One-Handed Recessed Mount for Fixed Dome Cameras

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2017

MASTER THESIS

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Published by
Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Machine Design for Engineers (MMK820),
Division: Product Development
Supervisor: Damien Motte
Examiner: Olaf Diegel

Abstract

This master thesis report describes a product development process with the aim to extend the existing range of mounts for surveillance cameras mounted recessed in ceilings. A recessed mount is an accessory for mounting cameras, or other devices, in ceilings when a discreet finish is wanted. The goal was to design a solution that can be mounted fast, easy and with the use of one hand only. The company at which this project has been performed is Axis Communications AB, who is market leading in network cameras.

A thorough background study was performed in order to acquire knowledge about the issues arising when mounting cameras recessed in the ceiling and what techniques are being used on products available on the market today. The result of the background study showed that two techniques are most common; using metal spring torsions, like what is used when mounting spotlights, or with a technique that requires screws and consequently tools which takes time.

The work resulted in a concept consisting of two main parts, a housing and a handle, and three parts aiming to connect the main parts. The handle and the housing are pressed together when the recessed mount is inserted in a hole in the ceiling which forces the arms connected to the handle outwards and the camera unit can then be mounted to the recessed mount. One important feature of the handle are the two living hinges that connects the arms to the handle. The living hinges have limited loadbearing capacity and are the critical point of the design and needs further testing to ensure the functionality.

This thesis work proves that a solution that offers one-handed and fast mounting of a recessed mount is possible.

Keywords: Product Development, Recessed Mount, Network Cameras, Axis Communications

Sammanfattning

Denna rapport beskriver en produktutvecklingsprocess med målet att förbättra det nuvarande utbudet av infällda fästen för övervakningskameror i inomhustak. Ett infällt fäste är ett tillbehör som används när kameror, eller andra produkter, skall monteras i innertak när ett så diskret resultat som möjligt är målet. Målet var att designa en lösning som kan monteras snabbt, enkelt och med bara en hand. Företaget där detta examensarbete är utfört är Axis Communications som är marknadsledande på nätverkskameror.

En grundlig bakgrundsstudie genomfördes för att erhålla kunskap om problemen som uppstår när kameror skall monteras infällda i tak och för att se vilka tekniker som används på de produkter som finns ute på marknaden. Resultatet av studien visade att det är två tekniker som används oftast; en där metallfjädrar används, likt när spotlights monteras i tak, och en teknik som kräver skruvar, och därmed verktyg, vilket är tidskrävande.

Arbetet resulterade i ett koncept som består av två huvuddelar, en kropp och ett handtag, samt tre detaljer som skall hålla ihop de två huvuddelarna. Kroppen och handtaget pressas samman med hjälp av en hand när fästet är infört i hålet i taket. Detta leder till att armarna som sitter fast i handtaget pressas utåt och kameraenheten kan sedan monteras på fästet. Ett viktigt inslag i designen är de två levande gångjärnen som sammankopplar armarna och handtaget. De levande gångjärnen har begränsad lastbärande kapacitet vilket gör de till kritiska punkter i designen och behöver testas vidare för att säkerställa funktionaliteten.

Detta projekt bevisar att en lösning som erbjuder en snabb enhandsmontering av infällda fästen är möjlig.

Nyckelord: Produktutveckling, Infällda fästen, Nätverkskamera, Axis Communications

Acknowledgement

This master thesis is the result of our Master of Science in Mechanical Engineering at the Faculty of Engineering at Lund University. Without some people, this would never have been completed.

Firstly, we would like to thank our supervisor at Axis, Johan Andersson, for supporting us during this bumpy ride through our master thesis work. We would also like to thank our supervisor at LTH, Damien Motte, for the incredibly fast responses and extensive knowledge about the product development process.

We would also like to thank some other employees at Axis; the polymer experts Magnus Klügel and Andreas Sjunnesson for showing interest in our project and always being available to us despite having loads of own work to do; the founders of this thesis work Stefan Larsson and Rasmus Anderberg for helping us with some detailed design work and acting as a sounding board when we threw different ideas in the air; thesis workers Max Guidotti, Michael Båth, Mattias Schölin, Niklas Ingemansson and, nowadays Axis employee, Rakel Hed for all the laughs in the green box in the canteen.

Finally, we would like to thank our families, friends, boyfriends and families-in-law for showing interest and supporting us in our work during this project and our education at large.

Lund, June 2017

Johanna Lehander and Johanna Morell

Table of Contents

1 Introduction

This chapter includes a short introduction to the thesis with information about the company, a problem description, delimitations and an explanation of the report disposition.

1.1 Axis Communications

Axis Communications AB (Axis) is market leading in network video. It is a Sweden based company acting worldwide selling their products through a partner network. They offer a wide portfolio of IP-based products and solutions for security and video surveillance. Axis operates with the vision “Innovating for a smarter, safer world.” Their mission is “Together, we pioneer intelligent network technology creating unique possibilities for partners, end users and employees.” [1]

The division at Axis at which this master thesis is carried out is "Fixed Domes Mechanics". Fixed dome cameras are cameras that are fixed, in other words do not rotate or move, once the installation is completed. The camera unit is normally covered by a dome housing.

1.2 Problem Description

1.2.1 **Background**

A recessed mount (RM) is a mounting accessory which allows for recessed installations of cameras into ceilings. A recessed mount solution is used when the user wants a discreet installation where, preferably, only the dome of the camera is visible. The RM is usually placed in a hole in the ceiling, in which a camera then is mounted. Recessed mounts are available at Axis in different designs and with various ways to be mounted. A selection of the available recessed mounts are shown in Figure 1.1.

Figure 1.1 Three of the existing recessed mounts at Axis.

1.2.2 Goals

The goal of the thesis is to further develop and design a concept for a one-handed recessed mount solution that can be mounted faster and easier than existing products. The thesis work will consist of concept development, testing and detailed mechanical design. The result will be a working prototype.

1.2.3 Resources

The master thesis is written by two students at the Mechanical Engineering guild of The Faculty of Engineering at LTH in Lund. The work has been divided equally by the writers and all activities has been done together. Axis will, during the given time frame of 20 weeks, provide such equipment which Axis evaluates is necessary for the assignment. The CAD software provided at Axis is PTC Parametric Creo 3.0. ANSYS workbench 17.1 is available at LTH for finite element method simulations. 3D printers are available for use in-house at Axis and at the university. The 3D-printer at Axis prints with stereolitography technique (SLA) and the material is ABS. At the university the technique used is selective laser sintering (SLS) and the material is nylon (polyamide).

1.3 Delimitations

The RM product should fit the P32-cameras primarily and be designed for indoor use only. Prior to the start of the thesis, two ideas were designed by Axis employees Rasmus Anderberg and Stefan Larsson. These ideas are presented in section 3.1.3 and they work as the starting point of the concept generation.

1.4 Key People at Axis

The following employees at Axis, listed in Table 1.1, have contributed with their time and knowledge throughout the project.

Table 1.1 Key people at Axis.

Name	Title	Role in Project
Johan Andersson	Experienced Mechanical Engineer	Supervisor
Magnus Lundegård	Engineering Manager, Fixed Domes Mechanics	Manager
Rasmus Anderberg	Consultant, EVP Mechanics	Idea creator and sounding board
Stefan Larsson	Consultant, EVP Mechanics	Idea creator and sounding board
Magnus Klügel	Senior Engineer, Development Services	Polymer Expert
Andreas Sjunnesson	Polymer Specialist, Development Services	Polymer Expert

1.5 Report Disposition

The report consists of the following sections:

- Chapter 2: Methodology
- Chapter 3: Background Study
- Chapter 4: Product Specifications
- Chapter 5: Concept Generation
- Chapter 6: Concept Selection
- Chapter 7: Testing of Concepts
- Chapter 8: Detailed Design
- Chapter 9: Results
- Chapter 10: Discussion and Conclusion

Chapter 2 gives an overview of the approach adopted to solve the problem. Each subsequent chapter starts with a brief explanation of the content and continues with a more detailed description of the method used.

Reflections from the different activities and discussions about the used methods and results in each chapter are gathered in Chapter 10.

Figures depicting a CAD-model are either retrieved from Axis database of existing products or modelled by the authors during the thesis work.

2 Methodology

This chapter presents a description of the methodology used in the thesis.

2.1 Planning

The total expected time for this thesis is 20 weeks. During the first week, a plan was made where each activity's duration was estimated, in which order the activities were to be done and important deadlines were identified. This can be found in Appendix A. While working, it became clear that some activities were more time-consuming than planned, why the plan was updated. The result of the performed activity schedule can also be found in Appendix A.

2.2 Approach

The product development process will follow the method stated in *Product Design and Development* by Karl T. Ulrich and Steven D. Eppinger, with some modifications. [2]

Since the prototype and the final product most likely will be made in plastic, the book *User's Guide to Plastic* by Ulf Bruder [3] will be used as a guideline during the design process.

Furthermore, the knowledge of Axis co-workers will be an important source of information. Through interviews, information will be gathered about the existing products and how the development process works at Axis.

2.3 Background Studies

Before starting the development of the product, background studies were performed. This was made regarding the company, the camera, the existing range of recessed mounts both which are offered by Axis and by competitors in the surveillance sector. Recessed mount solutions offered to other products on other markets are also researched.

2.4 Concept Development

The process of developing the RM was following the proposed process from Ulrich and Eppinger [2] where the whole product development process is divided into six phases and the focus is on the concept development phase. That phase is divided into seven phases and the input is a "Mission Statement" and the output is a "Development Plan". The proposed course of action was modified to suit the given mission. Since the thesis is a continuation of some other projects the first activity "Identify Customer Needs" could be removed. This activity was only done internally and is being covered in the background studies.

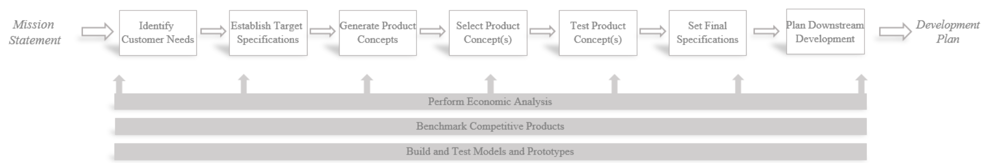


Figure 2.1 The original plan [2]

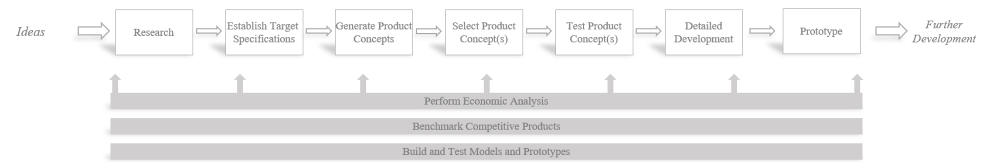


Figure 2.2 The modified plan

2.5 Detailed Design

When one final concept was chosen it was divided into features which are treated one by one in the chapter called Detailed Design. The sections first covers some theory if needed and, finally, the final design is presented.

3 Background Study

This chapter presents the results of the background studies performed. Studies within Axis as well as outside of Axis has been carried out.

3.1 Within Axis

3.1.1 **The Camera**

Axis' wide range of network cameras on the market have product names that follow a specific naming structure including one initial letter followed by four numbers. The letter and the two first numbers, e.g. M30, is called the series name or product family.

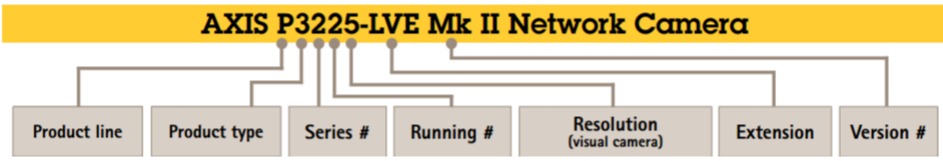


Figure 3.1 Naming structure of the network cameras at Axis [4].

The recessed mount is primarily going to be designed to be compatible with the indoor versions of the camera-series named P32. The P32-cameras are cost effective and vandal resistant, with target end customers being mostly retail stores. "P" in the name means "Versatile and advanced video products", "3" implies it is a fixed dome camera and "2" is the series number [4]. Figure 3.2 and Figure 3.3 show one of the cameras in the P32-series. Included in the P32-camera package, when it reaches a customer, is a mounting bracket which is used when the camera shall be mounted onto a ceiling or a wall, see Figure 3.2.

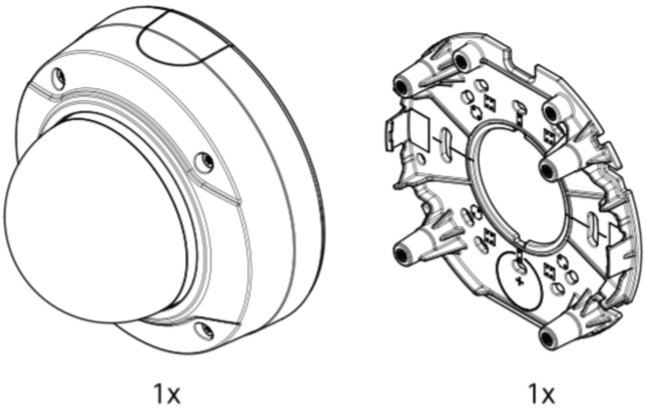


Figure 3.2 The dome housing and the mounting bracket of Axis P32-LV Mk II. [5]

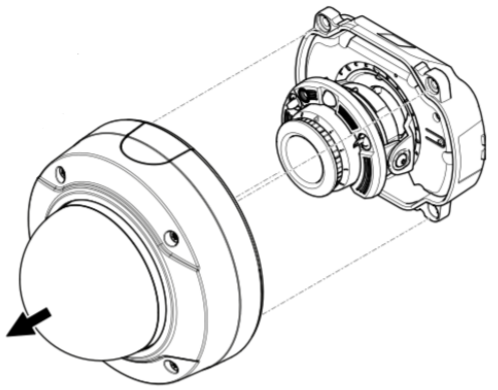


Figure 3.3 The dome housing and the camera unit of Axis P32-LV Mk II to the right.[5]

When mounting a P32-camera onto a wall or a ceiling the mounting bracket, see Figure 3.2, is first screwed to the wall or ceiling. An Ethernet cable is then connected to the camera unit and the camera gets its electrical power and data connection through that cable. The camera unit is then attached to the bracket mount through snap fittings at first, and after that the dome housing secures the camera unit to the bracket mount through four screws.

When mounting a P32-camera recessed in a ceiling the first step is to install the recessed mount. The Ethernet cable is then connected to the camera unit and the same steps follows. The last step is to attach a trim ring which gives the installation a discreet result.

The relevant dimensions and measurements of the camera is listed in Table 3.1**Fel! Det går inrte att hitta någon referenskälla.**.

Table 3.1 Relevant dimensions of the P3225, one of the indoor versions of the P32-series. All indoor versions have the same dimensions. [6]

Specification	**Value**
Weight	550 g
Diameter	149 mm
Height	101 mm
Distance between screw holes	87.7 mm

3.1.2 Existing Recessed Mounts at Axis

There are several recessed mounts in Axis product portfolio. They differ in design mostly because of the weight of the camera they are designed to be applicable with, what environment they are mounted (indoor or outdoor, plenum rating, vandal proof, protection provided against intrusion) and in what market they are sold. The most interesting recessed mounts are presented in this section.

3.1.2.1 T94K01L

The T94K01L Recessed Mount is compatible with a range of fixed dome cameras including the P32, P33 and P35 series. The RM is installed by inserting it into a hole in the roof. A flange which is bigger than the hole prevents it from being fully inserted. By tightening the screws, the wings rotate to prevent the RM to fall out of the hole. By continue to tighten the screws, the wings are pushed down towards the inner side of the ceiling. Finally, the wings are clamping the ceiling tile from the top and the flange from the bottom. The camera is then attached to the RM first by the snap fittings and then by tightening the screws attached to the dome of the camera. The final step is to attach the trim ring to hide the product as much as possible. Since this product is made to fit with cameras of different size there are a few steps that has to be performed prior to mounting the RM in the ceiling. These include fastening the snap fittings and screws corresponding to the correct camera. Figure 3.5 shows the parts included in the product. [7]

The mounting bracket, which is used when installing a camera on for example a wall, included in the camera is not used, but has to be discarded by the installer.

Figure 3.4 The T94K01L with attached trim ring. [7]

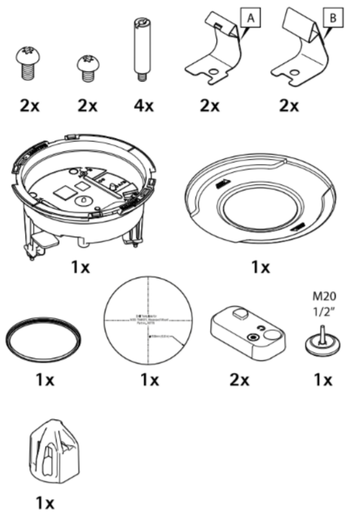


Figure 3.5 Excerpt from the installation guide to T94K01L showing the parts included in the product. [7]

This mounting accessory is plenum rated in order to be sold in USA where the UL standard UL 2043: "Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces" must be followed. [8]

3.1.2.2 T94S01L

In 2015, two students from LTH performed their master thesis at Axis aiming to develop a concept for recess mount that offers easier installation compared to existing options (e.g. T94K01L), with no need of plenum rating the product [9]. The thesis work was further developed at Axis and was released in spring 2017. The official product name is T94S01L. The product consists of three parts made in glass reinforced PBT/PET-plastic and one part, the trim ring, made in PC/ABS. The parts are shown in Figure 3.6.

