. A significant decision regarding the assembly method has not been made for this thesis, forcing the presented concept to account for both methods. In a further development, when this choice is made, the concept of the fin plug can be optimised towards that assembly method.

Before a manufacturing ramp-up would take place, Radinn should also consider their options when it comes to manufacturing. The material and manufacturing method presented in this thesis is solely a proposal to how the concept can be manufactured. A cost analysis of different manufacturers and evaluation of order size depending on market would be a reasonable further development.

8.2 Fin

To be able to conclude optimal jetboard fin designs that please the needs brought forward in this project, further design, simulation and test iterations could be required in a later development. The single iteration performed in the process presented test results that led to conclusions about desired fin designs. However, completely new concepts could potentially have been generated based on said conclusions and resulted in refined future test results.

Performing mentioned potential future iterations could preferably be done with prototypes made in a stiffer material. The 3D printed fins in this project lacked structural stiffness and resulted in them feeling wobbly when going at higher speeds, thereby adding an additional factor of flex to take into account when analysing the test results. An alternative to changing the type of material could be to change the geometry and add volume, thus increasing the stiffness. The problem with the latter solution is the potential increase of drag forces that could tamper with the feel of the jetboard, resulting in an inaccurate representation of the dynamic.

Looking into the choice of material and manufacturing on a more detailed level could require a complete structural analysis using the finite element method (FEM) to validate that the fins will be able to withstand extreme riding situations repeatedly, something that's also worth considering in further development. To increase accuracy of the load simulation, the CFD-analysis could be made more complex. Simulating the full geometry of a jetboard, taking into account both the water it is riding in and the air above the water surface, as well as having the fin concept simulate solid mechanics simultaneously and flex dynamically, could possibly generate a higher accuracy in further development. For a quick progressive improvement of fin concepts that make use of four fins, a CFD-case with all four fins simulated simultaneously would add understanding about their correlation.

After having potentially simulated more cases there are also a lot of potential additions to be made to the physical testing of the fins. One aspect could be to have more test users try out the different concepts and afterwards having them rate the fins with numbers in various categories. Doing so would potentially make the test results more easily comparable and simplify the interpretation. Another interesting aspect regarding testing would be to collect data such as speed, throttle usage, angles and the force used to push the jetboard with the rider's feet, as well as tracking global positioning system (GPS) data. This would quantify the results from testing and enable further optimisation of the fins.

9 Conclusion

This chapter summarises and concludes the entire project. It reconnects to the scope and goal presented in the introduction and gives a concise recap of the process. More specifically, interesting take-aways are highlighted from the procedures conducted in this project. Finishing both this chapter and the entire thesis is a final presentation of the concepts and the knowledge passed on through this thesis.

Reflecting on the scope and goals in section 1.2, this thesis has conducted a product development process resulting in a fin plug that does not require any tools when attaching a fin. The fin plug's design is based on prior art and consequently does not infringe on any existing patents, a requirement for Radinn to be able to use the concept. With this primary goal of a fin plug developed, it has allowed the thesis to also conduct a research and development process regarding jetboard fins. It is that process which will help Radinn to create their own original jetboard fins. The tools that Radinn acquire from this thesis will aid them in giving their customers a unique and original feeling when riding a jetboard.

The fin plug concept developed has been generated through an iterative process with the use of different ideation methods. The selection has used input from patent lawyers and user tests to support the concepts. During the final phase where the concepts have been reduced to two, the last selection included aspects such as manufacturing. Even though the goal was for Radinn to be able to create their own tool-less fin plug for further developing new jetboard fins, the final concept makes use of prior art and is therefore free to access by the whole jetboard community and other third parties. This entails that not only is it unlocking Radinn's freedom to originate, but everyone creating watercraft's.

In Radinn's further development of the fin plug concept, they can make use of customer needs presented and focus on qualities that have been deemed necessary in a fin plug. The fin plug development also helps Radinn on their journey towards an even more economically competitive product, unlocking the world of jetboarding to more people. This was done both through cost reductions in their purchase of fin plugs and fins as well as in producing their own ones. A wider customer base would benefit further development towards original experiences, since more input from a larger variety of users will help explore new sought-after qualities in jetboarding.

The fin section of this thesis gives knowledge to Radinn about simulated values and their corresponding properties when physically riding a jetboard. Not only does it give knowledge to Radinn, but to the whole jetboard community. Potentially, this thesis is one of the first foundations available for the jetboard community regarding simulated values, users' input when testing concepts of said values and conclusions about the results.

The mentioned foundation led to the final fin concepts presented in this thesis; Stable Understeer and Stable Oversteer. Two concepts, one aimed towards traction and control, the other towards sliding and playfulness. They have been developed with support from interviews of users familiar with jetboarding. The interviews yielded a direction for the concept generation where fin designs later were simulated in CFD to theoretically validate their functions. The physical testing could confirm and discard the hypotheses created with foundation from the simulated values. It validated qualities sought-after in jetboarding as well as presented a way to find the corresponding characteristics in a simulated environment.

The physical testing resulted in an insight that different fins attached to the board can change the overall dynamic. More specifically, different fins can generate more desired jetboarding experiences than surfboard fins, an incentive to continue exploring the possibilities. Going forth, Radinn can make use of the needs presented by users in this thesis and the reasoning about sought-after qualities. The thesis also presented a foundation about a jetboard's dynamic properties and how fins can alter these properties for a new way of riding a jetboard.

To conclude, this thesis passes on a concept for further fin plug development to Radinn which requires no tools for attachment nor detachment. It is theirs to ramp-up for production after final refinements. It will allow them to expand their freedom to originate and continue with their radical innovation. To aid them in developing their own fins, the thesis presents a couple of concepts to consider in further development, knowing that they possess qualities sought-after when riding jetboards. Hopefully, this thesis can act as a foundation for further research of jetboard fins' properties, both simulated and physical.

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Appendices

A Work Distribution and Time Plan

A.1 Work Distribution

Both Albin and Alex put the same amount of hours into the thesis and shared the workload equally. The exact work distribution can be seen in Table A.1.

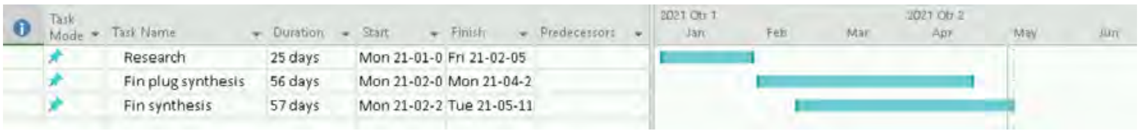
Table A.1 Work distribution of activities.

Activity	Percentage of work performed by Albin	Percentage of work performed by Alex
Literature study	50	50
Patent study	50	50
Material, manufacturing and assembly study	50	50
Fin plug concept generation	50	50
Fin plug prototyping	50	50
Fin plug user testing	50	50
Fin concept generation	50	50
CFD-analysis	50	50
Fin prototyping	50	50
Fin user testing	50	50
Photography and explanatory illustrations	10	90
Rendering	90	10
Report writing	50	50

A.2 Time Plan

The initial time plan, seen in Figure A.1, divided research and the two different syntheses into three separate phases. The research phase, meaning literature, patent, material, manufacturing and assembly studies, was performed as planned. However, due to delays in the synthesis of the fin plug, because of processing time from patent analyses as well as prototyping, the synthesis of fin was started earlier than planned. Further delays in prototyping and physical testing of the fin prolonged that process too, extending the synthesis phase by approximately one week and reduced the amount of iterations performed to one. The exact outcome of the plan can be seen in Figure A.2

Figure A.1: Project plan.



Task Mode	Task Name	Duration	Start	Finish	Predecessors
	Research	25 days	Mon 21-01-0	Fri 21-02-05	
	Fin plug synthesis	56 days	Mon 21-02-0	Mon 21-04-2	
	Fin synthesis	57 days	Mon 21-02-2	Tue 21-05-11	

Figure A.2: Performed activities.

B CFD - Sensitivity Analysis

The following is the documentation of the performed sensitivity analysis.

Sensitivity Analysis

The sensitivity analysis conducted was made using Simcenter Star-CCM+ and is documented to present the reader with an understanding of the used variables and the effect they have on the result.

To simulate a fin on a jetboard, two decisions were made prior to the sensitivity analysis. The first was to have a wall with a no-slip condition to represent the board, and the second was to use a symmetry plane that mirrors the effects of one fin, i.e., simulating the effects of two fins with equal distance to the said symmetry plane.

Next, to ensure a scientific structure, the parameters that will be taken into consideration has to be determined. These parameters and the reasoning behind them are presented in the section *Output Parameters*.

After determining parameters, the iterations began. In order to isolate the difference in the output parameters, one major variable was evaluated at a time, with minor variables altering the said major one. Each major variable has its own section below named accordingly; Domain, Mesh and Turbulence.

Output Parameters

The parameters chosen to be evaluated were determined with the assistance of supervisor Robert-Zoltán Szász, a researcher and expert in the field of fluid dynamics.

The output parameters require some connection to the purpose of performing the CFD-analysis. The CFD-analysis in this project is made to evaluate drag and lift forces and how they affect momentum around various axes, as well as the vortices created in the wake of the fin. This adds the coefficient of drag, the drag force and the lift force to the list of output parameters. These are extracted from each case of simulation to investigate how they differ in accordance with the evaluated variables.

The coefficient of drag was later removed due to the redundancy of its value. The actual force acting in the dragging direction is more interesting for the creation of new fin designs and evaluation of current fins set in different angles.

Furthermore, the turbulent viscosity was also evaluated through the scalar scenes created in the post-processing of the simulation. This is due to the nature of turbulent viscosity and its difficulty to concretize its arithmetic values to realistic turbulence. Therefore a scalar scene visualizes the areas of turbulent viscosity that can be evaluated and acted upon.

To ensure the validity of the simulation, the quality of the mesh was needed to be examined. Thus, adding wall y+ to the list of output parameters. Wall y+ is a dimensionless parameter indicating the distance normal to the wall. In order to capture the fluid dynamic near-wall, i.e., within the boundary layer, the mesh cells closest to the wall need to be small enough to fit inside the *Viscous Sublayer* and *Buffer layer*. To put it in other words, seeing as the velocity of the fluid increases the further away from the wall it flows within the boundary layer, y+ can be described as a value for how the mesh relates to the existing Reynold's number. This however depends on the chosen turbulence model. Both K-epsilon and K-omega are possible to use with different y+. However, to use a y+ of approximately 30 and above the simulation will need to make use of wall functions. These do not always give a fair representation of the flow when direction changes occur at a trailing edge. By having a y+ value of 1, there is no need for wall functions and the simulation is reasonably more accurate. The K-omega SST model on the other hand, is a combination of K-epsilon and K-omega. It makes use of K-omega close to a wall where this usually is preferable and changes into K-epsilon in the free stream where K-omega has a tendency to be too sensitive.

Domain

Testing the sensitivity of the domain was done by changing the dimensions of the boundary box and the distance from the boundary inlet to the fin. The output parameters looked at when comparing the varying domain-dimensions were drag force and the drag coefficient. To verify that an accurate result from the simulations had been acquired, the output parameters *Continuity, X-momentum, Y-momentum, Z-momentum, Tdr* and *Tke* were checked for convergence. Listed in the table below are the results from said simulations.

Domain-size(WxHxL) (m)	Length in front (m)	Iterations	Drag Force
1x1x2			
	0,25	145	6.619782N
	0,5	151	6.525019N
	1	165	6.454393N
0,5x0,5x1,5			
	0,25	151	6.573871N
	0,5	151	6.533019N
	1	50	6.465075N
0,5x0,5x2			
	1		6.463423N
2x2x4			
	1	170	6.457050N
	2	199	6.315791N
0,3x0,3x1			
	0,25	50	6,825529N
0,75x0,75x1,5			
	0,25	308	6.583981N

	0,5	350	6.509728N
0,75x0,75x2			
	1	170	6.440728N

Mesh

In order to validate accurate results while simultaneously minimizing the computational power needed to deliver said results, variants of mesh settings were simulated. Meshing a model in CFD allows the user a lot of freedom, meaning there are an infinite amount of ways a mesh can be generated. In this project, mesh settings were set up for the overall domain, as well as customized surface control settings for the fin, the no-slip plane simulating the board, the symmetry plane and for the surfaces simulating the surrounding water. As can be seen in the table showcasing different mesh settings below, volumetric control settings were introduced in mesh variants 4, 5 and 6 on a cylinder that was placed in front of the fin. This was done in order to generate a finer mesh right before the leading edge of the fin.

As mentioned, the used input parameters can be seen in the table below. Highlighted cells signal where the mesh variants differ from the reference *Standard*.

		Standard	1	2	3	4	5	6
DOMAIN	Base Size - **domain**	0,03	0,03	0,03	0,03	0,03	0,03	0.1
	Target size	100	100	100	100	100	100	100
	Minimum size	10	10	10	10	10	10	5
	No. of prism layers	2	2	2	2	2	2	2
	Stretching of prism	1,3	1,3	1,3	1,3	1,3	1,3	1,3
	Tot. thickness of prism	33	33	33	33	33	33	33
FIN	No. prism layers - **fin**	4	8	10	30	16	16	16
	Stretching of prism	1,3	1,3	1,1	1,1	1,3	-	-
	First layer thickness	-	-	-	-	-	3e-6	3e-6
	Tot. thickness prism	20	50	20	20	10	10	10
	Target surface size	-	-	-	5	-	-	-
	Minimum surface size	5	2	3	2	2	2	2
	Wake refinement	25	25	25	25	50	50	50
	Wake length	1	1	1,4	1,4	1	1	1
	Wake angle	20	20	15	15	20	20	20
	Wake growth	1,3	1,3	1,3	1,3	1,3	1,3	1,3
BOARD	Target surface size - **board**	300	100	300	300	100	100	100
	No. of prism layers	4	8	4	4	16	16	16
	First layer thickness	1,3	1,3	1,3	1,3	1,3	3e-6	3e-6
	Tot. thickness prism	-	50	20	20	100	50	50
	Minimum surface size	10	5	10	10	5	5	5
SYMMETRY	Target surface size - **symmetry**	300	100	300	300	100	100	100
	Min. surface size	10	10	10	10	10	10	10
WATER	Target surface size - **water**	300	100	300	300	100	100	100
ADDED VOLUME	Target surface size - **volume**	-	-	-	-	50	50	50

The different mesh settings were simulated and output parameters such as the value of wall y+, the drag coefficient and the drag force were noted. Furthermore, the number of iterations required to generate converged results were checked in order to establish how efficient the different mesh variants were.

	Iterations	Wall Y+	Drag force
Standard	500	43-355	7.082919N
1	420	11-400	6.250231N
2	140	13-385	6.920102N
3	370	0,6-346	6.589638N
4	405	0-435	6.531703N
5	250	0-232	6.532717N
6	215	0-850	6.781765N

Turbulence

To acquire reliable results, varying turbulence settings were tested. The different test iterations examined the effects of asserted turbulence models, inlet and outlet intensity as well as inlet and outlet length scale. Additionally, some changes in mesh settings were performed simultaneously. To find the optimal candidate, consistency in output parameters as well iterations required to generate converged results were checked.

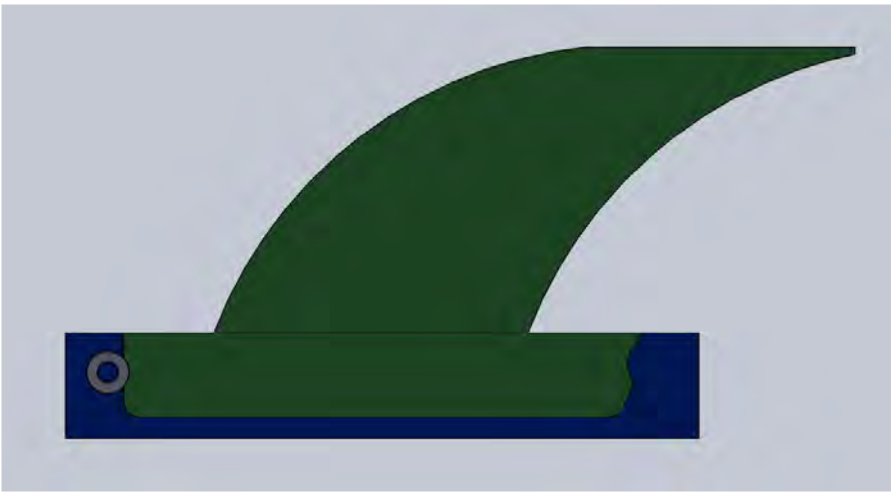
	inlet	drag(N)	lift(N)	cells	Iterations	Lift/Drag
k-Epsilon		**6,09**	**61,1**	**4383600**	**562**	**10,03284072**
intensity	0,01					
length	0,02m					
k-Omega SST		**5,63**	**63,3**	**4383600**	**338**	**11,24333925**
gamma						
intensity	0,01					
length	0,02m					
k-Omega SST		**5,82**	**62,6**	**4383600**	**200**	**10,75601375**
turb. suppressing						
intensity	0,01					
length	0,02m					
k-Omega SST		**5,64**	**62,4**	**4383600**		**11,06382979**
turb. suppressing						
intensity	0,001					
length	0,01m					
curvature control	ON					
k-Epsilon		**6,78**	**65,51**	**915084**	**215**	**9,662241888**
intensity	1e-5					
length	0,001m					
curvature control	ON					
k-Omega SST		**5,57**	**63**	**4383600**		**11,31059246**
turb. suppressing	same without transition					
intensity	1e-5					
length	0,001m					
curvature control	ON					

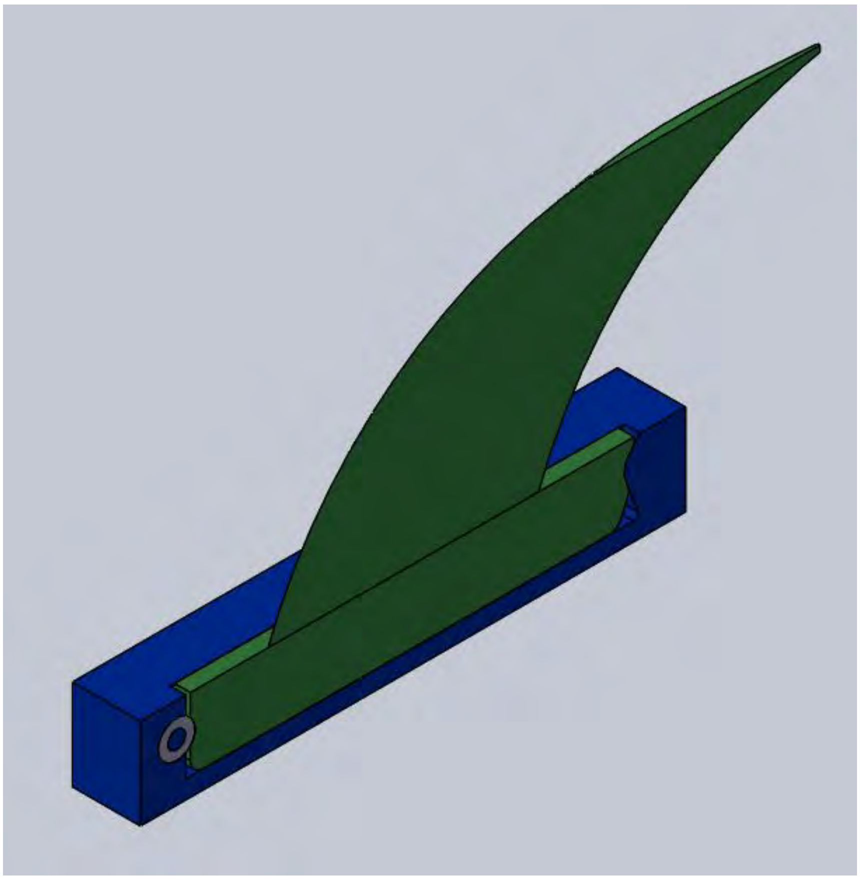
	inlet	drag(N)	lift(N)	cells	Iterations	Lift/Drag
Spalart-Allmaras		**6,06**	**62,2**	**2929177**	**copy_spalart**	**10,2640264**
intensity	1e-5					
Length	0.001m					
curvature control	ON					
Spalart-Allmaras		**6,58**	**61,29**	**598157**	**copy**	**9,314589666**
intensity	1e-5					
Length	0.001m					
curvature control	ON					
k-omega SST		**6,57**	**63,33**	**1423058**		**9,639269406**
intensity	1e-5					
Length	0,01m					
curvature control	ON					
k-Omega SST		**5,56**	**62,9**	**4383600**		**11,31294964**
mesh box in front						
w.o. transition						
intensity	1e-5					
length	0,001m					
curvature control	ON					
k-omega SST		**6,09**	**63,9**	**1423058**		**10,49261084**
mesh box in front						
w.o. transition						
intensity	1e-5					
Length	0,01m					
curvature control	ON					

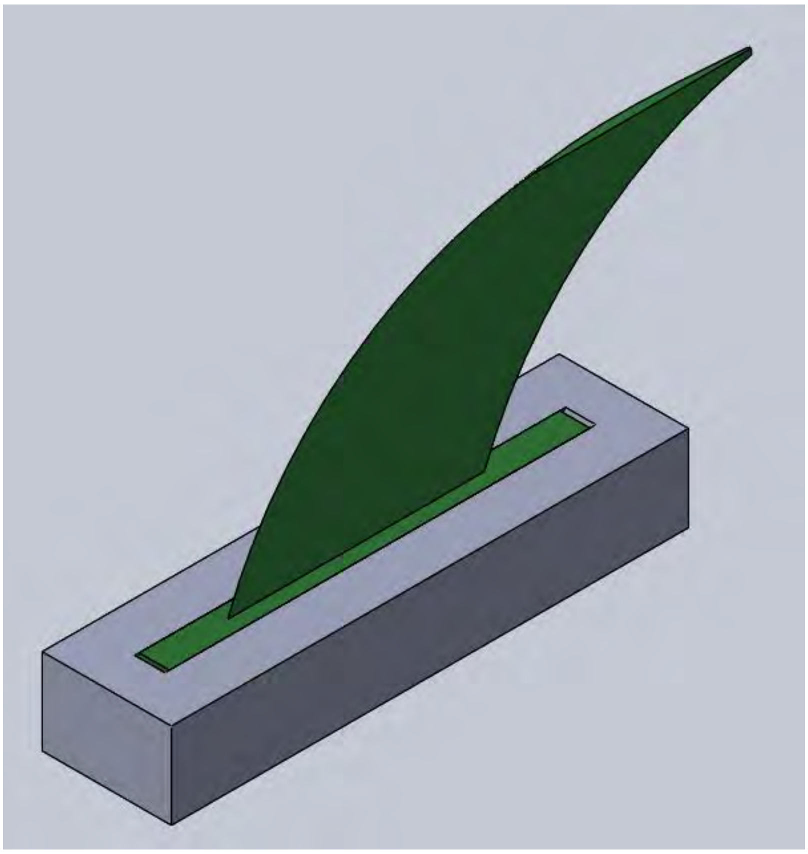
C Patent Draft 1

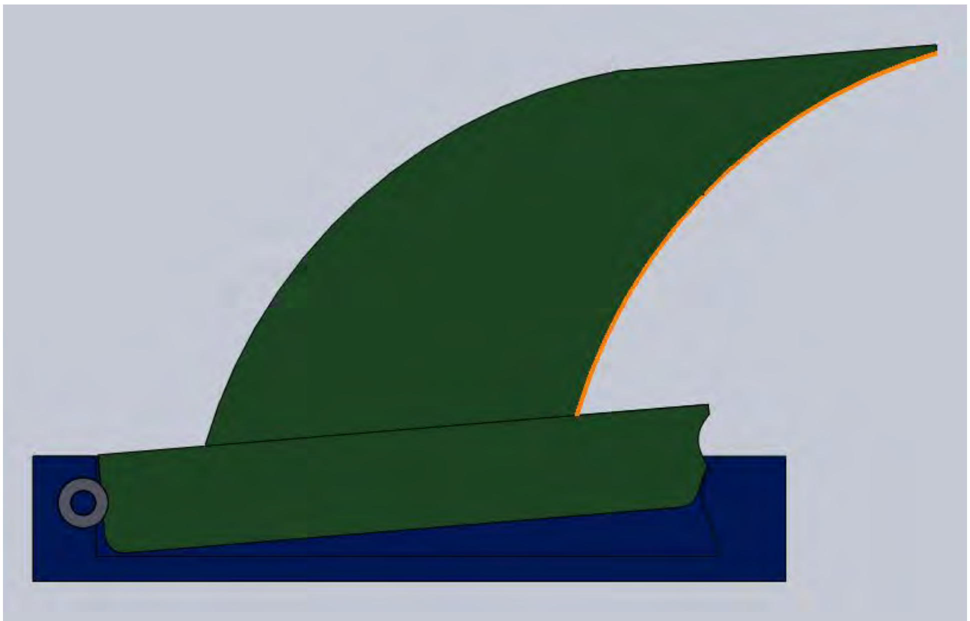
The following is the first draft sent to an IP attorney for analysis of potential infringement.

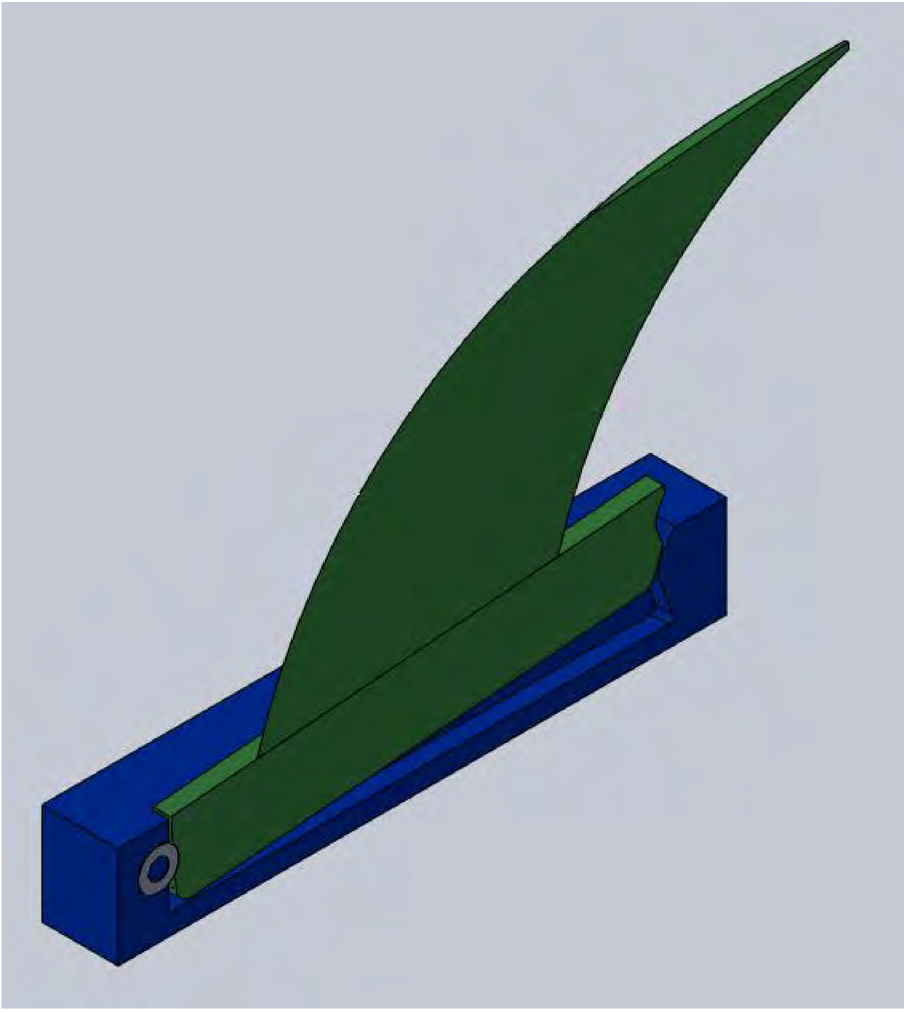
Ring - Bump











The fin plug consists of a single cavity, with a front end, rear end and opposed sides.

The front end of the plug contains a ring-shaped member, attached on a resiliently flexible axis which allows said ring-shaped member to rotate around it.

The rear end of the plug contains a protrusion, that could be described as a “bump”, which presents no flexible characteristics.

The base portion of the fin is shaped to fit inside the fin plug.

The front end of the base consists of a recessed geometry, that could be described as concave, to match that of the convex geometry presented by the ring-shaped member in front end of the fin plug.

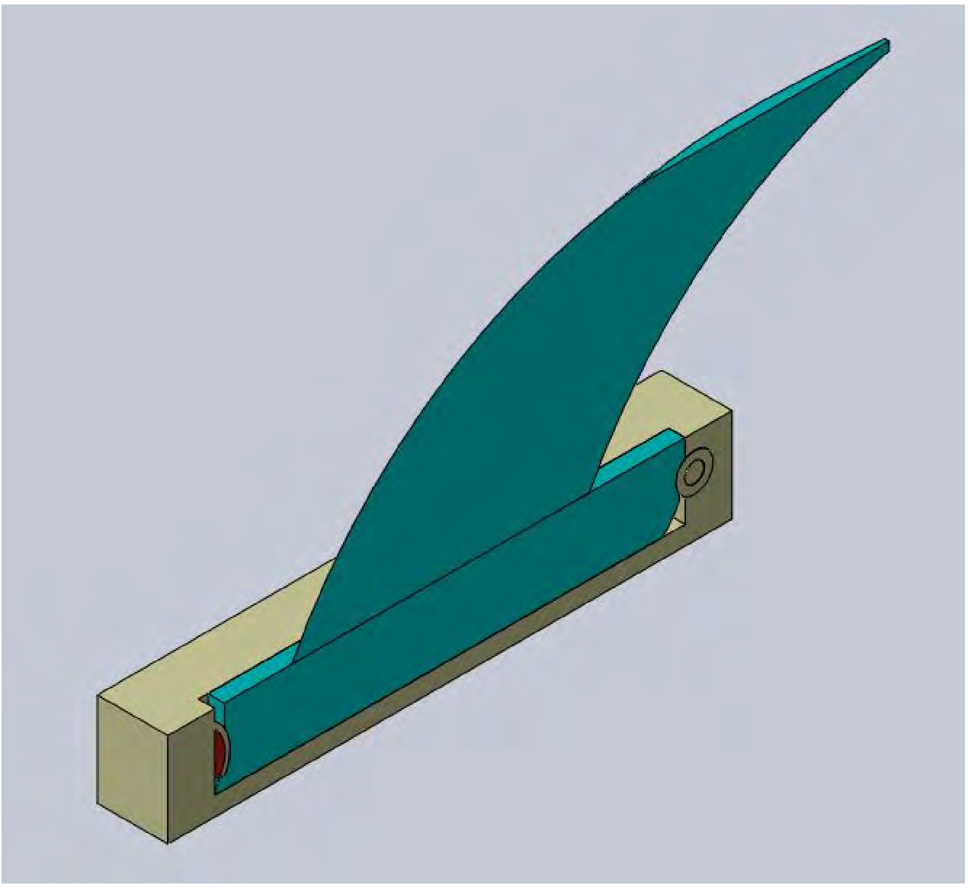
The rear end of the base consists of a recessed geometry that matches that of the "bump" on the rear end of the fin plug. At the bottom of the rear end of the base portion, a slanted cut-out exists, which is designed to abut the "bump" on the rear end of the fin plug during the process of inserting the fin.

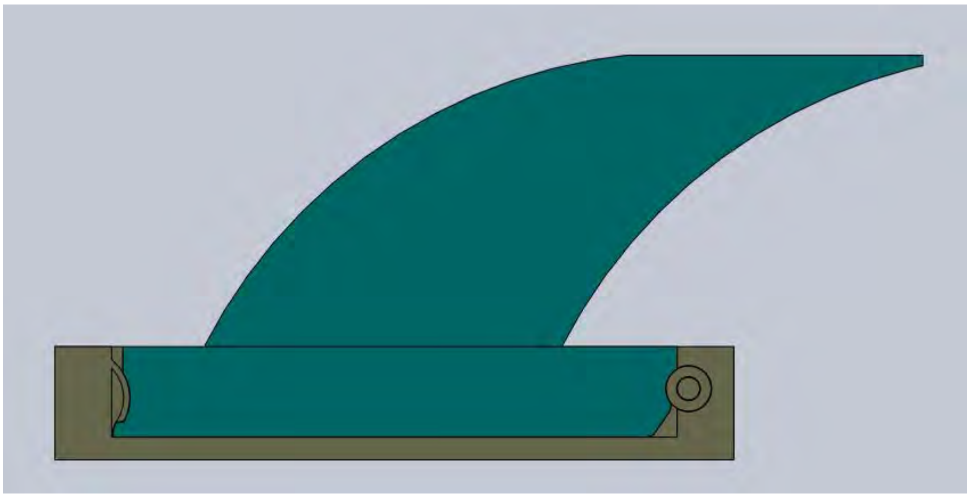
The base portion of the fin is inserted into the plug by pressing the recessed geometry on the front end of the base portion onto the ring-shaped member in the front end of the plug. The ring-shaped member will act as a pivot point when pushing the rear end of the base portion downwards, onto the "bump". Thanks to the angle of the slanted cut-out at the rear end of the base portion pushing the flexibly mounted ring-shaped member at the front end of the fin plug, the base portion is forced past the "bump". The base portion is inhibited from moving due to the pressing forces presented by the ring-shaped member and "bump".