The working principle is that one part, the upper left picture in Figure 3.6 is inserted in a hole in the ceiling, with the plastic screw (lower left picture) fastened in the centre hole. The third part (upper right picture) is then slided on to the lower part of the centre screw. The screw is then tightened and the ceiling is clamped between the upper part and the lower part. The camera is then attached to the RM first by snap fittings and then by tightening the screws attached to the cover of the camera. Finally, the trim ring is fastened to the RM. Figure 3.7 shows pictures of the product when mounted in a ceiling. The mounting bracket included in the camera is not used, but has to be discarded by the installer. [10]

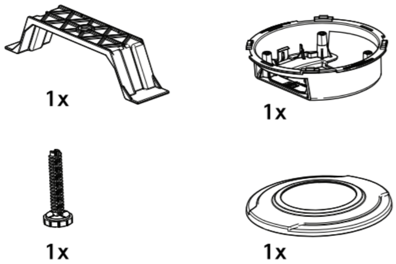


Figure 3.6 Parts included in T94S01L [11]

Figure 3.7 T94S01L mounted with trim ring and T94S01L mounted with trim ring in a ceiling tile. [10]

3.1.2.3 Axis Chassis Recess Mount for M3014

The Chassis Recess Mount for M3014 camera (further on referred to as chassis RM) is a recessed mounting solution for a camera at Axis that is significantly smaller than the P32-cameras; it weighs approximately 200 grams, compared to the P32 that weighs approximately 550 grams. It is a metal cup with three torsion springs attached to the body. The torsion springs are manually bended upwards prior to installation and when the RM is inside the hole in the ceiling the arms are let down and the springs act to hold the weight of the camera up. [12]

Figure 3.8 The chassis RM. [12]

3.1.2.4 Axis F8224 Recessed Mount

The F8224 is the smallest recessed mount available at Axis, with a diameter of only 72 mm [13]. The mounting solution consists of three main parts (if the trim ring and the camera cover is not taken in consideration) which are assembled when the product reaches the customer. The wings that are shown in Figure 3.9 are first pressed in towards the body by the outer edge at the top of the body. When the RM is inserted in the ceiling the installer rotates the inner part. This forces the wings downwards due to the threads, leading to the ceiling being clamped.

Figure 3.9 Left: Axis F8224 including the cover [13]. Right: An excerpt from the installation guide of the Axis F8824 showing the installations working principle. [14]

3.1.2.5 Testing of the existing recessed mounts

Installation tests were carried out, on the mounts applicable to the P32-series, to fully understand the issues arising when mounting a camera recessed in the ceiling. T94S01L was mounted three times, and the T94K01L twice, in a drop ceiling plate. The ceiling plate was placed on a framework 2.5 meters above the ground so that it would resemble a real life mounting experience. This created the need of a ladder. The main learnings from the tests are listed in Table 3.2 below. The camera was only mounted to the RM during the test; the Ethernet cable was not connected. The small F8224 was mounted once and a dynamometer was used to examine how much weight it could carry.

Table 3.2 Main learnings from installation tests of existing recessed mounts.

Snapping the camera to both of the RMs was a bit tricky since no force upwards could be used due to light ceiling plates.
After mounting three times in a row, a light pain in the arm arose.
Standing on a ladder trying to stay in balance was somewhat scary, especially when one needed to use both hands to mount the camera.

Mounting the T94K01L was time consuming due to the steps needed before mounting in order to fit to the correct camera.
T94S01L is a product that fulfils many of the needs that the T94K01L does not; it is a lot faster, more intuitive and more light weighted.
The tests of the F8224 showed that it could withstand more than 5 kg.

3.1.3 **Presented Ideas**

Two ideas were presented to the authors of the thesis in order to work as a starting point. The ideas arose during the development of T94S01L, when Anderberg and Larsson who developed them thought that they were interesting. They realized that the ideas were so interesting that a new thesis work should be performed in order to analyse and further develop one of them.

The ideas are presented in this section and called "Idea 1" and "Idea 2". Both were at a conceptual level and needed further development to work. The ideas were presented as 3D-models in Creo and as 3D-printed models.

3.1.3.1 Idea 1

Idea 1 consists of two parts, further on referred to "upper part" and "lower part". The upper part has three wings that are meant to act as counter force to the cameras weight. The two parts are connected to each other by two upright protrusions that are supposed to act like snap fittings. When the RM is inserted in a hole in the ceiling, wings are forced inwards and when the upper part reaches above the ceiling tile the wings are let out. The two parts are then pressed together with one hand, thus clamping the ceiling tile between the wings and the flange on the lower part. The idea was evaluated and the main strengths and weaknesses are listed in Table 3.3.

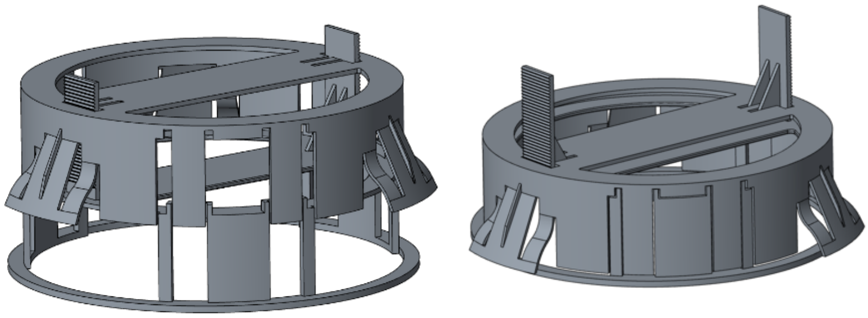


Figure 3.10 Idea 1. Left: Upper and lower part separated. Right: Upper and lower part pressed together

Table 3.3 Strengths and weaknesses of Idea 1

Strengths	**Weaknesses**
The concept gives a robust impression.	The snapping function that connects the two parts needs improvement.
Relatively simple to manufacture.	Inserting the wings in a drop ceiling plate will be difficult since no force upwards can be applied to it without it lifting from the framework.
Three load bearing points are a lot better than two.	This idea does not allow demounting in this stage.

3.1.3.2 Idea 2

Idea 2 consists of two parts: the main body and the handle. Included in the main body is two arms that are connected to the body by so called living hinges. The arms should be pointing straight upwards when inserting the RM in the hole in the ceiling tile. When the RM is inserted sufficiently, the handle and the main body are pressed together with some kind of snap fittings as connecting feature. The handle presses the arms outwards which leads to the ceiling tile being clamped between the arms and the flange on the body (the flange is not included in the figures). To demount the RM the handle is rotated relative to the body. This disconnects the snap fittings, allowing the handle to be pulled out from the body which leads to the arms turning upwards and the body can be pulled out of the ceiling. Figure 3.11 shows the main body in grey and the handle in brown. The red, yellow and blue parts represents different positions of the arms, depending on ceiling thickness. The idea was evaluated and the main strengths and weaknesses are listed in Table 3.4.

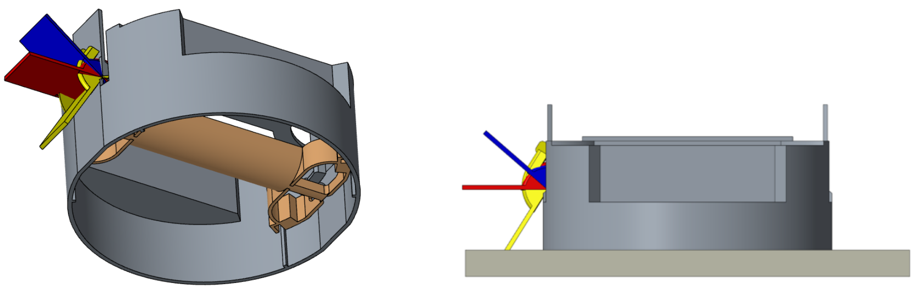


Figure 3.11 Idea 2. Left: from below. Right: from the side

Table 3.4 Strengths and weaknesses of Idea 2

Strengths	**Weaknesses**
Gives a more elegant impression.	Living hinges have limited load bearing ability.
Has a conceptual solution for demounting.	Only two load bearing points, which can lead to an unstable mounting experience.
The living hinges is an interesting unexplored feature.	The arms need careful design to ensure robustness and strength.

3.2 Outside of Axis

The background study outside of Axis covers a patent search, benchmarking and a description of ceiling types.

3.2.1 **Patents**

To further investigate existing solutions for recess mounting a search for patents was performed. The search covers recessed mounting solutions for several different products including spotlights, sprinklers and cameras.

The search for patents showed that the most common ways of recess mounting in ceilings are either using the technique used in the Axis product T94K01L, described in section 3.1.2.1, or using metal torsion springs, as in the chassis RM described in section 3.1.2.3. However, the springs are often used in applications with more lightweight products than cameras, such as spotlights. The solution used in T94S01L, described in section **Fel! Det går inrte att hitta någon referenskälla.**, seems unique and was not found in other patents. Some techniques differed from the rest making them more interesting, but since none of the patents found were applicable to one-handed mounting they are not described here.

3.2.2 **Benchmarking**

Benchmarking is the study of existing products with functionality similar to that of the product under development. Axis is not the only company acting on the market for surveillance cameras why competitors is. The focus of the search is on their accessories and mounting alternatives. Beyond that, there are other business where recessed mounts are used for installation of as speakers, spotlights, sensors and ventilation.

3.2.2.1 Competitors

Some of Axis biggest competitors were benchmarked. This was done by visiting their websites but also examine resellers collected product range of mounts. The desired products were those called recessed or in-ceiling mounts. The pictures and the description of the products functionality were studied and conclusions were drawn whether the technique could be interesting for the about-to-be-developed RM.

3.2.2.1.1 Aventura CCTV

At Aventura CCTV one recessed mount is offered at the website. The technique is the same as in the solution at Axis called T94K01L.

Figure 3.12 Recessed Mount for Indoor IP Domes from Aventura [15]

3.2.2.1.2 Avigilon

At Avigilon one in-ceiling mount is offered in which the technique is the same as in the chassis RM.

Figure 3.13 In-ceiling mount from Aviglion [16]

3.2.2.1.3 Pelco

The company Pelco do not provide any in-ceiling mounts on the official website but through resellers. The technique is the same as in T94K01L.

Figure 3.14 Heavy-duty in-ceiling fixed mount from Pelco [17]

3.2.2.1.4 Clinton Electronics

At Clinton Electronics two recessed mounts was found which uses the same technique as in T94K01L. One of them had an interesting solution to the interface between the mount and the cover of the camera where magnets are used.

Figure 3.15 Vandal X Recess Mount and Indoor Recess Mount Kit for Vandal X Series from Clinton Electronics where magnets are used to fasten the cover of the camera [18]

3.2.2.1.5 ACTi

ACTi has a broad range of different mounts, but all of them uses the same technique as in T94K01L. The most significant difference between the different mounts is to which camera it is recommended for.

Figure 3.16 Recessed mounts from ACTi. Left: PMAX-1004, Centre: PMAX-1010, Right: PMAX-1013 [19]

3.2.2.1.6 Hikvision

Hikvision offers two different in-ceiling mounting solutions. They both use the same technique as in T94K01L but the one depictured in Figure 3.17 is a simplified construction which makes the RM much lighter. Only the three screws with the wings are used to fasten the mount in the ceiling. A screwdriver and two hands are still needed during installation.

Figure 3.17 In-ceiling Mount Bracket for Dome Camera from Hikvision [20]

3.2.2.2 Other businesses

3.2.2.2.1 Speakers

The solution for mounting the speakers from Dali in the ceiling is very similar to the technique used in T94K01L; "The dogleg mounting system makes the install process an easy one-step action simply by tightening the dedicated screws to swing out the dogleg brackets." [21]

The same technique is used for recessed speakers offered by other companies such as Yamaha and GoldenEars.

Figure 3.18 Dali Recessed Mount to speakers [21]

3.2.2.2.2 Spotlights

For spotlights the technique used is metal torsion springs, like the chassis RM. This is probably not feasible on the P32-cameras because of the weight difference of a small spotlight compared to a camera. Companies offering this is, among many, IKEA, Biltema, and LED-Giganten.

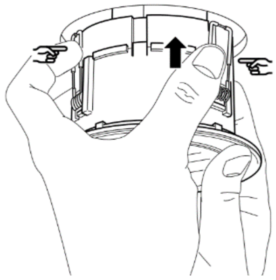


Figure 3.19 IKEA Häggum (recessed spotlight) [22]

3.2.2.2.3 Sensors

Simple RM with a plastic cover and metal springs. The solution is for smaller holes (the size of the hole made in the ceiling is approximately 68 mm) and lighter products.

Figure 3.20 In-ceiling kit from Esylux [23]

3.2.2.2.4 Ventilation

Companies offering ventilation that is mounted in a drop ceiling where the unit covers a whole ceiling tile.

The few recessed ventilation solutions found that could be of use were not specified how the mount was constructed.

3.2.2.3 Conclusion

The existing solutions of in-ceiling/recessed mounts offered from the competing surveillance camera companies is very similar to the technique used in T94 with screw-activated wings that grasps onto the upper side of the ceiling (or other mounting material). No solution was found where only one hand can be used to fasten the mount. This indicates a possibility to design a new product using other techniques which might have great chances to beat the existing range in both installation time, simplicity and production costs.

The benchmarking and patent search made on other products did not give any other interesting findings. All the techniques found is already used in Axis products in one way or another. This indicates that there is a great potential for new solutions to be attractive in other markets too.

3.2.3 Ceiling Types

3.2.3.1 Dropped Ceiling

A dropped ceiling is a ceiling typically found in retail stores, offices, shopping malls and other public places. It consists of a framework of metal profiles in a grid where the tiles are placed. The dropped ceiling hung is below the main ceiling, hiding cables as well as providing a good acoustic environment by sound absorption. The tiles are often made of one layer of glass tissue covered by one layer of painted glass tissue on the visible side. The glass tissue layer on the non-visible side of the tile is often soft and the visible side is stiffer. [24]

Figure 3.21 Example of a dropped ceiling. [25]

3.2.3.2 Hard Ceiling

In this report, all ceilings that are not dropped ceilings are referred to as hard ceilings. What differ hard ceilings from drop ceilings is that they are hard both on the lower side and the upper side, the fact that the installer cannot take down the tiles as in a dropped ceiling when installing the camera and that force can be used upwards without any problem.

4 Product Specifications

This chapter covers the establishment of product specifications which are set up in order to make sure the product fulfils the requirements.

4.1 Background

To achieve specific and concrete guidance on how to design a product measurable specifications are established. These specifications specify what the product has to fulfil in order to fulfil the customer needs [2]. The end-product of this sections is a final list of target specifications containing marginal value, ideal value and a value describing the importance of the need.

4.2 Method

The method follows the proposed method from Ulrich and Eppinger with activities completed in the following order:

- Prepare the list of metrics
- Collect competitive benchmarking information
- Set ideal and marginally acceptable target values

Since this project is a continuation of an earlier project at Axis, where the needs were investigated thoroughly, the specifications are collected primarily from the report *Development of Recess Mount for Fixed Dome Cameras* [9] and the Product Requirement Specifications from T94S01L (PRS) The ones that are applicable to this project are selected and listed in Table 4.1 with the source of the specification marked by brackets. If the specifications are insufficient new specifications are added. The new specifications are results of the new problem description and tests performed by the authors.

4.3 List of Product Specifications

The values of the metrics that are measurable are achieved by testing the mounting solutions offered at Axis today.

Table 4.1 Product Specifications with references, relative importance, unit and values. *Product specification number 22 Suitable material contains several more specifications connected to the choice of material. These are elaborated in section 8.9.

No	Ref.	Specification	Importance	Unit	Marginal Value	Ideal Value
1		One handed mounting	5	Binary	Yes	Yes
2		Time difference to complete mounting (without cables) compared to T94S01L	5	%	-30	-50
3	(PRS)	Allow demounting	4	Binary	Yes	Yes
4	[9]	Allow remounting	3	Binary	Yes	Yes
5		Intuitive design	3	Subj.	-	-
6	(PRS)	Ceiling thickness allowed	5	mm	1-40	1-60
7	(PRS)	Possible to mount on different ceiling material (dropped and hard ceilings)	5	Binary	Yes	Yes
8	(PRS)	Possible to mount without taking down ceiling tiles	5	Binary	Yes	Yes
9	(PRS)	Total cost	5	USD	15	<5,5
10	(PRS)	Attachment point for Axis safety wire	5	Binary	Yes	Yes
11	(PRS)	Compatible with existing parts	3	Binary	Yes	Yes
12	(PRS)	Robust feeling	5	Subj.	-	-
13		Width of hand to install the mount	4	cm	12	14
14	[9]	Scalable to work with different cameras	2	Binary	No	Yes
15		Mounting of the RM without screws	3	Binary	No	Yes
16	(PRS)	Other materials used than plastics	3	No.	1	0
17	(PRS)	Easy, fast and safe installation of the trim ring	4	Subj.	-	-
18	[9]	No loose pieces	3	Binary	No	Yes
19	(PRS)	Tools needed when installing the RM	3	No.	1	0
20	(PRS)	Pass Axis tests	5	Binary	Pass	Pass
21	(PRS)	Warranty	5	Years	3	3
22		Suitable material*	5	Binary	Pass	Pass
23		Only the dome of the camera is visible after mounting	5	Binary	Yes	Yes

5 Concept Generation

This chapter covers decomposition of the problem, solution fragments for each sub problem and combination of the solution fragments into concepts.

5.1 Background

A product concept is a description of a product's working principles and design. Designing a product can sometimes be too complex to treat as one single problem. Therefore, it can be useful to make a problem decomposition and divide the problem into several simpler sub problems. These sub problems can be analysed separately at first and later combined if possible [2]. When referring to the camera unit in this section, the metallic backside of the camera is what is intended; it is the interface that connects the camera unit to the mount. It has holes where the screws from the dome is screwed through and protrusions used to snap the camera in place in the different mounts, see Figure 5.2.

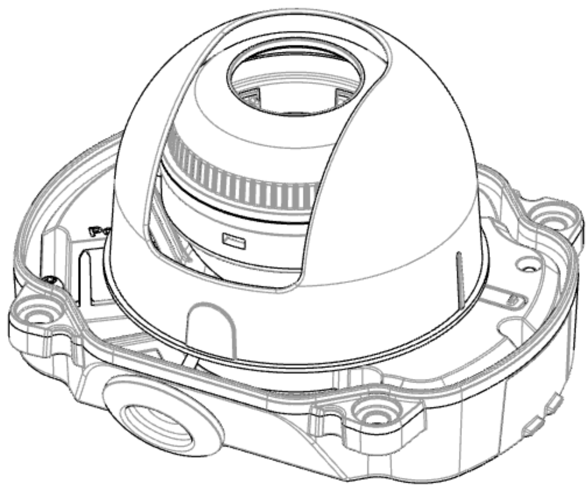


Figure 5.1 The camera unit.

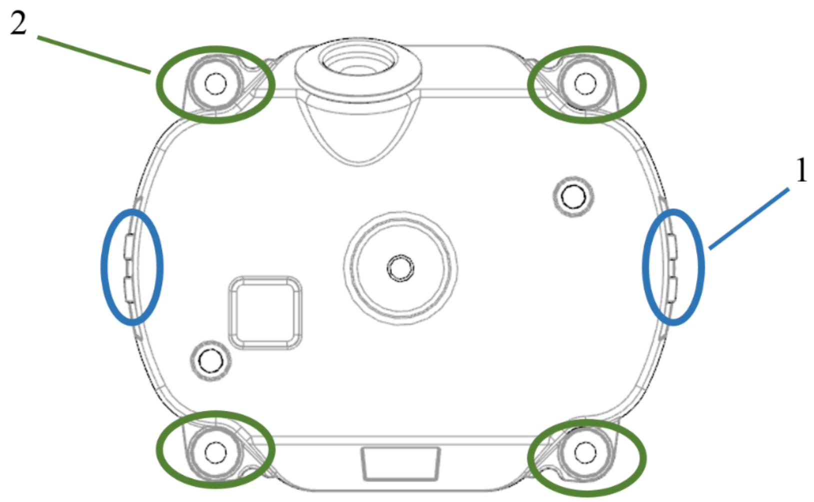


Figure 5.2 The metallic backside of the camera which connects the camera to the mount. (1) Marks the protrusions which are snapped to the mounting device and (2) marks the screw holes.

5.2 Method

To make sure that the entire categories of solution is being considered, a brainstorming session was held without regard to the two given ideas at first (3.1.3). Sketches and explanations from the first brainstorming can be found in Appendix B. After the first brainstorming session and discussion with Andersson, Anderberg and Larsson, some conclusion could be drawn. Many of the concepts generated were not feasible due to the limitations of different thickness of the ceilings. The reason for the ideas being discarded can also be found in Appendix B.

A problem decomposition was made, with the two ideas described in section 3.1.3 as a starting point, where the different interfaces in the RM were identified. To come up with solution fragments to the sub problems, discussions were held once again with Andersson, Anderberg and Larsson for input as well as internal discussions and brainstorming. The sub problems were treated separately at first and solution fractions to the sub problems were generated. It was decided that sub problems 3 and 4 could be combined regardless to any other combination of sub problems 1 and 2. Therefore, the focus was on sub problems 1 and 2. After performing a first screening, with criteria derived from the target specifications with high importance, some solution fractions could be discarded. The remaining solutions fractions were combined into concept combinations.

The result of the concept combination table is finally summarized with description and pictures of the models of the final concepts.

5.3 Problem Decomposition

The interfaces of interest were identified and processed separately as four sub problems. The two concepts, presented in section 3.1.3, were used as a starting point to identify the main interfaces. The identified interfaces are listed Table 5.1. A visual representation of the interfaces is shown in Figure 5.3.

Table 5.1 Identified interfaces and sub problems.

Sub Problem	Part one	Part two
Sub problem 1	Housing	Ceiling
Sub problem 2	Upper part of housing	Lower part of housing
Sub problem 3	Housing	Camera
Sub problem 4	Housing	Trim ring

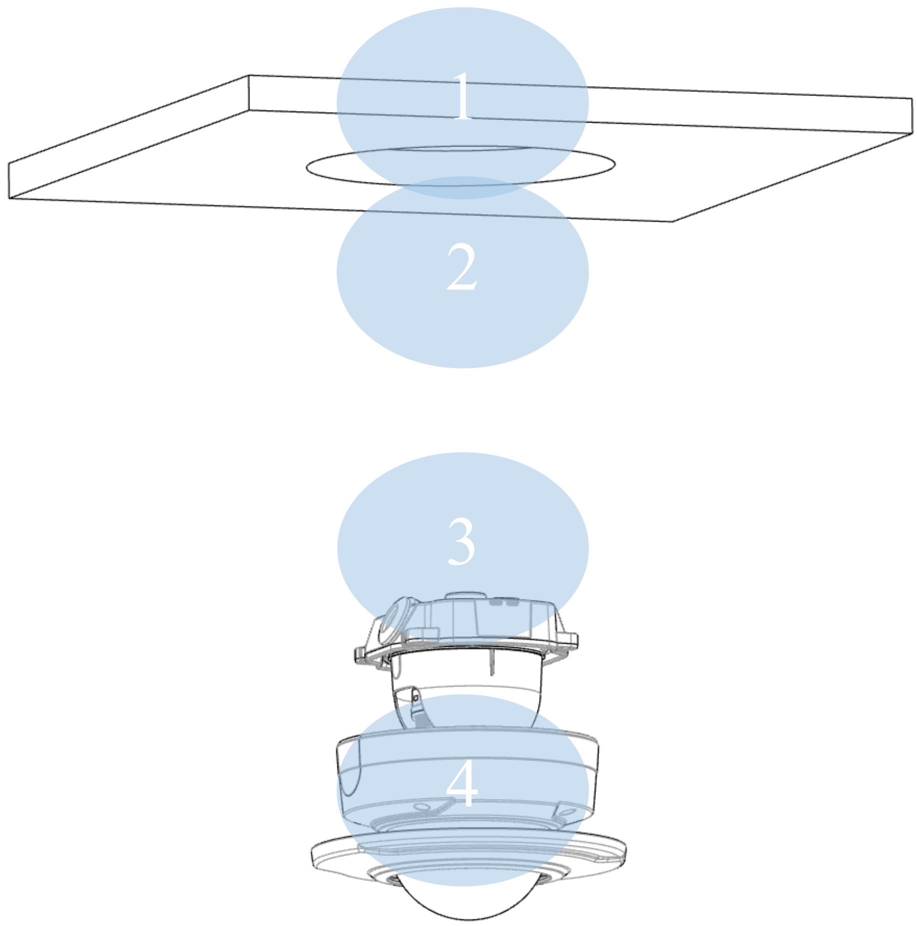


Figure 5.3 Exploded view of the different parts where the interfaces can be seen.

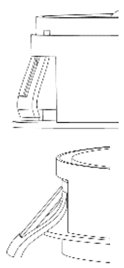
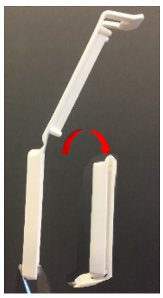
The two latter, sub problem 3 and 4, can be treated separately since they do not depend on the other sub problems. The two first, however, depend on each other to function. All sub problems were discussed, at first, without consideration to the total functionality and whether it would actually be applicable to the main problem.

5.4 Sub Problem 1

The first sub problem is the interface between the housing and the ceiling in order to hold the RM up. Solution fractions to the sub problem are presented in Table 5.2.

The main challenges to this sub problem are the fact that the ceiling thicknesses to which the mount shall be compatible with is 1-60 mm, the fact that camera is relatively heavy and that it should be possible to demount the RM.

Table 5.2 Solution fractions to sub problem 1 with sketches (modelled in Creo or photographed by the authors) and descriptions.

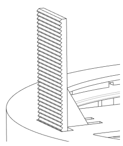
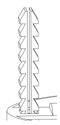
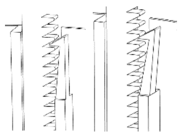
Solution Fraction No.	Name and sketch	Description
1.1	Wings 	Working principle as in Idea 1 (3.1.3.1) with large wings to fasten the housing to the ceiling. Added to the concept is a "cage" that surrounds the lower part that can hold the snaps in while inserting the housing in the ceiling hole, similar to the Axis F8224.
1.2	Living hinge arms 	Arms connected to the upper part of the housing with a type of living hinge, which is thought to be used in Idea 2 (3.1.3.2). The arms are upright when the housing is inserted to the ceiling hole and are then forced outwards by the lower part to fasten the housing to the ceiling.
1.3	Springs 	Similar to the chassis RM; arms with metal springs can be used to fasten the housing to the ceiling and keep the camera from falling down.

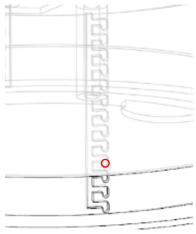
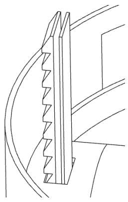
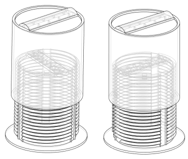
5.5 Sub Problem 2

The second sub problem is the interface between the upper part of the housing and the lower part of the housing. Solutions to the sub problem is presented in Table 5.3.

The main challenges to this sub problem are identical to those of sub problem 1; the fact that the ceiling thicknesses to which the mount shall be compatible with every thickness in the range of 1-60 mm and that the camera is relatively heavy. The fact that it should be possible to demount the RM is also a challenge.

Table 5.3 Solution fractions to sub problem 2 with sketches (modelled in Creo by the authors) and descriptions.

Solution Fraction No.	Name and sketch	Description
2.1	Thread 	One part is externally threaded and the other is internally threaded. Turning the parts relative to each other fastens them together as well as adjusts the distance between them in order to allow different ceiling thickness.
2.2	Ladder snaps external 	As in Idea 1 (3.1.3.1).
2.3	Ladder snaps in pair external 	As in Idea 1 (3.1.3.1) except that the snap fittings sit in pairs.
2.4	Ladder snaps internal 	As in Idea 2 (3.1.3.2).

2.5	Bayonet 	A pin projecting from the side of an object which secures and holds in place the other object in a bayonet socket by twisting it in the right direction
2.6	Magnet	Magnets hold the parts together.
2.7	Screws	Screws hold the parts together.
2.8	External snaps in pair with one smooth surfaced 	As in solution fraction 2.3 but one of the surfaces is smooth in order to make demounting easier.
2.9	Partly threaded 	Similar to 2.1 but instead of the parts being threaded all way around they are only partly threaded. This means one can insert the lower part into the upper part at one position and when the ceiling is fastened, the lower part is twisted making the threads connect and fastens the parts together.

5.6 Sub problem 3

The third sub problem is the interface between the housing and the camera. The solution fractions can be found in Table 5.4. The main challenge to this sub problem are that the ceiling tiles are very light weighted and cannot withstand any force upwards.

Table 5.4 Solution fractions to sub problem 3.

Solution Fraction No.	Name	Description
3.1	Snap fitting	Simple snap fittings using existing protrusions on the camera.
3.2	Magnet	A magnet that holds the camera in place.
3.3	Bayonet	A bayonet fitting that holds the camera in place.
3.4	Centre screw	The camera has a hole in the middle with internal threads where a centre screw could fit.

5.7 Sub Problem 4

The fourth sub problem is the interface between the housing and the trim ring. The trim ring is attached to the lower part of the housing as the final step of the installation of the camera. The solution fractions can be found in Table 5.5. The challenges to this problem are the same as sub problem 3; the ceiling tiles are very light weighted.

Table 5.5 Solution fractions to sub problem 4.

Solution Fraction No.	Name	Description
4.1	Magnet	A magnet that holds the trim ring in place.
4.2	Bayonet	A bayonet fitting that holds the trim ring in place.
4.3	Snap fitting	The trim ring is attached to the housing by snap fittings.

5.8 Systematic Exploration

A first screening was made in order to exclude the unfeasible solutions and thus reduce the number of solution combinations. Table 5.6 below describes which solution fractions were excluded and the reason to why they were excluded. The decision to exclude some of the solution fragments were done through internal discussions, tests and by the help of the supervisor at Axis.

Table 5.6 Screening of the solution fractions generated in Table 5.1-5.4.

Solution Fraction No.	Working Name	Reason Why Excluded
1.3	Spring	The results from the tests performed on the chassis RM showed that the springs can't withstand a load as high as the P32-cameras will lead to. Stronger springs will lead to difficulties when mounting and safety issues for the installer.
2.1	Thread	The solutions deprives the installation to be fast, easy and one-handed.
2.6	Magnet	Magnets are generally expensive. In this case really strong magnets are needed since the parts will not be in contact at all times.
2.7	Screws	The solution cannot be made using only one hand.
3.2	Magnet	The solution requires new construction of existing parts. The metal back side of the camera is not magnetic.
4.1	Magnet	The solution requires new construction of existing parts. The trim ring has no metal parts that are magnetic.

5.9 Combination of Concepts

5.9.1 Concept Combination Table

The remaining solutions to sub problems 1 and 2 are combined into concept combinations using a concept combination table. The feasibility of each combination was discussed. The feasible combinations are presented in the next section as concept combinations. An illustration of the process can be seen in Figure 5.4.

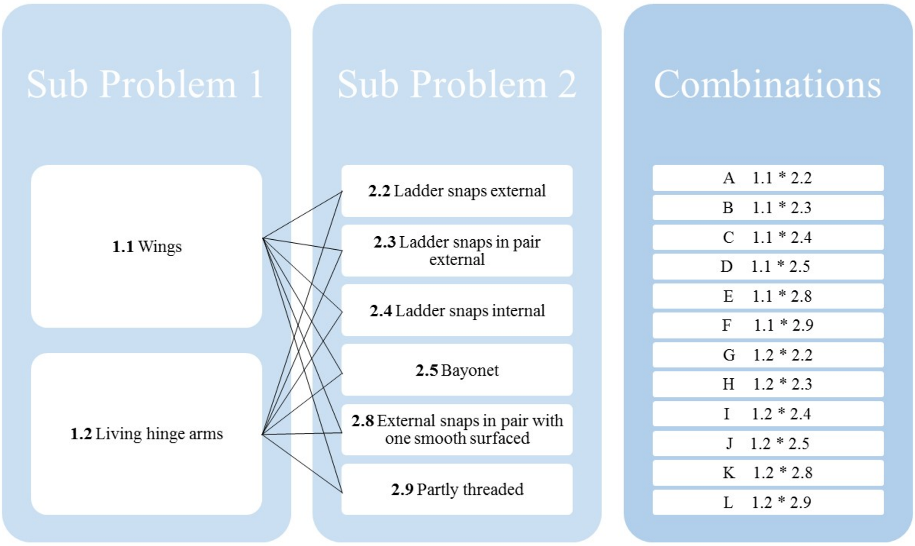
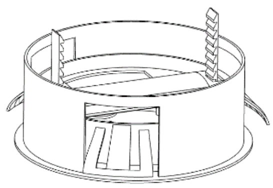
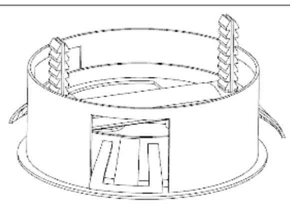
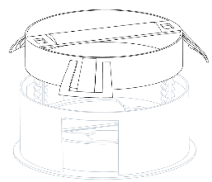
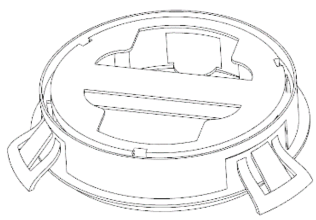


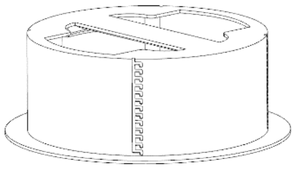
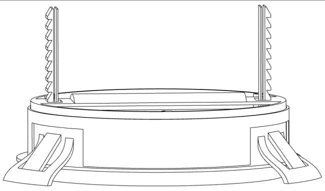
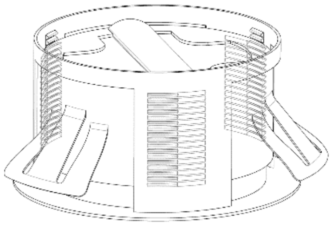
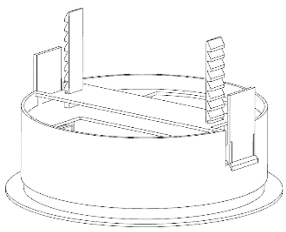
Figure 5.4 The twelve combinations of the solutions to sub problems 1 and 2.

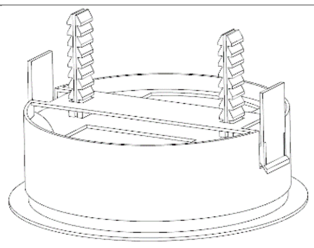
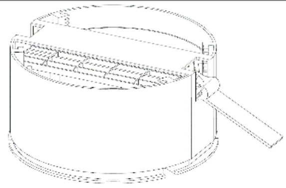
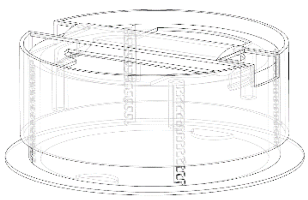
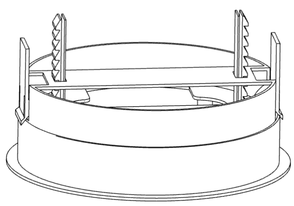
5.9.2 Concepts

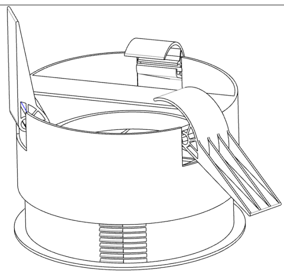
The feasible concept combinations are presented in Table 5.7. The sketches are made in PTC Creo by the writers of the master thesis. These are conceptual and only aims to show the basic working principles. This was done to investigate whether the concept combinations were compatible and if any new challenges emerged.