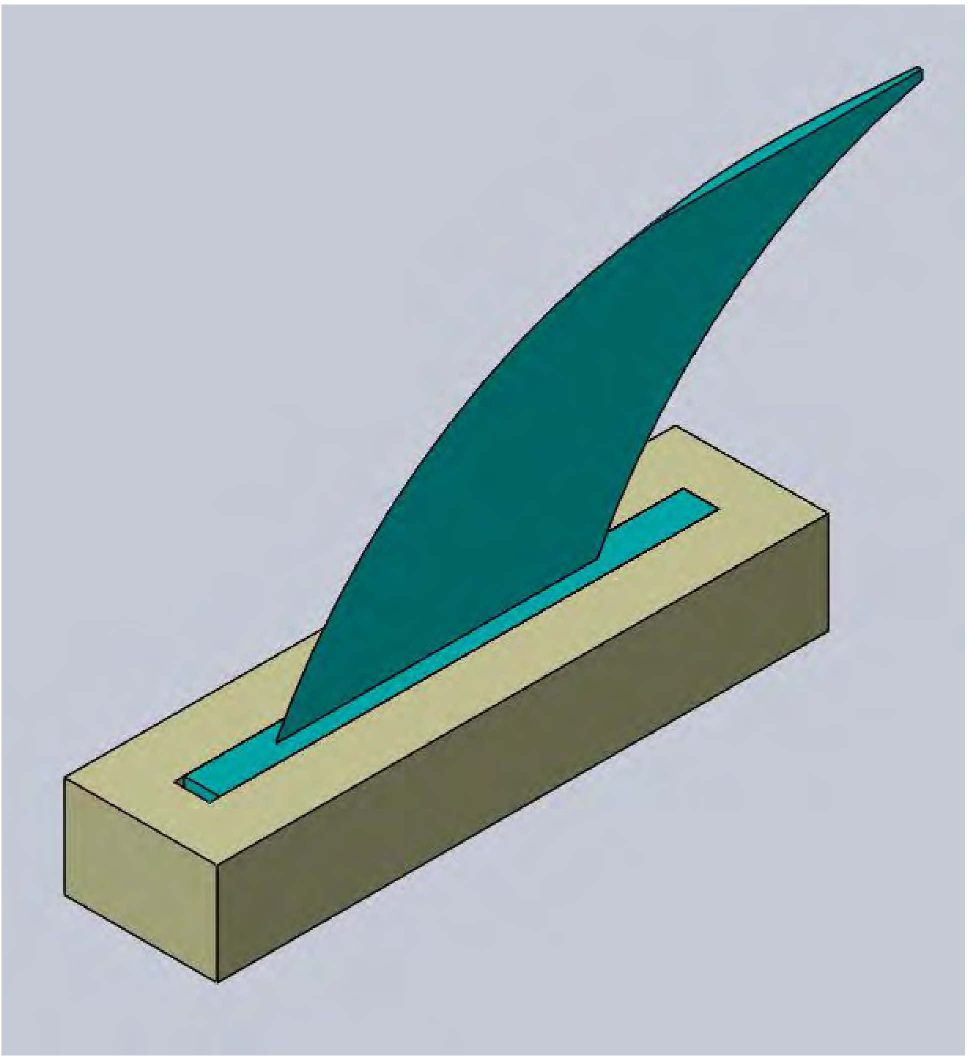
Reasons for not infringing on current patent:

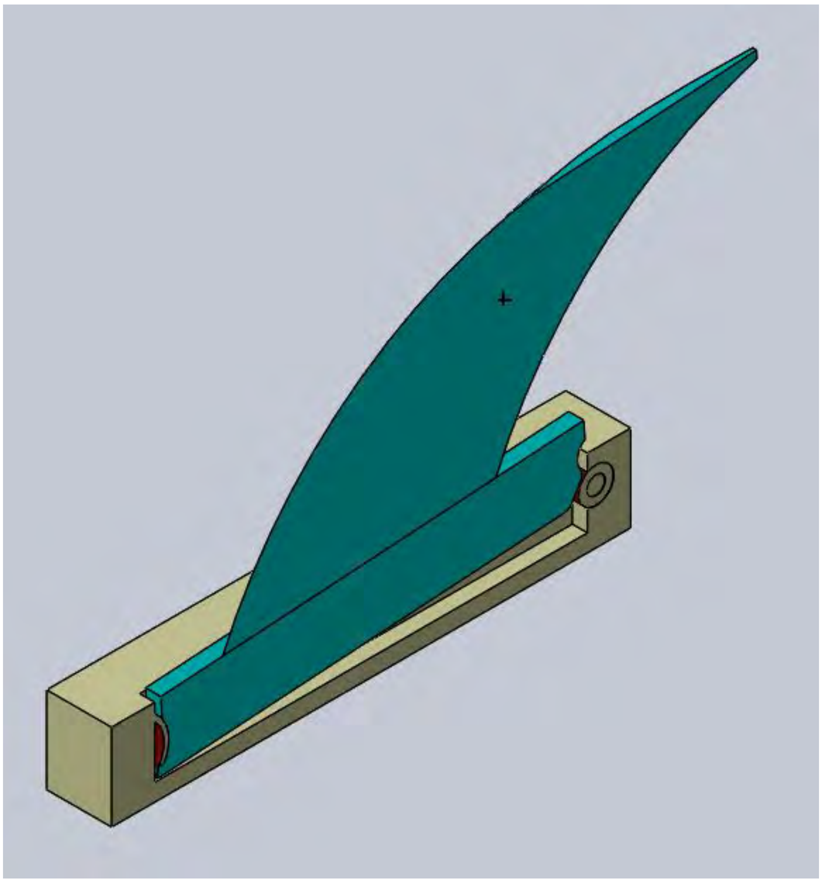
- ring-shaped member is located on the end, not on the opposed sides in the cavity
- use of a "bump" instead of a ledge
- ring-shaped member acts as pivot point, not the ledge or "bump"

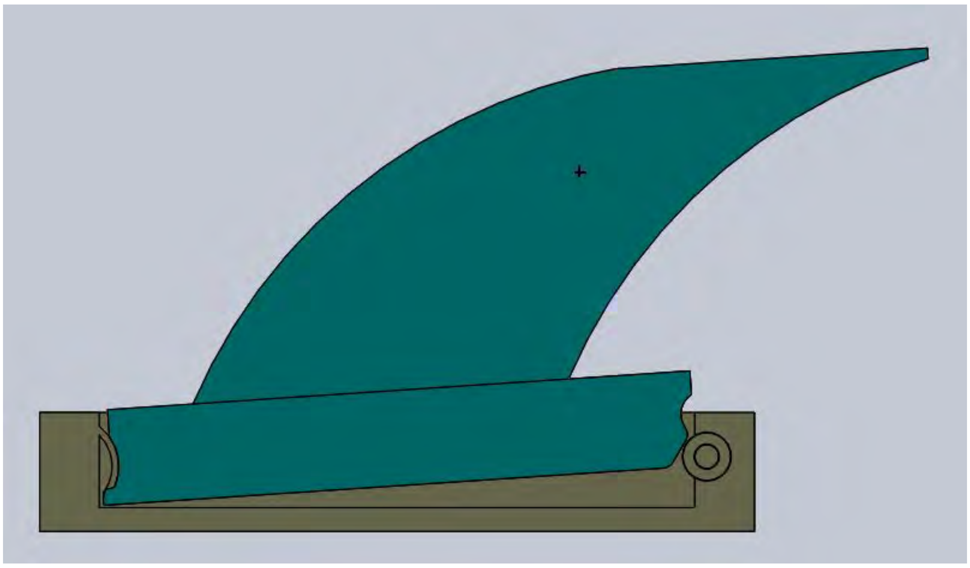
Flex - Ring











The fin plug consists of one cavity, comprising a front side, rear side and opposed sides.

The front end of the fin plug contains a protruding (convex), resiliently flexible, member.

The rear end of the fin plug contains a ring-shaped member which is mounted about a fixed axis. The ring-shaped member is able to rotate around said axis.

The front end of the base portion is recessed (concave) and shaped to fit the flexible member at the front end of the fin plug. The bottom of the front end of base portion is protruded (convex) in order to press on said flexible member in both an upwards and a forwards direction whilst being in its locked position.

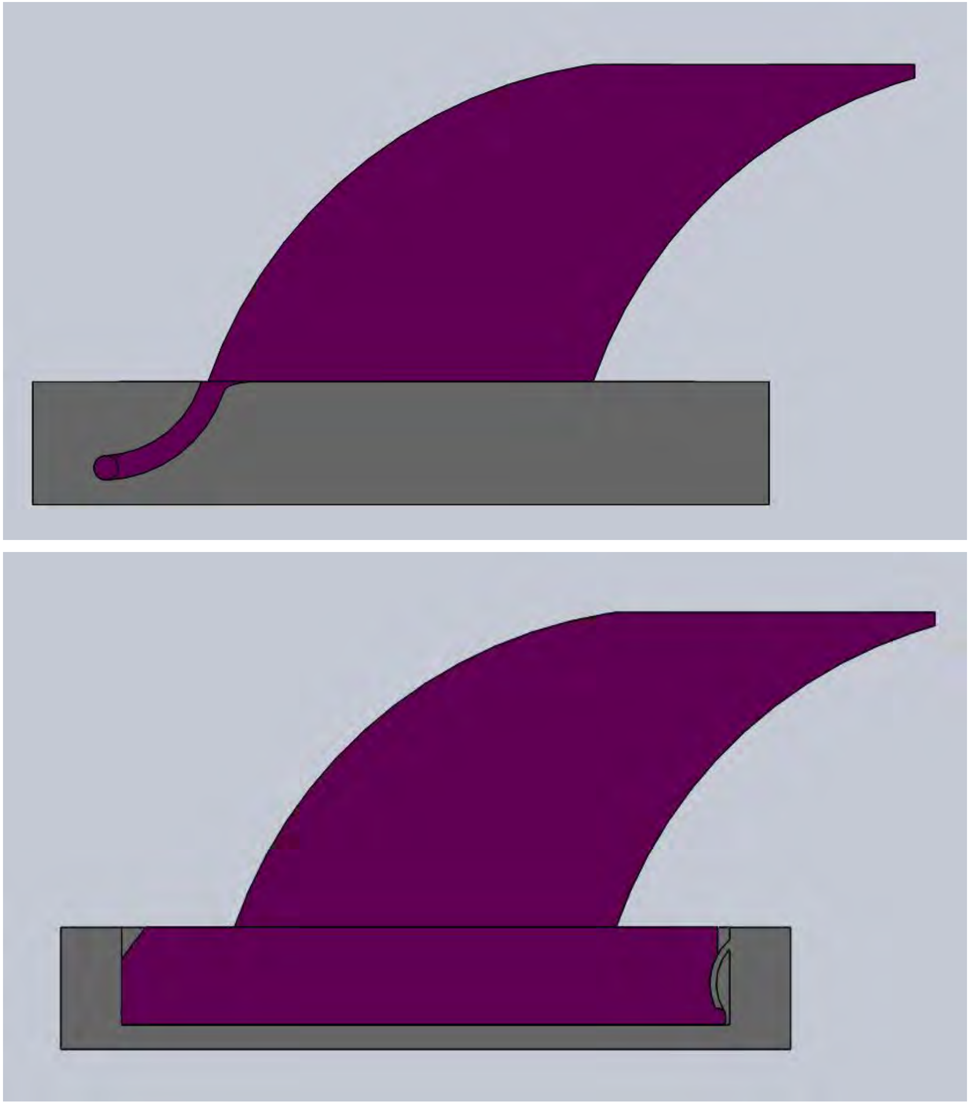
The rear part of the base portion consists of a recessed (concave) shape, matching that of the ring-shaped member on the rear part of the fin plug. The geometry underneath the recessed shape is slanted, allowing the surface to abut the ring-shaped member during the process of inserting the fin. The slanted surface increases the force/resistance the further down the base portion is pushed into the fin plug.

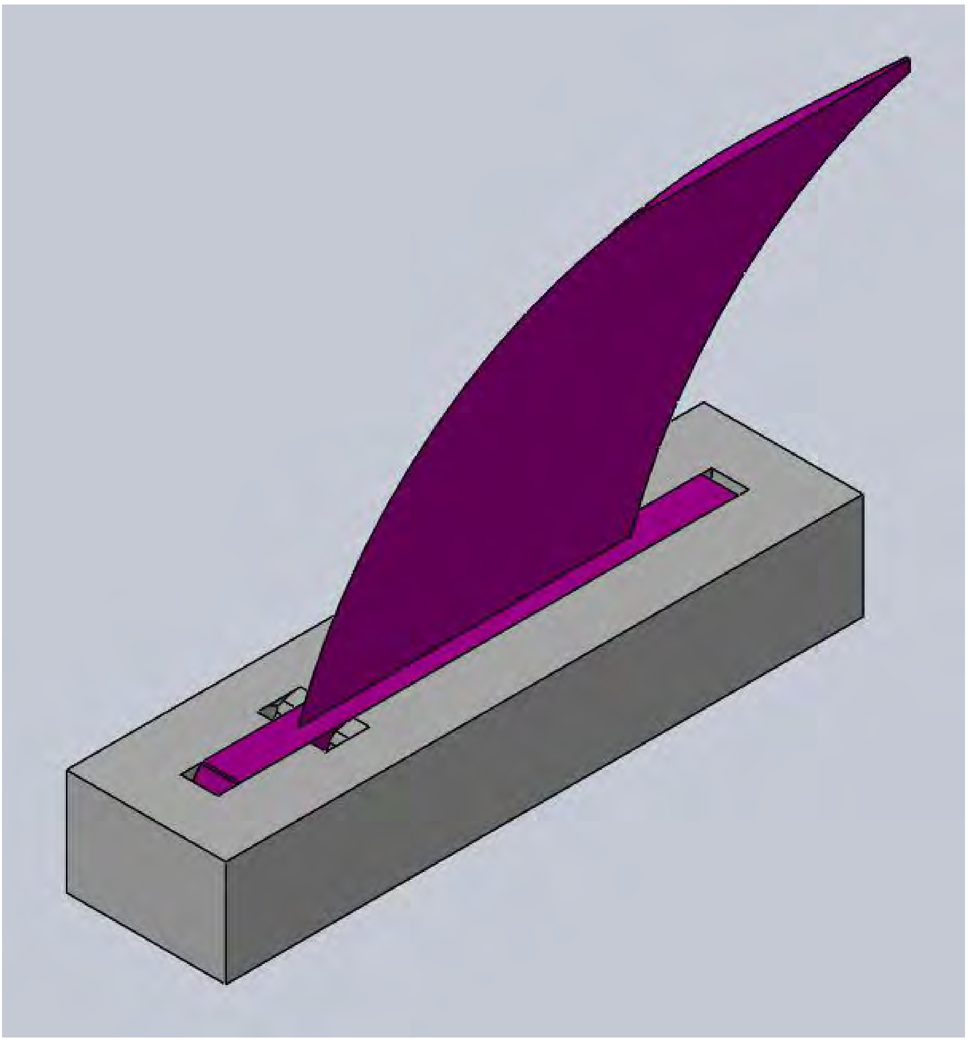
The base portion is inserted by pressing its front end onto the flexible member at the front end of the fin plug, thereby generating a pivot point. The rear end of the base portion is then pressed downwards. Thanks to the slanted surface at the bottom of the rear end of the base portion and the ring-shaped member at the rear end of the fin plug, the fin base portion is forced onto and under the flexible member in the front end of the fin plug. The fin is locked when the peak of the slanted surface at the rear end of the base portion is pressed under the ring-shaped member on the rear end of the fin plug, thereby leaving said ring-shaped member pressing on the convex surface, at the rear end of base portion, in a state of equilibrium.

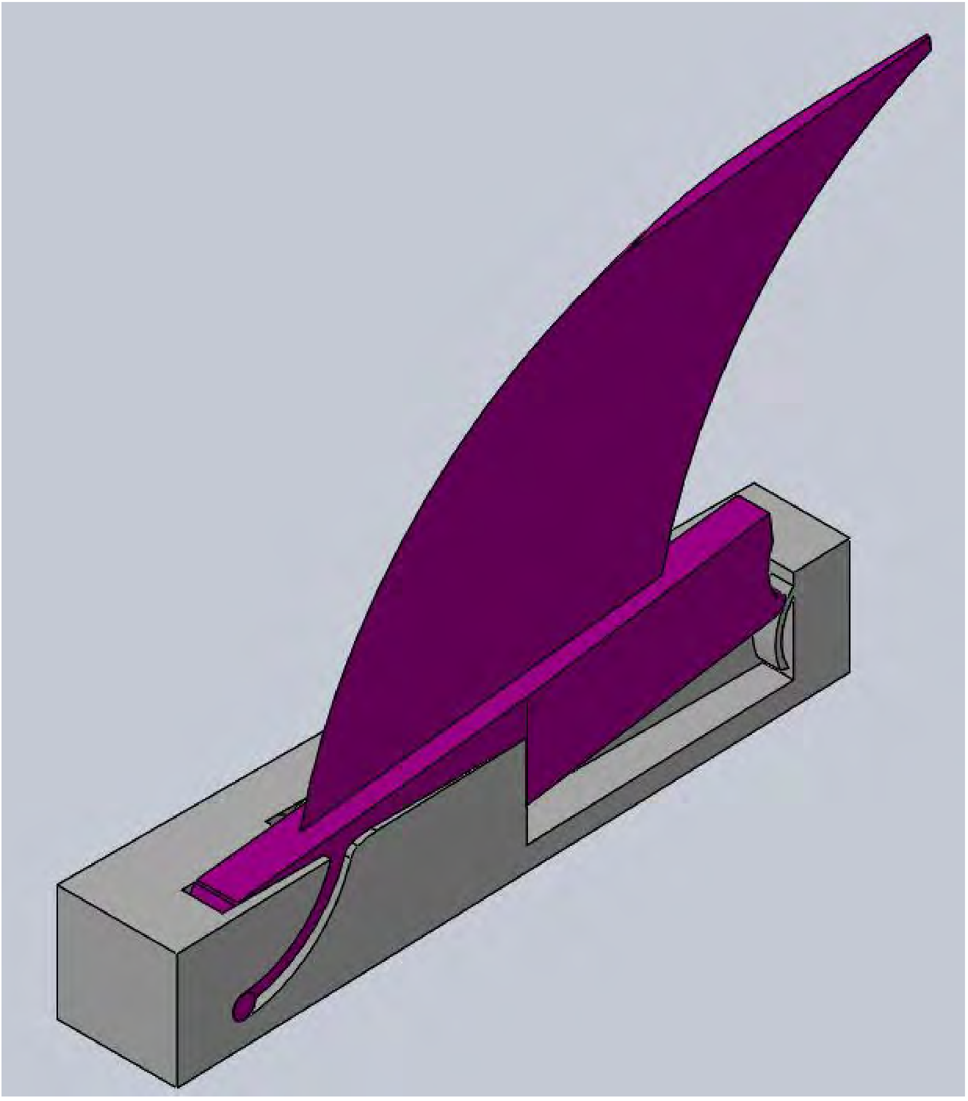
Reasons for not infringing on current patent:

- ring-shaped member is located on the end, not on the opposed sides in the cavity
- use of a flexible member that is not a ring-shaped member or is attached to an axis that is resiliently flexible
- ring-shaped member and its axis do not present flexible properties, their function is only to allow the ring-shaped member to roll when the fin is being inserted

Tracks - Flex







The fin plug consists of one cavity, with a front side, rear side and opposed sides with cut-out tracks swept through them.

The front end of the plug consists of extruded tracks, which starts at the top surface and leads down to the bottom, most forward point of the cavity in the plug.

The rear end of the plug consists of a resiliently flexible, protruding (convex), member.

The bottom of the front end of the base portion consists of an extruded geometry with similar dimensions as the cross section of the tracks in the front end of the fin plug.

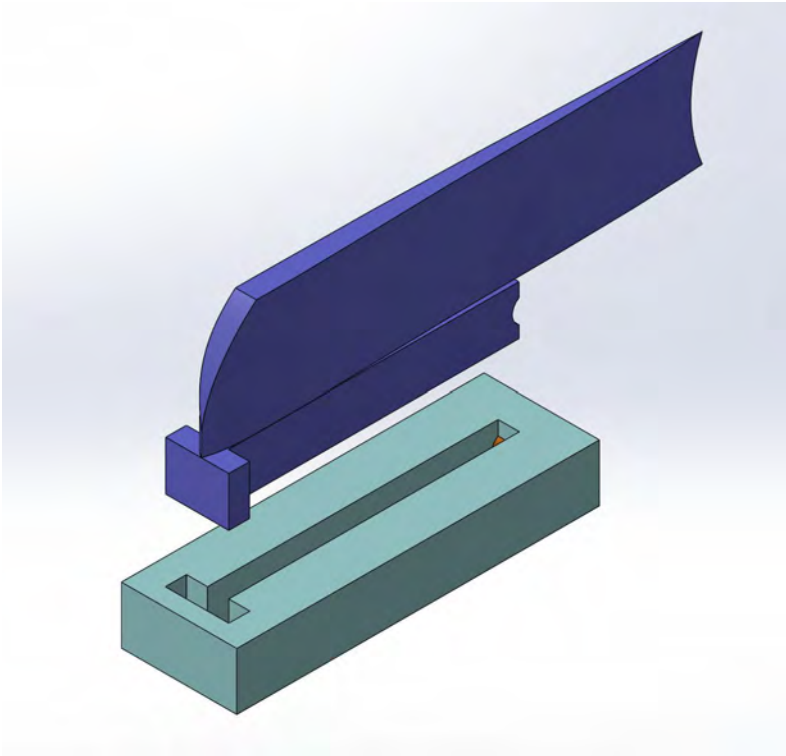
The rear end of the base portion is recessed (concave) to match the protruded shape of the flexible member on the rear end of the plug. The bottom part, underneath said recessed shape, is protruded (convex), meaning it will fit under the flexible member on the rear end of the plug whilst pushing the flexible upwards and rearwards, when in locked position.

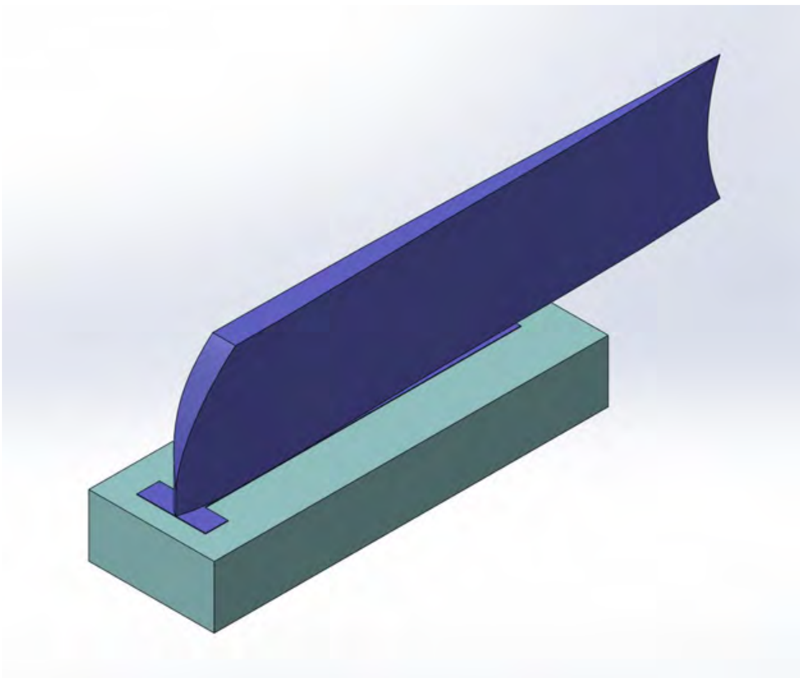
The base portion is fastened by inserting the extruded geometry on the front end of the base portion into the tracks on the front end of the plug. By sliding the geometry along the tracks and simultaneously pressing the rear end of the base portion downwards, the protruded geometry on the rear end of the base portion will be pushed under the flexible member. The forces from the walls at the end of the tracks in the front end of the plug and the flexible member on the rear end of the plug will inhibit the base portion from moving.

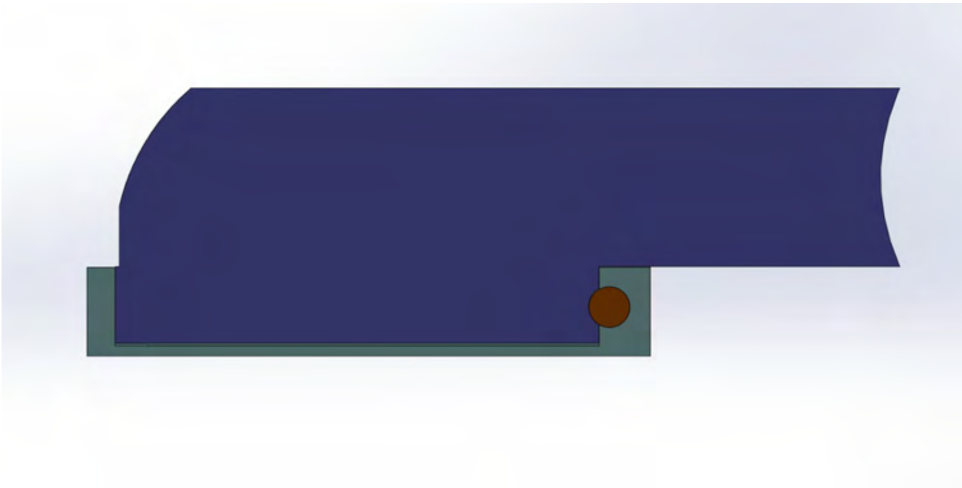
Reasons for not infringing on current patent:

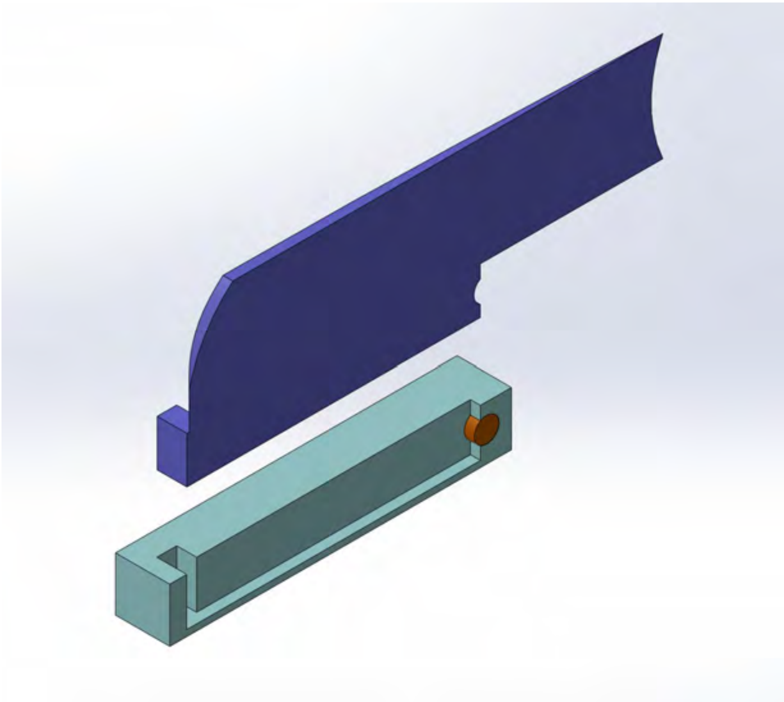
- flexible member is located on the end, not on the opposed sides in the cavity
- different geometry and mechanical function is used when inserting the nose of the fin
- use of a flexible member that is not a ring-shaped member or is attached to an axis that is resiliently flexible

T-shape - Ring









The fin plug consists of one cavity, with a front side, rear side and opposed sides.

The front end of the plug consists of a T-shaped cavity, allowing the corresponding fin base portion to be slid into the right place.

The rear end of the cavity consists of a ring-shaped member, mounted on an axis. The protruding ring-shaped member is able to rotate around said axis.

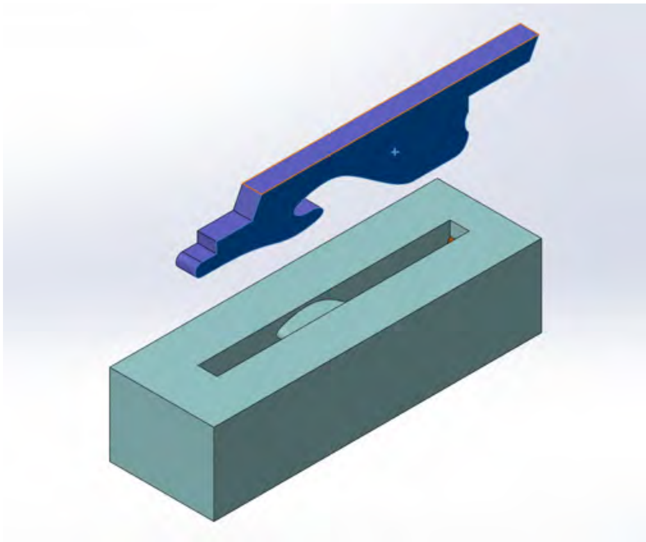
The rear end of the base portion contains a recessed geometry cooperating with the previously mentioned ring-shaped member.

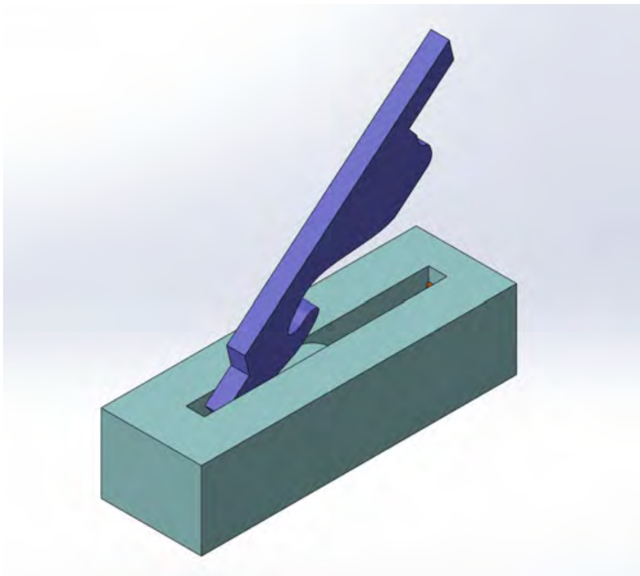
Assembling of the fin base portion and the fin plug is achieved through a uniform pressing force from above. Sliding the T-shaped base portion into the corresponding slot. Simultaneously, the rear end of the fin's base portion passes the protruding ring-shaped member, ending up in the recess of the base portion.

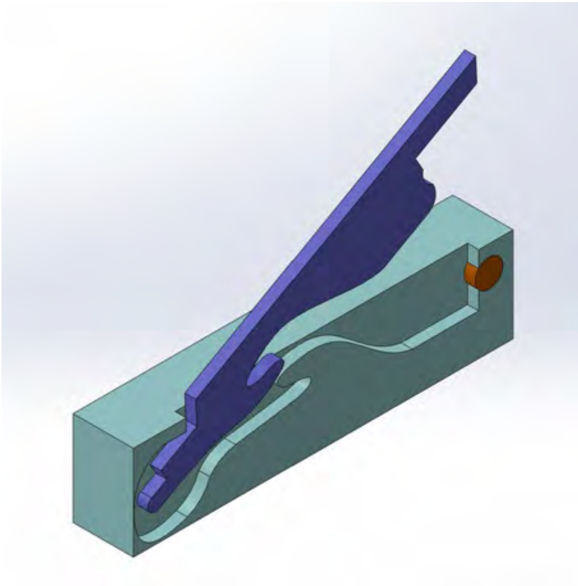
Reasons for not infringing on current patent:

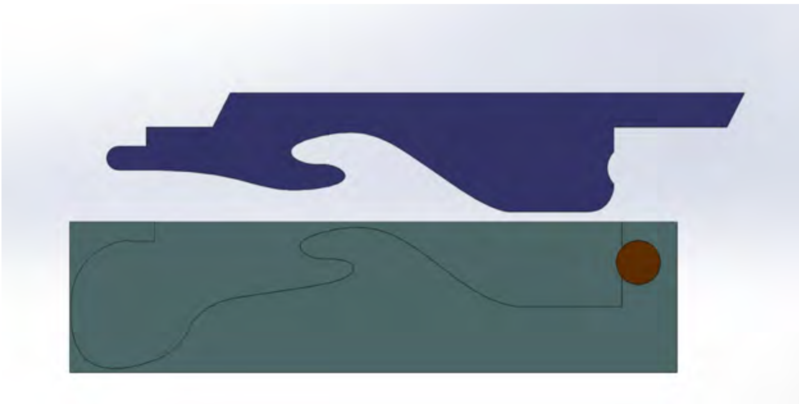
- ring-shaped member is located on the end, not on the opposed sides in the cavity
- using a different mechanical function, no pivoting is used, only uniform pressing from above
- different geometry in the cavity and base portion is used, thanks to the T-shape

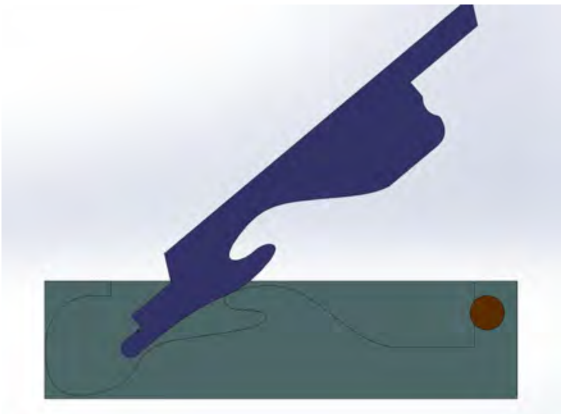
Protruding engagement ledge from centre bridge

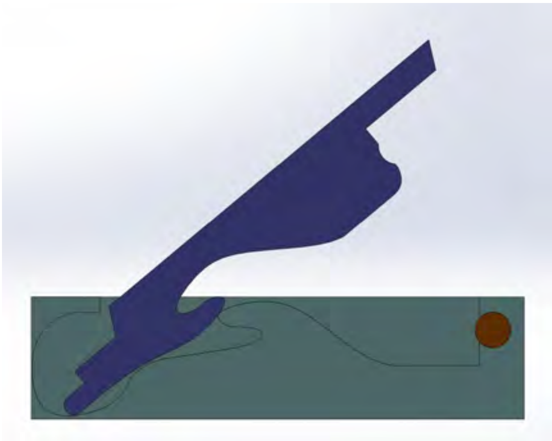


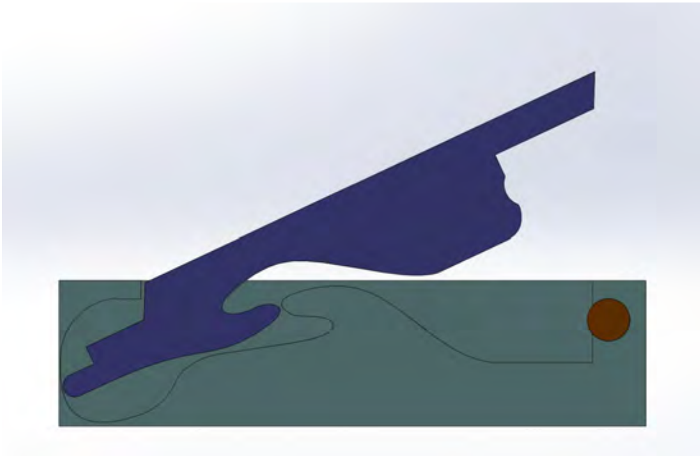


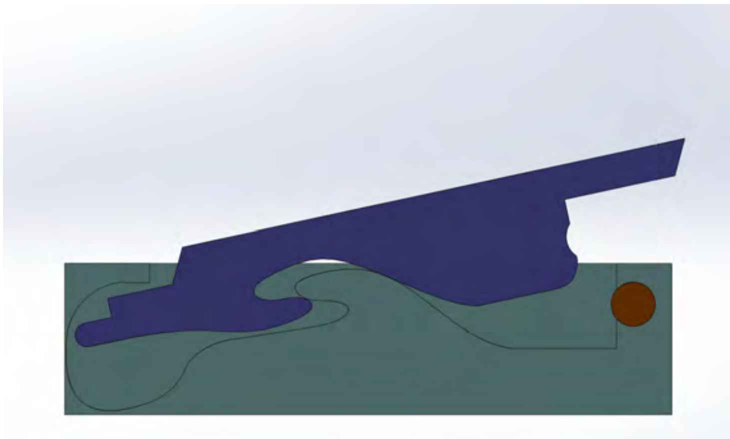


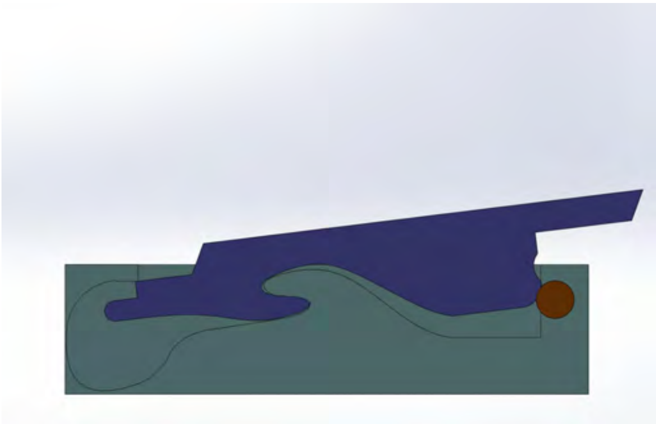


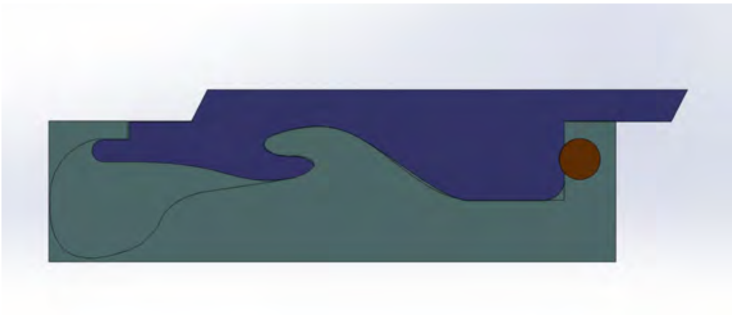












The fin plug cavity consists of two open cavities, connected through an organically-shaped bridge section.