Table 5.7 The results of the concept combination with sketches (made by the authors) and descriptions.

Concept	Sketch	Description
A		This concept works as the idea 1, described in section 3.1.3.1 with the three wings on the upper part. The two parts are, by the installer, put together and the wings are inserted underneath the surrounding "cage" from the lower part. When the housing is inserted in the hole in the ceiling the wings are folded in. When the parts are pressed together by the handles the wings are let out and acts as the stop from above. The two parts are connected to each other by snap fittings placed on the top side of the parts, which allows different ceiling thicknesses.
B	 	This concept is identical to concept A above but instead of the single snap fitting on each side there are two on each side working as a pair which gives extra support when the installation is done but might be harder to demount. When adjusting the height for thinner ceilings it might be a problem because of the fixed lower part of the snap fits.
C		This concept works as concept A and B but instead of the ladder snap fittings placed externally on the outside they are placed on the inside.

D		This concept works as concept A, B and C with the wings and the cage. The upper and the lower part are connected to each other by a pin projecting from the side of the upper part which secures and holds in place the lower part in a bayonet socket by twisting it in the right direction.
E		This concept works in the same way as concept A and B but with the difference that one of the surfaces on the external snap is smooth which might ease the demount.
F		This concept includes the partly threaded way of connecting the two parts. This makes it easier to demount but might cause troubles because of the twisting movement the installer has to perform.
G		The two arms are standing up when inserted into the hole in the ceiling. The distance between the upper side of and the lower side of the handle is big. When the other part is inserted in the upper part by pressing the handle, the arms is triggered by the movement and are folded out. When the thickness of the roof is adjusted, the arms are holding the mount above the ceiling and the lower part of the mount is making sure the arms are fixated that way. The external snap fits are connecting the upper and lower part.

H		Same principle as concept G, but with two-sided ladder snap fits for extra support. The two sided snap fits might make demounting harder and it might also cause a problem when adjusting for thin roofs because of the more fixed lower part of the snap fits.
I		Resembles idea 2 (found in chapter 3.1.3.2) with some adjustments. The arms are standing up when inserting the mount into the hole. The lower part is pushed up against the upper part which triggers the arms to fold out. When the thickness of the roof has been adjusted for, the mount is resting on the arms. This is secured by the four internal snap fits. Demounting might be possible by a twisting movement.
J		The arms are not shown in the picture but it is supposed to work in the same way as concept I but the ceiling is clamped and secured by a twisting movement which leads the pin into one of the bayonet sockets. This implies a greater challenge of how to design the living hinge arms because of the arched surface to attach them which might be needed to make the twisting movement possible. The adjustability of the ceiling thickness might also be affected because of the space required between the bayonet-sockets makes it less precise.
K		Same principle as concept G and H but with the difference that one of the surfaces on the external snap is smooth which might ease the demounting.

L		The functionality of this concept resembles concept J's functionality and challenges. In the sketch an alternative to the living hinge arms has been proposed which might make the twisting movement possible. This concept contains three arms instead of two, which will be more thoroughly investigated later in the report.

6 Concept Selection

This chapter covers the first evaluation and selection of the generated concepts. Two concepts are selected and will be further evaluated in the next chapter.

6.1 Background

Concept selection is a way to evaluate the concepts generated earlier in the process and select one or more concepts to continue with. The evaluation is made with respect to customer needs as well as other criteria and it compares the concepts relative to each other. One or more concepts are chosen to further develop. [2]

6.2 Method

Ulrich and Eppinger present a five-step process which was followed to score the concepts. The steps are:

- Prepare the selection matrix.
- Rate the concepts.
- Rank the concepts.
- Combine and improve concepts.
- Select one or more concepts.

The selection was performed twice; first a concept screening was made to eliminate some concepts and then a concept scoring was made to select two concepts that could be more thoroughly evaluated. Sub problem 1 and 2 are now treated as combined concepts and sub problem 3 and 4 are treated separately.

Models and prototypes were built of some concepts, prior to this step, to get a better understanding of some of the concepts. Furthermore, the authors attended a course in plastic design to get a deeper understanding in design and manufacturing in thermoplastics and had meetings with polymer experts at Axis. Notes from the meeting can be found in Appendix C.

6.3 Concept Screening

To screen through the concepts a Concept Screening matrix was prepared. As a reference concept T94S01L (found in chapter **Fel! Det går inrte att hitta någon referenskälla.**) was used. Some relevant criteria were chosen to make it possible to compare the different concepts. The fact that the concepts has been generated with the main focus on one-handed and fast mounting makes these two criteria irrelevant in a comparison between the concepts and in reference to T94S01L. The criteria are listed in Table 6.1.

Table 6.1 Concept screening criteria.

Criteria	Explanation
Innovation height	The grade of innovation which might be of interest for Axis and the ability of certain new-to-Axis features to be tested more thoroughly in this thesis.
Processability	An estimation of the complexity when the different parts of the RM are about to be manufactured. The material of the RM is preferably plastics which means that injection moulding is the suitable method of manufacturing.
Compatible to existing parts	An estimation of how the design of the interfaces will be compatible to existing accessories such as the available range of trim rings, the camera and the cover.
Adjustability of ceiling thickness	The possibility to adjust the RM to different ceiling thickness within the desired range (1-60mm) and that the clamping is the same for every height within the range.
Ease of demount	The possibility to in an easy way demount the RM from the ceiling.
Intuitive design	The RM should be possible to install without the need of manuals or guides and with simple movements.
Robust impression	"Heavy is quality" is a preconception which is might cause a trouble when designing in plastics. The feeling and look of the product has therefore to be designed in a way that gives the customer and user a feeling of robustness.

The concepts were one by one compared to the reference, one criteria at the time. If the concept was considered better than the reference, a (+) was marked in the corresponding field. If the concept was considered equally good it received a (0) and if it was considered worse, it received a (-). The rating was made without consideration to the fact that all concepts could be further developed and more advanced because not all could be continued with.

Table 6.2 Concept Screening Matrix (N=no, Y=yes).

Selection Criteria	***Ref.***	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Innovation height	*0*	-	0	-	0	-	0	+	+	+	+	+	+
Processabililty	*0*	+	0	+	+	0	+	-	-	-	-	-	-
Compatible to existing parts	*0*	-	-	-	-	-	-	+	+	+	+	+	+
Adjustability of ceiling height	*0*	0	0	0	-	0	+	0	0	0	-	0	+
Ease of demount	*0*	0	-	0	+	0	+	0	-	-	+	-	+
Intuitive design	*0*	+	+	+	0	+	0	+	+	+	0	+	0
Robust impression	*0*	-	-	0	+	-	+	-	-	0	0	-	0
Sum +	*0*	2	1	2	3	1	3	2	3	3	3	3	4
Sum 0	*7*	2	3	3	2	3	2	2	1	2	2	1	2
Sum -	*0*	3	3	2	2	3	1	2	3	2	2	3	1
Net Score	*0*	-1	-2	0	1	-2	2	0	0	1	1	0	3
Rank	*4*	5	6	4	3	6	2	4	4	3	3	4	1
Continue?		N	N	N	Y	N	Y	N	N	Y	Y	N	Y

Some conclusions could be drawn from this. The fact that living hinges is an unexplored technique at Axis gave the concepts with these features higher score and those with wings were given lower since there is product containing this features. The processability criterion was a rough estimation where features as long protrusions or narrow cross-sections were given a lower score since this makes the tools of injection moulding more complicated. The concepts that might need wider dimensions to function were given a lower score when comparing compatibility with existing products. Concepts with lower accuracy were given lower scores, as the bayonet and the snap fittings due to the fact that there must be some distance between the steps, when estimating the ability to adjust the RM to different ceiling thickness. Concepts with threads or bayonet were given higher scores since this makes demounting possible, but lower scores on the intuitive design because of the twisting movement that must be made both when mounting and demounting. The concepts with long protrusions and thin cross-sections were given lower score on the robustness due to how that can be perceived. This led to seven concepts being discarded. For further investigation of the remaining concepts a concept scoring matrix was prepared.

6.4 Concept Scoring

In the concept scoring matrix the selection criteria were the same but the scoring process was different. This was done to make the six concepts more comparable between each other, rather than in reference to T94S01L.

The criteria have various importance and was therefore weighted. This was done together with Andersson, Anderberg and Larsson.

A reference was chosen for each criterion when rating the concepts. The remaining concepts were compared to the reference and given a score according to Table 6.3. The result of the concept scoring matrix is shown in Table 6.4.

Table 6.3 Condition when rating the remaining concepts

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Table 6.4 Concept Scoring Matrix

Concepts		D		F		I		J		L	
Selection criteria	Weight	Rating	WS	Rating	WS	Rating	WS	Rating	WS	Rating	WS
Innovation Height	15%	2	0,3	3	0,45	4	0,6	4	0,6	4	0,6
Compatible to existing parts	15%	2	0,3	2	0,3	4	0,6	4	1	4	0,6
Intuitive	20%	2	0,4	3	0,6	4	0,8	3	1	3	0,6
Adjustability of ceiling height	10%	2	0,2	4	0,4	4	0,4	2	0	4	0,4
Ease of demount	10%	4	0,4	4	0,4	2	0,2	4	0	4	0,4
Processablilty	10%	4	0,4	4	0,4	3	0,3	3	0	2	0,2
Robust impression	20%	4	0,8	5	1	3	0,6	3	1	3	0,6
Total Score		20	**2,8**	25	**3,5**	24	**3,5**	23	**3,3**	24	**3,4**

Rank	6	2	1	5	3
Continue?	No	Yes	Yes	No	No

6.5 Selection of Remaining Sub Problems

6.5.1 **Sub Problem 3**

The interface between the RM and the camera before screwing the mandatory screws is evaluated through discussions between the authors, the supervisors and other employees at Axis.

When tests were performed on the existing mounting brackets that uses a snap fitting for this purpose the main problem was that a force is needed upwards and the ceiling tile cannot withstand the load. Otherwise snap fitting works satisfyingly. When considering a bayonet lock tests showed that the screw towers prevent a rotating movement of the camera, making it unfeasible.

Consequently, snap fitting is the best solution to sub problem 3. The problem with the ceiling tiles can be solved by designing the housing so that there is space to withstand the force upward with a finger placed on the handle to the housing.

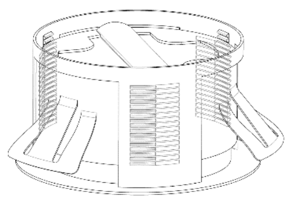
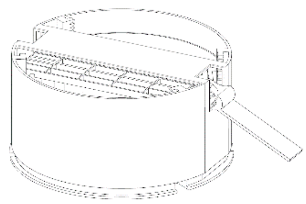
6.5.2 **Sub Problem 4**

The interface between the RM and the trim ring does not need a formal evaluation. A bayonet fitting is used in the T94K01L as well as in T94S01L. There is no problem with the mounting of the trim ring in either of them, it is fast and easy to mount, so the technique will be used in this project too.

6.6 Final Selection of Concept

The two complete concepts that got selected for testing are listed in Table 6.5 below.

Table 6.5 Summary of the selected concepts.

Concept	**F**	**I**
Sub Problem 1	Wings	Living hinge arms
Sub Problem 2	Partly threaded	Ladder snaps internal
Sub Problem 3	Snap fittings	Snap fittings
Sub Problem 4	Bayonet	Bayonet
Picture of concept		

7 Testing of Concepts

This chapter covers the evaluations and testing of the two selected concepts.

7.1 Background

To be able to choose between the two selected concepts a more thorough testing has to be carried out. The purpose is to gather more information to be able to select the final concept and gather information on how to improve the concept.

7.2 Method

Before the tests were performed the master thesis writers developed the concepts based on the insights from the concept selection phase.

The purpose of the test was defined and the conclusion was that inputs from different units at Axis were needed to make a final decision. The two concepts that were to be chosen from were also on a conceptual stage and ideas on how to improve them to better meet customer needs were also wanted from different units. Instead of performing tests with end-customer, units that represents the end customers on Axis were held. This is very similar to what they at Axis calls “Concept Review” or “Workshop”.

The format that the tests were to be communicated through was chosen to be face-to-face interaction. The concepts were communicated by verbal description, photos, simulation on CAD-models performed in ANSYS workbench and 3D-printed working prototypes. This was presented to the chosen Axis employees and feedback was gathered.

The people from Axis that the meetings were held with was:

- Global Product Manager of EVP, Michael Chen
- Polymer Experts Klügel and Sjunnesson
- Manager of the department of Fixed Domes Mechanics Lundegård
- Andersson, Anderberg and Larsson

The interviews were informal and the outcome will be reported in the context of the changes that were made from it.

7.2.1 **Testing of Concept F**

The challenges with this concept was how intuitive the twist of the handle and how the wings would function. The latter could mean a risk of the need of the trim ring with bigger dimensions.

7.2.1.1 Modelling and Simulation

The concept was modelled in Creo in a more detailed way with right dimensions and with more consideration of the units that is going to be assembled with the RM. This was done to be able to communicate the concept to the people reviewing it.

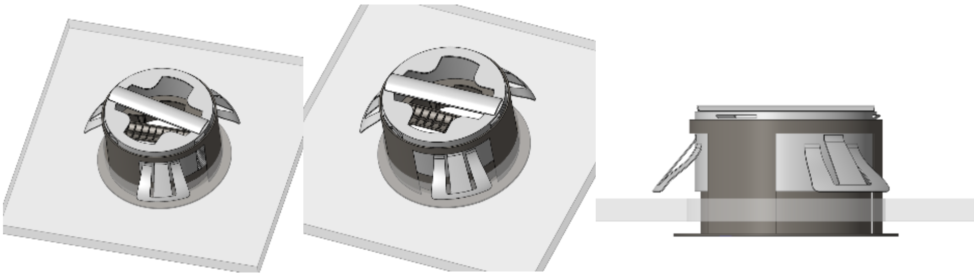


Figure 7.1 CAD-model of Concept 1 with a ceiling plate. Left: Before the twisting movement. Middle: After the twisting movement. Right: Seen from the side.

The wings whose function was to carry the recess mount and the camera had to be tested. This was done by FEM-simulations in ANSYS Workbench. The following boundary conditions were set up:

- Fixed support in the outer edge of the wings
- Forces simulating the forces made by the weight of the camera

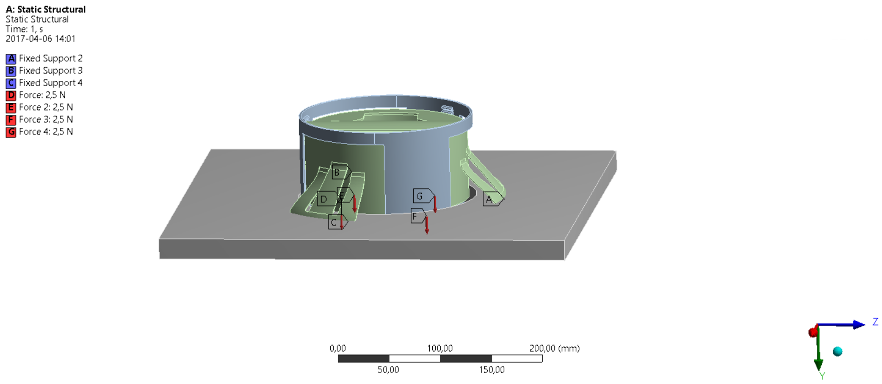


Figure 7.2 Boundary Conditions with the applied force of 10 N (2.5 N in each wing)

What was studied was the stress distribution (in MPa). That was the only interesting thing to investigate at this stage. To be able to estimate the deformation (in mm) a material with the right properties must be decided.

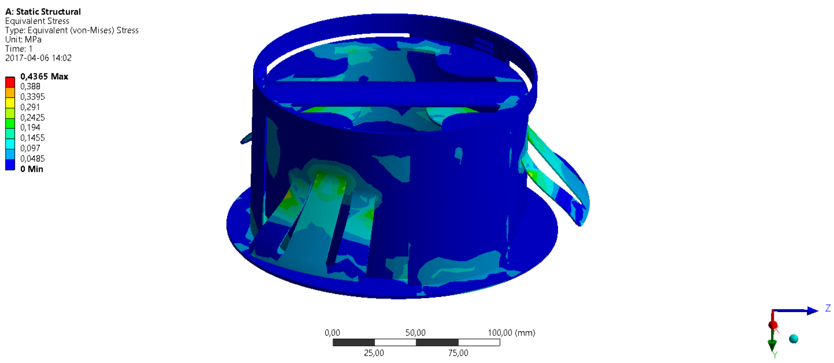


Figure 7.3 Results of the Stress Distribution when applying the total force of 10 N

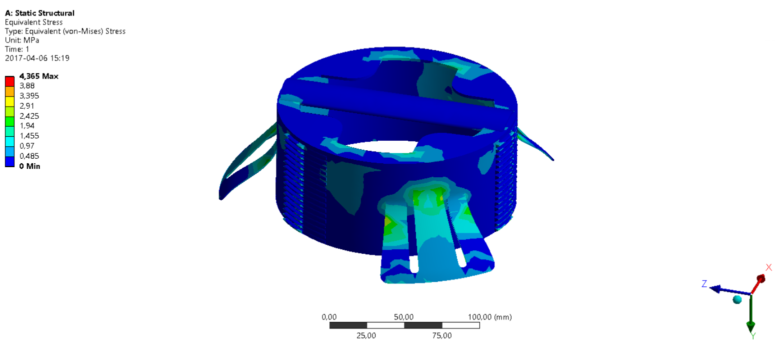


Figure 7.4 Results of the Stress Distribution when applying the total force of 100 N

The simulation showed that the magnitude of the stresses rising when supporting the RM and camera by resting at the upper surface of the ceiling, are low and below the yield strength for most plastics. The second simulation, with the higher magnitude of the force, was done to examine how the wings behaved under a higher load. This might be the more realistic result when mounting it due to the wished clamping force needed to make sure the RM is mounted to the ceiling tightly.

To be able to test the twisting movement a test rig was built. This was done with two sawed pieces of wood, connected with a screw and a nut in the middle. One of the pieces acted as a friction against the upper surface of the ceiling and the other as a handle that was to be twisted. Tests were performed by the writers with different levels of clamping force that was increased systematically by regulating the screw relative to the nut.

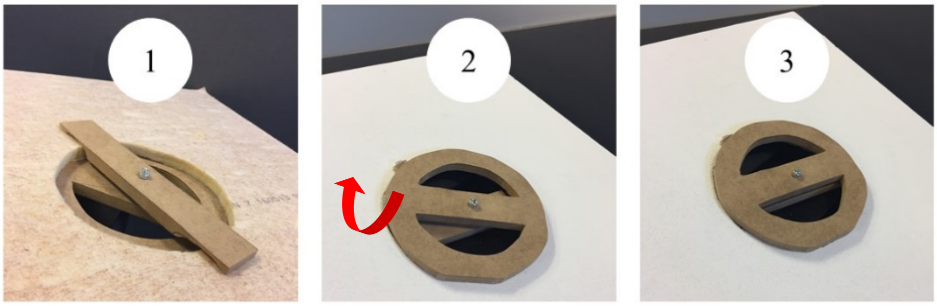


Figure 7.5 Pictures of the test. 1) The backside of the ceiling tile, 2) The rig before the twist, 3) The rig after the twist

7.2.1.2 Prototyping

The CAD-model was 3D-printed in one of Axis 3D-printer using an ABS-blend as material which resulted in the prototype. This required some preparation of the CAD-models. Due to the size of the prototype it had to be divided in many parts. The choice made to not scale it down was conscious because of the missed-out opportunity of measuring the perception of the RM. The wings were made thinner with the ambition of creating some flexibility. A handle in wood was made and used to assemble the parts together with glue.

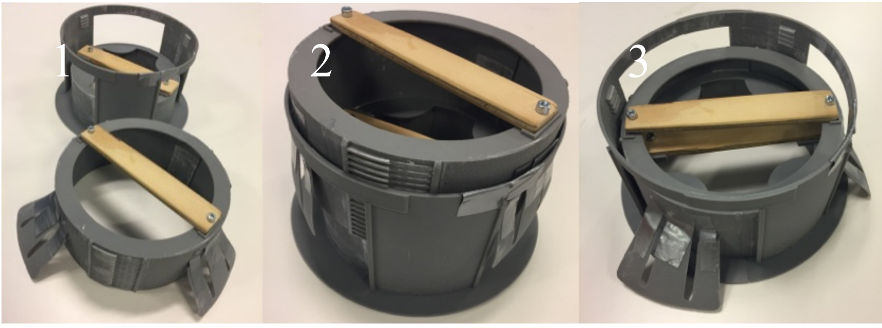


Figure 7.6 The 3D-printed prototype. 1) The two parts individually. 2) The position when inserting the RM through the hole in the ceiling. 3) The position after pressing the handle which enables the wings to flap out and hold the RM above the ceiling.

The prototype functioned to get a more realistic way of how it would look, feel and work. Unfortunately, the material in which the prototype was 3D-printed in, made the wings too stiff to be able to flex in the desired directions. Therefore, they were taken off and attached to the RM with duct tape.

7.2.1.3 Interviews and Reviews

The interviews and meetings with the selected group resulted in several insights. Firstly, the trim ring needed in this concept would be a larger one than used to the one in T94S01L which would not be accepted by the customers according to the product manager. The idea with a recess mount is for the installation to be as discrete as possible; the smaller the trim ring is, the better. Secondly, the product T94S01L is a recess mount for the exact same camera family (P32). T94S01L is currently in production, and an additional recess mount will probably be superfluous. Finally, the concept with the wings that hold the weight up is already a known technique at Axis since the product Axis F8224 contains the same feature, making the concept less interesting in the long-term perspective, in terms of examine new techniques for Axis, than concept I.

7.2.2 **Testing of Concept I**

The challenges with this concept was the robustness of the arms that were to be connected by living hinges. This concept was not as detailed designed as concept F during the time of the test.

7.2.2.1 Modelling and Simulation

The concept was modelled in Creo.

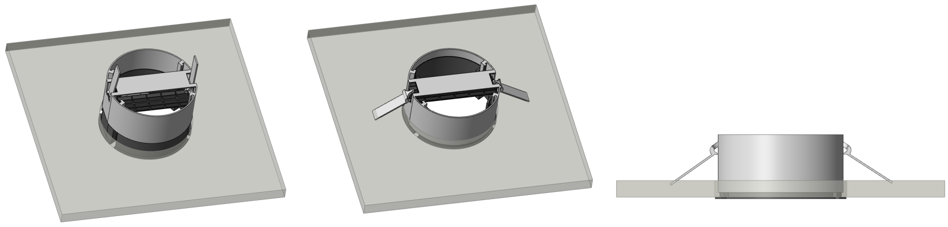


Figure 7.7 CAD-model of Concept 2 with a ceiling tile. Left: The position of the arms when inserted through the hole. Middle: The position of the arms after pressing the handle and snapping the snaps. Right: Seen from the side

No simulations were made at this stage on this concept due to the complexity of simulate the stresses distribution in the area of the living hinge.

Some alternatives were developed with some modifications. To make the concept more robust CAD-models with three arms (instead of two) were developed. Instead of using living hinges regular hinges were modelled where the arms were separate parts that were connected to the body by snapping them on. The arms were stiffened by adding ribs.

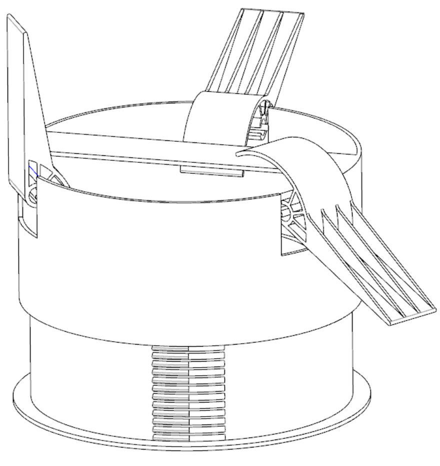


Figure 7.8 Modified concept with three arms connected with a joint which the arms are snapped on.

The arms reaction to the load they are expected to carry was simulated in ANSYS Workbench. Two simulations were made; one with an upward force of 10 N was applied and one with 100 N. In both simulations, the boundary conditions used was a frictionless support in the vaulted part that is supposed to be snapped on to the joints and fixed support in the outer surface of the arch that will be supporting the arm and make it stay in the angled position.

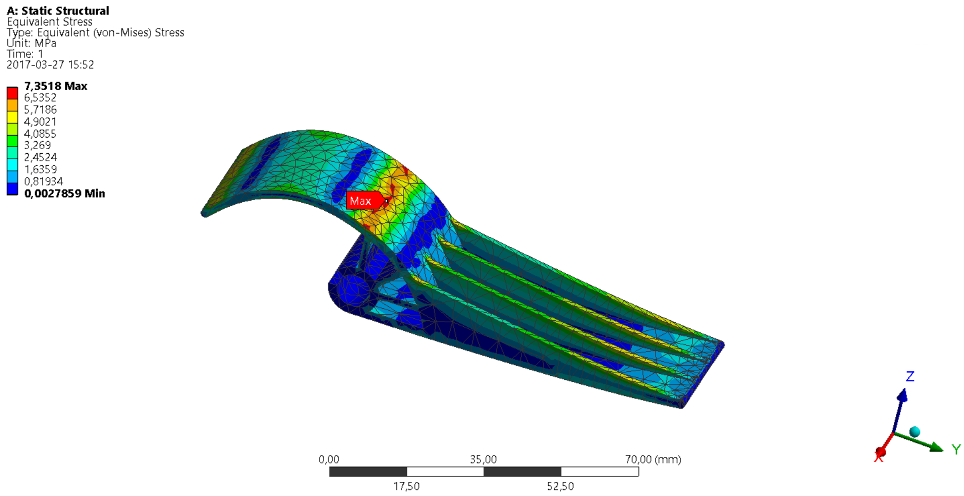


Figure 7.9 Results of the Stress Distribution in one arm when applying the total force of 10 N

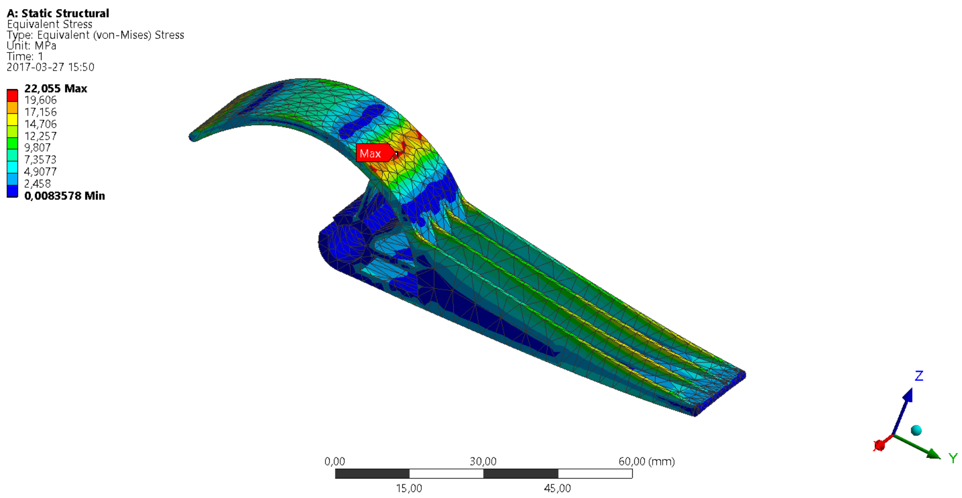


Figure 7.10 Results of the Stress Distribution in one arm when applying the total force of 100 N

What could be seen was that the ribs make the stress distribution much more even and stiffens the arms. The support arch can be made stiffer by adding ribs. The results from the simulation could be used when designing the arms although another way to connect them with the housing might be selected.

7.2.2.2 *Prototyping*

Prototypes were 3D-printed to get a better understanding of the functionality.

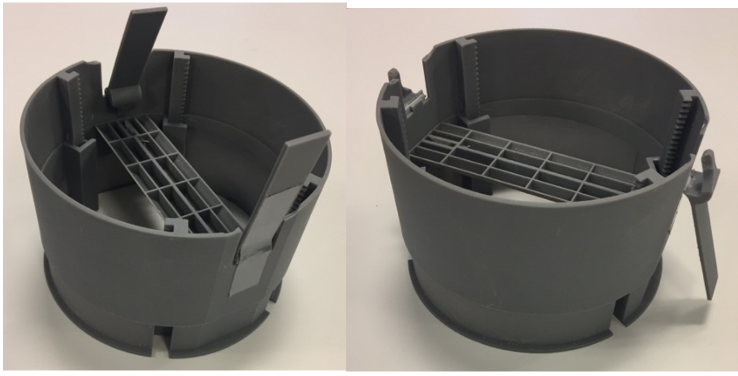


Figure 7.11 Left: Arms are standing up to be able to get it through the hole. Right: Arms folded out.

The living hinges could not be 3D-printed instead duct tape was used to attach the arms to the upper part.

7.2.2.3 *Interviews and Reviews*

The concept makes it more possible to use the smaller trim ring available, which will give a more discreet result than Concept F. The manager at the division where the master thesis is carried out stated that this concept would be more interesting for Axis in the long-time perspective, in terms of examine new techniques which are the living hinge arms in this concept.

7.3 Results

7.3.1 **Concept F**

The test rig that tested the twist was good and gave a feeling of how hard the expected hand movement would be. It was, however, very simplified and the handles in wood were a lot more robust than the final product with the wings would be.

The ANSYS simulations of concept F showed that the design could carry the load of the camera with great margin. The 3D-printed prototype did not work fully, but gave a feeling of that the concept would work if some trimming could be done.

The concept review did, in contradiction to the previous test results, dissuade further development of this concept since the trim ring needed is not a desirable alternative for the customers.

7.3.2 Concept I

The concept review of this concept encouraged further development since the technology, with the living hinges, is interesting for Axis's future projects.

The findings when simulating the arms in ANSYS Workbench could be used although that the type of hinge was not to be developed.

7.3.3 Conclusion

Taking the insights from the two concept tests in consideration and with the division manager as the final decision maker, the concept which was to be further developed was concept I with integrated living hinges as an important and interesting feature.

A great deal of work has to be done in order to make sure the concept will work; dimensioning of the living hinges has to be done thoroughly, as well as dimensioning of the arms in order to get the desired characteristics of the clamping. Further on, the connecting feature between the handle and the housing needs thorough development to ensure stability, strength and the ability of demounting.

8 Detailed Design

This chapter covers detailed design of the recess mount including design for manufacturing, the living hinges, the arms, the snap fittings, the body, design in plastic and material choice.

8.1 Background

To further develop the concept systematically it is divided into different main features. These are, however, not developed sequential but rather in an iterative manner. These sections cover both theory about the features and the design used in this specific recess mount.

8.2 Method

The features were developed iteratively so that they would work together as a functioning concept. The aspect of Design for Manufacturing (DFM) and design in plastic was constantly considered, but one major change was done with DFM in mind and is described in section 8.3. To develop the specific features such as the living hinges, the arms, the connecting interface and the housing, the needs of the feature was first established. In case some theory was needed to understand the design issues, this is stated first in each chapter. Development of the features was later modelled in Creo and the results are shown in the respective chapters.

8.3 Design for Manufacturing

The manufacturing process applicable for this design at Axis is injection moulding. Living hinges can be difficult to mould if the part is big and includes complex features and requires soft plastics for injection moulding. The housing has these unwanted features; it is relatively big and contains many features which can be defined as complex and would require a stiffer plastic to add robustness to the RM. The handle, however, is smaller and less complicated. The living hinges and the arms was therefore placed on the handle instead and the design was modified according to Figure 8.1 below. The decision to only have two arms, and not three for increased stability, was also made because of this.

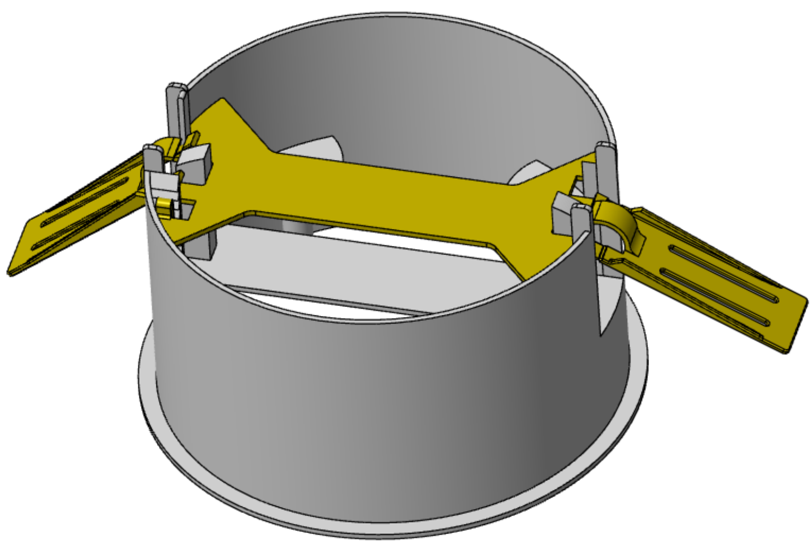


Figure 8.1 The conceptual solution of placing the arms on the handle.

8.4 Living hinges

8.4.1 Theory on Living Hinges

Living hinges, or integral hinges, are flexible hinges connecting two parts and allowing one part to rotate with respect to the other. The parts are made in thermoplastics and the entire part is made in one piece [26]. Living hinge is formed by creating a thin section where the two parts shall be joined. The parts are then injection moulded and immediately after cooling the hinge is flexed a few times. If designing and manufacturing correctly the molecule orientation will arrange in a desirable manner and create a section with increased tensile strength [27].

Living hinges are primarily designed for allowing multiple flexes, and are used in applications such as sealing clips and boxes with lids where no external hinge is wanted. The hinge will, if properly designed and processed, obtain an unlimited fold endurance and will never break due to too many flexes.

It is recommended to use polypropylene (PP) when creating living hinges since it can be moulded into thin sections and obtain the great flexural fatigue ability.

Main design issues of living hinges include [27]:

- Limited number of plastics can be used, PP is recommended.
- Gate location is of great importance in order to control the weld line. The weld line cannot be in, or close to, the hinge.
- Flow must take place across the hinge, not along.
- Limited ability to carry load.
- The hinge has to be thin enough to have the correct molecule orientation but too thin hinge will create problems when injection moulding, because it will act as a bottleneck.
- No sharp corners can be present. This will create stress concentrations.
- Recommended thickness of the thinnest section is 0.25-0.50 mm for a PP hinge.

The geometry of the cross-section in a living hinge should be designed according to Figure 8.2.

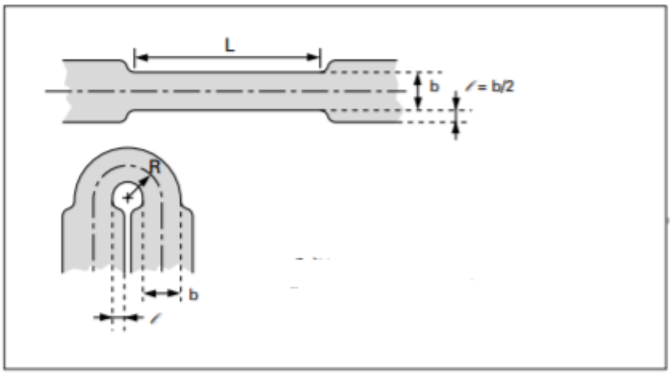


Figure 8.2 Recommended design of a living hinge [28]

If the hinge is too thick, the stress in the outer fibre can exceed the elastic limit of the material. If the hinge is too thin it will break easier when a load is applied and the manufacturing process will be more challenging, since the bottleneck is even narrower which makes it hard for the material to flow through.