The front open cavity having a fin engagement interacting with the rear end of the front base portion of the fin. The cavity geometry is adapted to allow for a smooth insertion of said fin. The front end of the open cavity is of a circular shape. The roof of the plug in the front end acts as a stopping agent together with the protrusion from the bridge section.

The front base portion of the fin is adapted to underlie the bridge protrusion as well as the protruding roof of the front end of the cavity.

The rear open cavity consists of a resiliently protruding ring-shaped member from the rear-side surface.

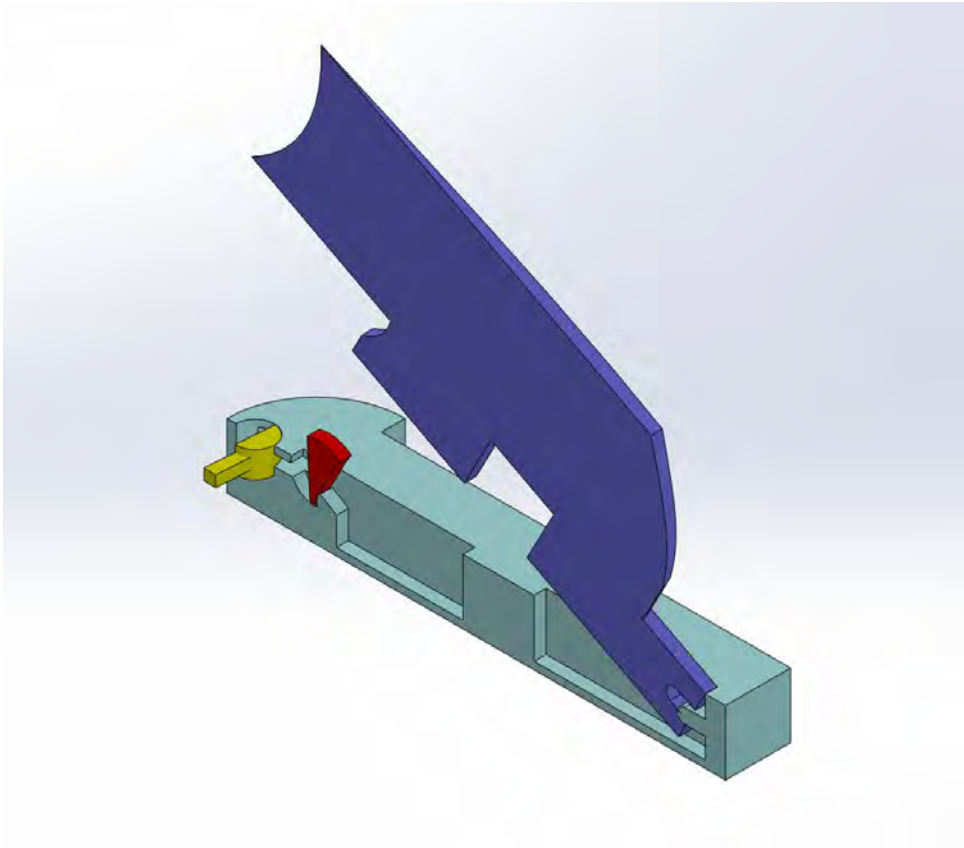
Insertion of the front base portion through an angle allows a pivoting motion of the fin (around the pivot point at the bridge section). Enabling a mechanical advantage when inserting the rear base portion. Said rear base portion consists of a recess cooperating with the ring-shaped member. Adding another mechanism fixating the fin into the cavity.

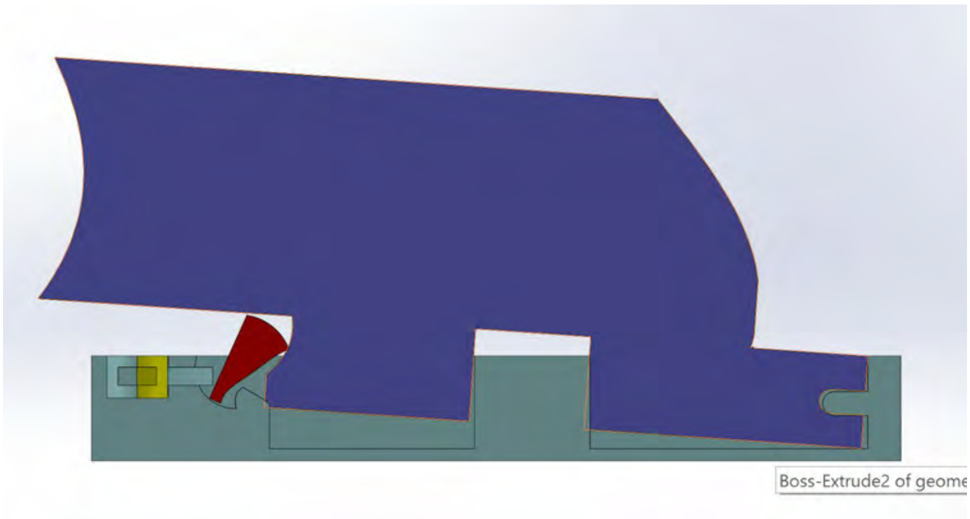
Reasons for not infringing on current patent:

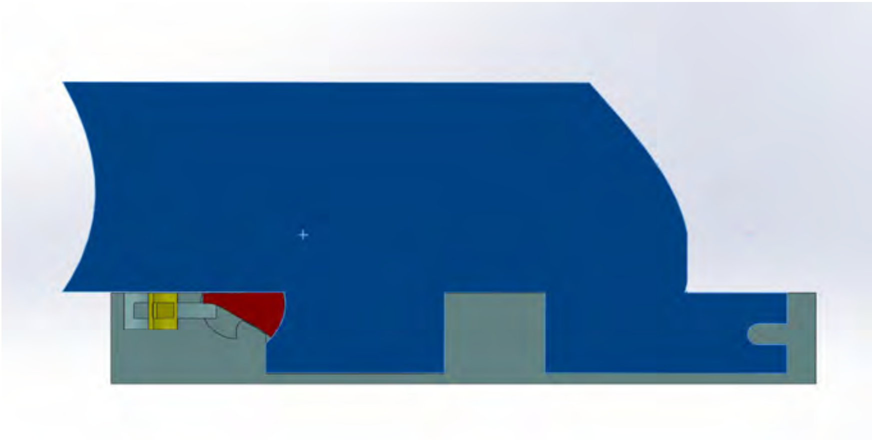
- ring-shaped member is located on the end, not on the opposed sides in the cavity

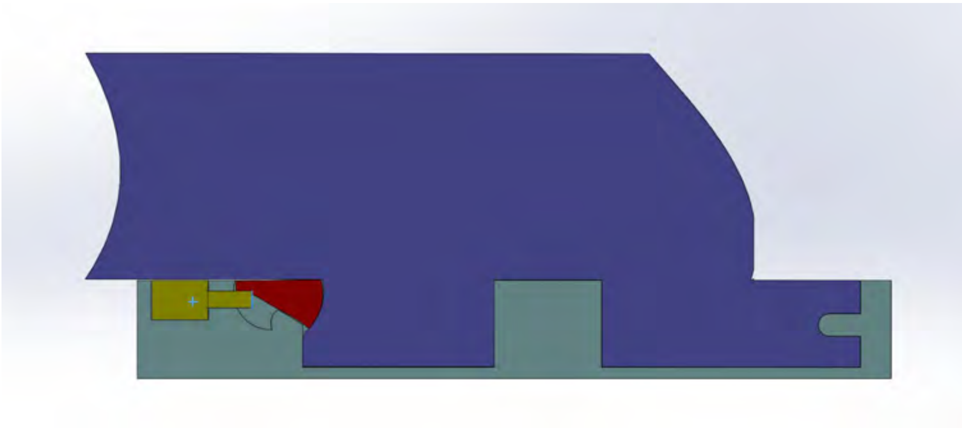
- different mechanical function is used, requires different movement when inserting the fin, in comparison to current patent
- pivot point is not in the front, it’s placed towards the center
- the geometry of the cavity is different to that of the current patent

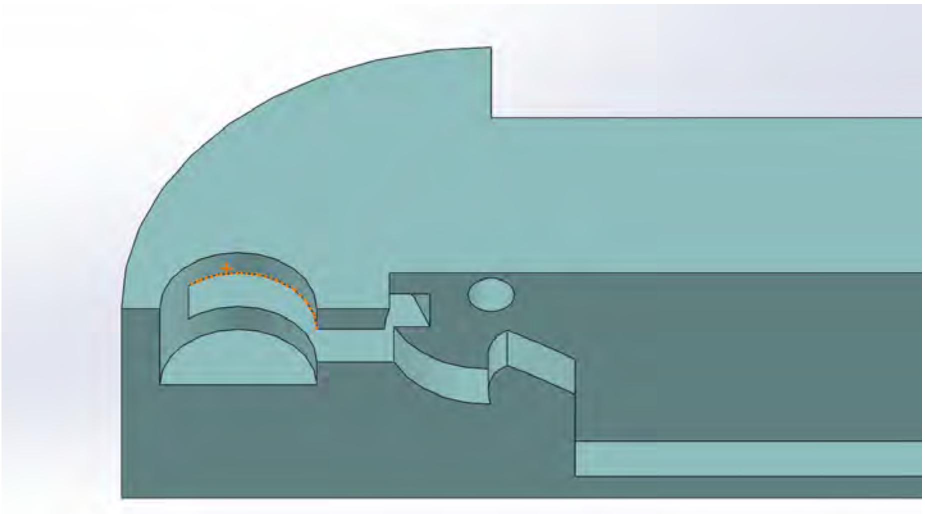
Rotating convex shape member











The fin plug consists of two open cavities, with a front end, rear end and opposed sides.

The front open cavity having a fin engagement in the front end, consisting of a protrusion and cooperating with a recess in the front end of the fin's base portion.

The rear open cavity consists of a rotating convexed-shaped member (RED). Said member resemble a circular sector with a degree less than 90. The axis of rotation is located in the middle of the said sector. Enabling an interaction with the sector and fin as well as a locking agent (YELLOW).

The rotating convexed-shaped member is locked in place via a horizontally rotating locking agent.

Inserting the front base portion of the fin through an angle allows for a mechanical advantage, pivoting the fin to insert the rear base portion.

The rear base portion consists of a recess cooperating with previously mentioned convexed-shaped member. Through a frictional grip and a downwards pointing force, the fin's base portion is fixed in place.

When pivoting the rear base portion into place an interaction is supposed to guide said rotating member to its locking state.

The rotating member is preferably, not exclusively made of a frictional material e.g. rubber.

The horizontally rotating locking agent fixates through a small ledge which holds it in the locking position.

Reasons for not infringing on current patent:

- different geometry on rotating (convex) member that locks fin into position
- rotating member is placed at the end of the cavity, instead of opposed sides
- mechanical function requires use of locking agent, a feature that does not exist in current patent

D Concept Screening

The following is the conducted screening process as well as sketches of the initial fin plug concepts.

Table D.1 Table over Concept Screening of the first 15 chosen concepts. Illustrations and descriptions of the concepts can be found in Appendix D.

	Ref	Ring - bump	Round flex - bump	T-shape - Ring	Tracks - Round flex	Slide - hinge	Stapler	Slide - Ring	Pivot - Rear pressure	Pivot - Pie	Center pivot organic cav.	Air pressure	Water pressure	Scissor	Axe head	Thread-ed puck
EoA	0	0	0	0	0	-	-	0	0	-	0	+	+	-	-	-
EoD	0	0	0	0	0	-	0	0	0	-	0	0	+	-	0	-
AoP	0	0	0	0	+	-	-	0	+	-	0	+	+	-	-	-
RoT	0	0	0	0	0	-	-	0	0	-	0	-	-	-	-	-
EoM	0	0	0	0	0	0	-	0	+	-	0	+	+	-	-	-
Rel G	0	0	-	-	0	0	0	0	-	0	0	-	-	-	0	0
Dur	0	0	-	0	-	-	-	-	-	-	0	-	+	-	-	-
NET	0	0	-2	-1	0	-5	-5	-1	0	-6	0	0	+3	-7	-5	-6

Explaning Rows

EoA - Ease of Attaching
EoD - Ease of Detaching
AoP - Amount of Parts
RoT - Risk of Turbulence
EoM - Ease of Manufacturing
Rel G - Reliability of Grip
Dur - Durability

Explaning Columns

Ref - Reference value, today's solution

Ring - Bump

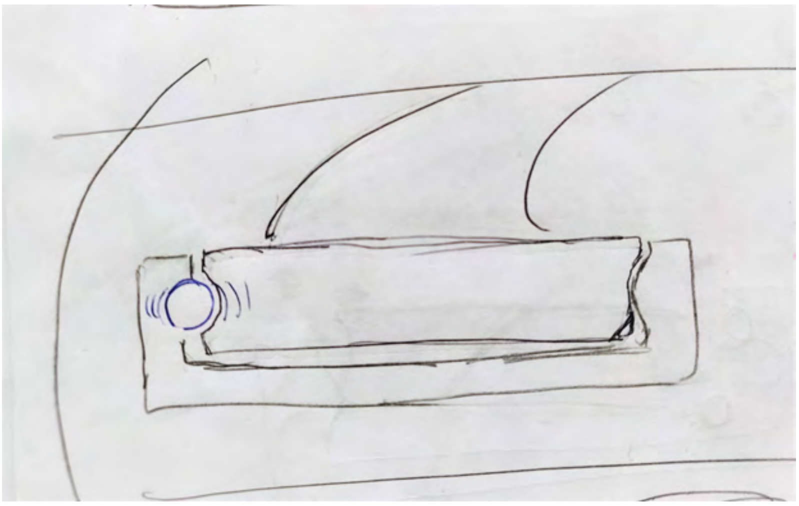


Figure D.1: Sketch of Ring - Bump concept. The ring in the front end of the cavity is intended to resiliently flex when attaching the fin.

Round flex - Bump

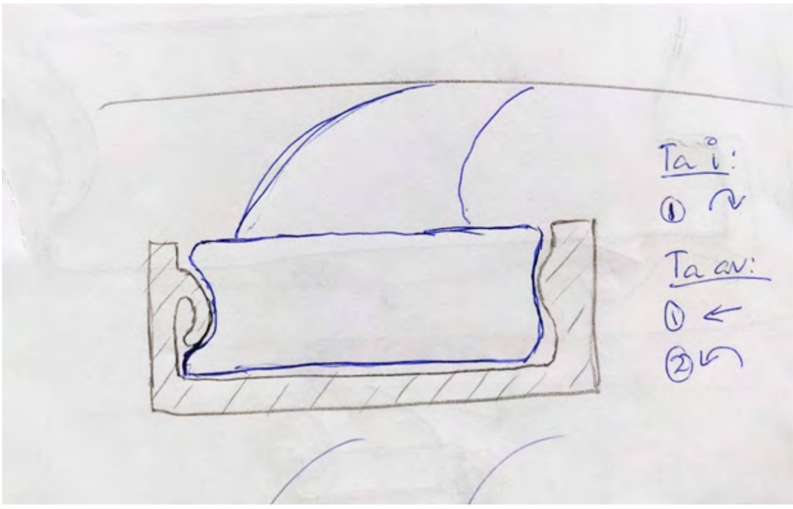


Figure D.2: Sketch of Round flex - Bump concept. The round agent in the front end of the cavity is intended to resiliently flex when attaching the fin.

T-shape - Ring

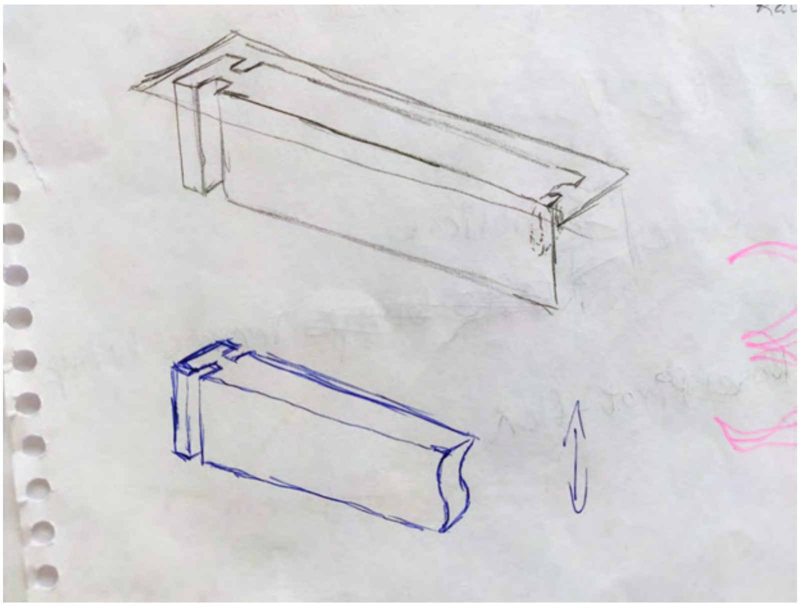


Figure D.3: Sketch of T-shape - Ring concept. The ring in the rear end of the cavity is intended to resiliently flex pressing the fin into the t-shaped track.

Tracks - Round flex

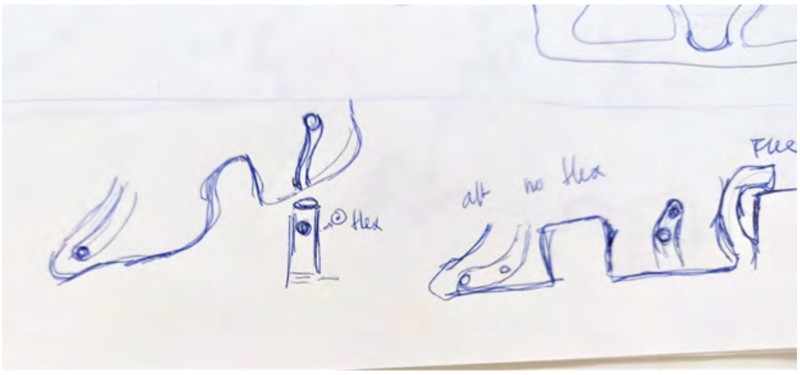


Figure D.4: Sketch of Tracks - Round flex concept. The resiliently flexing round agent, located at the side of the rear cavity, is intended to lock the fin into place when sliding the fin's nose into front cavity and pushing down the rear end.

Slide - Knäpp fast

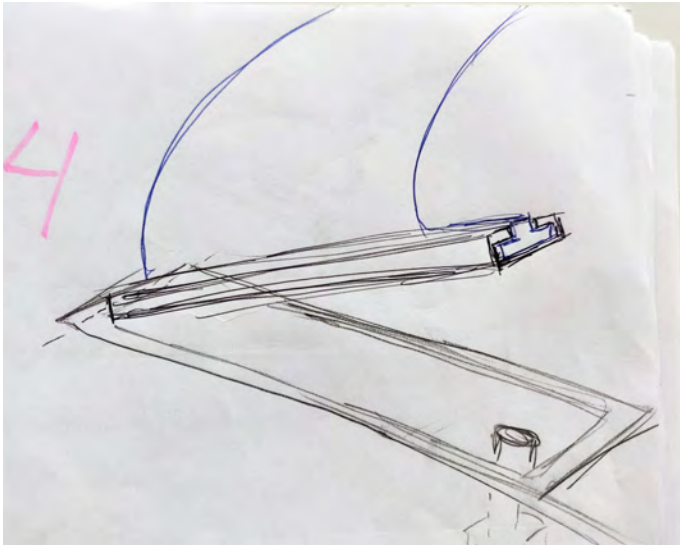


Figure D.5: Sketch of Slide - Knäpp fast concept. The fin is intended to be slid into a fin guide and afterwards having the assembly be pushed down, into the cavity. The fin guide is attached in the front end and is able to rotate around an axis, whereas the rear end features means for locking the guide by clicking it into place.

Häftpistol

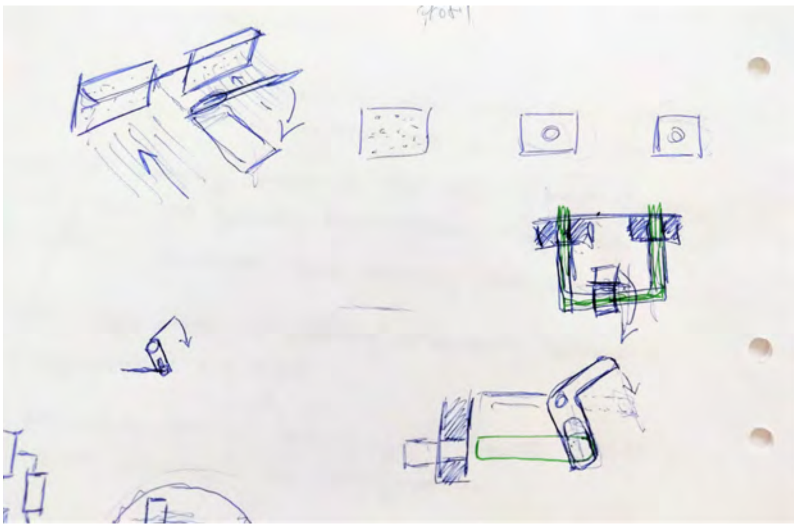


Figure D.6: Sketch of Häftpistol concept. The concept uses similarities to a stapler as the means for fastening mechanism. By pushing a lever, a staple shaped part locks the fin into place.

Slide - Ring

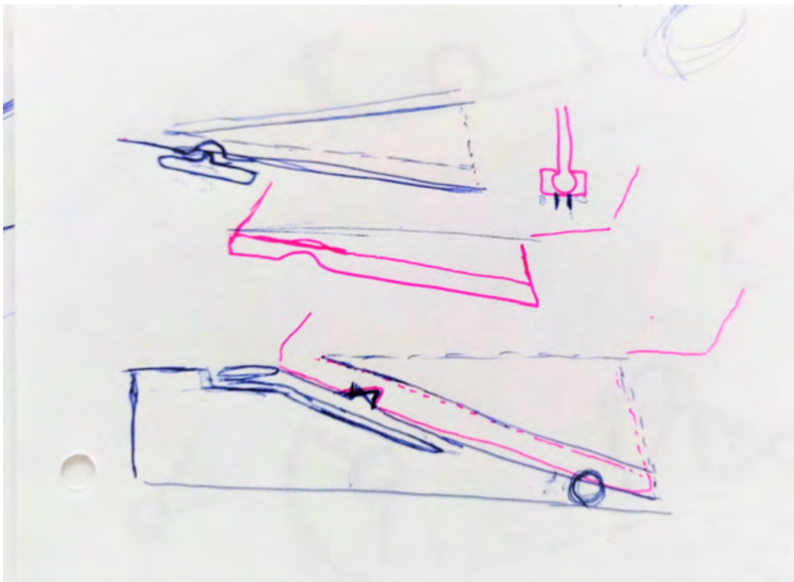


Figure D.7: Sketch of Slide - Bump concept. The fin slides into the cavity and locks in place via a flexing bump.

Pivot - Rear pressure

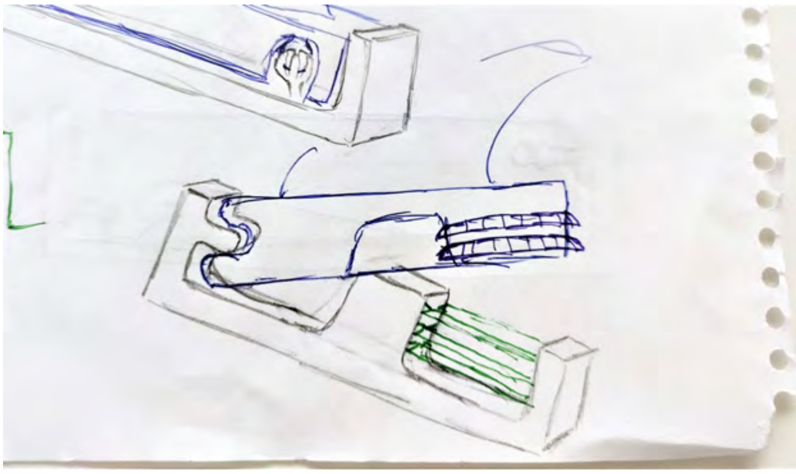


Figure D.8: Sketch of Pivot - Rear pressure concept. When pivoting the rear end into the rear cavity, a gasket lets the air pass and create an under pressure to fasten the fin.

Pivot - Pie - Amount of Parts

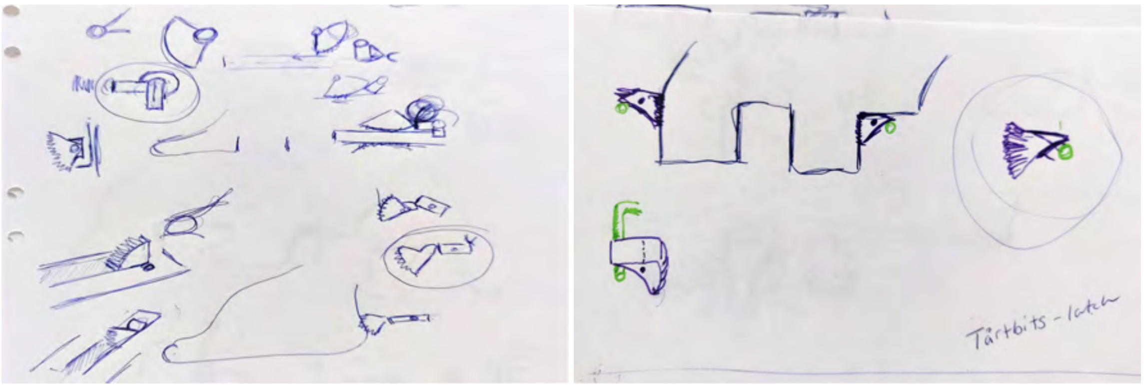


Figure D.9: Sketch of Pivot - Pie concept. A rotating member, in the shape of a pie slice, creates an acting force on the fin into the cavity when pushed into the inserted state.

Center pivot - Organic cav.

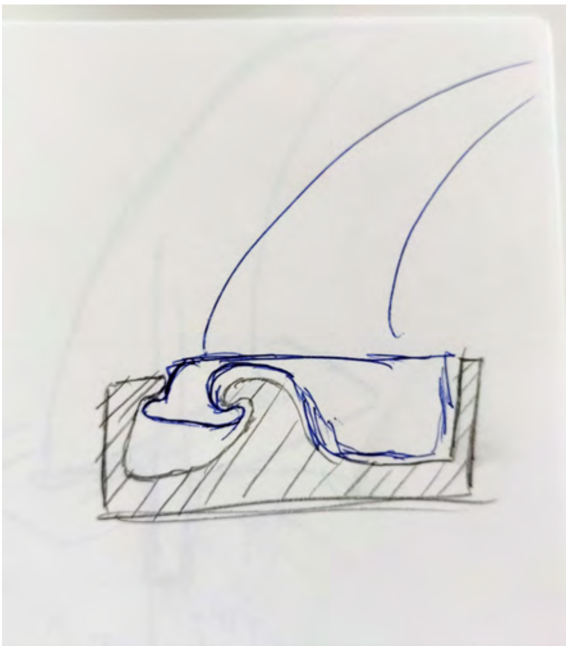


Figure D.10: Sketch of Center pivot - Organic cavity concept. With the organic shape, this concept is smoothly inserted and at the same time locks into place via the shape of the fin and fin plug.

Air pressure

Figure D.11: Sketch of Air pressure concept. This concept uses a check valve to create an under pressure in the fin plug cavity.

Water pressure

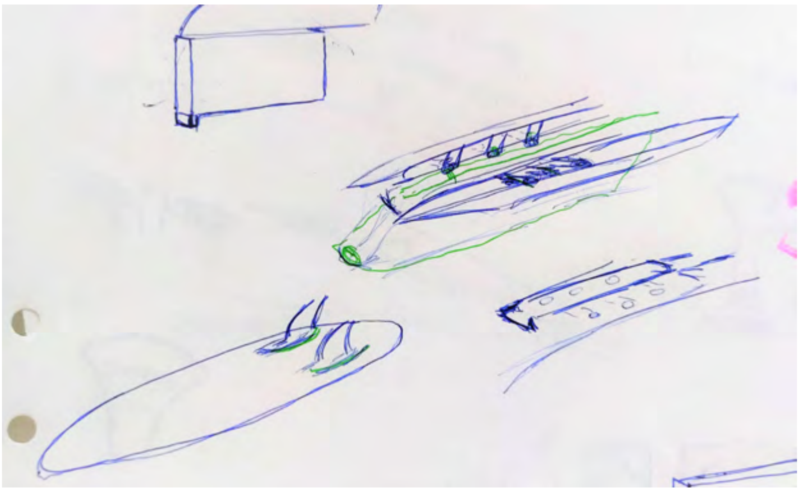


Figure D.12: Sketch of Water pressure concept. This concept makes use of the pressure built up by the water flow and would create a suction in the cavity to fasten the fin.

Scissor

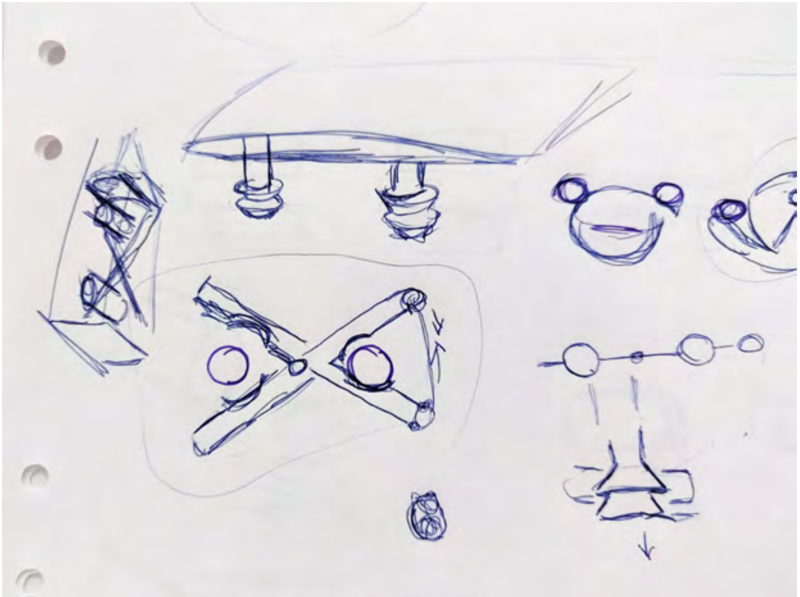


Figure D.13: Sketch of Scissor concept. With an axis of rotation inserted between the tabs, a fastening motion similar to a pair of scissors' tightens the fin into the plug.

Axe head

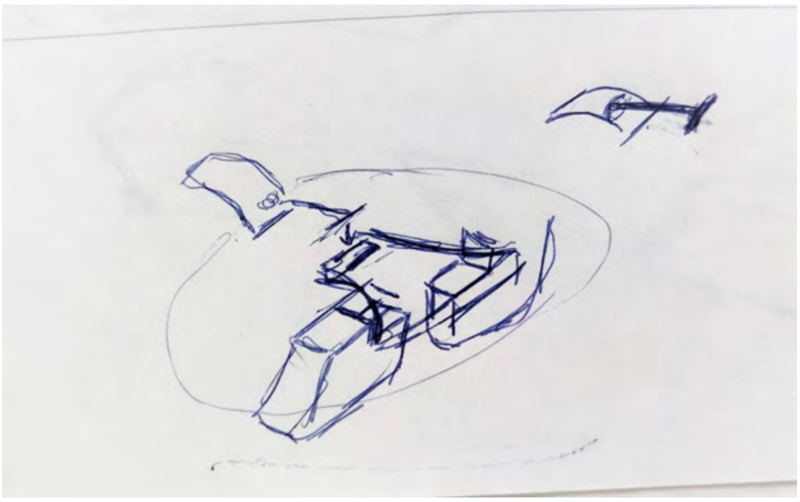


Figure D.14: Sketch of Axe head concept. The axe head shape is working as a wedge when fastened via a mechanical clasp.

Threaded puck

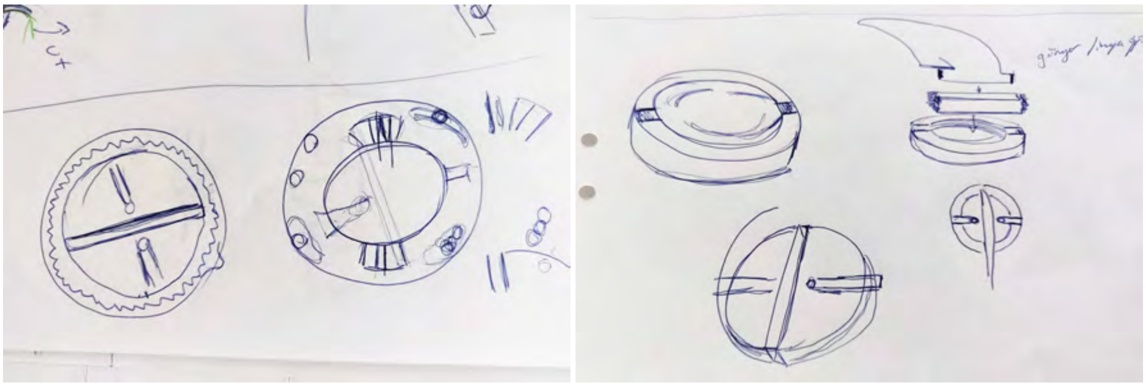


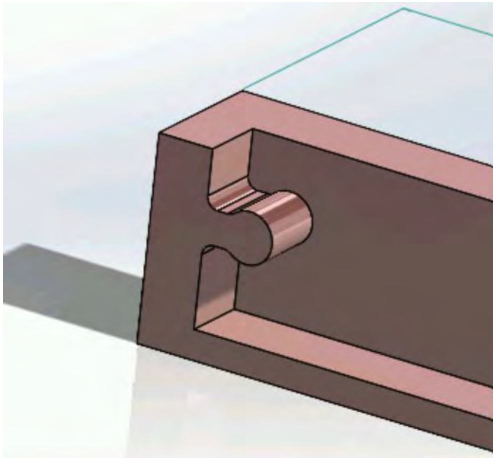
Figure D.15: Sketch of Threaded puck concept. The concept is supposed to make use of a vertical rotation and fastens similar to a screw with the use of threads.

E Patent Draft 2

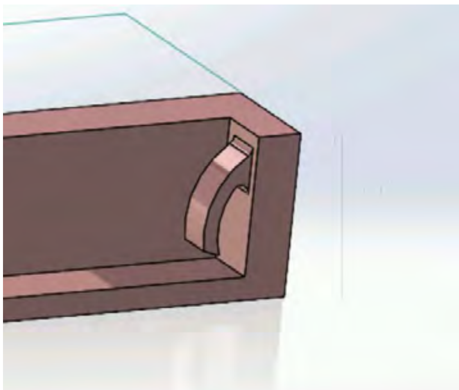
The following is the second and final draft sent to an IP attorney for analysis of potential infringement.

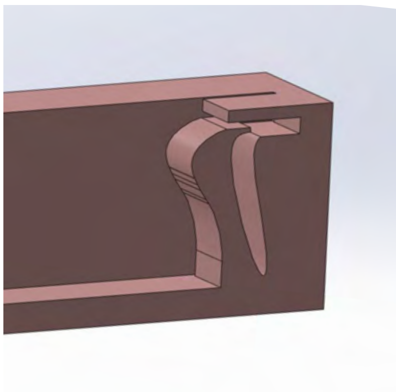
1. Ledge

Designs where the ledge is on the front end of the plug



Can be combined with the following components at the back end of the plug:

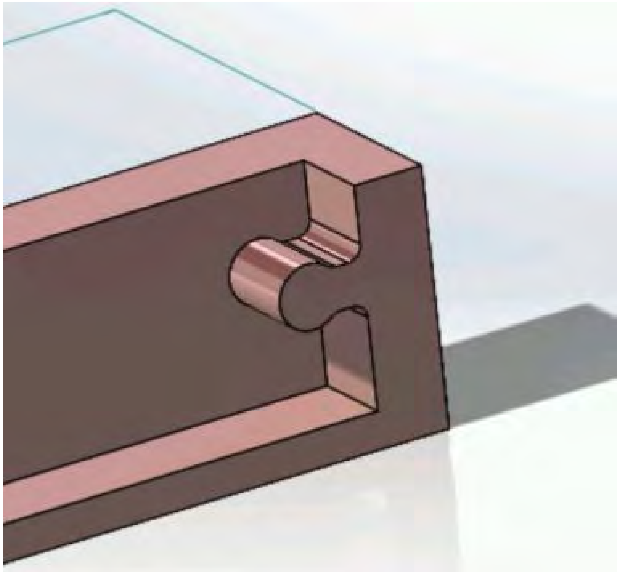




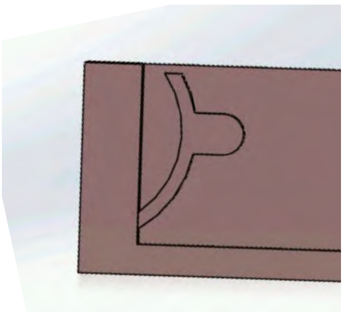
1.1 Flex down (bump)

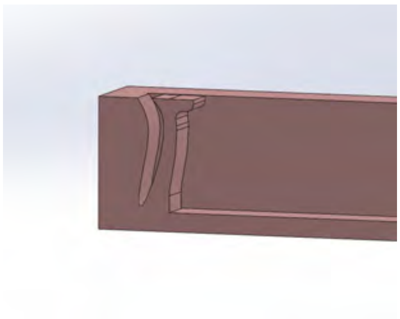
1.2 Flex up (bump)

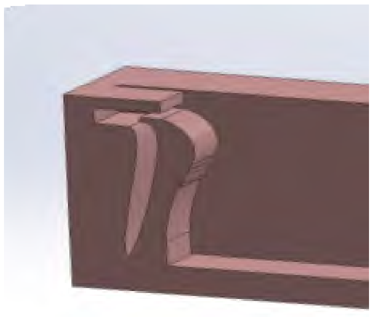
Designs where the ledge is on the back end of the plug



Can be combined with the following components at the front end of the plug:



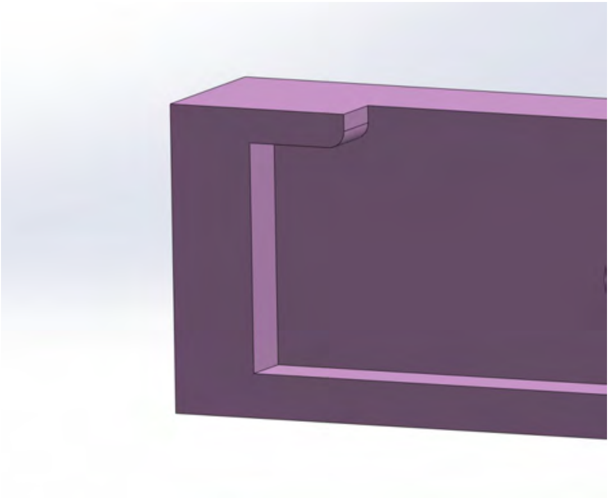




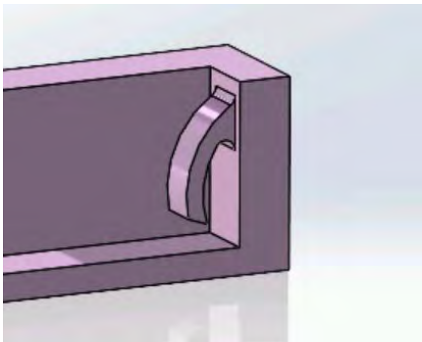
1.3 Flexing-Ledge 1.4 Flexing Tongue 1.5 Flex up (bump)

2. Tongue

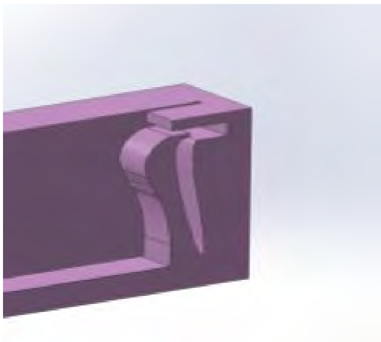
Designs where the tongue is on the front end of the plug



Can be combined with the following components at the back end of the plug:

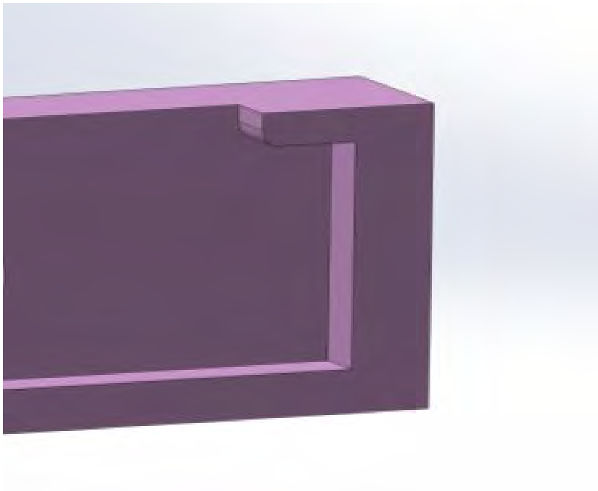


2.1 Flex down (bump)

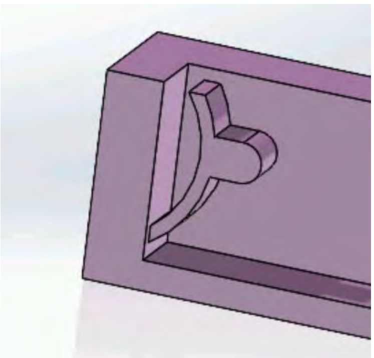


2.2 Flex up (bump)

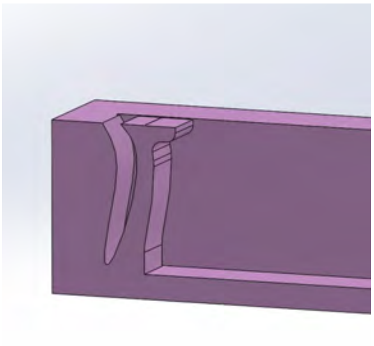
Designs where the tongue is on the back end of the plug



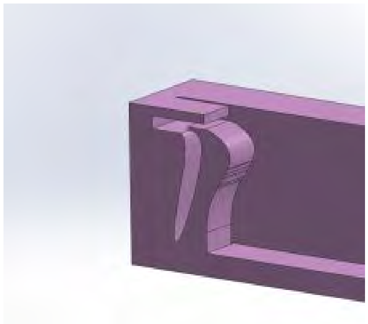
Can be combined with the following components at the front end of the plug:



2.3 Flexing-Ledge



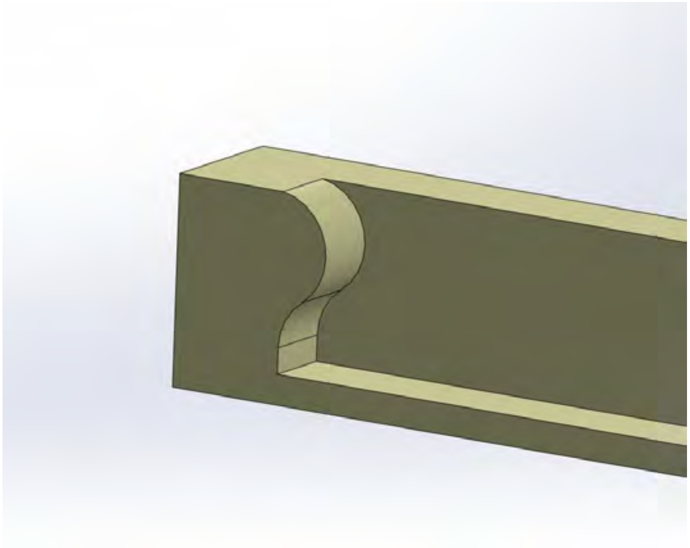
2.4 Flexing-Tongue



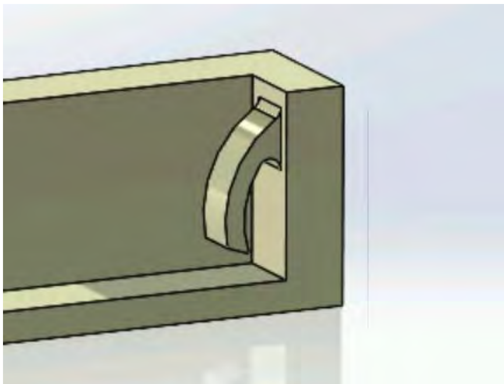
2.5 Flex up (bump)

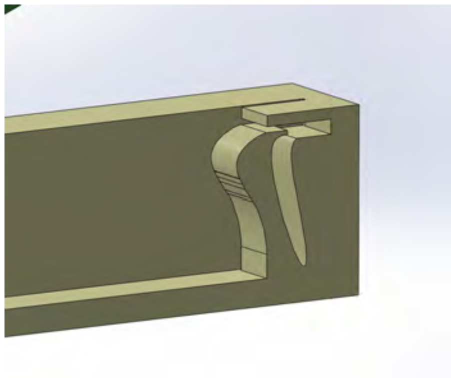
3. Bump

Designs where the bump is on the front end of the plug



Can be combined with the following components at the back end of the plug:

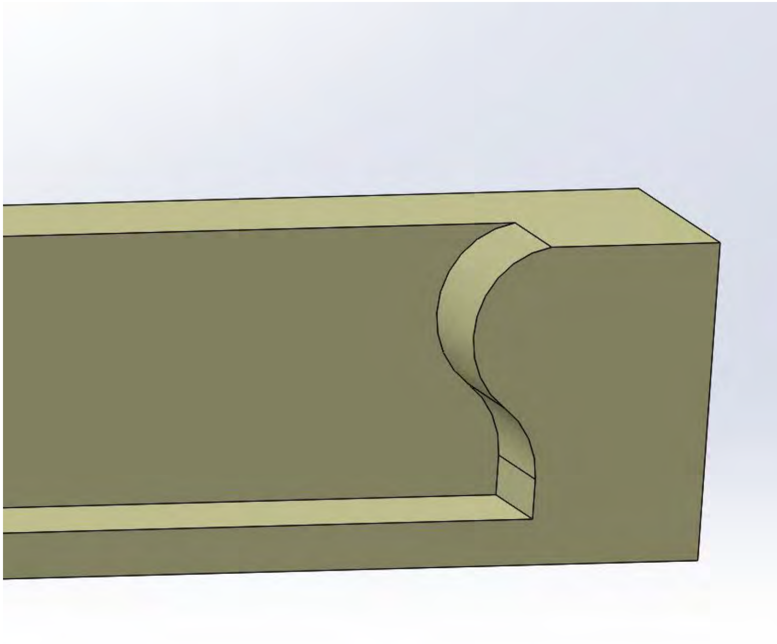




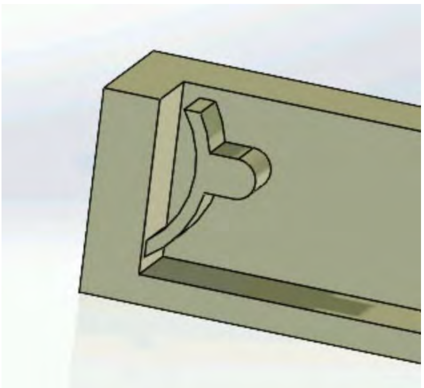
3.1 Flex down (bump)

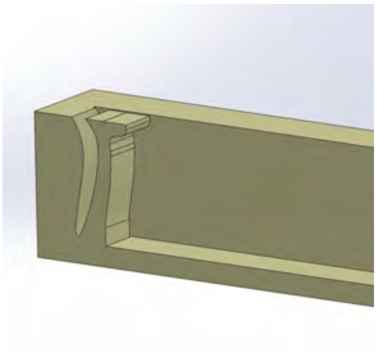
3.2 Flex up (bump)

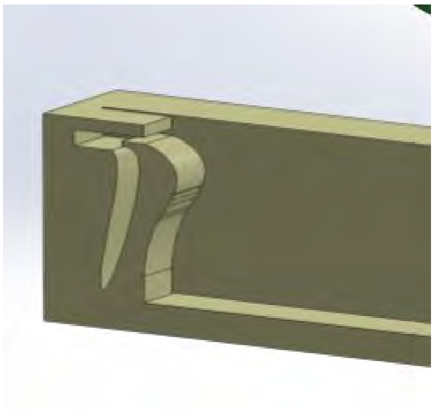
Designs where the bump is on the back end of the plug



Can be combined with the following components at the front end of the plug:







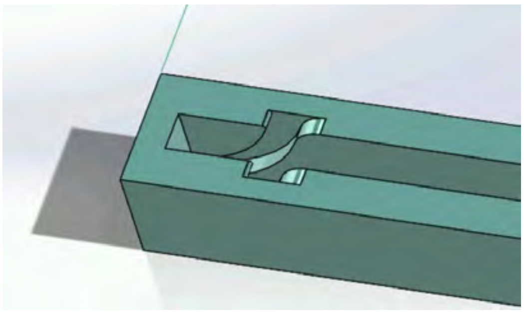
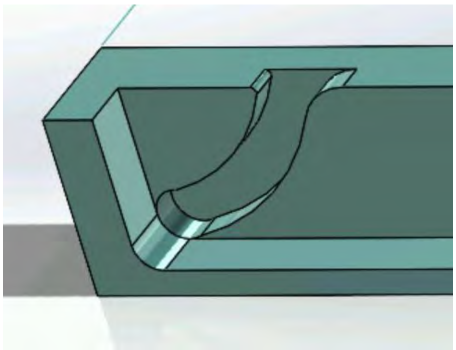
3.3. Flexing-Ledge

3.4 Flexing-Tongue

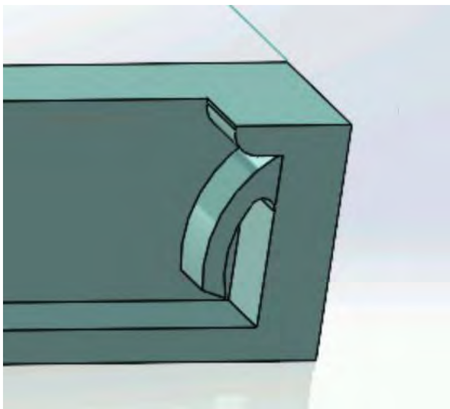
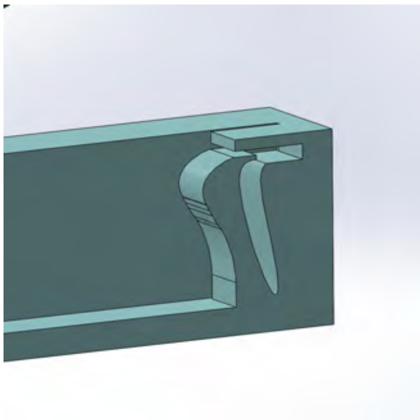
3.5 Flex up (bump)

4. Tracks

Designs where the tracks are on the front end of the plug

Can be combined with the following components at the end of the plug:

4.1 Flex down (bump)

4.2 Flex up (bump)

F Fin Plug User Test

The following is the summarization of the results from user testing of the fin plug.

User Testing

To receive feedback from users regarding the usability of the fin plug prototypes, user tests were conducted with both experienced and inexperienced fin users. In each test, the test user had the opportunity to try five different prototypes, attaching and detaching fins in their respective fin plugs. For each prototype, the user was asked to rate the fin tabs and fin plug in different questions to extrapolate quantitative data from the test. This was followed up by asking the user which prototype was their favorite as well as which features were considered to be positive and which were considered to be negative. The tests were conducted in Swedish and the following are the results from each test.

Quantitative Results

Translation:
Hur enkelt är det att förstå hur fenan ska fästas? - How easy is it to understand how the fin is attached?
Hur enkelt är det att förstå hur fenan ska tas av? - How easy is it to understand how the fin is detached?
Hur enkel är den att använda? - How easy is the system to use overall?
Hur säker kände du dig på att du använde systemet "rätt"? - How confident do you feel while using the system?
Hur lätt tror du gemene person lär sig använda infästningen? - How easy do you think an average user will learn to use the system?

User 1

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	3	5	5	5	4
How easy is it to understand how the fin is detached?	1	1	4	4	4
How easy is it to use the system overall?	2	3	5	5	4
How confident do you feel while using the system?	3	3	4	4	5
How easy do you think an average user will learn to use the system?	4	4	4	4	4

User 2

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	2	3	4	5	4
How easy is it to understand	2	2	5	3	5

how the fin is detached?					
How easy is it to use the system overall?	2	3	4	5	4
How confident do you feel while using the system?	1	3	5	3	5
How easy do you think an average user will learn to use the system?	3	5	5	5	5

User 3

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	3	3	4	5	4
How easy is it to understand how the fin is detached?	4	4	5	5	5
How easy is it to use the system overall?	3	3	3	5	4
How confident do you feel while using the system?	3	4	5	4	3
How easy do you think an average user will learn to use the system?	4	4	4	5	4

User 4

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	2	4	4	5	3
How easy is it to understand how the fin is detached?	1	5	4	5	5
How easy is it to use the system overall?	2	4	4	5	4
How confident do you feel while using the system?	2	3	4	5	4
How easy do you think an average user will learn to use the system?	2	4,5	5	5	5

User 5

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	2	3	4	5	4
How easy is it to understand how the fin is detached?	1	5	5	5	5

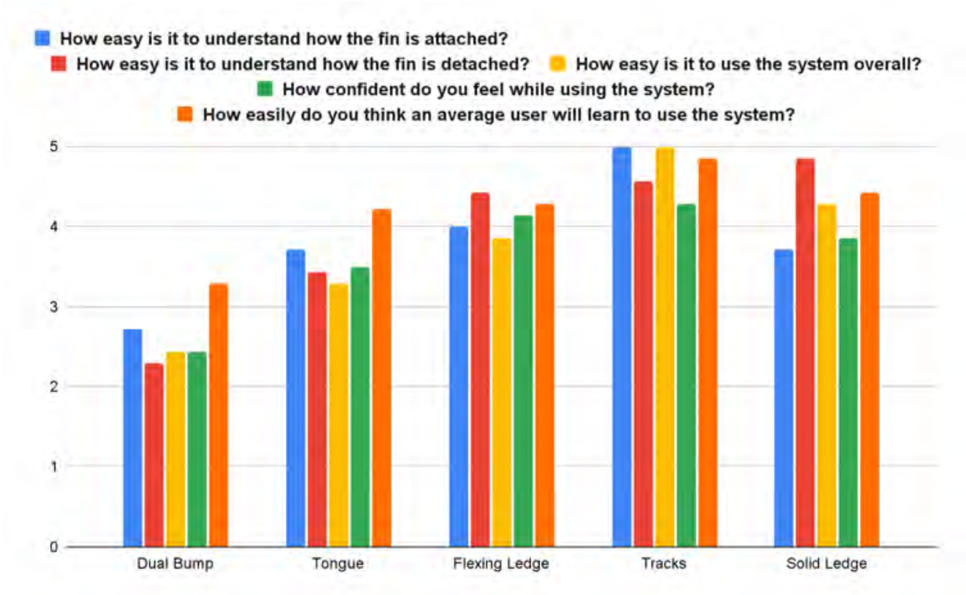
How easy is it to use the system overall?	1	4	4	5	5
How confident do you feel while using the system?	1	4,5	3	5	4
How easy do you think an average user will learn to use the system?	2	5	4	5	5

User 6

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	4	5	4	5	4
How easy is it to understand how the fin is detached?	4	4	4	5	5
How easy is it to use the system overall?	4	3	4	5	5
How confident do you feel while using the system?	4	3	3	5	3
How easy do you think an average user will learn to use the system?	4	4	4	5	4

User 7

	Dual Bump	Tongue	Flexing Ledge	Tracks	Solid Ledge
How easy is it to understand how the fin is attached?	3	3	3	5	3
How easy is it to understand how the fin is detached?	3	3	4	5	5
How easy is it to use the system overall?	3	3	3	5	4
How confident do you feel while using the system?	3	4	5	4	3
How easy do you think an average user will learn to use the system?	4	3	4	5	4



Qualitative Results

Testing was conducted with test users that were both experienced and inexperienced with using jetboard/surfboard fins. Users with experience were not asked to rate the fins quantitatively, rather only asked open questions where they could express themselves freely in an attempt to gather qualitative results. Furthermore, the reader should be informed the responses from the test users are paraphrased.

User 1

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Flexing Ledge.

Why?
Higher ease of attachment/detachment compared to other prototypes.

Which features do you consider to be positive?
When the fin is perceived to be securely in place.

Which features do you consider to be negative?
When it's hard to understand how to detach the fin.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
I would choose a smaller ledge as the front part and a smaller protrusion on the rear part, like on the *Tracks*.

Other comments or observations.
I liked attaching the *Tongue* prototype, but it was a shame it was relatively hard to detach. I also liked the sound the *Dual Bump* made when attaching.

User 2

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tracks.

Why?
It generated a satisfying feeling of sliding the front of the fin tab into position and following it up with a minor snap on the rear tab to lock it in place.

Which features do you consider to be positive?
The feedback that the sound generated when you attach the fins. The feedback tells you the fin won't detach unwantedly when using the jetboard.

Which features do you consider to be negative?
The symmetry of the *Dual Bump* prototype made attachment confusing. Furthermore, using a tongue as a front part made attachment unclear. Using a ledge would generate a better understanding of how the mechanism works.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of the *Tracks* prototype and the rear part of the *Tongue* prototype, i.e., the flexing bump, preferably with a protruding top part on the fin tab which lets the user know the fin is detached by pulling the fin upwards.

Other comments or observations.
Only at the end of the test did the user see that there was a protruding tongue portion on the *Tongue* prototype.

User 3

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tracks.

Why?
Very easy to perceive how one is supposed to attach the fin.

Which features do you consider to be positive?
The sound some of the prototypes made when attaching them was satisfying. The bent shape on some of the rear parts of the fin tabs, i.e., the protruding top part, lets the user know how the fin is fastened.

Which features do you consider to be negative?
Some prototypes didn't require a lot of force to attach them, which made me feel uncertain on whether or nor the fin would stay attached.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of the *Tracks* prototype and the rear part of the *Tongue* prototype, because of how easy it was to understand how to attach the front part and the sound the rear part made when locked in place.

Other comments or observations.
The user highly appreciated the sound from the *Tongue* prototype.

User 4

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tracks.

Why?
Obvious that the cylinder on the nose of the tab should be placed inside the tracks. How to attach the rear also became obvious as a result.

Which features do you consider to be positive?
When it's easy to perceive which part is the front and which is the rear. When detachment doesn't require a lot of force.

Which features do you consider to be negative?
If there is a gap or play in the attached assembly that makes it feel like the assembly is broken. The assemblies where the two parts are fastened very tightly together. Don't want to feel like one is wearing the fin tab or fin plug out because of excessive force.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
Both the front and the rear parts of the *Tracks* prototype.

Other comments or observations.

Would prefer a technique when attaching and detaching instead of using excessive force. The user did not have full support in the durability of the *Tracks*.

User 5

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tracks.

Why?
It's easy to understand how to insert the nose. The attachment is overall considered easy and smooth.

Which features do you consider to be positive?
When it's easy to understand which part is the front and which is the rear. When one hears a click sound when attaching and when attaching doesn't require too much force.

Which features do you consider to be negative?
If it's hard to perceive which part is the front and which is the rear. Furthermore, when detachment doesn't require a lot of force.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of the *Tracks* prototype and the rear part of the *Tongue* prototype. The click sound of the *Tongue* rear part lets one know the fin is attached.

Other comments or observations.
The user liked that *Tracks* didn't require as much force as *Tongue*.

User 6

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Flexing Ledge.

Why?
Easy to understand how to attach and when it is attached it feels sturdy. Detachment was also easy.

Which features do you consider to be positive?
When detachment is easy. Sliding the fin tabs when using the *Tracks* prototype felt very smooth. When there is a feedback to tell the user that the fin is attached, like the clicking-sound.

Which features do you consider to be negative?
When the fin is fastened too hard or too loose.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of *Flexing Ledge* combined with the rear part of *Tongue*, because of the clicking-sound generating feedback

Other comments or observations.
The user attached *Dual Bump* in the opposite intended direction and felt certain it was the correct use.

User 7

No previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tracks.

Why?
Easy to understand how to attach the fin.

Which features do you consider to be positive?
Having the fin tab being symmetrical is aesthetically pleasing. Having a nose which clearly indicates how to fasten the fin as well as a clicking sound when locking the fin into place.

Which features do you consider to be negative?
When only a small amount of force is required to attach the fin or when too much force is required to attach or detach the fin. The nose of the *Tracks* prototype is not aesthetically pleasing. It would potentially be hard to pack the fin if the nose of the fin tab has a protruding cylinder sticking out.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of the *Tracks* and the rear part of the *Tongue*. It would generate a clear indication on how to fasten the fin and the sound when locking the rear part would be pleasing.

Other comments or observations.
The prototypes where the top surface contains cavities when the fin is attached do not express a sporty or flashy feel, according to the user.

User 8

Previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tongue.

Why?
Simple design in the front part of the fin tab. The nose always ends up in the correct place no matter which angle or place you insert the nose into the fin plug cavity.

Which features do you consider to be positive?
The sound from inserting some fins was satisfying. Lets one know the fin is attached properly.

Which features do you consider to be negative?
Symmetrical fin tab is confusing.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of the *Tongue* prototype and the feeling of the rear part of the *Flexing Ledge* prototype.

Other comments or observations.
Using a ledge requires the user insert the fin tab in a certain place and with a certain angle, which makes it harder to attach the fin, according to the user.

User 9

Previous experience attaching jetboard/surfboard fins.

Favorite prototype?
Tongue.

Why?
The feedback from the sound allows me to know the fin is locked in place and when attached it feels like it won't come off unwantedly. The assembly doesn't require too much force to detach the fin either.

Which features do you consider to be positive?
The sound that generates the feedback that the fin is in place. Feeling that there's something pushing on the fin tab, other than the friction from the walls, gives assurance that the fin won't come off by accident.

Which features do you consider to be negative?

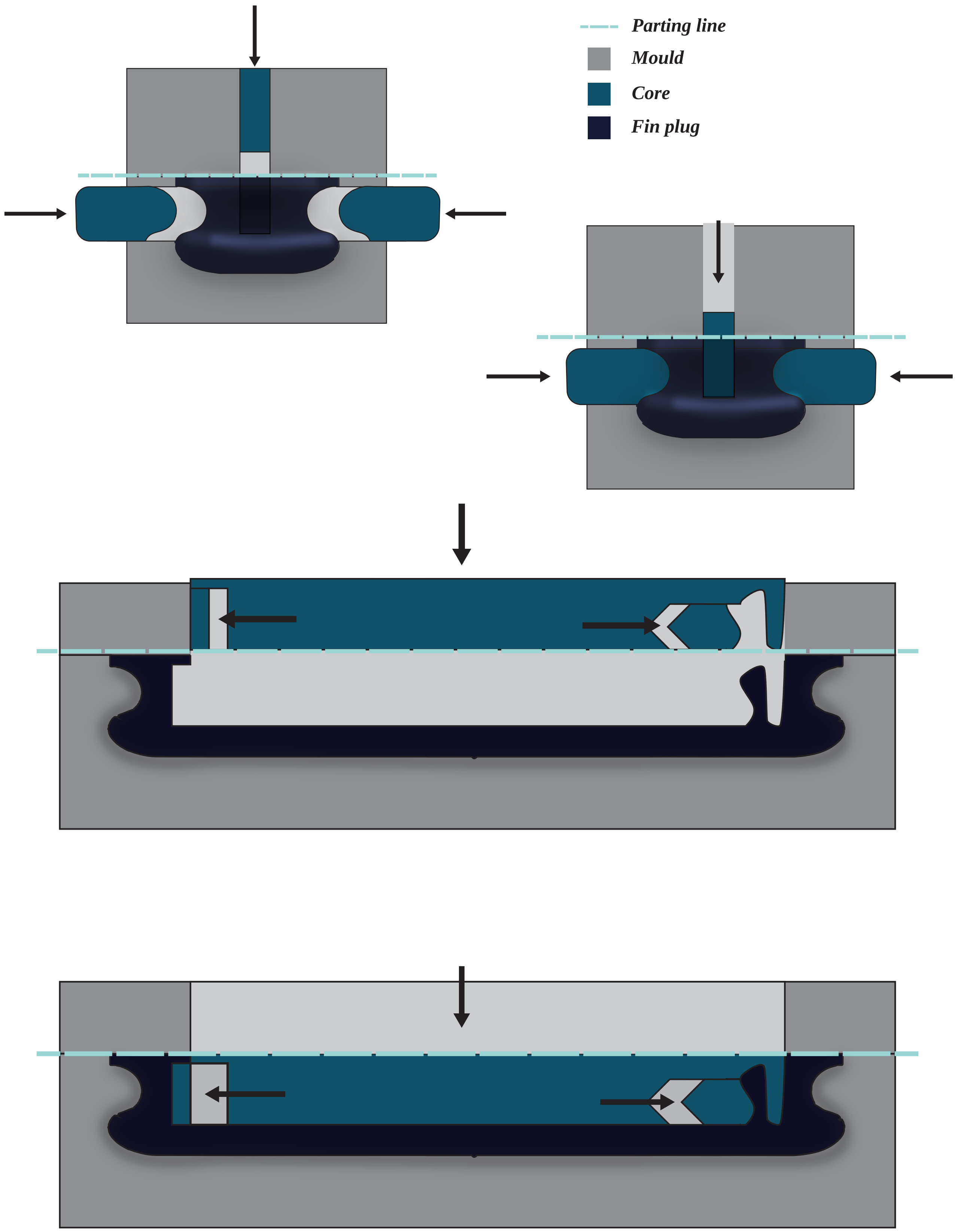
The risk of having dirt or similar build up inside the fin plug cavity, especially in the tracks or behind flexing parts, and preventing the fin tab from being inserted properly. The symmetry of the *Dual Bump* is confusing. If the fin requires only minimum force to be detached.

If you could combine any front part with any rear part to form a fin plug, which ones would you choose?
The front part of *Solid Ledge* and the rear part of either *Tongue* or *Dual Bump*.

Other comments or observations.
User believes the front part of *Flexing Ledge* doesn't look durable after looking at its geometry. The user likes that the fin tab can be seen lifting from the fin plug just slightly, just before the fin is detached, which encourages the user to stick to the same technique for detaching the fin completely.

G Injection Mould Illustrations

The following are the illustrations of proposed mould designs.


Parting line
Mould
Core
Fin plug

H Interviews

Interview 1 - Morgan Brovertz

Jag har vågsurfat en del i Mölle och Kåseberga och hållt på en del på 90-talet. // 30-40 timmar har jag åkt kanske, Aleks kom till mig med detta för kanske ett år sedan. // Jag har snöat in mig lite på fenorna själv faktiskt. För att, jag är gammal kanotist där vi har rodert. Ett race-roder, lite mindre, när man gör sprint. Ett lite större när vi masstart. // Nu har vi gjort så att vi kört lite fenlöst. Det var med Zafer Taylor som vi började testa det. Jag är rätt så novis på det men när du ligger i maxfart strax över 30 knop, då går brädan lite fram och tillbaka, ingen stabilisering som du får med fenor, men vi vill ha maxfart. De vanliga traditionella fenorna vi har, dels så är de inte bästa shapen. Jag skulle vilja testa mindre fenor för att få upp farten och få bort lite av wobblen när man kommer upp i hastighet. // Nu är jag inte hemma direkt men jag har lite fenuppsättningar, jag blickar ju in lite på vindsurfing, Radinn kör ju på vågsurffenor men jag vet inte riktigt om det är riktigt rätt, spekulerar bara. Jag har googlat på vindsurfing med olika fenuppsättningar, speed osv vågrätsfenor. Vindsurf är lite mer likt Radinn i tyngden och hastigheterna när vågsurfen är med för att ta vågen och svänga. // Du nämnde vindsurfbrädor och deras tyngd, hur skiljer sig de fenorna? De är lite längre, men det är också fenuppsättningarna. Fenupssätningar på vindsurf går ner i size vid speed och har ingen sväng, mer som ett roder, se bild. Fundera på om man ska en liten mindre sån till Radinn för stabilitet i hög fart. // Har du själv nån erfarnhet av vindsurfing? Nej, där är jag helt lost, men när jag tänker på vikt så kan jag ändå känna igen lite skillnad. Hade varit kul och höra vad Zafer (Taylor) säger också. Han nämnde "nej, men här behöver du inte ha några fenor" så då körde vi lite utan. Men jag undrar om inte en lite roder-liknande (fena) hade gjort susen. // Hur ser din optimala åktur på en jetboard ut? Det är helt spegelblankt, då är det som bäst. // För då kan du...? Då är det bara full fart, då är det som bäst. Jag vill ha farten men sen kan det också bli lite bumpigt när det är krabbt. // Vad är det som händer när det blir bumpigt? Ah du kan ju inte gasa på fullt då. Vi var ute och åkte i somras på förmiddagen jättefint sen blåste det upp vid lunch. Då körde vi på men slog oss och ramla av en hel del. // Så du vill hellre ha fart än massa svängande? Nej nej, svängande också. Men i hög fart. Det är det jag vill uppleva, så fort som möjligt kunna svänga mycket. Det hade varit kul att testa en massa olika fenupsättnignar. // Du som surfat lite vågsurfing, hur brukar du ha din fenuppsättning där? På min longboard kör jag en lite större singelfena och en shortboard där jag kör med tre, lite mer som FCS. // Vad är det för egenskaper man är ute efter när man använder olika fenuppsättningar sådär? Ja det är ju att ta vågen och svänga, själva surfingen. Nu kör jag mer longboard för man har väl blivit lite trött på äldre dagar. Då kan man ha en singelfena för inte lika mycket kontroll behövs, man åker mer rakt fram. // Om du skulle jämföra två eller fyra fenor istället, vad säger du genom dina erfarenheter om dem? Vet inte riktigt. Det är nog en fråga för sig. Klart med fyra blir det mer stabilitet men du vill ju ha farten också. Ju mer du plockar på undertill ju mer bromsar du farten. Därför tänker jag två små fenor. När du ligger i toppfart utan fenor då går brädan lite så vänster till höger, men hade man haft två mindre racefenor så får du stabiliteteten och vobblar inte och då kommer du få högre hastighet, det är jag helt övertygad om. // Med vanlig surfbräda har du expreminterat något hur man vinklar fenor osv.? Nej, så vass är jag inte på det, men jag ska ta ett foto på en vågsurffena och en fena som jag skulle vilja sätta på en Radinn-bräda. // Gå in och googla lite vindsurfing-fenuppsättning. Surfers paradise rekommenderar jag varmt, står väldigt utförligt vad de olika fenorna är till för. Tänkte speciellt på en fena då det kan fastna sjögras/ogräs i motorn på Radinn, nu spekulerar jag bara. Men på en vindsurffena finns där som kan klippa av sjögräs. Beroende på insug kan man kanske kolla hur det skulle kunna användas. Kolla vattenströmmen med hur vattnet ska gå men med en fena kanske man kan slippa avbrotten. När vi åkte i Lödde-å så kom det in nån vass nån gång och då sa det bara stopp. Sen va vi ute nån gång när det var is och så. Då kom där in slush, det satte igen direkt tvärstopp. // Hur djupt är det i en sån å? I mitten är där max 2 meter. // Hur upplever du att det är att kontrollera en sån bräda när det gäller acceleration och retardation? Acceleration kommer ni märka själva, men det var nästan det svåraste för min del, det här med gasen. Den är så direkt, det blir sån push. Och när du släpper den så stannar den direkt också. Men det är känslan mellan tumme och gas, Det tar ju ett tag men man vänjer sig. Kontrollen frös gjorde inte det lättare, fråga Aleks om det. // När det är så kraftig retardation och acceleration anspassas åkstilen något då? Ja man får jobba lite med benen och flytta runt. Om ni åker snowboard, så är det lite så. Man måste böja på benen lite så för att inte stå med raka ben när det kommer vågor. // När du nu ändå nämner snowboardåkning, där kan man inte riktigt röra på benen, är det något man tar nytta av vid jetboarding? Ja man flyttar ju runt lite. Jag har tittat mycket på Youtube på Radinn-åkare och de flyttar rätt mycket på foten över hela brädan. Jag skulle nästan vilja ha en vaxad bräda, den nya paden de har är lite bättre grepp i men den gamla paden hade för dåligt grepp tyckte jag. Kanske kan ta bort den, och vaxa hela istället. // Du som ändå vågsurfat en del, där förflyttar man ju kroppsvikten för att justera fart och kan pumpa osv.. Är det något man tänker på med Radinn-brädan, justera viktpositionen? Ja när det blir vågigt då flyttar man fram lite. Som en båt som gasar på och ligger med aktern som bara matar, då kan man luta sig fram för att plana ut den lite. Där är sådan jäkla kraft i den så det kanske inte behövs så men, ja, lite sådana ändringar i ställning. // Vad är det som gör att du vill plana ut brädan? Man vill upp snabbt för att kunna åka iväg snabbt och åka snabbare. // Generella skillnader på vågbräda och jetboarding, vad är de största skillnaderna? Det är ju vikten och den är ju lite trögare att svänga med. Men det har ju att göra med vikt och storlek. // Hade du velat ändra det om du kan? Nä jag vet inte, det kan va rätt gött och ha. Lite vikt och vågor, har du en lättare bräda bumpar du och tyngre går igenom vågorna lite mer. // Kanske när det gäller trögstyrningen så kan det finna möjligheter? Ja där tror jag bara Radinn har tagit vanliga fenor. Tror inte Radinn har snöat in sig på det nånting. De har bara tagit fenor från vågsurfkulturen. // Lite ledande, men är det alltså kvickheten i svängarna man vill åt då? Ja jag vill ha allt, kvickare svängar snabbare bräda allt. // Då kanske du till och med vill testa lite koncept när det börjar närma sig? Självklart grabbar, självklart. // Vi snacka lite om vågbrytning men hur brukar nosen vara när du åker, hur plant försöker du ha den? Ja den brukar plana ut direkt. Sen ställer jag mig lite lite fram. För när man ställer sig bak, du vill ju ha den så plant som möjligt så man ställer sig mitt på brädan. När du ligger där i full fart, det är då den kan börja gå lite så höger vänster. // Varför skulle anledningen vara att ställa sig bak, hade det kunnat underlätta styrningen? Nej, asså jag tycker det är förhållandevis bra grepp i den brädan. De har lagt ner mycket timmar på undertill (designen på undersidan av brädan) och så. Men fenuppsättningen, där kan man nog göra mycket. // Vad skulle din erfarenhet säga om placering av fenor när man bara använder två? Där känner jag mig lite för novis för det, men kolla med Zafer (Taylor) där på den frågan. Annars samma placering som de har men med lite mindre fenor för att få bort lite wobbling i hög fart.