8.4.2 **Tests and Results**

The theory concerning living hinges all state the hinges shall not carry load [26], [27], [28]. To investigate approximately how much load a living hinge can withstand tests were carried out on sealing clips produced by Twixit made in PP. Short time tests as well as long-time tests were carried out. To thoroughly investigate effects of time on plastics, longer time is needed than what is possible in this project. In this case a four-week test is what was possible given the time frame. The tests will, however, continue at Axis over the summer so that the results can be used in future projects.

8.4.2.1 Short Time Test

To investigate the short time effects of loading the living hinge a simple tensile pull tests was carried out with the use of a Zwick – Static Material Testing Machine. A total number of seven samples were tested. Three of the samples were sealing clips with size 4 cm and four samples were of size 11 cm. The smaller clips had a living hinge with the width of 13 mm and the larger ones 14 mm.

See Figure 8.3 for test setup. For further information on the test setup see Appendix D.

Figure 8.3 Test setup for pull test of sealing clip.

The tests were considered successful. The samples all failed in the hinge, as they were assumed to, and their ability to withstand force was greater than expected considering the thin section. The results of the different test samples are summarized in Figure 8.4 and Table 8.1.

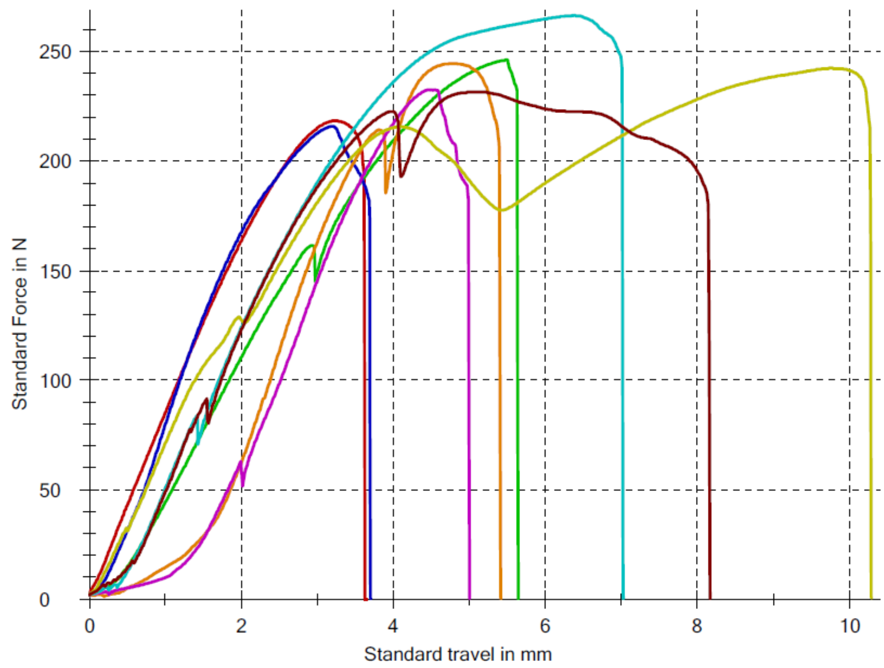


Figure 8.4 Graph showing force in N and standard travel in mm on eight test samples

Table 8.1 Pull test results

Type	Sample	Maximum Force (N)	Time until break (s)	Standard travel (mm)
Long	1	215,83	44,60	3,8
Long	2	244,49	65,10	5,4
Long	3	232,44	60,25	5
Short	1	246,08	67,95	5,5
Short	2	266,41	84,55	6,25
Short	3	242,29	123,57	10
Short	4	231,52	98,20	8

8.4.2.2 Time Dependency Test

To test the time dependency on loaded living hinges a test rig was built. Once again sealing clips were used as test samples. Different weights were hung in the sealing clips according to the following list:

- 3 à 1.5 kg
- 3 à 4 kg
- 3 à 6 kg
- 3 à 10 kg

The surrounding temperature was an inner-temperature of 21°C with negligible minor changes during the time of the test. The goal of the time dependency test was to investigate at which load creep must be taken in consideration.

Table 8.2 shows the results of the time dependency test.

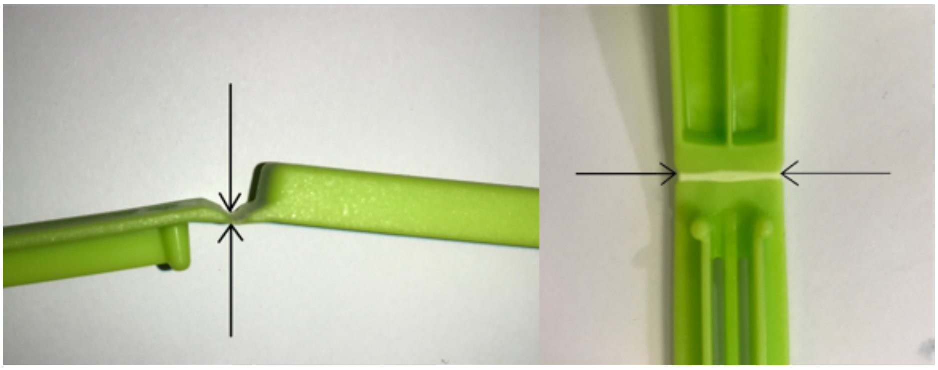


Figure 8.5 The sealing clip used as test sample. The left picture shows the thickness of the living hinge and the right picture shows the width.

The cross section area of interest is according to equation 8.1. The stress rising in the living hinge is according to equation 8.2.

$$Area = thickness * width = 0.25mm * 13mm = 3.25mm^2 \quad (8.1)$$

$$Stress = \frac{Force}{Area} \quad (8.2)$$

Table 8.2 Results of the time dependency test after three weeks. ΔL

Weight [kg]	Force [N]	Stress [N/mm^2]	ΔL [mm]	Creep occurred?
1.5	14.7	4.52	0	No
4	39.2	12.06	0-1	Some
6	58.9	18.12	1	Some
10	98.1	30.18	3-4	Yes

8.4.2.3 Conclusions after tests

The short time tests showed that the living hinges could withstand an average of 238 N, which corresponds to just over 24 kg when the surrounding temperature is 21°C. The small sealing clips were stronger than the larger ones, which is slightly unexpected since the hinges are approximately one millimetre thinner on the smaller clips compared to the larger ones, leading to a smaller area taking up the force. The time until break as well as the standard travel has quite a large standard deviation due to deformations appearing in other places than the hinge. The test gave a hint that living hinges could withstand quite big forces without breaking.

The time dependency test showed that creep occurred on the sealing clips when loaded with 10 kg, resulting in a tensile stress of 30 MPa (or N/mm^2).

Appendix E contains pictures of the sealing clips after being loaded for three weeks and a reference which is a clip that has not been loaded.

The RM has a specification of high importance which says that the temperature range it should be working in is 0-50°C. This specification makes testing of the living hinges in both higher and lower temperature necessary in order to be able to make final decisions whether it can be used or not. The camera units thermal radiation might also affect the temperature in the RM, therefore this is important to investigate although the RM will most likely be in 21°C (indoor environment).

8.4.2.4 Design of the Living Hinge

The final design of the living hinges with relevant dimensions is shown in Figure 8.6, Figure 8.7 and Figure 8.8.

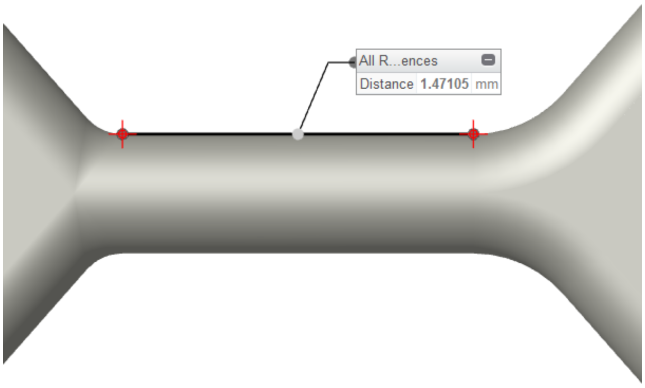


Figure 8.6 Length of the hinge (1,47 mm).

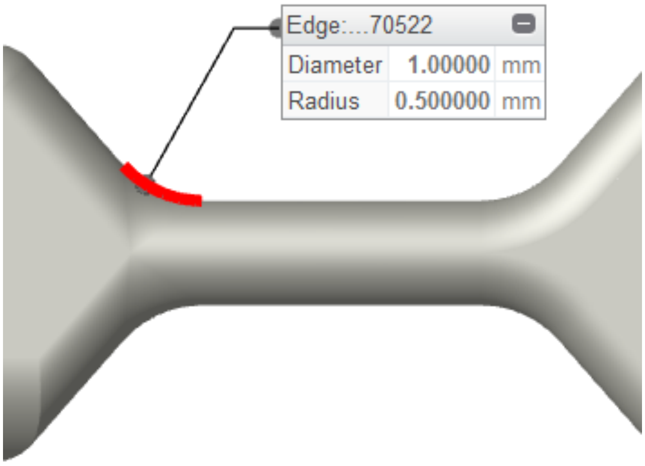


Figure 8.7 Radius of the hinge (0,5 mm).

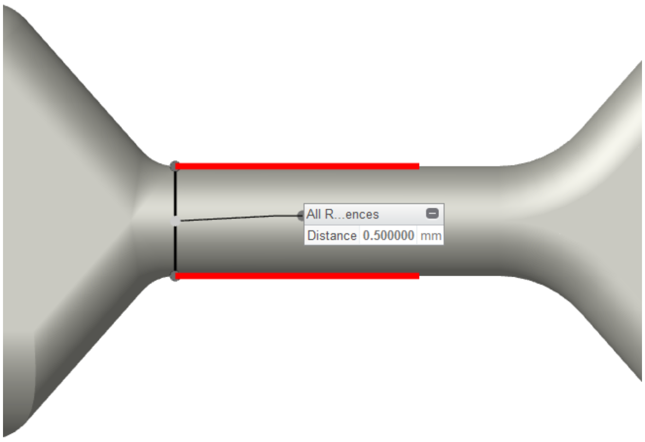


Figure 8.8 Thickness of the hinge (0,5 mm).

8.5 Arms

To be able to clamp ceilings with different thicknesses the arms has to be somewhat flexible. The main issue concerning the arms are the fact that relaxation will occur. The clamping that occurs when installing the mount will lead to the arms bending and a stress will act in them. This stress will decrease with time, a phenomenon called relaxation which is typical for plastics [3], and will eventually lead to some slack in the mount. The arms should be made in PP because the living hinges that are integrated in the part. PP is a soft plastic, so the arms has to be designed in a correct way to create stability, like adding ribs to the arm makes it stiffer. Integration of a metal part, such as a spring steel, was discussed with the polymer experts Sjunnesson and Klügel. This would diminish the relaxation effect as well as provide further stability to the arms and can be investigated when further developing the product. This was not further investigated in the project since the product should be made only in plastic if possible. Should the relaxation become a problem when testing the product, the metal part could be the solution to the problem. The ribs were designed to make the arms thicker at the bottom and thinner at the end. This was advised by the polymer experts in order to evenly distribute the stress in the arm.

Three views of the chosen design of the arms are shown in Figure 8.9.

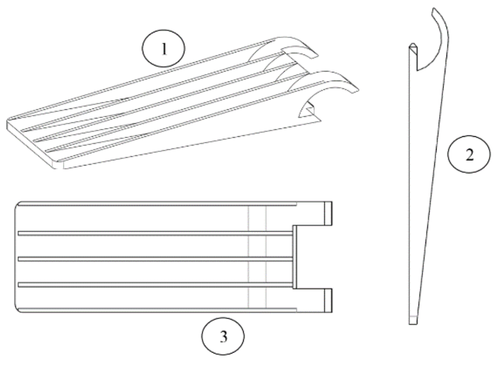


Figure 8.9 Design of the arms

Simulations were made in ANSYS; to investigate how much the arms would deform when applying the load that the cameras weight results in as well as how the stress distribution looks. A force of 10 N was added pointing upwards at the outer end of the arm and it was fixed in the other end. The applied material was chosen from the database of ANSYS and was Polyethylene with similar specification as PP.

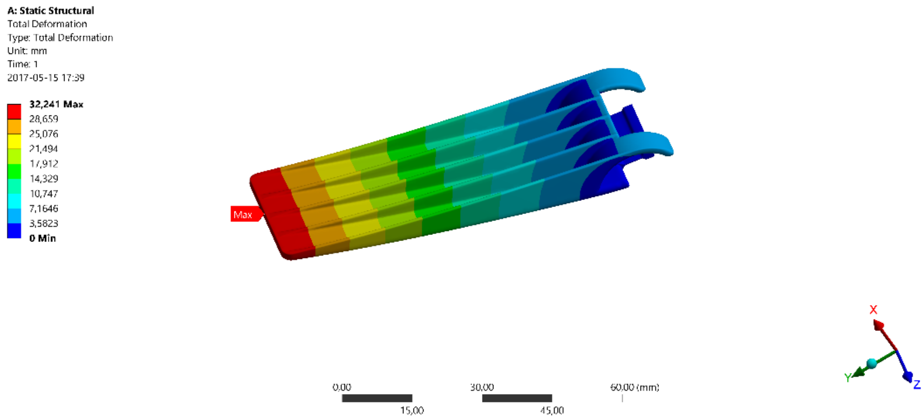


Figure 8.10 Showing the total deformation of one arm when 10 N is applied to the end of the arm.

The maximum deformation of the end of the arm was 32.24 mm. This is too much for this application, but since the force of the weight of the camera acting on each arm only would be 2.7 N, see equation (8.3), the design is considered good enough.

$$F = \left(\frac{m_{camera} * g}{number\ of\ arms}\right) = \frac{0.55 * 9.81}{2} = 2.7N \qquad (8.3)$$

8.6 Connecting Interface

The connecting feature between the handle and the housing needs to be height adjustable and demountable. Two main techniques were considered: snap fittings and starlock washer in combination with a threaded rod/bolt. The idea with the starlock washer came up during the evaluation of the concept and has not been reported as a solution fragment to sub-problem 2 (5.5). Fitting snap fittings into the design was difficult and demountable snap fittings usually lack ability to carry loads. The starlock in combination with a threaded rod/bolt is therefore chosen since it allows demounting in a simple way.

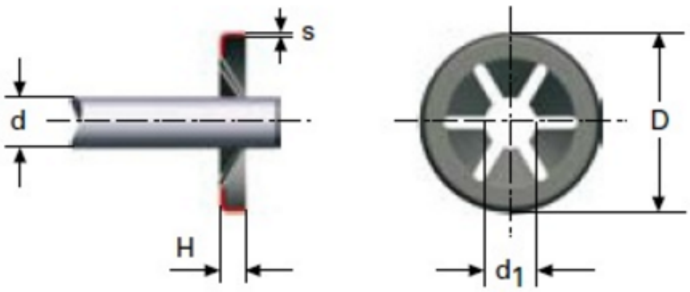


Figure 8.11 Starlock washer with a smooth rod.

A starlock washer is used as a lock to secure a rod in axial direction. The shape of the starlock washer allows the rod to be pushed into the washer but prevents it to be pulled out. An 8 mm rod pushed into a certain kind of starlock washer from Baker and Finnemore Ltd, a supplier of starlock products, with 215N needs 1471N to pull the rod out [29]. If a threaded rod, or a bolt, is used instead of a smooth rod the lock can be unlocked by turning the rod outwards. This is a technique that is currently being tested at Axis by two master thesis writers, and is therefore an insecure yet interesting technique [30]. Even though this technique is unexplored, it is the one that will be used in this project to secure the handle to the housing.

The starlock washer will be placed in the handle and the rod will come from below, inserted in the housing. Figure 8.12 shows the handle in yellow and the housing in green, as well as the placing of the starlock washer and the threaded rod. Two alternatives where thought about: the washer and rod both made in steel, or both made in plastic.

Should the steel alternative be used, standard components could be used. Should plastic components be used, the washer could be integrated in the handle and injection moulded in the same part, and a pitch could be used in the washer leading to a better fit between the parts.

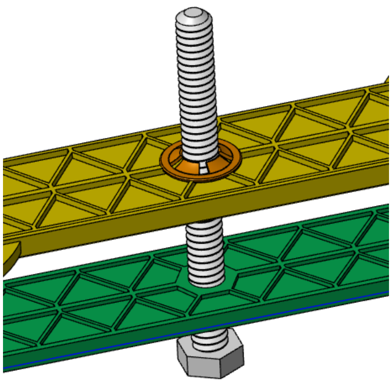


Figure 8.12 Starlock washer connecting feature

8.7 The Housing

The housing has three main functions that is needed; it has to hold the camera in place, include an interface that forces the arms outwards and it has to securing the handle. One concern that arose when some of the prototypes were compared to each other was that with the full-size prototypes it was more difficult to insert the upper part to the lower part in a smooth way compared to the down-scaled prototypes. This is an effect that is called the drawer effect (which is a translation of the Swedish word "byrålådseffekten"). When the diameter is great compared to the height, it is difficult to avoid struggle in the sliding action. When the height was greater than the diameter the insertion worked without difficulties. To avoid the drawer effect a cylindrical protrusion was added in the centre of the handle. When the rod is inserted in there the sliding will occur without problem.

To force the arms outwards two vertical protrusions with rounded upper sides were designed on the handle of the housing.