Interview 2 - Julian Cieplik

Hur länge har du åkt jetboard? Sen september till december, typ varannan vecka. // Har du åkt nån surfboard innan? Jag har åkt lite kitesurf och wakeboarding innan. // Har du under tiden du åkt jetboard hunnit uppfatta vad den optimala brädan skulle va, kan du beskriva den? Jag fick testa några olika, där va en som var jättebra och nån som var rätt svår, lite smalare. // Upplevde du den som att den är för snabb eller instabil, eller att den va svår att stå på? Ja, den var ju instabil. Man sitter på dem och trillar i vattnet, men den trillade man i med ännu mer. // Var det i vänster-höger-riktningen (roll) då eller vilken riktning var den instabil i? Ah det var väl i varje riktning. Men den var lättare att svänga på det hållet dit tårna pekar. När man skulle svänga andra hållet blev det mycket större ringar när man skulle snurra runt. Man var även tvungen att hoppa runt lite och byta position. // Var du tvungen att flytta fötterna längre åt vänster då? Ja jag tror att främre foten fick gå lite till vänster. // Hade du velat att det räckte med en position eller uppskattar du att du kan flytta runt och använda många positioner? Jag hade nog velat ha en men det är ändå lite skoj och byta lite positon. Man behöver bara hitta en position som passar i början, sen när man svänger kanske man får ändra lite. Det är bara lite svårare som nybörjare. // Du sa att där va en av brädorna som var lite lättare att åka på, vad var det den erbjöd till skillnad från de andra? Man kunde ju sitta på den utan att trilla och man tappa inte balansen när man åkte in i vågorna. // Var det svårast att hålla balansen när man accelererade upp eller i maxfarten? Det var ju svårt i början innan man fått fart men när man väl hade accelererat upp var det ju lätt. // Hade du velat ha mer kontroll från stillastående till att du är uppe i hastighet? Det är rätt bra som det är. När man åker snabbt när det är lite vågigt kan det vara lite svårt att svänga. Man flyger lite i luften så. // Uppskattar du den lekfullheten i brädan eller hade du velat ha mer stabilitet? Jag vet inte, jag tror att på grund av att den andra brädan var så svår att balansera på, att det var nog nån fördel med den, att det var lättare att svänga i hög hastighet, men jag kände inte det riktigt. // Var är det du åkt nånstans då, var det vågigt, grunt eller djupt eller alla förhållanden? Ja nästan alla förhållanden. // Vi snackade med en person tidigare som upplevde problem med sjögräs (som fastnar i jetpack), är det något du upplevt som problem, med växtlighet från botten? Ja, där va någon dag det var sjögräs på botten som gjorde motorn sämre när man körde in i dem. // Föredrog du att köra på grunt vatten eller på vågor när det blev djupare? Jag tyckte det var kul med vågor, men också kul när det var helt plant. // Vad var det som gjorde det kul med plant? Man kan ju maxa då, utan problem. Det är mer bekvämt. Medan med vågor blir det mer fysisk övning. // När du säger bekvämt är det att du kan mer förlita dig på brädan eller vad är det som gör det bekvämt? Nej, det är mer att det inte påfrestar lika mycket på benen. När man kör på vågorna tar det lite på musklerna och energin. // Anpassade du din åkstil då till de olika förhållandena? Ja jag tror att när man skulle köra i vågigt ville man ha den så platt som möjligt. Så att den skar in i vattnet lite lättare. // Var där någon skillnad i hur du lutade dig, stod eller accelererade för att anpassa detta då? Jo men det gjorde man ju när man svänger och så. När man svänger måste man begränsa farten och så, och om man inte har utrymme och så. // När du nämner begränsa farten, hade du helst varit utan det och ändå kunnat ta en sväng väldigt snabbt? Ja, ja svängarna till höger gick ju rätt bra att ta men svängarna till vänster gick inte lika bra. // Hade du fenor på när du åkte då? Nej, vi körde aldrig med fenor. // Du sa att du hade åkt kitesurf och wakeboard, vad ser du för stora skillnader mellan de olika brädorna? Det är ju stor skillnad men på jetboarden när jag först testade den trodde jag först den är ju så stor och ska flyta på vatten men den är ju som en stor klumpig sten. // Så du upplever den som tung? Ja. // Känner du det i alla hastigheter eller bara till en början? Ja bara i början, när man är nybörjare känns det mer som man åker på en sten. Lite som att lära sig cykla, det går lättare och lättare när man får lite fart. // Med din erfarenhet i wake- och kitesurfing, hur skulle du beskriva fenorna på de brädorna? Jag är inte så tekniskt inne på det. Jag kan maila nån bild på dem till er. // När ni nu åkte utan fenor på jetboarden, upplevde du att du skate:ade då, att bakdelen sköts ut? Ja tror det hade varit lättare att säga om man fick testat med fenor också. Inget jag tänkte på i alla fall. Det gick ju lite att boosta farten för att svänga ibland. // Martin Malmqvist från Radinn beskrev sin åkstil som lite pulsande i kurvor att accelerera och sakta in inför och ut ur kurvor, kände du att du gjorde något liknande när du åkte? Nja, man började kanske lite saktare och gasade på lite mer. // Men det blev inget åkmönster eller något sådant? Jo det blev ju lite att man gradvis ökade farten i svängar. // För att förtydliga, vilka egenskaper hade du velat se i den bästa brädan någonsin utan att behöva tänka på om det går att fixa eller inte? Utfällbara fenor om det hade fungerat och väga mindre. // Varför vill du att den ska väga mindre? För att det är svårt att transportera den. // Är det något mer? Kanske mer funktionalitet där man kan se hur långt man kan köra på batteriet och några UI delar. Nån slags ställningsigenkänning som kan se hur man har kört under tiden. // Annars tycker du att brädan är supernice att åka på som den är? Ja den är nice, om ni behöver hjälp att testa så ställer jag gärna upp. Vi brukade åka ut med skåpbil och två brädor. // Det du sa om att du skulle vilja se hur man står när man åker, är det något för att kunna utveckla sin åkning? Ja det hade varit kul att se hur man stod under sin åkning och kunna jämföra med. // Är det något du funderat över ifall du hade velat ha mer variation i brädans dynamik? Ja det hade varit kul om man kunnat anpassa den för långdistans, snabbt och svänga och kanske sjögräs eller åar och så.

Interview 3 - Zafer Taylor

Hur länge har du åkt jetboards? Jag har bara åkt en dag. Bara provat en gång. // Men du har åkt mycket surfbräda tidigare? Ja, jag har surfat jättemycket. // Hur hade du beskrivit en optimal känsla av att åka på en jetboard? Min analys av en elektrisk surfbräda är att man inte kan kalla det för surfing överhuvudtaget. Det är en kul leksak att ha, absolut. Men ska man göra det enkelt, så handlar surfing inte om brädan, utan om vågen. Ska man försöka återskapa det man kallar för surfing måste man ha en våg. Exempelvis med en jetboard så är det väldigt svårt att stå kvar på dem när man svänger på platt vatten. Man blir viktlös i fötterna vid minsta lilla gupp. Men när man åker på en våg så klistras man fast med brädan mot fötterna och utan ansträngning kan man stå kvar och svänga. Att bara stå på en bräda och svänga på platt vatten är helt annorlunda, för vågen gör att du trycks mot den. // Hade du velat att jetboarden skulle efterlikna en surfbräda mer (i dess känsla) eller gå i en annan riktning? Att kalla en jetboard för en surfbräda är helt okej då är en bräda man ska stå på. Men att försöka jaga att den (jetboarden) ska fungera som en surfbräda är omöjligt utan vågen. Man kan använda en träbit (eller vad som helst) och göra vad som helst i en våg, men om man tar bort vågen är det inte längre surfing. // En tydlig skillnad på pappret när man jämför surfing mot jetboarding är hastigheterna. Hur hade du velat utnyttja hastigheterna man kan uppnå på en jetboard? När jag åkte på dem upplevde jag att jag skulle velat ha ett handtag för att hålla i när det går för fort. Kommer det en minsta chock blir det blir problem. // Upplever du att du hade velat ha mer kontroll (ledande)? Jag tror att det hade varit bra att ha något snöre eller liknande för att hålla sig kvar. Handkontroll va inte så mjuk i hastigheten, utan rätt så ryckig och det va svårt att stå kvar. Som att någon rycker mattan under dig. Handkontrollen va också lite "dodgy" (obekväm) att hålla i handen också. Jag kommer ihåg att jag, för säkert 30 år sedan, provade en annan jetdriven bräda där kontrollen satt fast i vajer som satt fram i brädan. Det va ganska bra för då hade man något att hålla i när brädan ryckte iväg så man kunde hålla kvar balansen. De här brädorna är vad de är, men jag tror inte att man behöver åka så himla fort egentligen. // Vi tänkte gå in på fenor nu. Vi tänker att du har säkert massa erfarenhet i surfvärlden och vad rekommenderar du när du placerar fenor? När jag testade de här brädorna (Radinns jetboards) så tyckte jag att det var helt klart roligast att köra utan fenorna. Jag tyckte inte att fenorna (som var på) gjorde någonting bra för den brädan. Då kunde man slide:a den (brädan utan fenor) och göra lite tricks. Det blev som att brädan gick på räls annars och va trög att svänga med fenorna. Jag tror att det är roligare att köra den brädan utan fenor helt. Sen har jag sagt till killarna (anställda på Radinn) att om tanken är att man ska surfa på brädorna, behöver de inte alls gå så fort till att börja med och så behöver man få ner vikten och göra allting mycket mindre. Om det är så att man ska försöka surfa med den vill man bara att den ska gå så fort att vågen plockar upp dig, sen sköter vågen resten. // Varför tror du att man skulle behöva få ner vikten för att efterlikna en surfbräda? Den (Radinns jetboard) är väldigt tung. Det här är så svårt. Om någon av killarna som jobbar på Radinn surfade på riktigt så hade de nog reagerat wow det kanske inte går det här riktigt. Man har utgått från en annan grej och det är helt okej. Det är ingen surfbräda och det är helt okej. Det är det jag försöker säga, det är som en jetski man står på, det är en räddningsflotte, det är en rolig grej man ska bara ha, en pryl man kör omkring med. Kalla det vad som helst. Allt är okej och jag är helt öppen för allting men jag bara menar att överhuvudtaget efterlikna surfgrejen, att den ska kännas som en surfbräda när du svänger den och åker på den. Det är det jag säger, det går inte för man har ingen våg. Det här går inte, det kommer aldrig gå, du behöver vågen. Det är inte brädan som surfar i en våg, det är vågen som gör att du surfar. Då kan kan man åka på en gummibåt eller på något annat. Det är vågen som saknas i momentet när man svänger. De här brädorna nu när man åker på platt vatten, rockern funkar annorlunda på den, railsen (funkar annorlunda på den), allting är annorlunda. Hur den planar, hur den svänger, det är en annan grej. Det blir jättesvårt att säga vad fenorna gör och inte gör. Tänk så här med fenor, har man stora fenor så kanske det blir lite stelare men man har mer driv säger man kanske, att den får mer fart när du surfar. Du kan ha lite mindre fenor, ha det lite lösare. Men på de här jetbrädorna vet jag inte riktigt vad de ska göra. Man vill göra andra saker kanske (med jetboarden) så tänkte jag att det va roligare utan fenorna helt, så man kan slide:a den i sidan och åka runt. // Om den är tung kan det bli trögare att få den att svänga kvickt? Men det är det här som är skillnaden. Om du har fenor på din bräda, tänk dig att du står på en våg och vågen är helt vertikal och din bräda åker på en kant och skär (genom vågen). Du ska åka rakt fram, då kör du på railen (på brädan) och då kan fenorna också hjälpa till ganska mycket, om du tänker dig att vattnet står upp istället för att ligga platt. Om man åker på de här brädorna och bara åker rakt fram. Vattnet ligger platt. Nu plötsligt blir det en helt ny grej. Det är klart att det kommer bli en skillnad när du svänger. Det blir en helt annan funktion plötsligt för fenan. // Om vi går bort från jetboarding ett tag och funderar på surfbrädor, även om det inte går att jämföra. Om man snackar om cant och toe, är det några egenskaper som ger kvickare svängar? Om de (fenorna) är rakare, så går det lite rakare. Svänger man dem lite, svänger brädan lite mer. Man man kanske ska ha de så. Man får testa sig fram. När jag först såg brädan tänkte jag att den kanske skulle mer rocker, så kanske den svänger bättre. Men sen när jag testade det i huvudet så tänkte jag det är helt fel, den här svänger inte med rockern den svänger på railsen. Mer som en vindsurfbräda. Man behöver inte ha en rocker, en rund rail gör att den svänger. En vågsurfbräda fungerar mer som en banan, en banan som du lägger på en kula och så rullar den kulan. Vattnet går helt på andra hållet och det är så du svänger brädan, då måste du ha rocker. Är brädan platt då svänger den inte längre riktigt. Det blir dåligt, den går snabbt rakt fram men den svänger inte. Det funkar inte så med de här brädorna (jetboards) för de ligger på platt vatten och de ska bara plana. Då svängar du på kanterna (rails) istället. När den är rund får du en kurva, så svänger den. Små fenor kanske räcker. Som en vindsurfbräda kanske. Jag tror det tar bort det roliga från jetboards om man har fenor. Små fenor, ja (det hade funkat). // Man vill köra och slide:a lite? Ja, det blir väldigt enformigt om den blir svår att svänga. Till slut vill man nog ta av dem (små fenorna) ändå för att kunna göra mer (slide:a mm). // Med jetpack som sitter under brädan uppstår begränsingar i var man skulle kunna placera fenorna på brädan. Vad är din uppfattning om placering och antal? När jag surfar kör jag alltid tre fenor. Jag har twin-fins men jag brukar gilla att surfa med tre fenor. Med sådana breda brädor (som Radinns) så hade det nog funkat med quads eller twins. En center-fin hade nog inte hjälpt alls på en sådan bräda. // Hur brukar du sätta upp dina twin-fins för att få den bästa känslan och varför? Jag sätter dem under brädan. Det där får man anpassa till varje bräda. Det finns vissa sweet-spots på alla brädor, men man kan utgå ifrån var man står på brädan. // Att luta sig och pumpa, likt man kan göra på en surfbräda är kanske inte något som förekommer på en jetboard? Nej, det är det inte. Det första man ska tänka på (med jetboards) är vem ska ha brädan, vem är den till för. Om man säger att det är en surfbräda blir man trött efter fem minuter då man inte har någon våg. Jag tycker man ska utgå från någonting helt annat än en surfbräda. Det finns saker man skulle kunna göra för att få mer surfingkänsla, även om det är platt vatten. Det är jättesvårt att göra det, men det går säkert att få det lite bättre. Jag tror inte farten är lösningen (för surfingkänslan) men det (jetboarding) är någonting annat. // Du nämnde tidigare att en jetboard behöver va lättare för att efterlikna en surfbräda mer, kan det även handla om att ta svängar snabbare? Den behöver inte vara väldigt lätt. Om brädan blir för lätt kommer den säkert gå dåligt om det är hoppigt vatten. Om man surfar på väldigt stora vågor då är brädorna väldigt tunga för att de ska kunna skära genom små hopp och behålla kontrollen. Om man ska åka fort på den här brädan är det kanske bra om den har mer vikt. Men den är för bred och för platt, den studsar hårt på vågor om det går för fort. Det blir som att fötterna lyfter från brädan vid små hopp. Det händer inte på en surfbräda och det är det som gör det omöjligt (att återge känslan av en). Fotstroppar hade kanske funkat, vet inte hur säkert det skulle vara. // Det är vissa som efterliknat det med en snowboard, att man fäster fötterna i den och kan hoppa med den? Ja men den blir så tung. Det blir som att den (jetboarden) kör dig. Att man lyfter med fötterna gör att man i svängar måste "commit". Den sista pusselbiten som saknas för att det ska blir riktigt bra är vågen. Att se det som en jetski som man står på, absolut. Det är en kul grej, men jag tror de (Radinn) missat hela grejen med att kalla det för en surfbräda. Det handlar inte om brädan, utan om vågen. // Du nämnde att man måste "commit" i svängar, kan du utveckla? Det gör man väl alltid. Det är väl bara att hänga sig så hårt man kan i svängar så får man se vad som händer. // Du upplevde att du fick byta fotplacering och ställa dig på kanten? Ja, man får flytta sig ganska mycket. Sen får man köra hastigheten rätt så det händer någonting roligt. De var ju väldigt snabba. Ett väldigt tryck. // Var va det du åkte jetboarden? Det va Höllviken. // Va det grunt där? Ja, det va ganska grunt. // Upplever du att det hade varit en annan sak om du hade åkt längre ut, på djupare vatten? Det va väldigt platt och fint vatten. Så fort det kom lite hopp eller man körde över någon annans wake kände man hur ostadig brädan är. Det hade inte gått att köra den i vågor, om det blåst inlandsvind och det blivit skvalpigt. // När du accelererade, upplevde du att brädan låg platt eller att nosen steg uppåt? Brädan gick upp i planing. Lite konstig handkontroll, inte helt topp. Sen vill man nog ha fler handtag på brädan så att man kan ta tag i dem genom att bocka sig. Jag hade även velat använda båda händer för att greppa. Med handkontrollen kan man bara använda den ena handen. Man kanske vill byta hand man har kontrollen i.

Interview 4 - Roland Hummer

How long have you been using jetboards? Two and a half years. // Have you been surfing as well or done any other watersports? Yes, basic surfing. I got into jetboards 2016, but I think the marketing was far ahead of the products. I was following up the products and testing them but still, marketing was a little bit ahead. Now 2019-2020, I think the product really lifted up and compared well to the marketing. I invested and could look into all the different companies to meet my preference. Did some research on the market. // Tell us a little about your business in Lofoten... It started when I saw a video in 2016 and I knew sooner or later I'm going to own one or have one. The reason is that I could see the emotion and the feeling it provides and that is the only reason that I need. If it's possible to make a business out of it, even better. I am originally from Austria and have been working in Lofoten for two and a half years. I made a new contract with the lodge I rent now and was able to bring my own business, Lofoten E-riders. Actually this coming weekend we will launch our website. I also knew that I love the foil and the jetboards I like as well. For the future clientele it is always nice with two options. Maybe not everyone is going to be able to go on the foil so I can offer and use both things here. The business here was at first you take the basic course and rent the stuff. But after a couple of months of thinking about the business model I concluded that I am never going to be able to rent these things out, they are way too expensive. I don't know where the renters are going and some places they are not allowed. So before I start maybe my image already goes down because the boards I rent out go places they shouldn't. Maybe riding too fast and too close to birds and so on, so I said no renting. Instead I have courses with beginner, advanced and so on, I can send you the pdf. We're starting to teach next week, we offer a mandatory and from there you can expand to a more explanatory course or just go on to a three hour tour. Right now I have two foils and two jetboards. For all of them I have speedchargers and a second battery. // How would you describe your most optimal jetboard, what are the key properties? First of all, it's the material. They are using it on only the icebreaker but a material compatible with the conditions here at Lofoten, because I teach all year around. There is of course a difference if I use it in Caribbean islands when they do not need as rough surface, but when I use it here where it is sometimes ice and snow. The ideal for this geographical latitude is a more robust shell of course right, a different coating. I was sending some recommendations to Radinn already explaining that I would like a nose-cover. I have already had to fix it several times, because it is not strong enough. I also have beginners and in the beginning they are focused on different things and can hit the board a little bit. So a nose-cover like exclusive surfboards have a nose-cover could be a merchandise for Radinn. So the ideal is for me stronger. // The second thing is, I've told Radinn already, it is terrible to change the batteries on this latitude. The closing system, the latches on the battery, they are way too small. If you compare it with the Flite-board, the foil I have, it's magic. Even with gloves it is easy to open the battery compartment. With the jetboard I have to use something just to get this little thing up, so this should be bigger right. For several months I have had the problem that I was not able to close the front screw. Because of the productional line of Radinn, one of those screws, the front screw in this case, glued in, was tilted. It was stuck too deep as well so I was not able to close it. So I had to ask Radinn support for new screws but now we are talking about months. I had to change everything by myself of course. And so, after three-four months, I'm now able to close the front part, I mean, come on. Another problem is to get the battery out of the battery compartment. When it is like -5 (degrees) out and leave the things out for five minutes, it is freezing and I can't get it out at all. There is no chance. The dimensions of the screw and closing lids and the accessibility to get the battery out is probably nice and great for the Caribbean but here, no not really. // Now, getting into the remote. When you have gloves, 4-5mm you don't feel a thing. I can't actually get it around the gloves so I usually don't use the strap, it's too small. Much is designed for beach life, but not here. You know the remote control, it has this thing you put your hand through. But when you are going to use your thumb it is a bit in the way. It is hard with gloves. // Do you have two Icebreaker models then? No, I have the Urban Rebel. I was asking Eric, the manager of Radinn, 'Listen, this is Lofoten Islands, the location. I would like to buy two of the boards, what do you recommend?' I then said 'I like the Urban Rebel' and he wrote back 'The Urban Rebel is (a good choice). Later I told him 'Hey Eric, you should have told me about the material they use. You know, I am a beginner and can't know everything. It is way different than the Icebreaker and the Icebreaker is way stronger. I would have definitely bought the Icebreaker for here. // Have you experienced any problems with the fins? I have tried everything of course. Actually the fins are no big issues. The only thing is that they are not so easy getting in and out for inexperienced people. You need a glove or you will cut yourself, there should be a cover that you can take off to place and withdraw them. Something to grab it with since you need to apply so much pressure on a sharp fin. But in general I am not using the fins anymore at all actually. Also I don't give fins to the new students. The reason number one like for me, if I wanna do tricks and 360's, on my way at least, then I can't use the fins. For beginners I found out while teaching that they don't actually notice the difference. There is so much other things to focus on. I am showing how to make turns even without the fins. // Since you teach beginners, what do you notice is the most difficult part to grasp? The most difficult part is realizing the sensitivity of the remote. The second part is to realize that the movement from lying on the board to standing up needs to be as quick as possible. Three is showing that the board is really big and stable. You can walk around on it. Then I show them how to manoeuvre without the fins. If you lay on the stomach with a hand on the handle and one with the remote, we cruise around with one foot in the air and one in the water to get a feel of how the steering works. // Would you say you have developed a special riding pattern or style? No, just basics. Everyone has to do the basics first and it is all about getting to know the board and getting used to the steering and speed and control. Show them how to place the feet and so on but there is really no technique to it. // How do you perceive the stability of the board? Again, I have the foils and the jetboards. It's perfect because it is totally two different worlds. So the jetboard is for me the adrenaline, fun, fast, trick and that stuff. The learning curve of the jetboard is also much faster than on the foil. The e-foil is the Tesla on water. Way more elegant, and way less noisy. You can do way better carving style riding, totally two different things. And why we have these two different things is say, if there comes a couple or just two or three people and they have different physical fitness or experience, right. I can go out with all of them and even if you are not so fit you can have fun on the jetboard by laying on the stomach, kneeling or sitting. If you are a bit more experienced you can go on the e-foil and everyone can feel a thrill. // Since you have two different types of boards, are there any properties you would like to transfer from one board to the other? The jetboards, well my next level is to go to the Tarifa style, with the foot straps so I can do more tricks and stuff. The most important thing is still how to handle the battery, close and open it and get it out. That is one, and two is the material. Three is as I have already said to Radinn the hand controller. // The problem, with the hand controller could you explain that one more time? It's meant for warmer places without gloves. Some parts are to short when you have gloves. The hand controller, proportion is way to small for gloves, just try yourself to put on 4-5mm gloves and play around with it. // Have you been riding in more places than Lofoten, and how were the conditions there? Yes, I have been to Croatia and Germany riding jetboards. Mostly in Germany I went on a river and there were some waves. In Croatia we went in the ocean and of course there it could be some bigger waves and some days flat water so all different situations perfect to try out. Shallow surface is sometimes nice but you need to be careful because too shallow and the inlet will suck in stuff from the bottom. On some videos you see people having a laugh not so far away from shore but you forget that everything underneath gets sucked in. You can ruin the propeller you know. // What I teach the people again is the leach right. So with the first course everything is fun and your mind gets lost away. You forget that you still have the hand controller. That is where the most accidents happen. Now we have a rule when you are like 20 meters closing shore you take of the leach kill-switch and just paddle the last meters. Safety first you know. We also have like, I think the company is called BBTalkin. These waterproof walkie-talkies so I can stand on the dock and instruct the students out in the water. Or we go out together and its easier to talk to each other. // When using the jetboard, you said you like to do tricks and stuff, do you try that with fins as well? Always without fins. I mean sometimes if you just want to do quick carving and so I could have fins but usually and 90% of the tricks I don´t need any fins. I mean imagine doing a 180 or 360 with fins the fins would just slow you down. // So going straight or with longer turns is that something you are used to? If I go straight and want more speed I also do longer turns but I don´t need fins for that, at all. Because the boards are big and if I know how to shift my weight, it is enough to put my foot a bit to the edge and I do a simple turn. // So a lot of movement with your feet, changing up positions? Yes always! //Do you sometimes change the way you are facing as well? Yes, I mean I have tried everything. Now the jetboard is like a longboard, I walk around a bit, I sit down I get up. I try to use the handle some more, especially for some tricks. I try out how much I can go back on the board and how much to the front. Also when I turn, I try leaning 10 degrees, 20 degrees and see when I fall in. Sometimes with the fins of course and sometimes without. Mostly I don´t need the fins. // When you say you use the fins, is there something you want to expand on, the angle to lean? I don´t really know, I don´t really know what the board is capable of. It depends on my riding style as well. In general the fins for customers are to much to fix with. It is enough with the hand control to think about. There is usually complaints about the hand controller. // How would you describe your experience with surfing, you mentioned longboarding before. If we step away a little from the jetboard, what is your experience with different fin set-ups on a surfboard? Not much really, I am just a basic surfer when it comes to wave surfing. Spending 90% in the water and 10% on the board. I don´t feel like I can give you an answer that is reliable in this case. I have way more experience on the fins on a jetboard now than on a surfboard since I have been able to try them out a lot. // Back to the jetboard, when starting your ride, how would you describe your experience? It depends on the experience of the user. Sometimes I just sit on the docks and don´t go in the water at all just standing up on the board and take of. If there are waves I might go on one knee when I accelerate. On both the foil and the jetboard I would say I am up in the first 5 or 8 seconds. // How would you describe the beginners in the same situation? The first thing I do with beginners is to have them to hold one hand on the handle and lay on the stomach. Then feel the sense of the controller. I usually cruise along on a board next to them on a distance and then we go step by step up to a standing position. In the beginning it is mostly on the stomach, when you start. But it depends how the user feels. If you feel that you have good balance you can start on your knees, and so we go around and get a feel of the remote like that. The most important thing is that they learn that they need a little bit of speed to get up. Also show them the foot placement. Since you have a roll-axis in the middle of the board which can be unstable you need to place your feet with one on each side of the axis to have more control. The intervall as well from on your knees to getting up needs to be as short as possible. Sometimes I have people getting stuck on their knees and starting to hesitate so sometimes you just need to try to get up. // If you want a fast learning curve you just need to try, standing up, fall in, get on, try stand and fall in. // Going on these tours you have talked about, do people usually feel tired afterwards? Yes, all of them. At first they might think that it is a pretty passive activity, but there can actually be quite a lot of swimming for beginners when you have to swim to a board that has gotten 5-10 meters away. And getting up and falling off. But afterwards everyone think it is quite active. // Purely riding wise, what would you want to feel when riding, ideally? Riding wise, with my level of confidence I would want foot straps, because I can handle the board better and lean more. A lighter board with more mature and harder board, and more agile. That is what divides the different worlds right now. If you have some jetboard experience and I put you on a foil you will freak out. This thing reacts if you move your toe. Very sensitive. The jetboard is actually the clumsy one, so an idea would be to have it more agile as well. But still able to do 180s and 360. But super responsive if possible, because right now I have to move around a lot on the board when steering. // If you go for a long ride, with boards that are more responsive and less responsive. If you compare the foil and jetboard let's say, which one is more tiring? The jetboard have more surface friction and when it is wavy you can really need to work with your legs which is more tiring. When I go with the foil, it's just to lean back and it goes smooth and cuts through the water like a warm knife through butter, so it's less exhausting. // Just a recap, I have had these boards for three months now and I think I am in on my 7:th or 8:th remote control, doesn´t work or breaking down, but yeah. I see this as a teamwork so whatever I can do and help you with it's good.

I Interview Statements

The following is the translation from statement to interpreted need. The colour coding represents different types of needs.

	Statement	->	Need
Martin, Gustav och Magnus	Jetboarden bör ha mer "bett"		The fins offer direct response when riding
	Fen-urval är bra för kunden		There are several different types of fins that fit the boards
	Mellanläge mellan "skate" och "bett"		The fins offer slide and response in turns
	Tvinga brädan mot vattnet i höga hastigheter		The fins push board towards the water surface
	Går på "räls" med lång rake och flex		The fins inspire confidence to the rider
	Foil påverkade åkning negativt		The fins' section geometry allow desirable riding conditions
	Carve är instabil i roll		The fins generate stability in roll
	Svårt att initiera sväng i maxfart med Carve		The fins initiate turns
	Svårt att ta långa svängar utan att accelerera för att kunna hålla balans		The fins allow long turns, in lower speeds
			The fins help the rider keep balance
	Skapar puls i gasen		The fins allow riding patterns
	Vill ha samma kontroll över brädan i hela fartregistret		The fins offer the rider the same control throughout the entire speed range
	Ju mer man kan gräva ner kanten, desto bättre tryck		The fins enable the rails enforce more pressure
	Svårt att ta hårnålskrurvor		The fins allows for a small turning radius.
	Hastig retardation när man slutar gasa		The fins reduce retardation
	Initiera sväng när man lutar sig		The fins make use of the turning advantages given by the rails
	Betydelse av var man trycker på brädan		The fins allows different positionings of your feet
	Tvinga brädan mot vattnet så snart den börjar åka		The fins lead the board to a parallell position with the surface
Morgan Brovertz	Jag vill ha farten, men sen kan det bli bumpigt när det är krabbt		The fins decrease instability towards bumps, without sacrififcing speed
	Vill ha svängande i hög fart		The fins allow for better turning in high speeds
	Trött på äldre dagar, behöver inte lika mycket kontroll, åker mer rakt fram		The fins decrease rider's fatigue when riding
	När vi åkte i Lödde-å så kom det in nån vass nån gång och då sa det bara stopp.		The fins prevent sea vegetation from entering the jetpack
	Sen va vi ute nån gång när det var is och så. Då kom där in slush, det satte igen direkt tvärstopp		The fins prevent ice and slush from entering the jetpack
	Acceleration kommer ni märka själva, men det var nästan det svåraste för min del, det här med gasen. Den är så direkt, det blir sån push. Och när du släpper den så stannar den direkt också.		The fins stabilize the rider when accelerating and decelerating the board
	Man måste böja på benen lite så för att inte stå med raka ben när det kommer vågor.		The fins offer comfortable riding in the same standing position, in all conditions
	den nya paden de har är lite bättre grepp i men den gamla paden hade för dåligt grepp tyckte jag. Kanske kan ta bort den, och vaxa hela istället.		The fins prevent the rider from slipping on the board
	när det blir vågigt då flyttar man fram lite. Som en båt som gasar på och ligger med aktern som bara matar, då kan man luta sig fram för att plana ut den lite.		The fins ease the planning out of the board during choppy conditions
	Man vill upp snabbt för att kunna åka iväg snabbt och åka snabbare (om varför man vill plana ut)		The fins ease the process of getting into a standing position
	det kan va rätt gött och ha. Lite vikt och vågor, har du en lättare bräda bumpar du och tyngre går igenom vågorna lite mer.		The fins allow the board to push through waves
	Ja jag vill ha allt, kvickare svängar snabbare bräda allt		The fins make the board quicker
			The fins make the board more agile
	För när man ställer sig bak, du vill ju ha den så plant som möjligt så man ställer sig mitt på brädan.		samma med planing känns det som
	få bort lite wobbling i hög fart		The fins minimize the rocking state during high speeds
Zafer Taylor	man inte kan kalla det för surfing överhuvudtaget		The fins enable riding with the absence of waves
			The fins generate a unique riding feel
	med en jetboard så är det väldigt svårt att stå kvar på dem när man svänger på platt vatten.		The fins offer stability to the rider when turning on flat water
	Man blir viktlös i fötterna vid minsta lilla gupp.		The fins enable the feeling of control when hitting a bump
	vågen gör att du trycks mot den		The fins generate the feeling of control
	jag skulle velat ha ett handtag för att hålla i när det går för fort. Kommer det en minsta chock blir det blir problem.		The fins enable the feeling of control for a rider standing up
	Handkontroll va inte så mjuk i hastigheten, utan rätt så ryckig och det va svårt att stå kvar.		The fins smooth the acceleration and retardation
	jag tror inte att man behöver åka så himla fort egentligen		The fins affect the handling of the board at lower speeds
	Då kunde man slide:a den (brädan utan fenor) och göra lite tricks.		The fins allow sliding properties
	Det blev som att brädan gick på räls annars och va trög att svänga med fenorna.		The fins make the board agile and responsive
	om tanken är att man ska surfa på brädorna, behöver de inte alls gå så fort till att börja med		Fins that generate surfboard feel affect the handling of the board at lower speeds
	Man vill göra andra saker kanske (med jetboarden) så tänkte jag att det va roligare utan fenorna helt, så man kan slide:a den i sidan och åka runt.		The fins allow for different styles of riding
	Vattnet ligger platt. Nu plötsligt blir det en helt ny grej. Det är klart att det kommer bli en skillnad när du svänger. Det blir en helt annan funktion plötsligt för fenan.		The fins enable easy steering on flat water
	Man behöver inte ha en rocker, en rund rail gör att den svänger.		The fins make use of the board's geometry to enchance its properties
	Då svängar du på kanterna (rails) istället. När den är rund får du en kurva, så svänger den. Små fenor kanske räcker. Som en vindsurfbräda kanske.		The fins initiate turns using the board's geometry
	Jag tror det tar bort det roliga från jetboards om man har fenor. Små fenor, ja (det hade funkat).		The fins enable agile riding with sliding

Grupper
Turning/Agile
Stability
Product family
Speed handling
Symbios med övriga jetboard-funktioner
Perception of riding properties
User strength
Riding conditions
Extra/Rider conditions

	det blir väldigt enformigt om den blir svår att svänga.	The fins allow different riding styles and provide agility	Grupper
	En center-fin hade nog inte hjälpt alls på en sådan bräda.	The fins utilize the design constraints set up by using a jetpack	Turning/Agile
	Det finns vissa sweet-spots på alla brädor, men man kan utgå ifrån var man står på brädan.	The fins make use of the user's standing position to offer the desired properties	Stability
	Om man säger att det är en surfbräda blir man trött efter fem minuter då man inte har någon våg	The fins geneate a unique feel of riding on water	Product family
	jag tror inte farten är lösningen (för surfingkänslan) men det (jetboarding) är någonting annat.	The fins are focused towards a jetboard	Speed handling
	Om man surfar på väldigt stora vågor då är brädorna väldigt tunga för att de ska kunna skära genom små hopp och behålla kontrollen.	The fins make use of the weight of the board to enchance its stability in wavy conditions	Symbios med övriga jetboard-funktioner
	Men den är för bred och för platt, den studsar hårt på vågor om det går för fort.	The fins reduce the bouncing of the board in wavy conditions	Perception of riding properties
	Det blir som att den (jetboarden) kör dig.	The fins give the user an enhanced feeling of control	User strength
	Att se det som en jetski som man står på, absolut.	The fins generate the feeling of riding similarities to other water craft	Riding conditions
	Sen vill man nog ha fler handtag på brädan så att man kan ta tag i dem genom att bocka sig.	The fins allow turns while crouching on the board	Extra/Rider conditions
Julian Ciepklik	Ja, den var ju instabil. Man sitter på dem och trillar i vattnet	The fins stabalize the board	
	Men den var lättare att svänga på det hållet dit tårna pekar.	The fins allow the user to turn both ways with the same ease	
	Jag hade nog velat ha en men det är ändå lite skoj och byta lite positon.	The fins allow control of the jetboard in only one standing position	
		The fins allow varying standing positions	
	Man behöver bara hitta en position som passar i början, sen när man svänger kanske man får ändra lite. Det är bara lite svårare som nybörjare	The fins assist new users in finding balance on the board	
		The fins generate a forgiving board that allows for varying standing positions	
	Det var nog nån fördel med den, att det var lättare att svänga i hög hastighet men jag kände inte det riktigt.	The fins enhance the different boards' qualities	
	Ja, där va någon dag det var sjögräs på botten som gjorde motorn sämre när man körde in i dem.	the fins prevent sea vegetation from entering the intake	
	Jag tyckte det var kul med vågor, men också kul när det var helt plant.	The fins allow for riding in different surface conditions	
	Man kan ju maxa då, utan problem. Det är mer bekvämt. Medan med vågor blir det mer fysisk övning.	The fins maximize top speed of the board	
		The fins decrease rider's fatigue when riding	
	Ja, ja svängarna till höger gick ju rätt bra att ta men svängarna till vänster gick inte lika bra. (angående hastighet i svängar)	The fins allow same control of the board in only one standing position, in varying directions	
	när man är nybörjare känns det mer som man åker på en sten. Lite som att lära sig cykla, det går lättare och lättare när man får lite fart.	The fins provide the rider with enhanced balance at lower speeds	
	Utfällbara fenor om det hade fungerat	The fins are expandable/foldable	
	det är svårt att transportera den (vikten)	The fins allow for easier transportation	
	det hade varit kul att se hur man stod under sin åkning och kunna jämföra med.	The fins make the user understand how they are standing when riding	
	det hade varit kul om man kunnat anpassa den för långdistans, snabbt och svänga och kanske sjögräs eller åar och så.	The fins decrease rider's fatigue when riding long distances	
		The fins generate a quick and agile board	
		The fins prevent sea vegetation from entering jetpack	
		The fins enable enhanced riding in streams	
Roland Hummer	The fins are not so easy getting in and out for inexperienced people	The fins are easy to handle	
	You need a glove or you will cut yourself	The fins can be assembled with only your hands	
	if I wanna do tricks and 360's, on my way at least, then I can't use the fins.	The fins enable the rider to do tricks	
	For beginners I found out while teaching that they don't actually notice the difference. There is so much other things to focus on.	The fins offer a learning curve to get a feel of the properties of the fins	
	I am showing how to make turns even without the fins.	The fins use similar turning methods as one would use without fins	
	The most difficult part is realizing the sensitivity of the remote	The fins help users during their learning phase, getting to know the controller.	
	the movement from lying on the board to standing up needs to be as quick as possible.	The fins allow more time for the rider to go from lying down to standing up on board	
	Three is showing that the board is really big and stable. You can walk around on it.	The fins inspire confidence in the rider that the board is stable	
	Everyone need to get used to steering, speed and control	The fins enhance the users connection with the board	
	Showing how to place your feet for stability but no technique for it.	The fins allow varying standing positions for stability	
	The learning curve on the jetboard is much faster than the foil	The fins are considering the quick learning curve	
	If you are not so fit, you can still have fun on the jetboard by laying on your stomach, kneeling or sitting.	The fins allow riding by lying down	
		The fins allow riding by kneeling	
		The fins allow riding by sitting	
		The fins allow riding by standing while decreasing rider fatigue	
		The fins decrease the strength needed to get into a standing position	
	The next level is probably to get the tarifa style with footstraps so I can do more tricks	The fins allow for users to advance their riding without acquiring a new board	
	The controller is meant for warmer places and to use without gloves	The fins are suited for colder climates	
	The controllers proportions are too small for gloves	The fins can be attached and detached using gloves	
	I have been riding both on small and big waves on rivers and oceans.	The fins allow riding on big waves	
		The fins allow riding on small waves	
		The fins allow riding in open and closed waters	
	You can forget that everything underneath gets sucked in and can ruin the propeller.	The fins prevent damage to the propeller	
	Sometimes beginners forget that they still hold the controller and cause accidents when trying to get to the docks	The fins are not damaged by impacts in lower speeds	

Now the rule is to paddle the last 20meters without the kill-switch on		The fins allow users to paddle the board with ease		Grupper
I always do tricks and stuff without fins.		The fins enable tricks		Turning/Agile
I mean sometimes if you just want to do quick carving and so I could have fin		The fins enable carving properties		Stability
If I go straight and want more speed I also do longer turns but I dont need fins for that, at all		The fins allow higher speeds in longer turns		Product family
		The fins provide other functions than higher speeds		Speed handling
Because the boards are big and if I know how to shift my weight, it is enough to put my foot a bit to the edge and I do a simple turn		The fins act with the user's intuition		Symbios med övriga jetboard-funktioner
		The fins allow for steering with feet movement		Perception of riding properties
Now the jetboard is like a longboard, I walk around a bit, I sit down I get up		The fins allow the user to move around on the board		User strength
Also when I turn, I try leaning 10deg 20deg and see when I fall in. Sometimes with the fins of course and sometimes without		The fins allow for higher degrees of leaning before losing balance on the board		Riding conditions
Sometimes I just sit on the docks and dont go in the water at all just standing up on the board and take of		The fins allow the rider to step onto the board from docks		Extra/Rider conditions
If there are waves I might go on one knee when I accelerate.		The fins provide stability when riding on waves		
		The fins inspire confidence in the rider when riding on waves		
On both the foil and the jetboard I would say I am up in the first 5 or 8 seconds		The fins allow the user to stand up quickly		
The most important thing is that they learn that they need a little bit of speed to get up		The fins allow riders to stand up at lower speeds		
Since you have a roll-axis in the middle of the board which can be unstable you need to place your feet with one on each side of the axis to have more control		The fins make the board stable around the roll-axis		
		The fins ease the riders' balancing		
The intervall as well from on your knees to getting up needs to be as short as possible		The fins allow riders to go from kneeling to standing in a longer amount of time		
The jetboard is actually the clumsy one, so an idea would be to have it more agile as well		The fins make the board more agile		
But super responsive if possible, because right now I have to move around a lot on the board when steering		The fins make the board super responsive		
The jetboard have more surface friction and when it is wavy you can really need to work with your legs which is more tiring		The fins decrease the board's surface friction.		

J Needs Hierarchy

The following is the interpreted needs with corresponding rated importance.

Major needs:
There are different types of fins
The different types of fins offer different riding properties
The fins allow the rider to advance his/her riding style without the need to acquire a new board

*** **1. The fins offer Stability**
*** 1.1 The fins offer stability when riding against waves
*** 1.2 The fins offer stability on still water
** 1.3 The fins offer stability during high speeds
** 1.4 The fins offer stability in roll axis
*** 1.5 The fins offer stability in lower speeds
1.6 The fins prevent rider from slipping
*** 1.7 The fins reduce the bouncing of the board in wavy condiitons

** **3. The fins affect the position of the board's bottom surface**
** 3.1 The fins help the board to level out
** 3.2 The fins push board towards surface
** 3.3 The fins straighten the board in choppy conditions

* **5. The fins offer improved learning curve**
5.1 The fins help the rider get a feel of the fin properties
* 5.2 The fins decrease the amount of riding factors to think about

** **7. The fins offer ensuring impressions**
** 7.1 The fins offer a sense of control when riding against waves
* 7.2 The fins offer a sense of control when riding along waves
*** 7.3 The fins offer a sense of control when standing up
*** 7.4 The fins help the board to act according to the riders intuition
*** 7.5 The fins offer a unique riding feeling

*** **9. The fins transfer rider interaction**
*** 9.1 The fins enable rider to interact through change of position
** 9.2 The fins enable rider to interact through a single feet position
** 9.3 The fins allow the rider to turn using heels and toes with the same ease

*** **11. The fins make use of the board's geometry**
11.1 The fins enhance the different board models' qualities
11.2 The fins make use of rails/geometry to initiate turns

13. The fins offer extra features
The fins are foldable
The fins enable easy transportation of board
*** The fins are easy to handle
** The fins allow to be handled with gloves
The fins withstand impact at lower speeds

*** **2. The fins offer different riding styles**
** 2.1 The fins enable different standing positions
2.2 The fins enable riding patterns
** 2.3 The fins enable the rider to perform tricks with the board
*** 2.4 The fins allow the rider to kneel when riding the board
*** 2.5 The fins allow the rider to lay down when riding the board
* 2.6 The fins allow the rider to sit when riding the board

*** **4. The fins offer speed handling**
*** 4.1 The fins offer the rider control through the entire speed range of the board
** 4.2 The fins maximizes the speed of the board
*** 4.3 The fins offer smooth acceleration of the board
*** 4.4 The fins offer smooth deceleration of the board

* **6. The fins offer reduced rider effort**
* 6.1 The fins decrease the rider fatigue
* 6.2 The fins decrease the rider fatigue over long distances of riding
* 6.3 The fins allow the rider more time to stand up
6.4 The fins decrease the strength needed from the rider to stand up on the board

*** **8. The fins offer agility**
*** 8.1 The fins offer agility at lower speeds
*** 8.2 The fins offer agility at higher speeds
*** 8.3 The fins enable turns at different speeds
*** 8.4 The fins initiate turns
** 8.5 The fins offer a responsive board

*** **10. The fins offer sliding**
** 10.1 The fins enable altering between steering and sliding
** 10.2 The fins offer control when sliding

*** **12. The fins enable riding in different conditions**
* 12.1 The fins enable riding through sea vegetation
* 12.2 The fins enable riding through ice/slush
*** 12.3 The fins allow riding in lull
*** 12.4 The fins allow riding in small waves
*** 12.5 The fins allow riding in big waves
** 12.6 The fins allow riding on big waves
*** 12.7 The fins allow riding in cold conditions
12.8 The fins prevent damage of the impeller

K Fin Concepts and Corresponding Needs

The following are the fin concepts with corresponding needs.

Tight turns

1. The fins offer Stability
1.3 The fins offer stability during high speeds
1.4 The fins offer stability in roll axis
1.5 The fins offer stability in lower speeds

4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board

7. The fins offer ensuring impressions
7.3 The fins offer a sense of control when standing up
7.4 The fins help the board to act according to the riders intuition

8. The fins offer agility
8.1 The fins offer agility at lower speeds
8.2 The fins offer agility at higher speeds
8.3 The fins enable turns at different speeds
8.5 The fins offer a responsive board

9. The fins transfer rider interaction
9.3 The fins allow the rider to turn using heels and toes with the same ease

11. The fins make use of the board's geometry
11.1 The fins make use of rails/geometry to initiate turns

12. The fins enable riding in different conditions

Rookie

1. The fins offer Stability
1.1 The fins offer stability when riding against waves
1.2 The fins offer stability on still water
1.4 The fins offer stability in roll axis
1.5 The fins offer stability in lower speeds
1.6 The fins prevent rider from slipping
1.7 The fins reduce the bouncing of the board in wavy condiitons

2. The fins offer different riding styles
2.4 The fins allow the rider to kneel when riding the board
2.5 The fins allow the rider to lay down when riding the board

4. The fins offer speed handling
4.3 The fins offer smooth acceleration of the board
4.4 The fins offer smooth deceleration of the board

5. The fins offer improved learning curve
5.1 The fins help the rider get a feel of the fin properties
5.2 The fins decrease the amount of riding factors to think about

6. The fins offer reduced rider effort
6.3 The fins allow the rider more time to stand up
6.4 The fins decrease the strength needed from the rider to stand up on the board

7. The fins offer ensuring impressions
7.1 The fins offer a sense of control when riding against waves
7.3 The fins offer a sense of control when standing up
7.4 The fins help the board to act according to the riders intuition

8. The fins offer agility
8.1 The fins offer agility at lower speeds

9. The fins transfer rider interaction
9.3 The fins allow the rider to turn using heels and toes with the same ease

12. The fins enable riding in different conditions
12.3 The fins allow riding in lull
12.4 The fins allow riding in small waves

Smooth riding

1. The fins offer Stability
1.1 The fins offer stability when riding against waves
1.2 The fins offer stability on still water
1.3 The fins offer stability during high speeds
1.4 The fins offer stability in roll axis
1.5 The fins offer stability in lower speeds
1.7 The fins reduce the bouncing of the board in wavy condiitons

3. The fins affect the position of the board's bottom surface
3.3 The fins straighten the board in choppy conditions

4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board
4.3 The fins offer smooth acceleration of the board
4.4 The fins offer smooth deceleration of the board

6. The fins offer reduced rider effort
6.1 The fins decrease the rider fatigue

7. The fins offer ensuring impressions
7.1 The fins offer a sense of control when riding against waves
7.3 The fins offer a sense of control when standing up
7.4 The fins help the board to act according to the riders intuition

12. The fins enable riding in different conditions
12.3 The fins allow riding in lull
12.4 The fins allow riding in small waves
12.5 The fins allow riding in big waves
12.6 The fins allow riding on big waves

Long distance

1. The fins offer Stability
1.1 The fins offer stability when riding against waves
1.2 The fins offer stability on still water
1.3 The fins offer stability during high speeds
1.4 The fins offer stability in roll axis
1.5 The fins offer stability in lower speeds
1.6 The fins prevent rider from slipping
1.7 The fins reduce the bouncing of the board in wavy condiitons

2. The fins offer different riding styles
2.1 The fins enable different standing positions

4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board

6. The fins offer reduced rider effort
6.1 The fins decrease the rider fatigue
6.2 The fins decrease the rider fatigue over long distances of riding

7. The fins offer ensuring impressions
7.1 The fins offer a sense of control when riding against waves
7.3 The fins offer a sense of control when standing up

12. The fins enable riding in different conditions

13. The fins offer extra features
The fins withstand impact at lower speeds

Sliding/Tricks

1. The fins offer Stability
2. The fins offer different riding styles
2.3 The fins enable the rider to perform tricks with the board
2.4 The fins allow the rider to kneel when riding the board
7. The fins offer ensuring impressions
7.4 The fins help the board to act according to the riders intuition
10. The fins offer sliding
10.2 The fins offer control when sliding
11. The fins make use of the board's geometry
11.2 The fins make use of rails/geometry to initiate turns
12. The fins enable riding in different conditions
12.4 The fins allow riding in small waves
12.5 The fins allow riding in big waves
12.6 The fins allow riding on big waves

Instigate turning

1. The fins offer Stability
1.4 The fins offer stability in roll axis
2. The fins offer different riding styles
2.2 The fins enable riding patterns
3. The fins affect the position of the board's bottom surface
3.2 The fins push board towards surface
4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board
6. The fins offer reduced rider effort
7. The fins offer ensuring impressions
7.4 The fins help the board to act according to the riders intuition
8. The fins offer agility
8.1 The fins offer agility at lower speeds
8.2 The fins offer agility at higher speeds
8.3 The fins enable turns at different speeds
8.4 The fins initiate turns
8.5 The fins offer a responsive board
9. The fins transfer rider interaction
9.1 The fins enable rider to interact through change of position
9.2 The fins enable rider to interact through a single feet position
9.3 The fins allow the rider to turn using heels and toes with the same ease
11. The fins make use of the board's geometry
11.1 The fins enhance the different board models' qualities
11.2 The fins make use of rails/geometry to initiate turns

Stand quickly and get going

1. The fins offer Stability
1.4 The fins offer stability in roll axis
1.5 The fins offer stability in lower speeds
1.6 The fins prevent rider from slipping
2. The fins offer different riding styles
2.1 The fins enable different standing positions
2.4 The fins allow the rider to kneel when riding the board
2.5 The fins allow the rider to lay down when riding the board
3. The fins affect the position of the board's bottom surface
3.1 The fins help the board to level out
4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board
4.3 The fins offer smooth acceleration of the board
5. The fins offer improved learning curve
5.2 The fins decrease the amount of riding factors to think about
6. The fins offer reduced rider effort
6.4 The fins decrease the strength needed from the rider to stand up on the board
7. The fins offer ensuring impressions
7.3 The fins offer a sense of control when standing up
7.4 The fins help the board to act according to the riders intuition

Easy turning and sliding

1. The fins offer Stability
1.4 The fins offer stability in roll axis
2. The fins offer different riding styles
2.2 The fins enable riding patterns
2.3 The fins enable the rider to perform tricks with the board
7. The fins offer ensuring impressions
7.4 The fins help the board to act according to the riders intuition
8. The fins offer agility
9. The fins transfer rider interaction
10. The fins offer sliding
10.1 The fins enable altering between steering and sliding
10.2 The fins offer control when sliding
11. The fins make use of the board's geometry
11.2 The fins make use of rails/geometry to initiate turns

Standard - Overall

1. The fins offer Stability
1.1 The fins offer stability when riding against waves
1.2 The fins offer stability on still water
1.3 The fins offer stability during high speeds
1.4 The fins offer stability in roll axis
1.5 The fins offer stability in lower speeds
1.7 The fins reduce the bouncing of the board in wavy condiitons
2. The fins offer different riding styles
2.1 The fins enable different standing positions
2.4 The fins allow the rider to kneel when riding the board
2.5 The fins allow the rider to lay down when riding the board
4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board
4.3 The fins offer smooth acceleration of the board
4.4 The fins offer smooth deceleration of the board
7. The fins offer ensuring impressions
7.3 The fins offer a sense of control when standing up
7.4 The fins help the board to act according to the riders intuition
8. The fins offer agility
8.1 The fins offer agility at lower speeds
8.2 The fins offer agility at higher speeds
8.3 The fins enable turns at different speeds
9. The fins transfer rider interaction
9.1 The fins enable rider to interact through change of position
11. The fins make use of the board's geometry
12. The fins enable riding in different conditions
12.3 The fins allow riding in lull
12.4 The fins allow riding in small waves
12.5 The fins allow riding in big waves

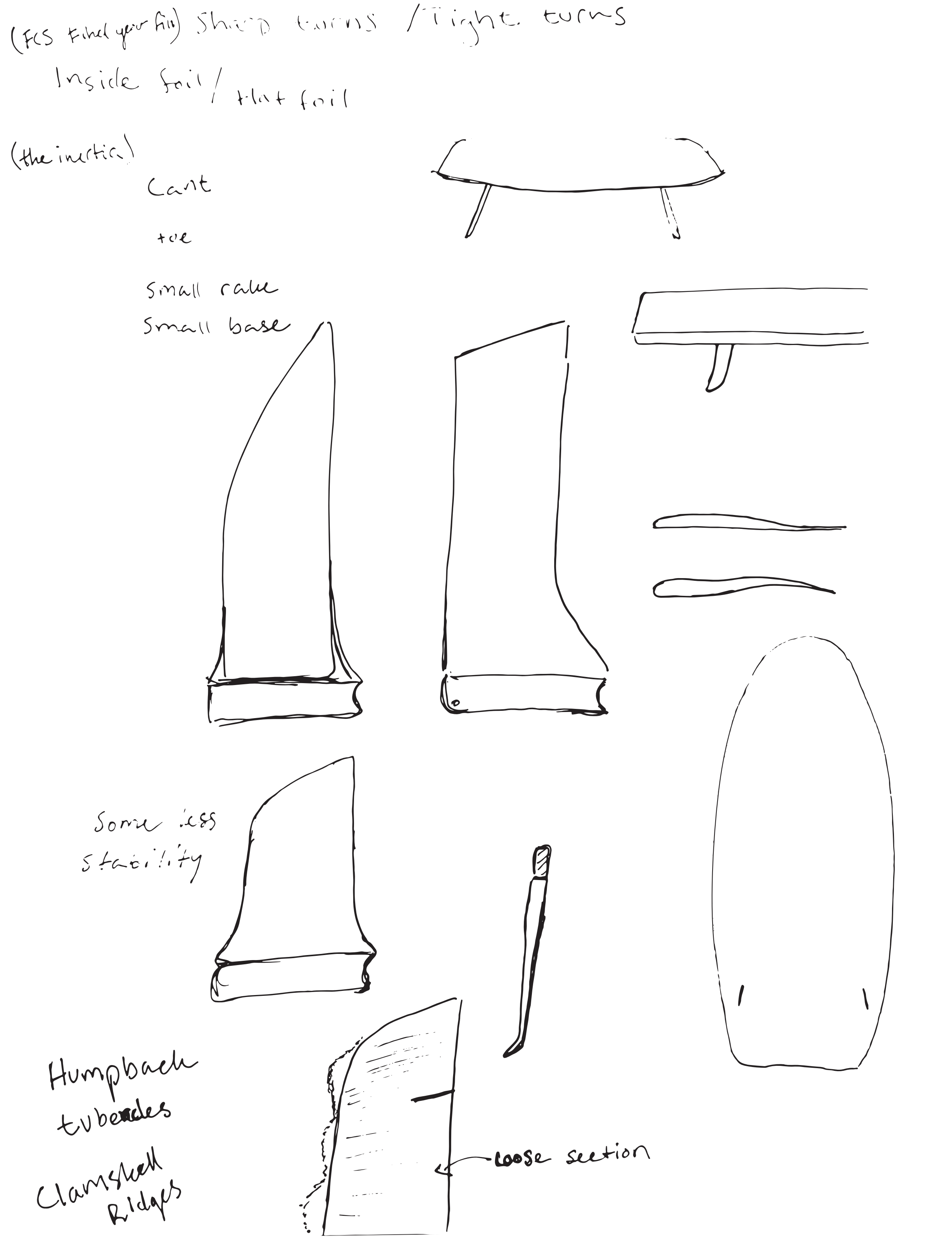
Max speed

1. The fins offer Stability
1.1 The fins offer stability when riding against waves
1.3 The fins offer stability during high speeds
1.6 The fins prevent rider from slipping
3. The fins affect the position of the board's bottom surface
3.1 The fins help the board to level out
3.3 The fins straighten the board in choppy conditions
4. The fins offer speed handling
4.1 The fins offer the rider control through the entire speed range of the board
4.2 The fins maximizes the speed of the board
7. The fins offer ensuring impressions
8. The fins offer agility
8.2 The fins offer agility at higher speeds
11. The fins make use of the board's geometry

L Sketches of Fin Concepts

The following are the sketches made on possible fin concepts.

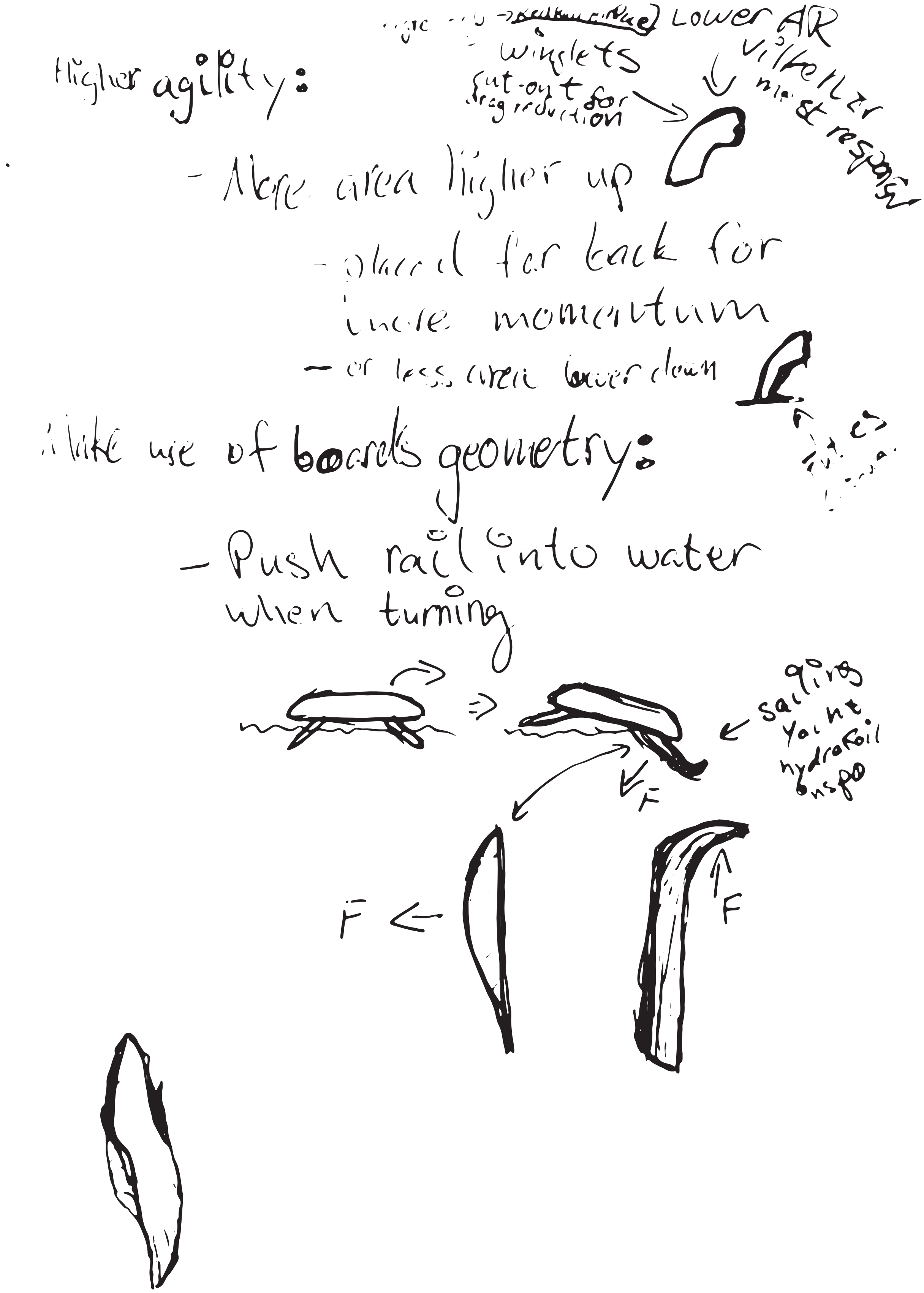
TIGHT TURNS

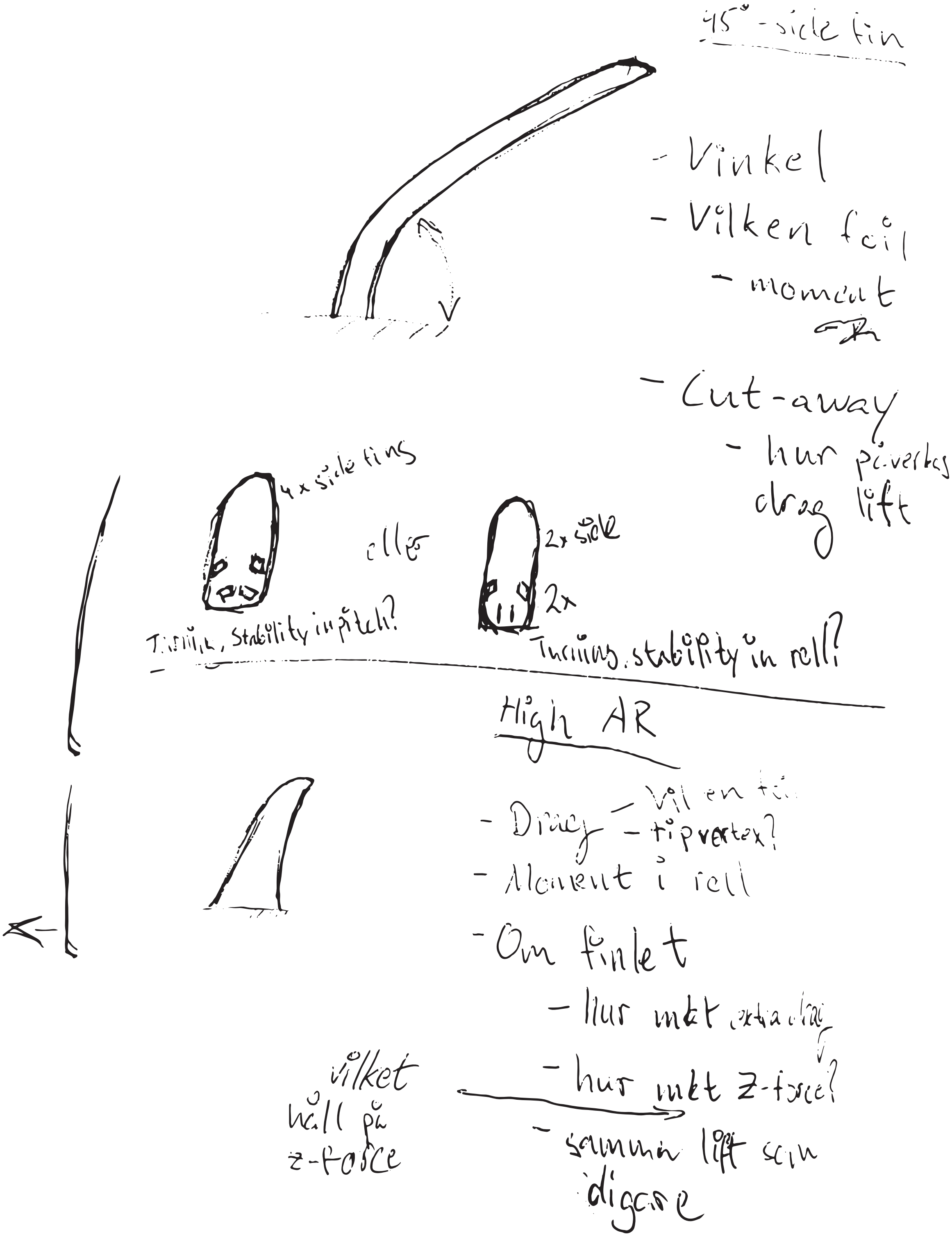

Sharp turns / Tight turns
Inside foil / flat foil
(the inertia)
Cant
toe
small rake
Small base
Some less stability
Humpback tubercles
Clamshell Ridges
loose section

Tight Turns

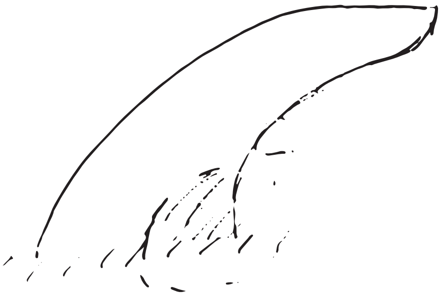
Responsive:

- High AR
- Short rake
- Higher stiffness
- More toe, angled inwards
- Cant, angled outwards
- 4 fins (more fins). ~~[illegible]~~
    - close together
- Flat foil (Futures Tomo Quad)


Lower AR
winglets
cut-out for drag reduction
Higher agility:
- More area higher up
- placed far back for more momentum
- or less area lower down
Make use of board's geometry:
- Push rail into water when turning
sailing yacht hydrofoil
F
F
F


45° - side fin
- Vinkel
- Vilken foil
- moment
- Cut-away
- hur påverkas
drag lift
4 x side fins
eller
2x side
2x
Turning, stability in pitch?
Turning stability in roll?
High AR
- Drag
- tip vortex?
- Moment i roll
- Om finlet
- hur mkt extra drag
- hur mkt z-force?
vilket håll på z-force
- samma lift som idag

Rake



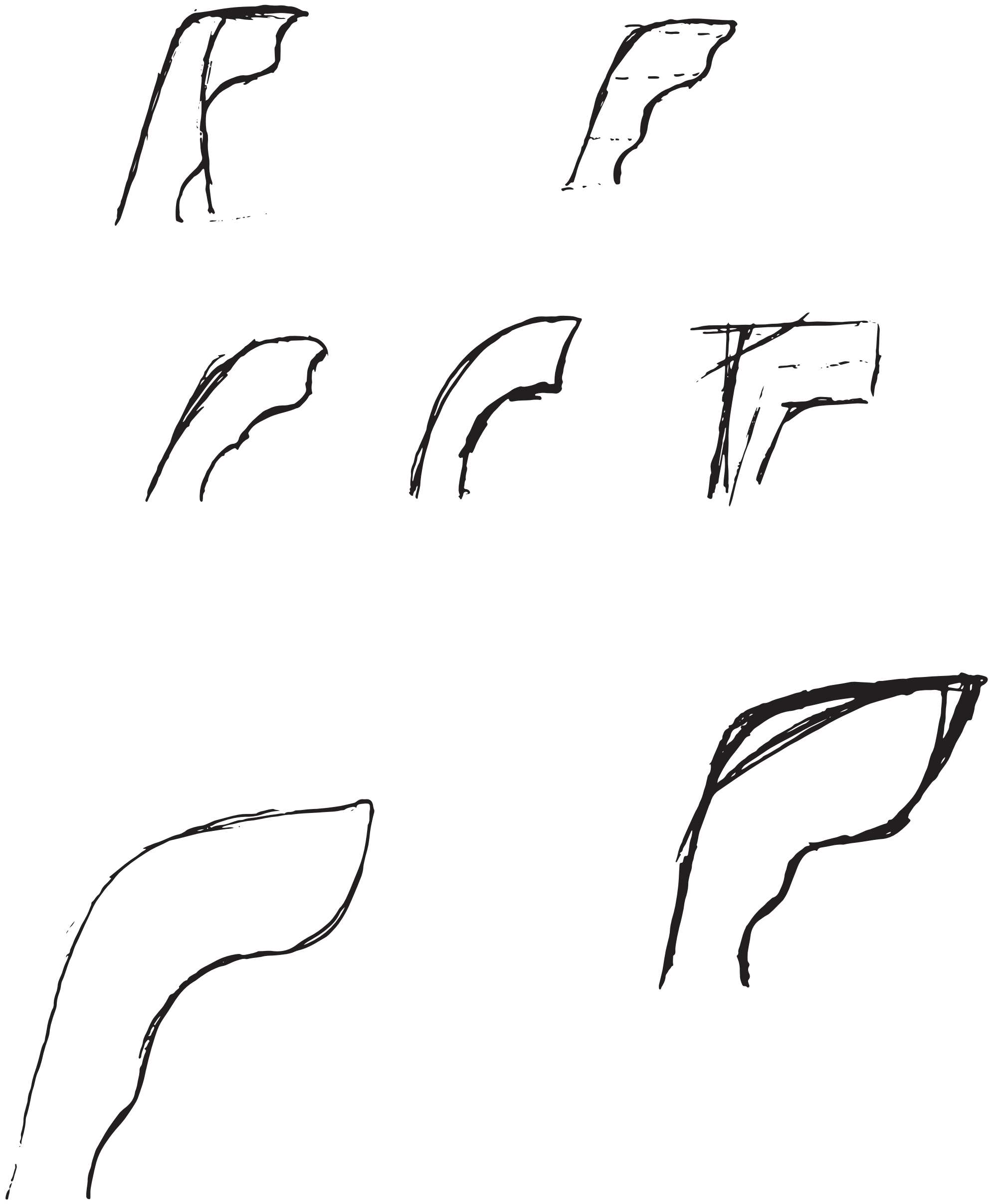
- När bred bas lossnar från vattnet, netto-moment i roll ändras?
- Skillnad i lift med cut-out?