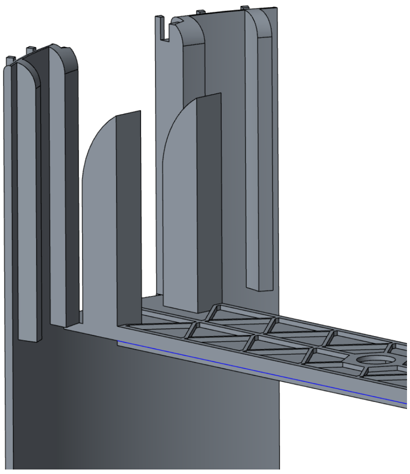


Figure 8.13 Protrusions to force the arms outwards.

The interface between the camera and the housing and the interface between the trim ring and the housing are designed as copies of the same interfaces on T94S01L.

8.8 Design in Plastics

Design in plastic differs in various ways from design in metal. Injection moulding is the desired process to use to manufacture due to large batch sizes. Bruder lists ten design rules for thermoplastic mouldings [3]:

1. Remember that plastics are not metals.
2. Consider the specific characteristics of plastics.
3. Design with regards to future recycling.
4. Integrate several functions into one component.
5. Maintain an even wall thickness.
6. Avoid sharp corners.
7. Use ribs to increase stiffness.
8. Be careful with gate location and dimensions.
9. Avoid tight tolerances.
10. Choose a suitable assembly method.

The handle, arms and the handle on the housing was stiffened by ribs according to the design rules stated by Bruder, see Figure 8.14 Handle with ribs.

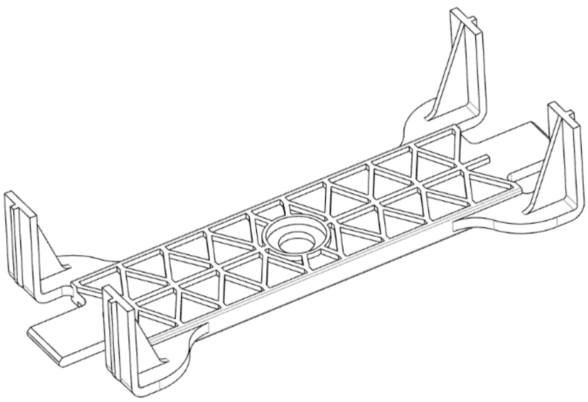


Figure 8.14 Handle with ribs.

Sharp edges were rounded with suitable radius. All features needed more stiffness were designed with ribs the same way as in Figure 8.14. The thickness of the ribs were given the value of 50-60% of the main thickness to avoid sink marks. Through discussion with Andersson, Sjunnesson and Klügel parts were functions were integrated in one component as much as possible and assembly methods were discussed.

8.9 Material Selection

The process of choosing a suitable material for the mount is an iterative process where the material depends on the modelling of the construction and vice versa.

The design consists of two main parts, the housing and the handle. In order to determine what materials should be used a specification list was set up for the two parts respectively. Due to the limited time given to this project a simplified material selection was carried out.

8.9.1 **Handle**

The handle includes the living hinges and the arms. Living hinges is most often made in polypropylene (PP) due to good fatigue resistance and flexibility in thin sections. In some cases, polyethylene is used but PP is often preferred [26].

In a previous project at Axis, a polypropylene homopolymer called TAIRIPRO K1011 has been used. The possibility to injection mould, the large tensile elongation and the UL-certification are factors that implies that it is a suitable material to use in this application.

Relevant properties of TAIRIPRO K1011 are presented in Table 8.3 below. A complete datasheet of TAIRIPRO K1011 can be found in Appendix E.

Table 8.3 Relevant properties of polypropylene photopolymer TAIRIPRO K1011

	Properties	**Value**
Mechanical		
	Tensile Strength	34.3 MPa
	Tensile Elongation	> 200 %
	Flexural Modulus	1420 MPa
Processing		
	Processing Method	Injection Moulding
	Mold Temperature	30.0-50.0 °C
	Injection Pressure	7.85-11.8 Mpa
Other		
	Supplier	Formosa Plastic Corporation
	RoHS Compliance	RoHs Compliant
	Flame Rating	UL 94 Certified

Late in the project, polyketone was discussed. Klügel contacted a supplier at a plastic fair and discussed living hinges and was recommended to look into polyketone. Polyketone is a semi-crystalline polymer with high temperature resistance, high impact strength and high cyclic fatigue strength [31]. Complete datasheet of one polyketone, Schulaketone NV, can be found in in Appendix G. This material was, however, not investigated thoroughly. Recommended for Axis is to manufacture and test parts of both polypropylene and polyketone.

8.9.2 **Housing**

The requirements of the housing differ in one main aspects from the requirements of the handle. The housing can, and should, be stiffer so that it can hold the camera in place without flexing. The number of possible materials are greater than for the handle since the requirement concerning a great tensile elongation is not present.

The housing in T94S01L is made of glass fibre reinforced PBT/PET. It has had some problems during the manufacturing process, mostly because warpage occurs due to uneven cooling. This was according to Klügel and Sjunnesson due to the cut outs in the housing and the thin section of the flange, a feature that this RM does not have. The same material is recommended to use in this product.

9 Results

This chapter covers the summarized results and recommendations on further work to Axis.

9.1 Background

The results are represented by parts modelled in Creo with corresponding explanations about selected details. A step-by-step guide on how the installation of the RM is executed and completed are presented and can be found in Table 9.1. Finally, the list of specifications (listed in section 4.3) is compared to the result.

9.2 Parts Included

The concept consists of two main parts and a connecting interface. The main parts are referred to as the housing and the handle. The parts are presented in this section one by one and thereafter the working principle is described.

9.2.1 **Housing**

Figure 9.1, Figure 9.2 and Figure 9.3 show the housing. The housing includes some main features which will be described in this section. The right picture in Figure 9.1 shows four screw towers. They work as the interface between the cover of the camera and the RM. These will contain metal inserts in the final product since the screws are in metal and metal shall not be screwed into plastic. The holes on the upper part of the cylinder are fastening points for the safety wire. The cut outs on the flange are where the trim ring is fastened. The handle is ribbed up to achieve the correct stiffness.

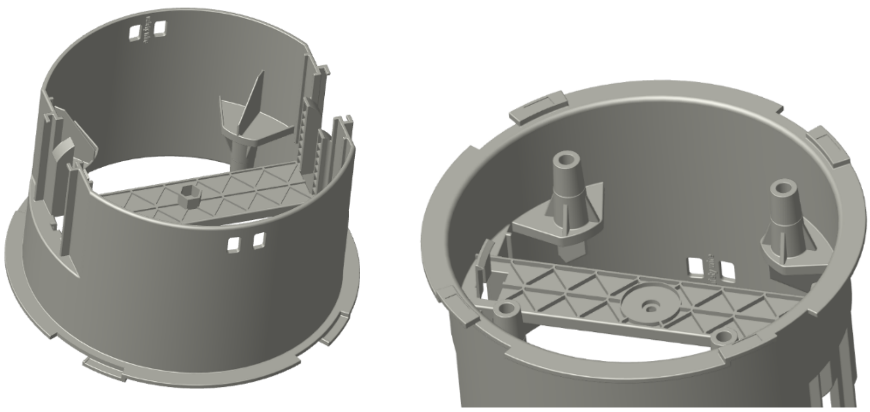


Figure 9.1 The housing. Left: from above. Right: from below.

Figure 9.2 shows four protrusions with rounded upper edges. These will force the arms outwards when installing the RM, which is explained in section 0.

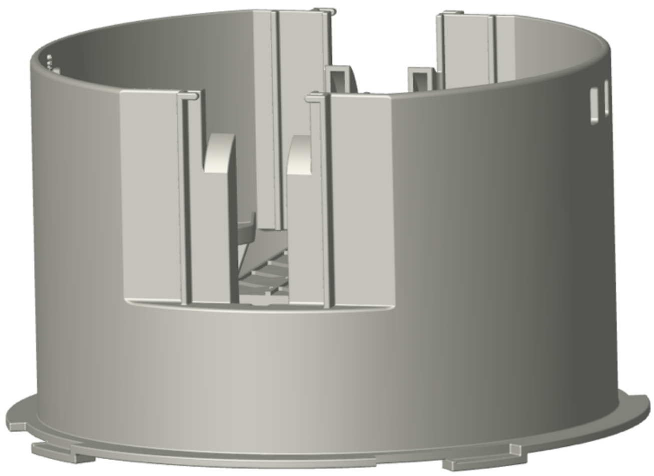


Figure 9.2 The housing with the interface that is supposed to make the arms fold down and support them.

Figure 9.3 shows one of the two snap fit that holds the camera in place before it is secured by the cover.

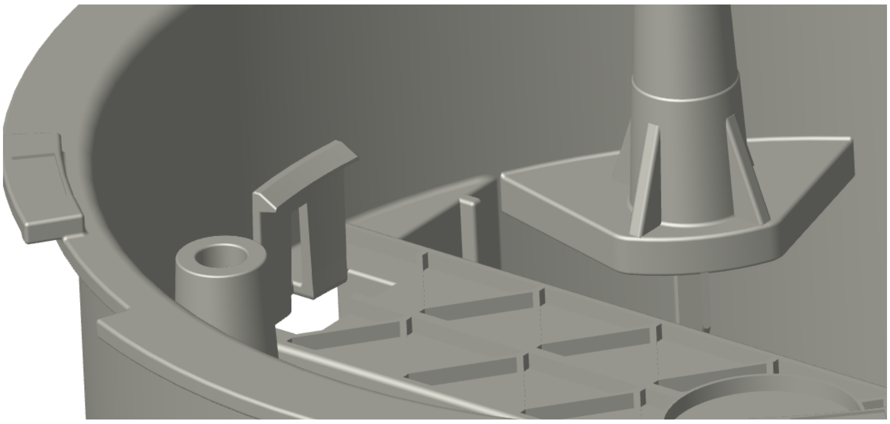


Figure 9.3 The snap fit.

9.2.2 **Handle**

Figure 9.4 and Figure 9.5 show the handle with the arms that are connected by living hinges. The four walls are added to minimize the drawer effect as well as to adjust the friction between the two parts. The handle as well as the arms are ribbed to achieve stiffness.

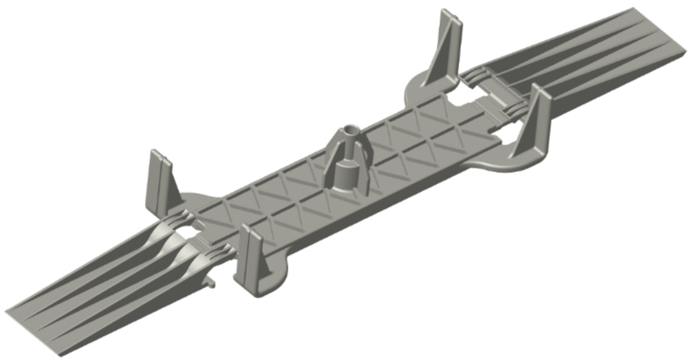


Figure 9.4 Handle.

The arms have the bended shape at the inner end in order to allow the outwards folding described in section 0. They grow thinner on the outer ends to distribute the stress that arises when loading RM with the weight of the camera evenly.

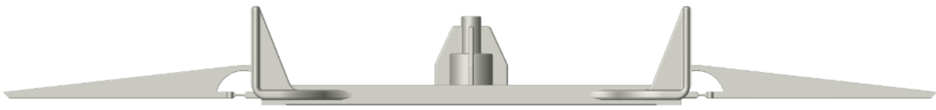


Figure 9.5 Handle from the side.

9.2.3 Connecting Interface

The connecting interface was finally designed to work in the prototype with three separate parts. One threaded rod (in the prototype a M5 screw), one corresponding nut that is connected to the housing and the 3D-printed starlock washer that is connected to the handle. The rod has to be a separate part in order to ensure that demounting is possible, but the nut and the starlock washer could possibly be integrated and moulded into the product. Figure 9.6 shows a picture of the connecting interface in the CAD-model.

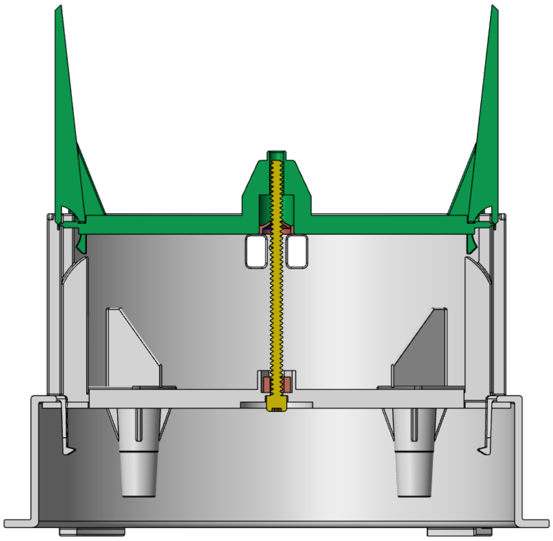


Figure 9.6 Cross-section that shows the connecting interface. Threaded rod in yellow, nut and starlock washer in brown.

9.2.4 Trim Ring

The trim ring used is the existing trim ring with the maximum diameter of 178 mm.

9.3 Working Principle

Figure 9.7 shows how the parts of the RM works together. Table 9.1 describes the mounting step by step. The protrusions on the arms meet the protrusions of the housing when the parts are pressed together. This results in the arms being forced outwards and when the handles have been pressed together enough, the ceiling will be clamped between the arms and the flange of the housing.

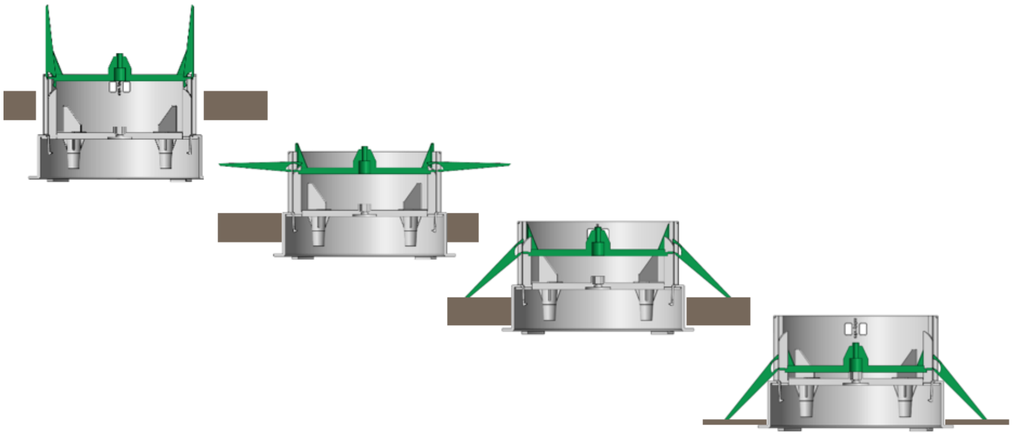


Figure 9.7 Working principle. Pictures from left to right: RM inserted halfway into a hole in the ceiling, arms pointing upwards. RM inserted in the hole, handles pressed slightly together, arms started to rotate. Handles pressed together and ceiling clamped between arms and flange in order to fit a thick ceiling. Handles pressed together and a thinner ceiling is clamped between the arms and flange.

9.4 Prototype

The final prototype was 3D-printed using a SLS-printer. It was made with consideration to the plastic rules, presented in section 8.8 but with adjustments to the material (nylon) which is not the most suitable material for this product. Walls were made thicker where more stability was needed and ribs could not be inserted. No consideration to drafts were taken due to the fact that the manufacturing method chosen (3D-printing) do not requires that.

The connecting method used in the prototype is a smaller bolt (M5) with a nut attached to the handle of the housing. Instead of using a starlock washer (in metal) a 3D-printed locking unit was used. This was due to brittleness in the prototype which could not withstand the forces needed to press the handles together.

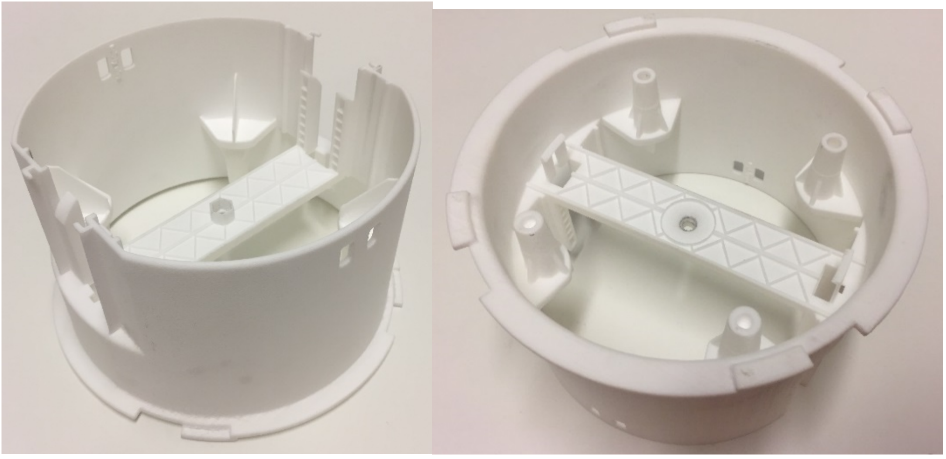


Figure 9.8 Pictures of the 3D-printed housing. Left: seen from above. Right: seen from below

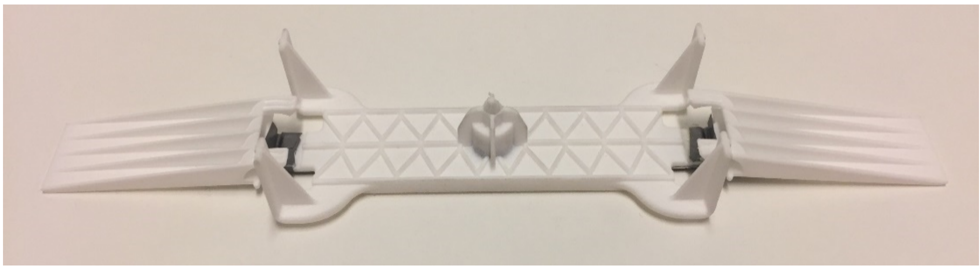


Figure 9.9 The handle from above with the arms folded out. The living hinges is modelled with duct tape.