Wet area

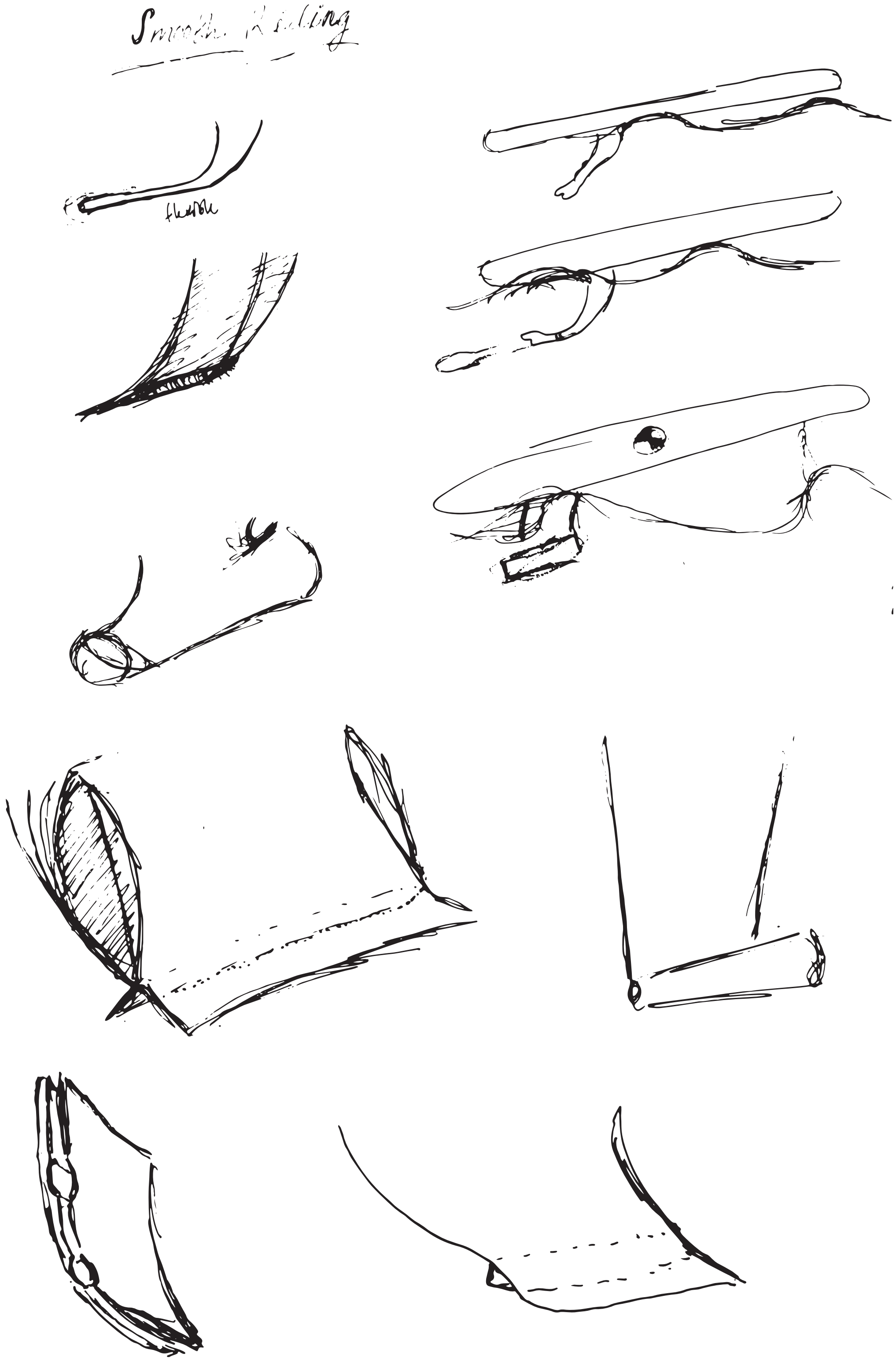
- Roll
- testa foil

Sammanfattning
- Vilken foil → lift/drag
- Roll moment från wide base
- Pitch från fillet

High AR



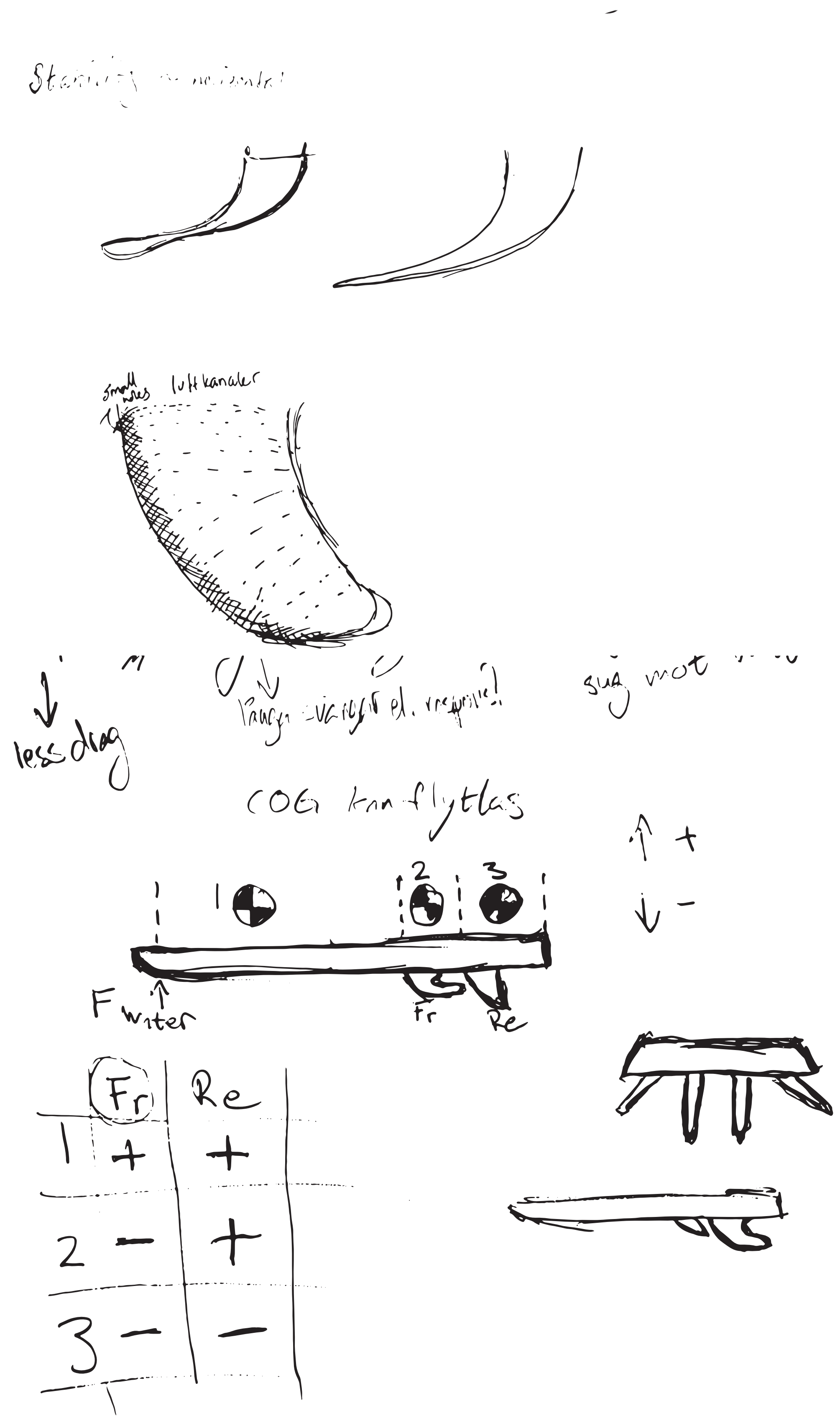
SMOOTH RIDING

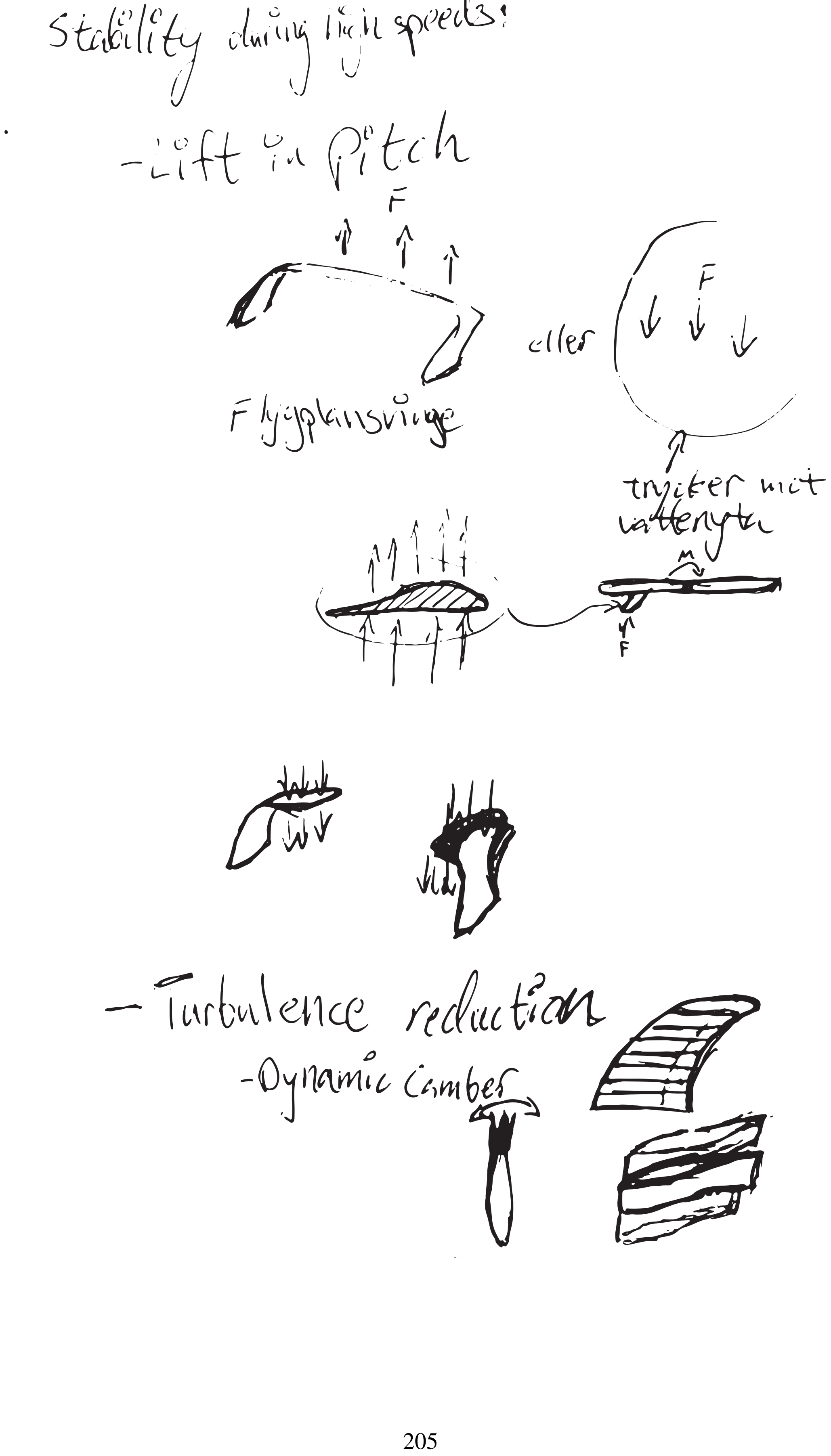


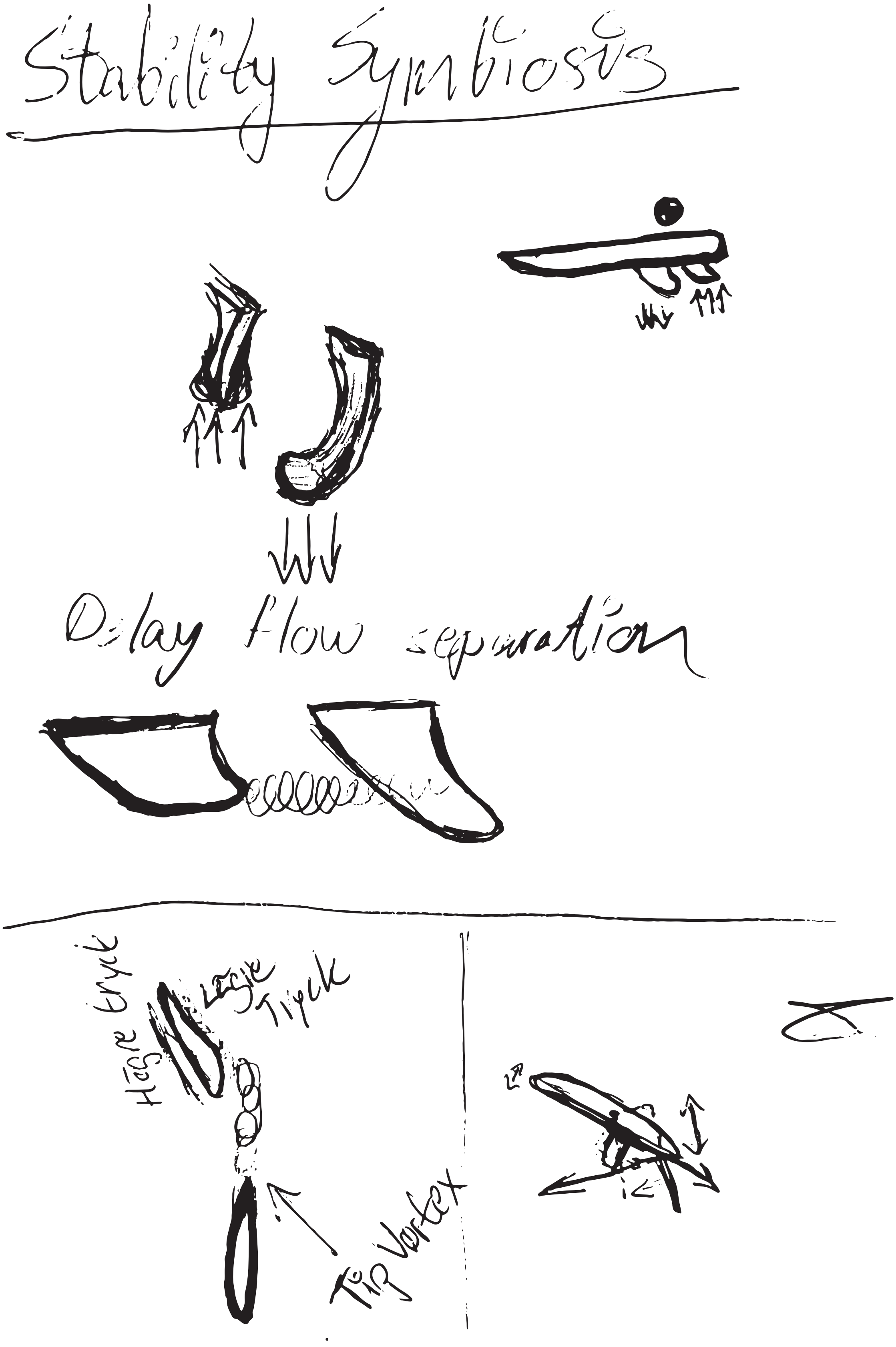
Smooth

winglets w. morphing foil
- eller very flexible material

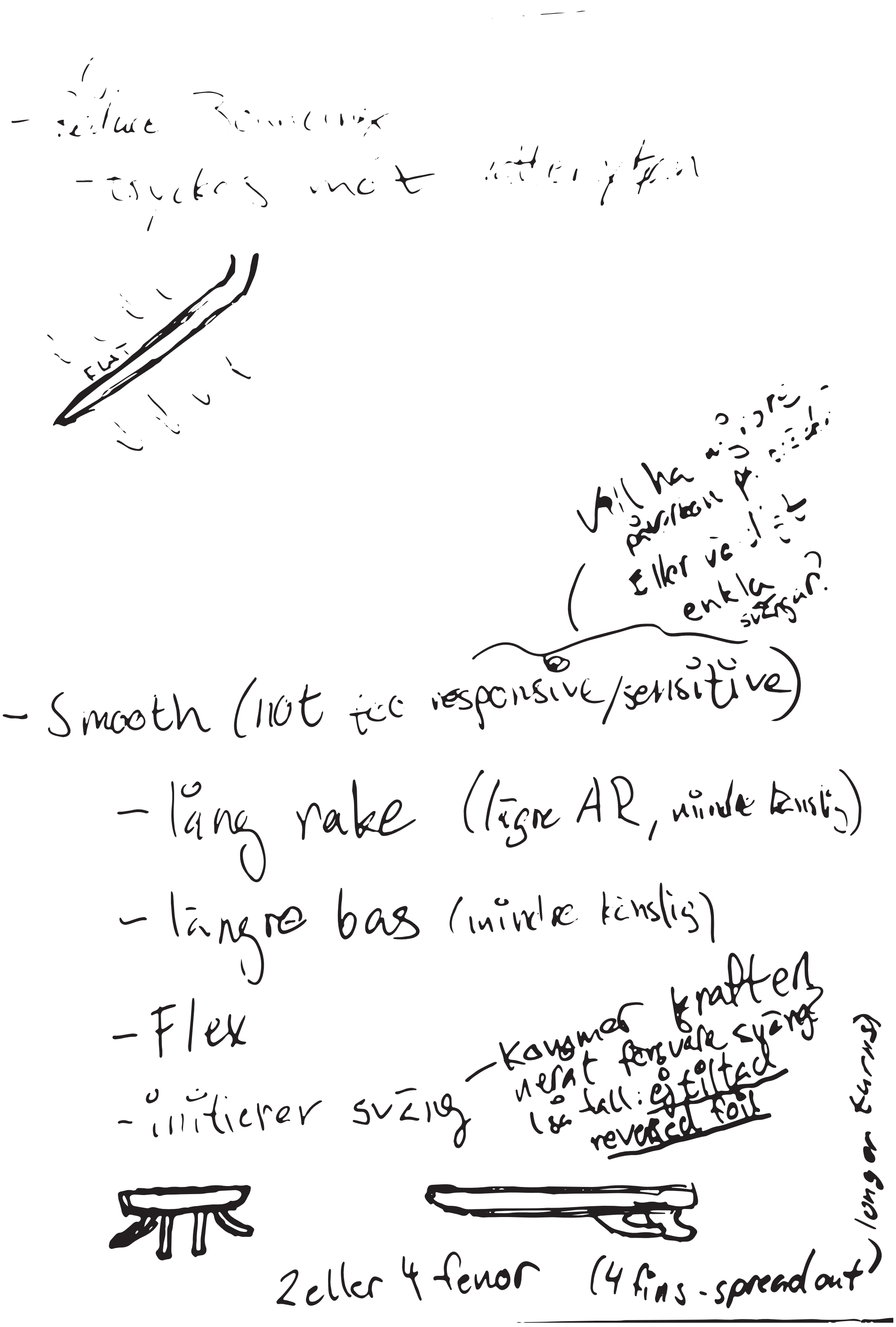
Absorberar krafter uppåt från
vågor


luftkanaler
less drag
1
2
3
F water
Fr
Re
Fr
Re
1 + +
2 − +
3 − −

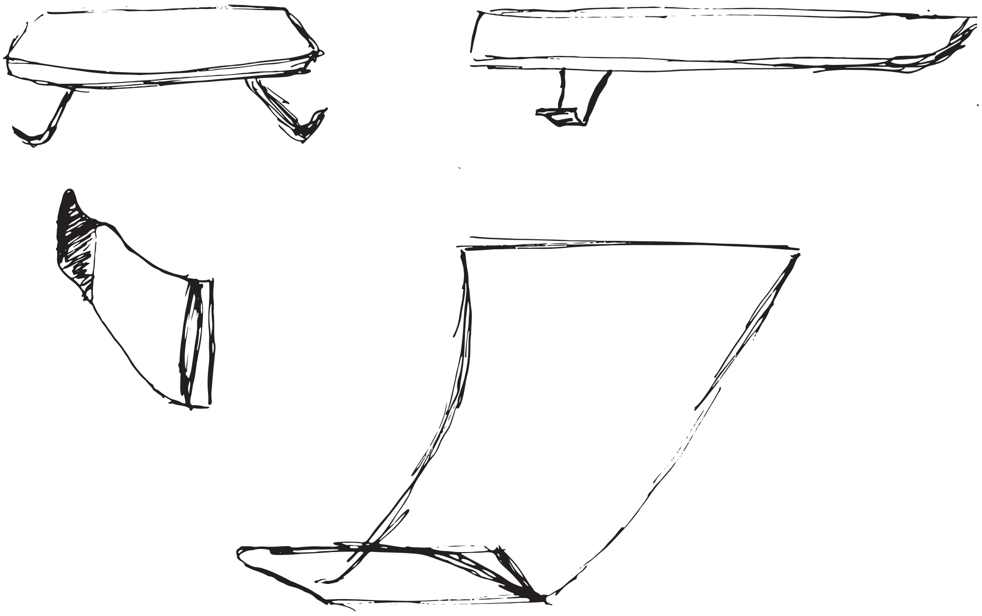

Stability during high speeds:
-Lift in pitch
F
Flygplansvinge
eller
F
- Turbulence reduction
-Dynamic camber

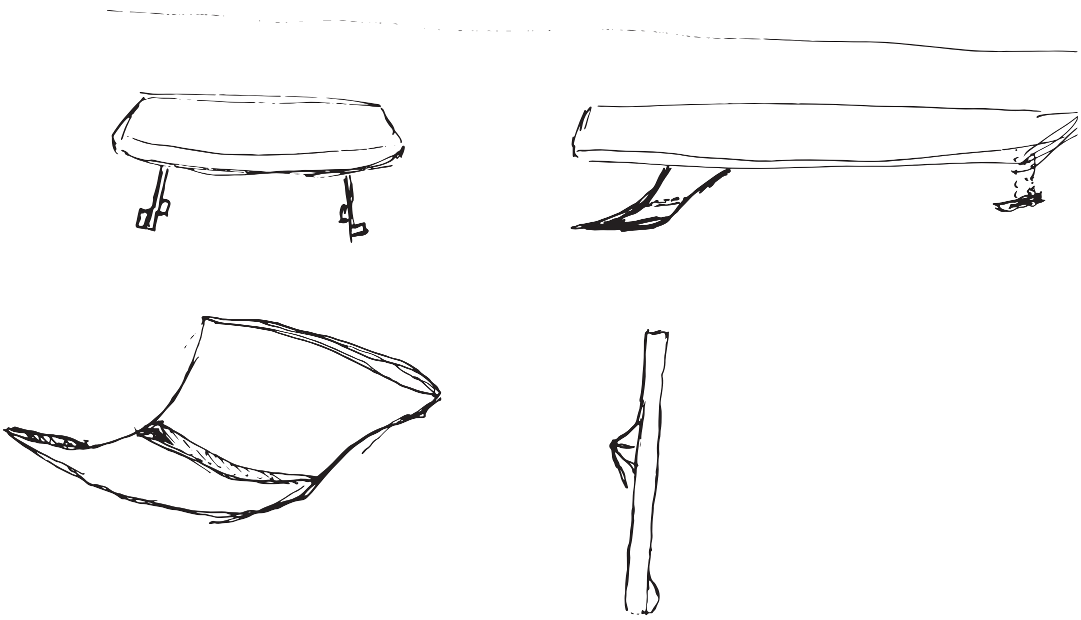

Stability Symbiosis
Delay flow separation
Tip Vortex

LONG DISTANCE



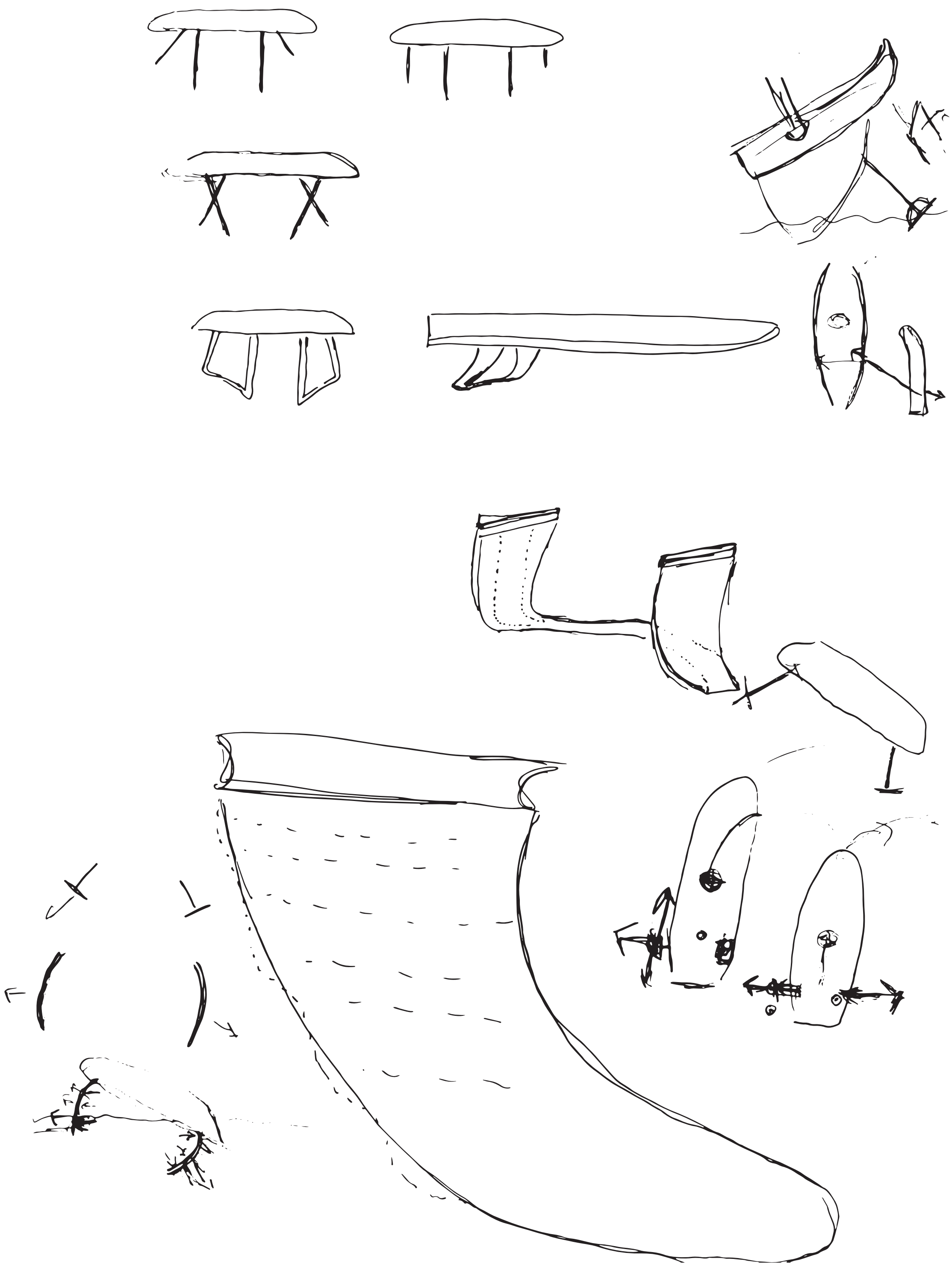
Long Distance






Long Distance
upside down
foil

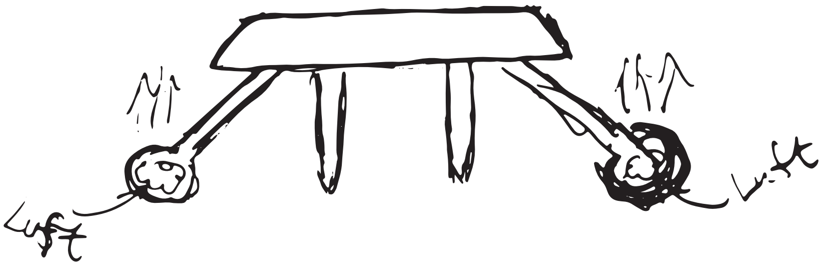
ROOKIE



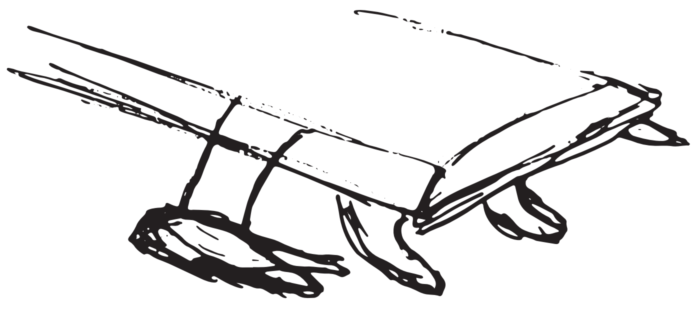
Rookie

- Stability

Stødig v/ Armputtar



- NOT sensitive → removes factor to think about

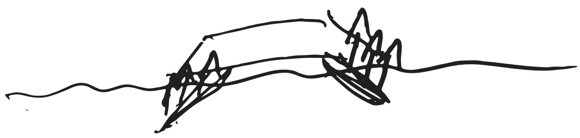


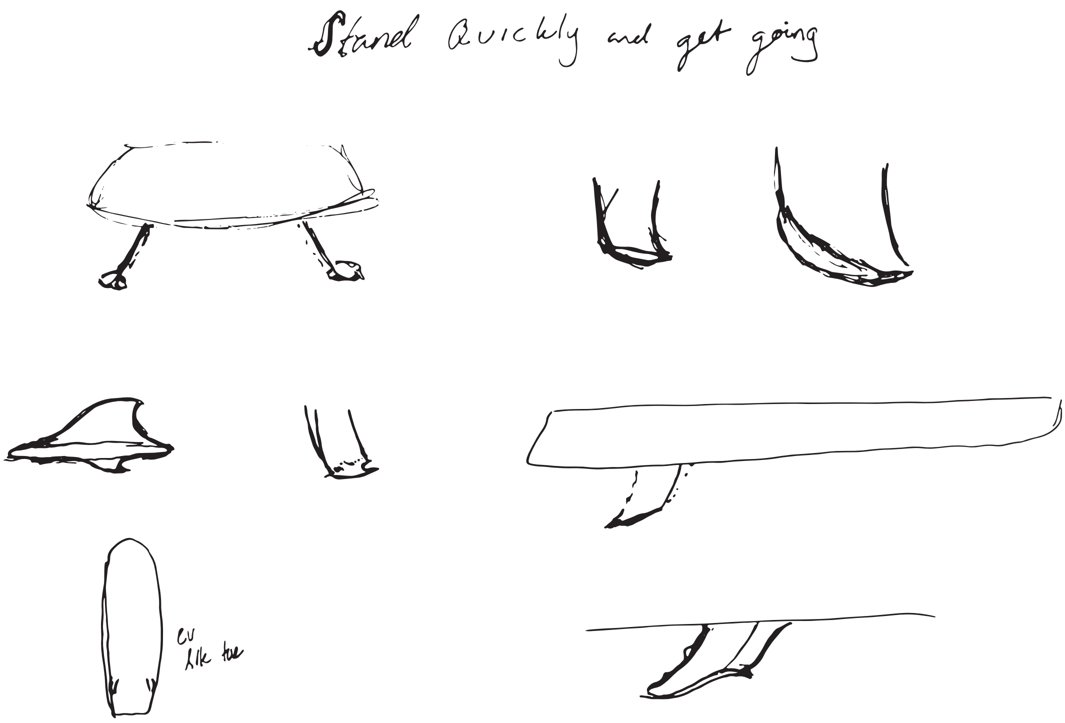
- Flex, delayed action, less sensitive

STAND QUICKLY AND GET GOING

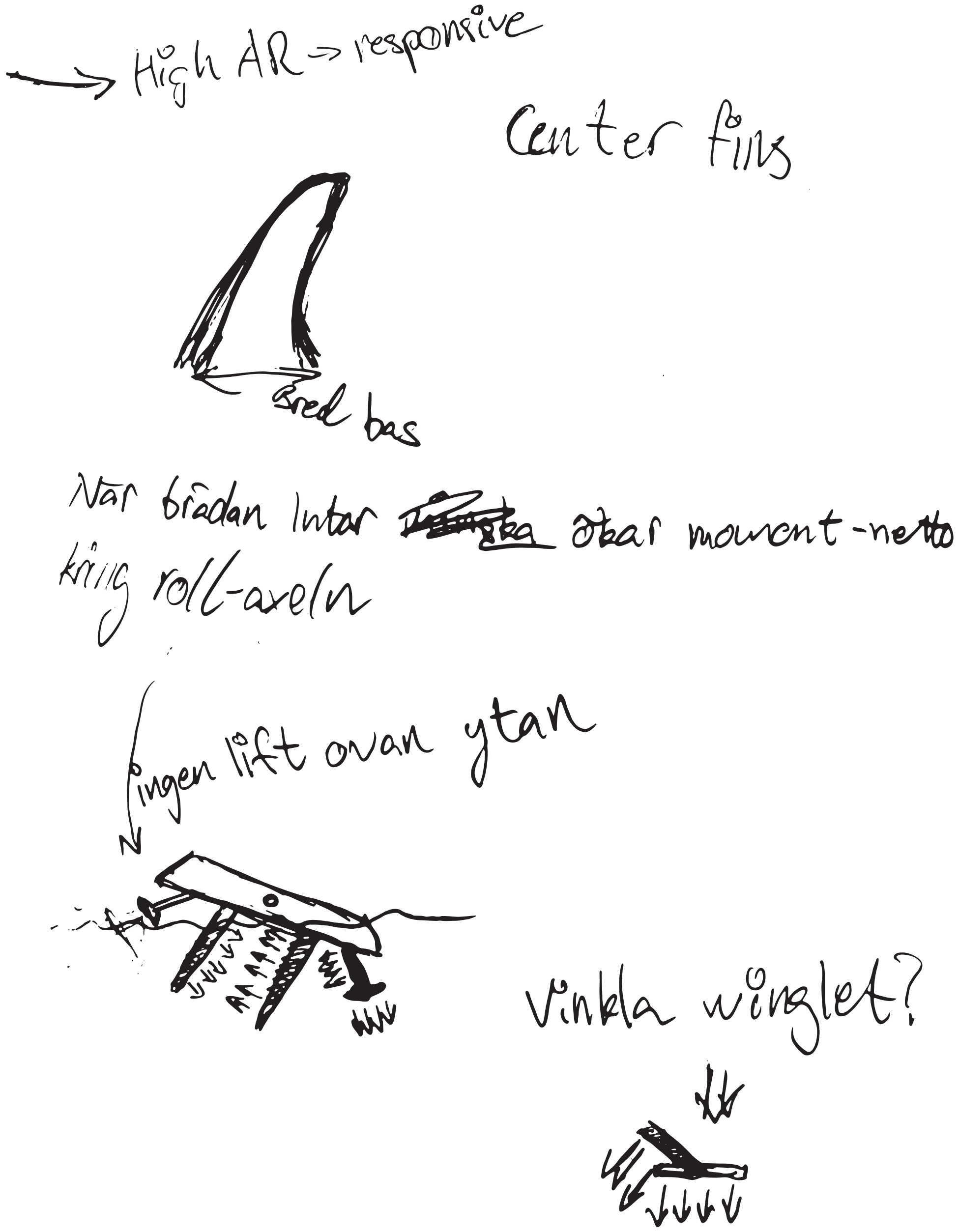
Stand quickly and get going

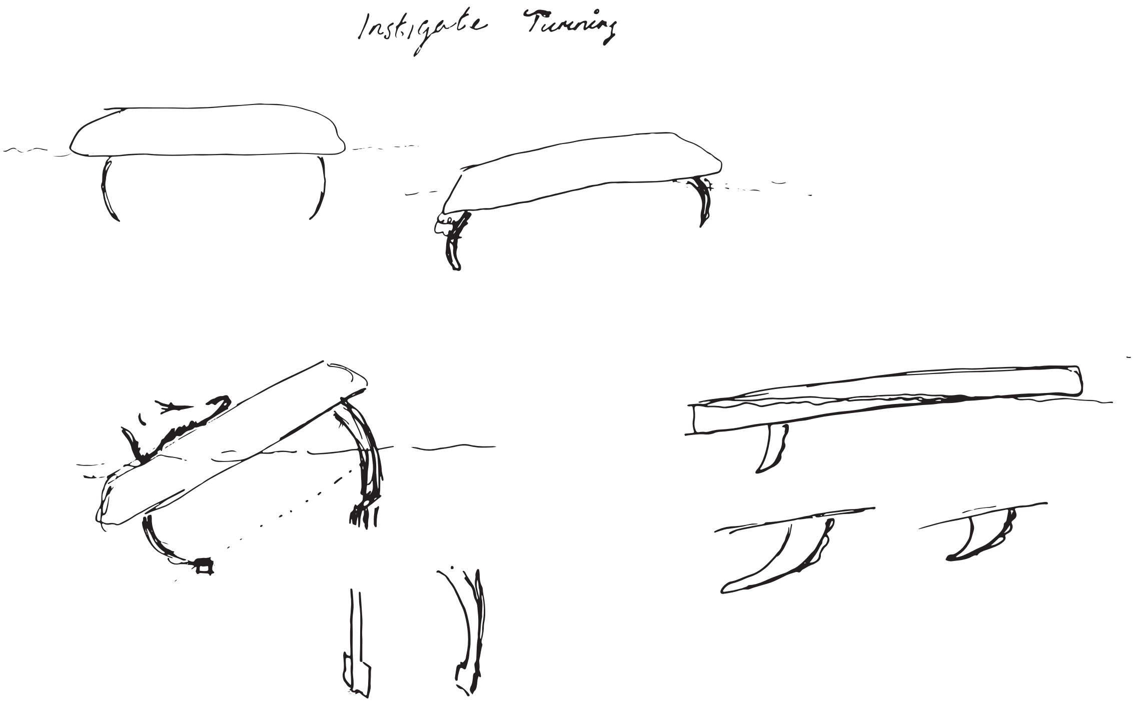
Vapor core ← flytkraft



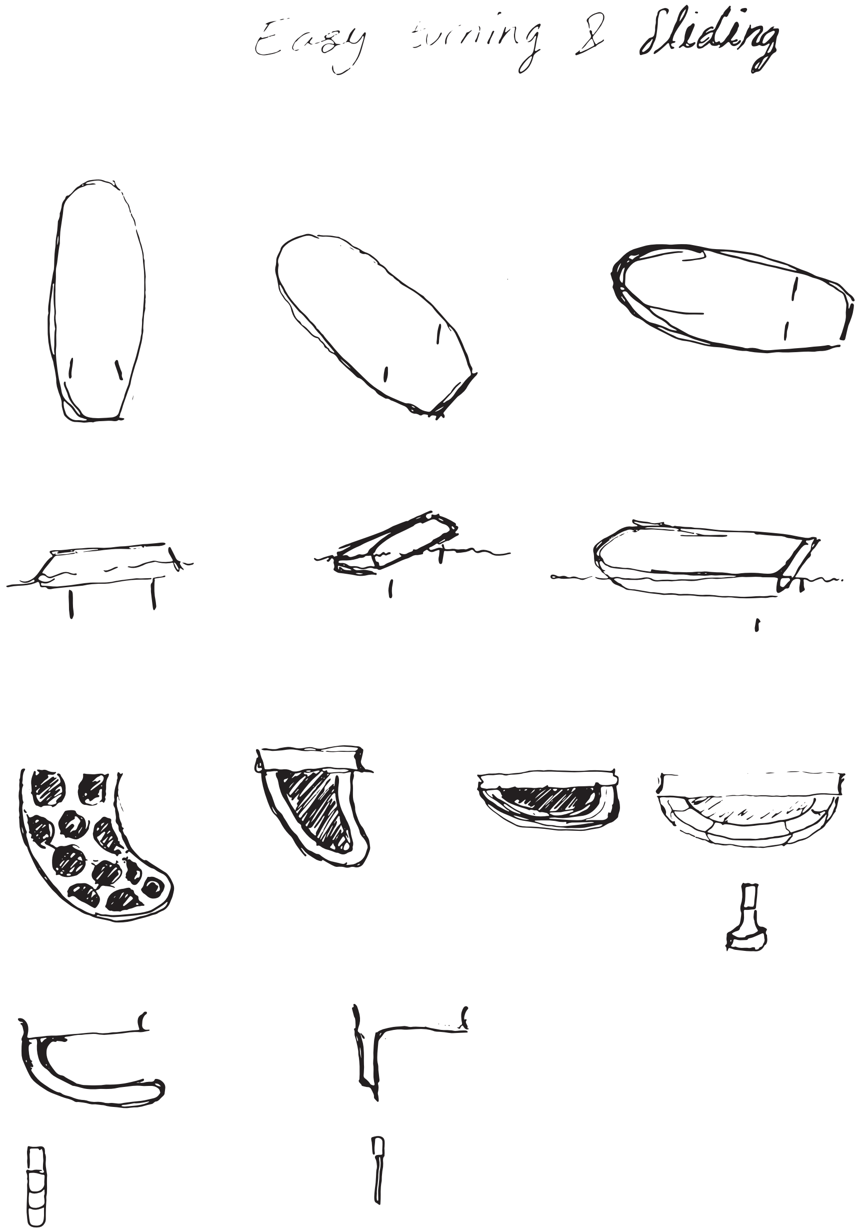

Stand Quickly and get going

INSTIGATE TURNING

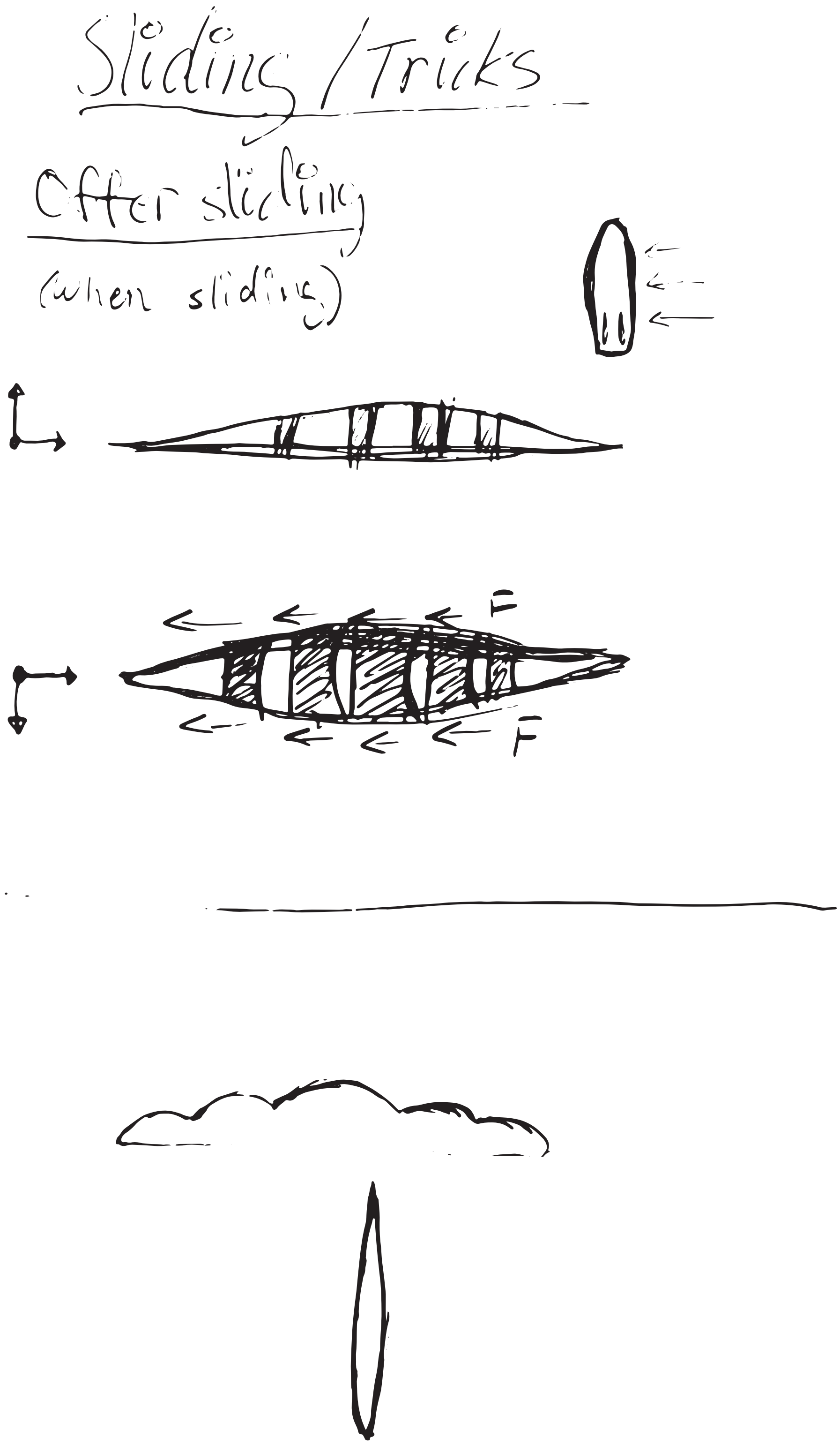

→ High AR → responsive
Center fins
Bred bas
När brädan lutar ökar moment-netto
kring roll-axeln
ingen lift ovan ytan
Vinkla winglet?

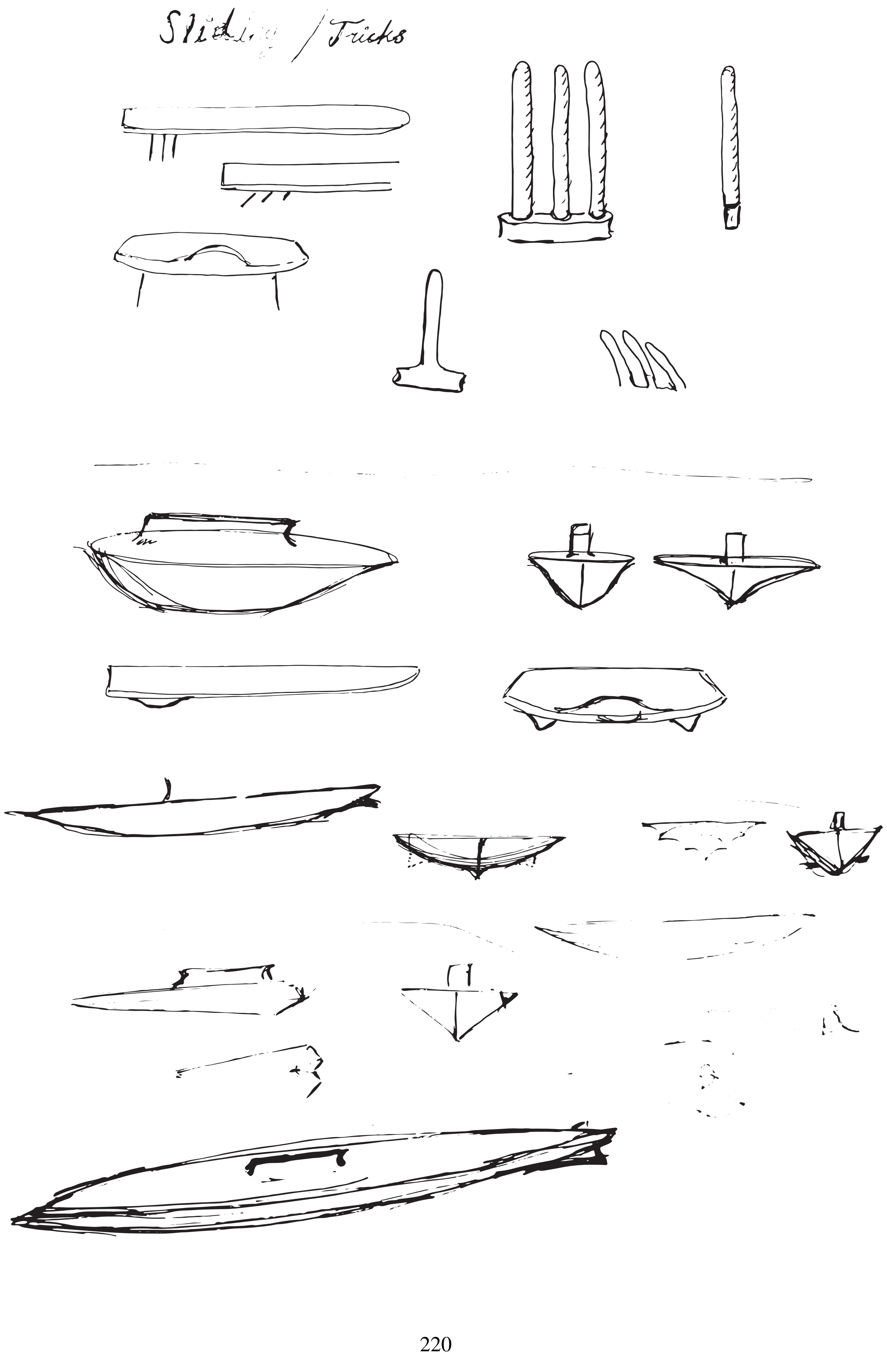

Instigate Turning

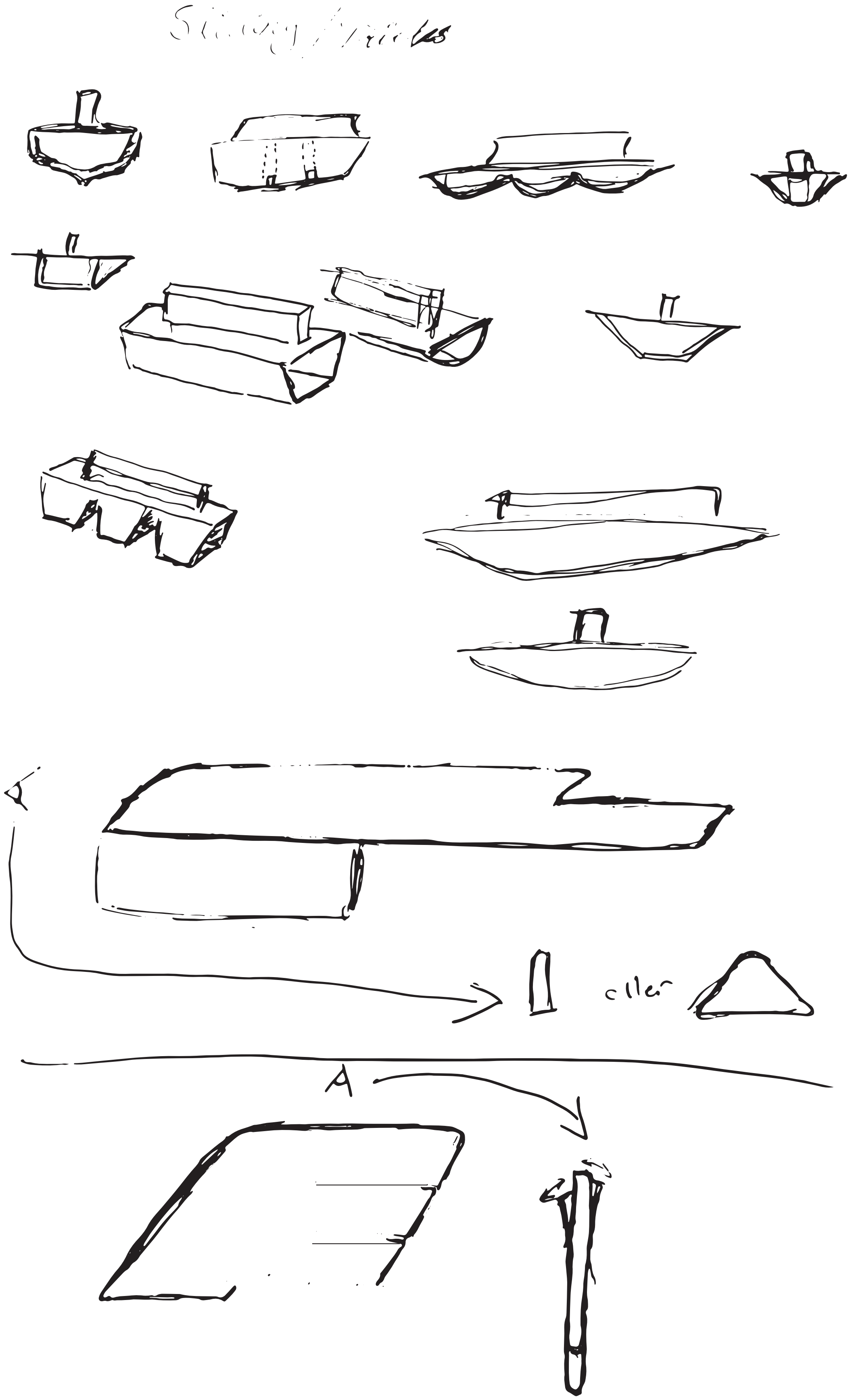
EASY TURNING AND SLIDING



SLIDING/TRICKS




Sliding / Tricks


A

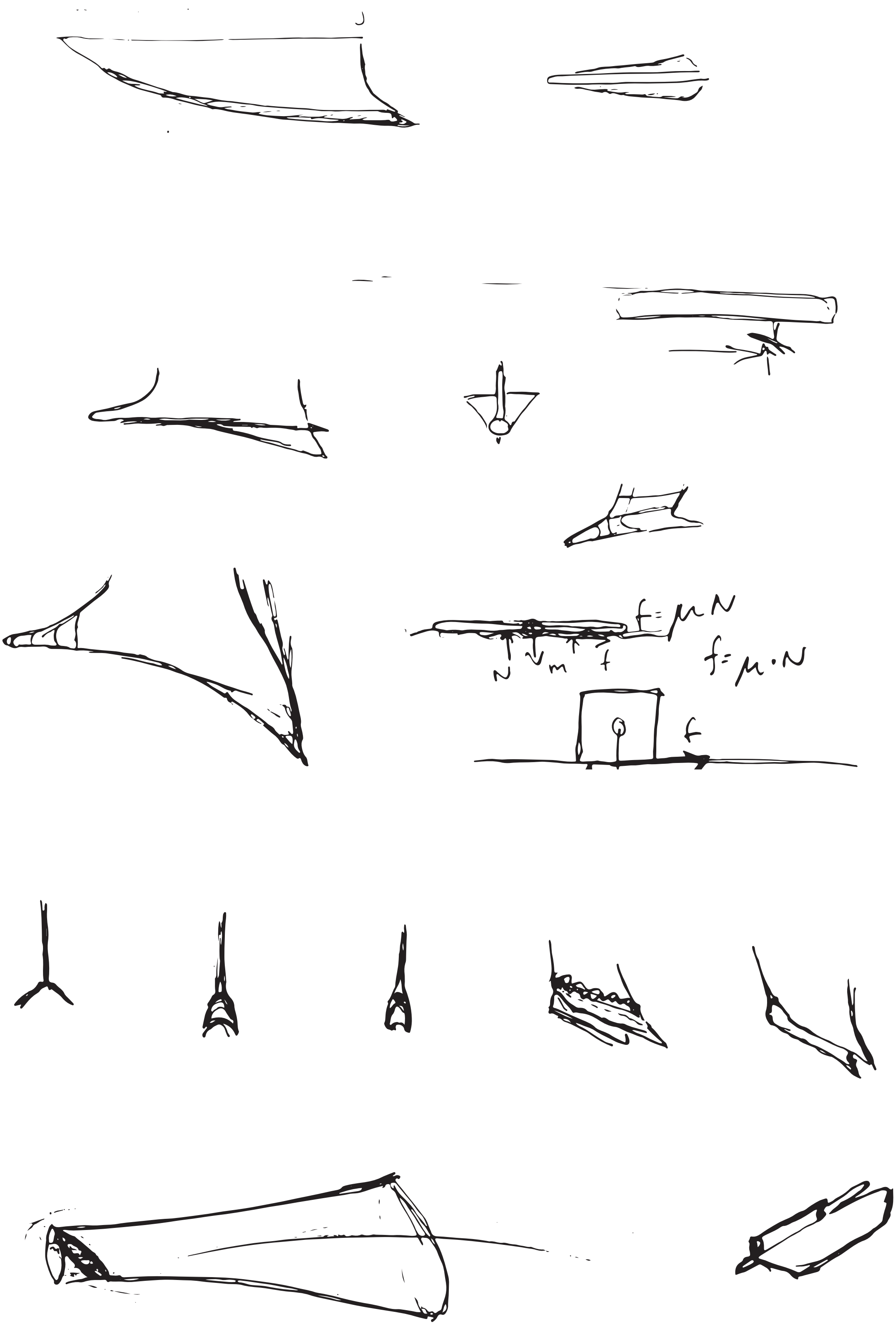
MAX SPEED

MAX SPEED

Maximize speed of board:

- 2 fins
- Long Rake ← with drag reduction
- Low AR
- Test different foils
  - Less drag w. symmetric foil?
  - Less responsive w. asymmetric?

AGILITY


f=μN
N m f
f=μ·N
f

STANDARD - OVERALL

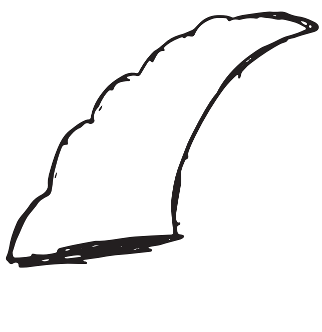
Stability ~ long/deep fins

Agile ~ Thin or Long rake (hermang)

Minimize drag ~ seashell / tubercles

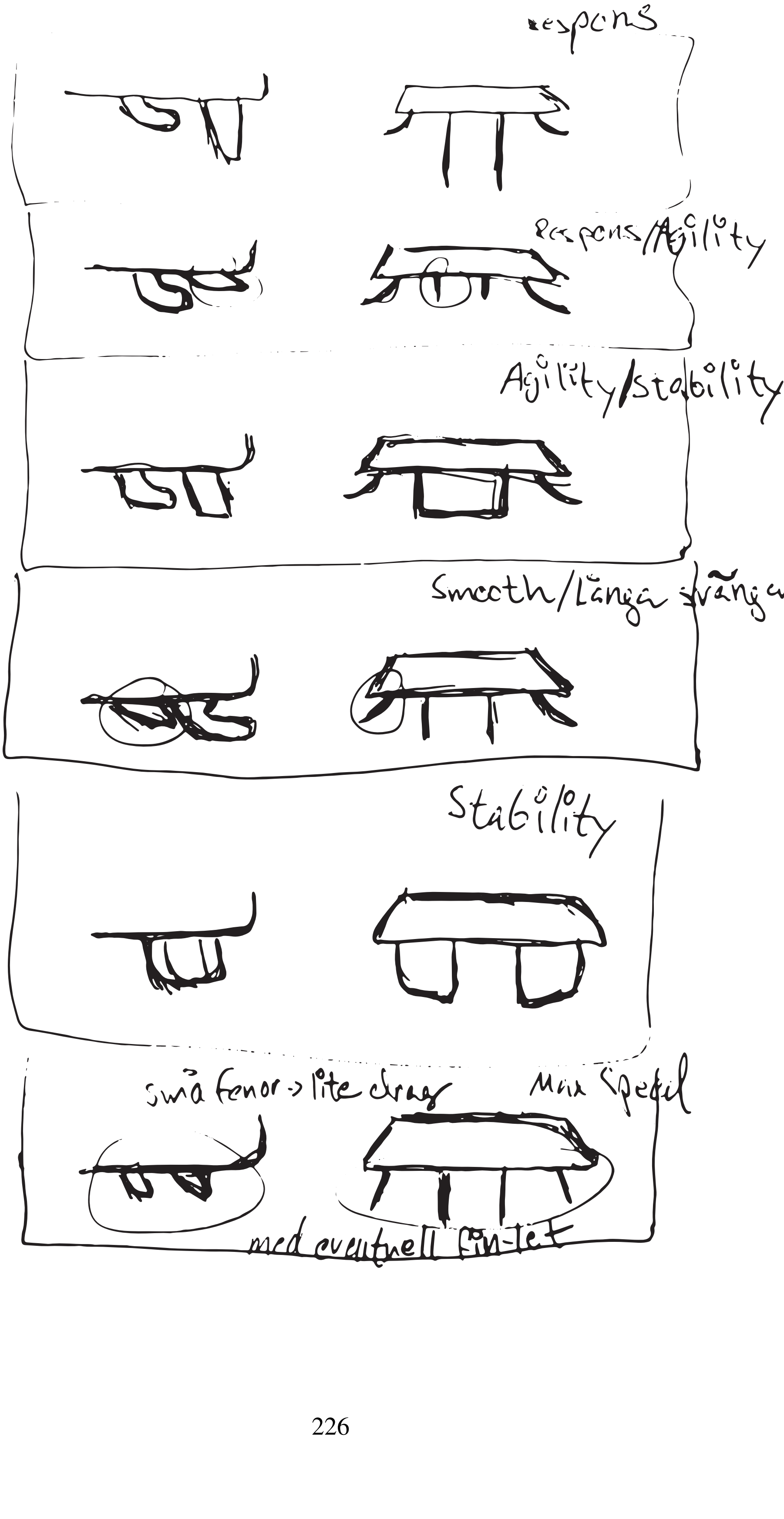
- Great White - Fin

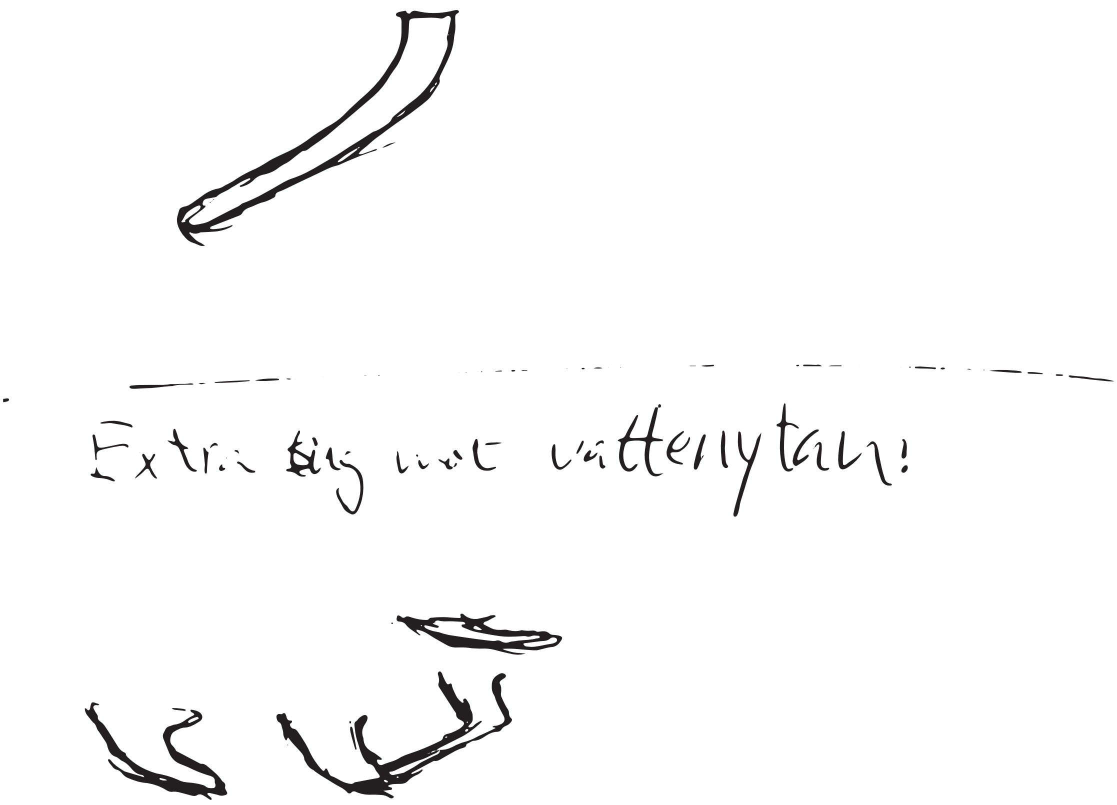
- Whale - Fin

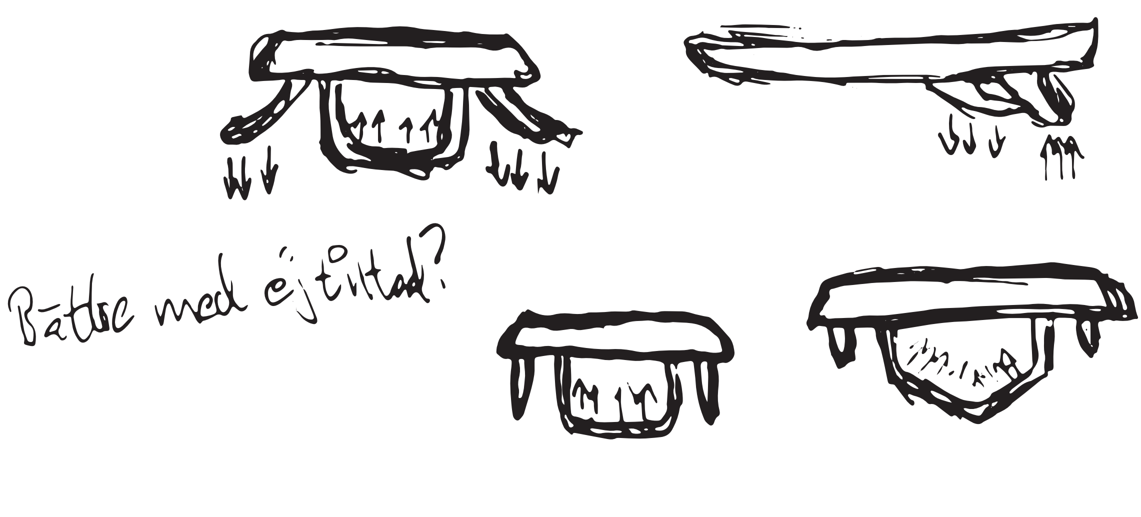


Owl feathers:

COMBINATIONS




Extra
mot vattenytan!


Bättre med ej tiltad?

M 3D Scanning Process

The following is a brief documentation from the conducted 3D scan of jetboard fin.

3D Scan of Fin

To generate a geometrically accurate replica of the fin that is currently shipped with Radinn jetboards, a 3D scan was conducted. An attempt with scanning the fin in its original state was initially done. However, because of the shiny surface and the fin being relatively transparent, the fin had to be spray-painted in a matte color, as seen in figure M1 below, for the scanner to precisely capture the topology.

Figure M1: The fin needed to be spray-painted before scanning.

The fin was then fixated by taping the fin tabs onto a table, as seen in figure M2. By scanning the fin from all angles available, a mesh depicting the object was generated. The result of the scan is seen in figure M3. Lastly, to be able to use the geometry in Star-CCM+, the mesh had to be converted to an STL-file.

The used scanner was Artec Space Spider with the software Artec Studio.

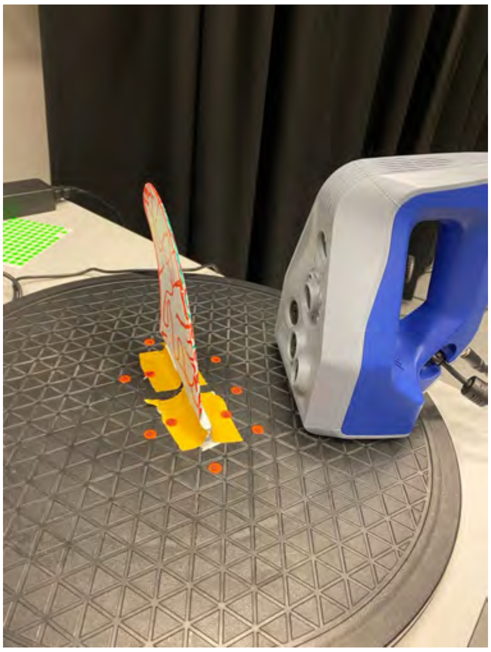


Figure M2: The 3D scanner captured the fin’s geometry from multiple angles.

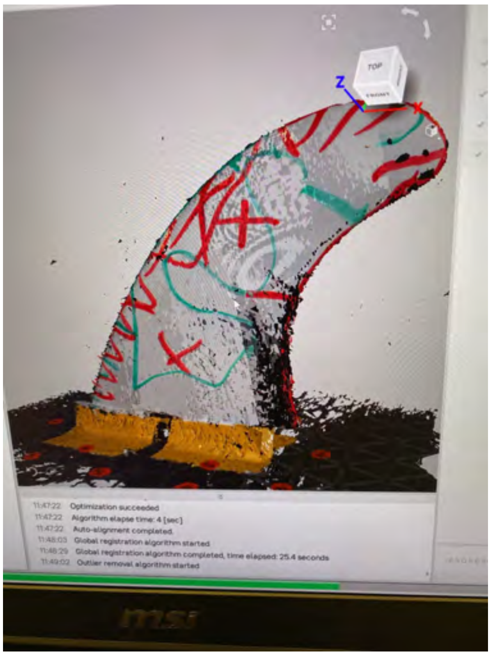


Figure M3: A mesh was generated and converted to an STL-file.