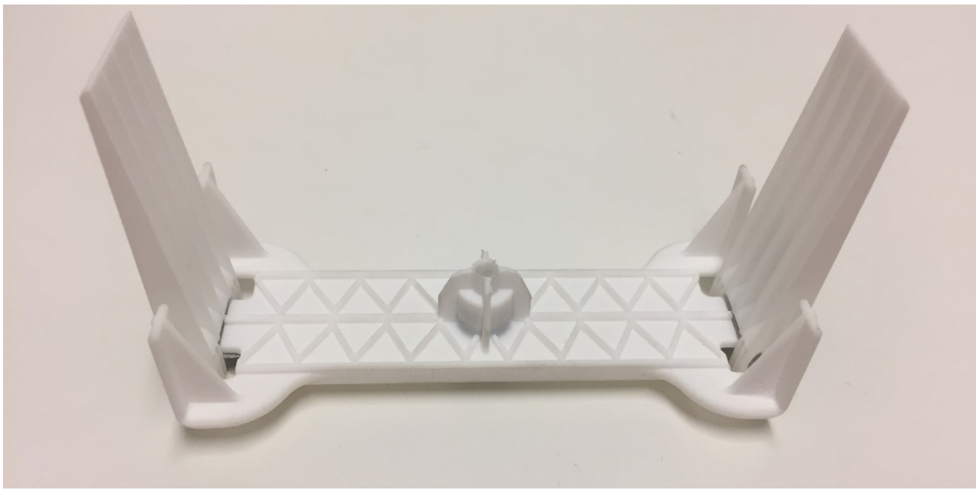


Figure 9.10 The handle from above with the arms folded in, this is the position in which the handle and the housing shall be inserted through the hole in the ceiling.

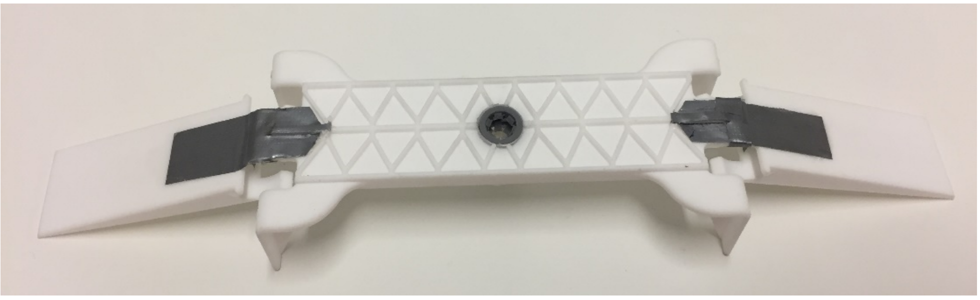


Figure 9.11 The handle from below. The connecting feature (Sub Problem 2) is the grey part in the middle. The living hinges is modelled with duct tape.

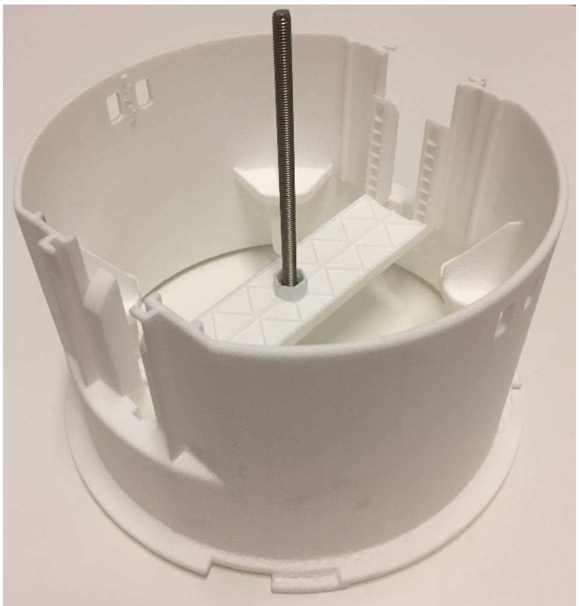


Figure 9.12 The housing with the rod inserted from below through the middle of the handle and secured with a nut.

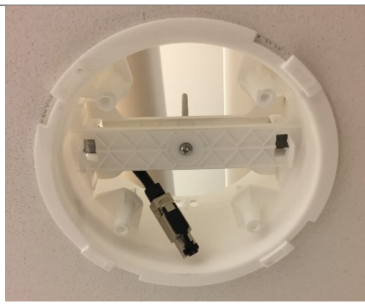
Figure 9.13 The housing and handle together with the handle placed at the starting position.

9.5 Mounting the Recessed Mount

Mounting the RM and the camera is done in 10 steps which are described in Table 9.1. The steps written in italic are steps corresponding to mounting and installing the camera.

Table 9.1 Mounting the RM.

1	Assemble the handle to the housing from the top. This step can be performed on the floor.	
2	Make sure that the arms are pointed upwards.	
3	Fasten the safety cable to the RM if it is wanted.	
4	Insert the housing into the hole in the ceiling.	
5	Press the handles together firmly until the ceiling is clamped between the flange and the arms.	

6	*Locate the Ethernet cable and insert it in the housing from above.*	
7	*Connect the cable to the camera.*	
8	*Snap the camera to the snap fittings in the housing.*	
9	*Mount the cover to the RM by screwing the four screws. This secures the camera to the RM as well.*	
10	Attach the trim ring by locating the four cut outs on the flange of the housing, bring the trim ring towards them, and thereafter twisting the trim ring slightly.	

9.6 Specifications

To summarize the result of the project the specifications that were established in chapter 4 were looked at. The table below lists the specifications once again, with an addition that marks if the specification has been fulfilled or not.

Table 9.2 Summary of specifications marked with achieved or not fulfilled.

No	Specification	Imp.	Unit	Marginal Value	Ideal Value	Fulfilled?
1	One handed mounting	5	Binary	Yes	Yes	Yes
2	Time difference to complete mounting (without cables) compared to T94S01L	5	%	30	50	Yes
3	Allow demounting	4	Binary	Yes	Yes	Yes
4	Allow remounting	3	Binary	Yes	Yes	Yes
5	Intuitive design	3	Subj.	-	-	Yes
6	Ceiling thickness allowed	5	mm	1-40	1-60	Yes, 1-60 mm
7	Possible to mount on different ceiling material (both dropped ceiling and hard ceiling)	5	Binary	Yes	Yes	Yes
8	Possible to mount without taking down ceiling tiles	5	Binary	Yes	Yes	Yes
9	Total cost	5	USD	15	<5,5	Cost analysis not performed
10	Attachment point for Axis safety wire	5	Binary	Yes	Yes	Yes
11	Compatible with existing parts	3	Binary	Yes	Yes	Yes
12	Robust feeling	5	Subj.	-	-	-
13	Width of hand to install the mount	4	cm	12	14	Approx. 11
14	Scalable to work with different cameras	2	Binary	No	Yes	No
15	Mounting of the RM without screws	3	Binary	No	Yes	Yes & No*
16	Other materials used than plastics	3	No.	1	0	Yes
17	Easy, fast and safe installation of the trim ring	4	Subj.	-	-	Yes
18	No loose pieces	3	Binary	No	Yes	No
19	Tools needed when installing the RM	3	No.	1	0	Yes
20	Pass Axis tests	5	Binary	Pass	Pass	Later
21	Warranty	5	Years	3	3	Later
22	Suitable material	5	Binary	Pass	Pass	Unsure
23	Only the dome of the camera is visible after installation					Yes

*** The mounting is made by just pressing the handles together but to demount it some screwing is needed.**

9.7 Future work

Before realization of this project some things need further development. Primarily this concerns testing of the product with focus on the living hinges and the arms. Tests have to be performed with correct material, correct load cases and correct temperature range. This is of high important in **this** product since the living hinges is such a critical design point. The tests performed in this project where simplified due to the short time left when they were set up, and needs more testing before reliable conclusions can be made.

Also, a cost analysis should be performed to investigate whether this is a cost effective concept or not. It will most likely cost more than T94S01L, but if the installation is much faster it might still be a better alternative.

The connecting interface between the two main parts can be further investigated; if the nut and the starlock washer should be integrated in the main parts and if the screw can be made in plastic.

A moldflow analysis should be performed on the two main parts, the housing and the handle. The most critical part is the handle, since the living hinge section will be a bottleneck in the moulding process. The number of gates has to be experimented with; if one gate in the centre is not enough to fill the arms fully, two more might be needed, one on each arm too. This might lead to unwanted weld lines in critical places in the design, why the placing of the gates will be of great importance.

10 Discussion and Conclusion

This chapter covers reflections made during the different activities of the process and a final conclusion.

10.1 Discussion

The most important product specification was that the RM should be possible to mount with the use of one hand only. This specification considers the mounting of the RM only, not the camera unit and cover. Installing the camera includes inserting the Ethernet cable to the camera unit. This has to be done with two hands. To attach the cover of the camera to the RM four screws has to be screwed, an action that also requires two hands. This is a fact that this project could not affect, because in that case some existing parts had to be modified.

The product specifications were in this project retrieved directly from earlier projects at Axis. No contact with installers or other customers were initiated to get input on customer needs. This was an intentional decision that was made since the work of gathering needs had already been thoroughly done in the previous master thesis by Caroline Jacobson and Linnea Karlsson. This might, in the end, have been a bad decision since this might been why the specification about the trim ring was missed out in the first specifications. The fact that customers wanted the trim ring as small and discreet as possible was something that came up about half way into this project, and it led to delays in the development work.

The outcome from the first brainstorming performed was of little use technically but the session was of great value thanks to the insights it gave. The challenges and complexity of the problem became clearer. It also gave ideas to some features that might come to use later on in the detailed design and further development of the RM. The problem decomposition was necessary to systematically explore the different solution possibilities. Considering one interface at the time was good to minimize the risk of missing some interesting solutions fractions.

The process of selecting a concept can be hard and it was in this thesis as well. Too much time could not be spent on developing a lot of concepts, why the selection has to be made although they all can be made more detailed and functional. The estimations done in the screening and scoring matrices are roughly. In this case a lot of useful help were taken from more experienced employees at Axis. They had valuable inputs on the different features from different perspective (material, impression of the product, manufacturing among many).

One can think that it might have been interesting to select the different interfaces individually, because of the realization that the scores the concepts were given depended much on which type of solution fragment it contained. But that would also be an ineffective way of selecting way because the many ideas and insights that became clear when combining them in a concept. The conclusion is that the selection was done in the right way.

The decision to continue with two concepts after the first evaluation turned out to be good because of the many specifications that were mentioned later on by Axis employees. Specifications that were not stated when starting the concept generation and became clear during the testing of concepts.

Modelling all the twelve different concept combinations in Creo was time-consuming. This was, however, considered valuable since the authors gained inputs about the different problems that came with each of the combinations. It was also a good way to communicate the concepts with employees at Axis during the evaluation of them.

When the concept with the living hinges was the one that was chosen to further develop a lot of work had to be done to study living hinges. While the polymer experts, at first, advised against the living hinges, it was stated from other key people that the feature is interesting for Axis as a company. A thorough background study was necessary to get a full understanding of the issues concerning living hinges. When studying literature about the feature, a conclusion was drawn that a practical approach towards it was to prefer since there was no reported study on loaded living hinges. The tests on the sealing clips, however, are not optimal for the RM application but it was the best alternative for the short amount of time that was left. The load case is significantly different, where on the concept for the RM the sealing clips are loaded in an angle and with a clamping force acting on them. The tests were performed with only tension and with different load. However, the tests gave a hint that living hinges were rather robust and that the hinges are the weak point of the design. The time-dependent tests would have been more interesting if they would have been set up in the beginning of the project, but they do give some hints about the load bearing ability.

The tests were performed in rooms with a temperature of around 21°C. It is likely that this is the temperature that the RM will be in when installed in different ceilings but one of the specifications were that the temperature range the RM must function in and withstand is 0-50°C. This makes testing in lower and higher temperatures necessary if living hinges is planned to be used in the final product. The relatively low temperature range has a great impact when plastic is the material.

Had this been a project without the time limitation of 20 weeks, the material selection would have been done in a different way. Since the living hinges are such a critical feature in the design these would have to be tested to make sure they would withstand the load. Different polypropylene materials, as well as at least one polyketone, would probably be tested in the correct design with different load cases and the most suitable one would have been chosen.

The design is possible to fit with different camera families if the interface with the camera is modified. Two main criteria, however, has to be fulfilled; the camera has to be somewhat light weighted and it cannot be smaller than the P32-series. Should the camera be smaller, the installer will not fit the hand inside the RM in order to press the handle and the housing together.

An additional important finding that has come out of this thesis work is that the product called Axis T94S01L, or T94S01L, is a very good and unique product that fulfils many of the needs one has when mounting a camera in a ceiling. It is a robust and discreet mounting solution, and completing the installation (without the cables) took only slightly more than two minutes. It has no direct weak spots (like the living hinges in this project) and should be possible to scale in order to fit many different cameras with different size and weight. The downside with it is that installation is hard to complete with only one hand.

10.2 Conclusion

The recommendation for Axis is to use the findings from section 8.4 Living Hinges as guidelines if living hinges should be used in an application similar to a recessed mount. Furthermore, additional tests have to be performed on the loading of the hinges that is directly applicable to the actual load case. The product has to be tested carefully, especially the loading of the living hinges, since this is an unexplored technique with poor documentation prior to this thesis work.

The product can be scaled to fit other cameras if they are the same size as, or bigger than, the P32-series. The working principle builds on the fact that a hand fits inside the housing so that the handles can be pressed together.

This project and the resulting prototype proves that a product that offers one-handed fast mounting of a recessed mount is possible to produce.

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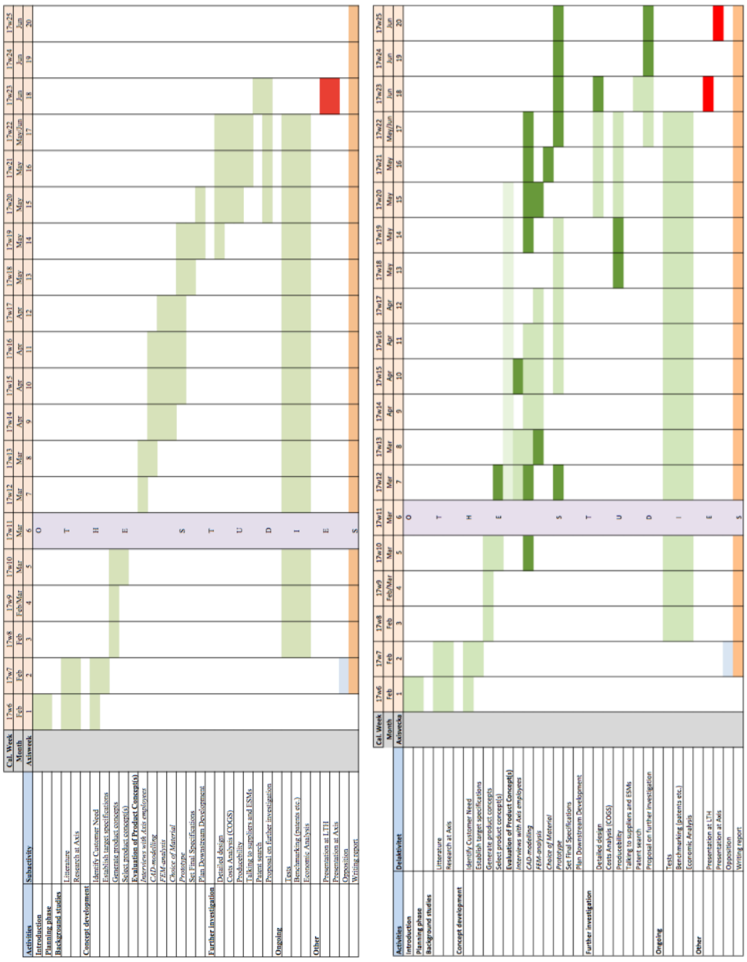
Appendix A Time Schedule

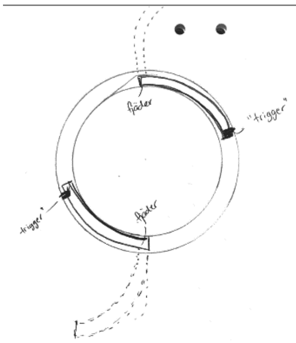
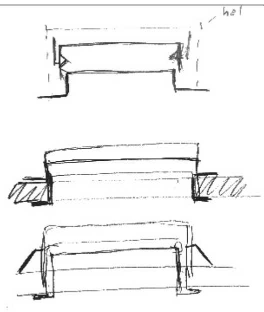
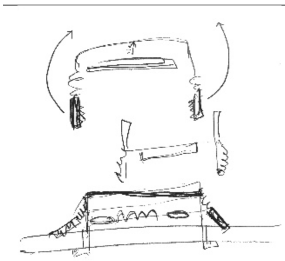
The GANTT-schedules, planned and performed.

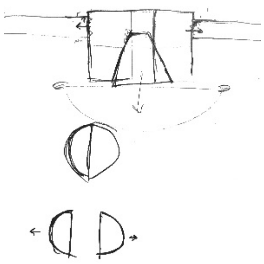
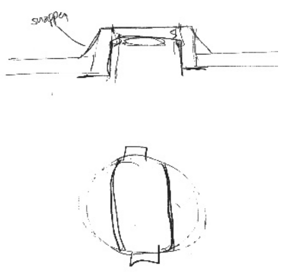
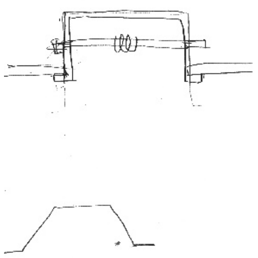
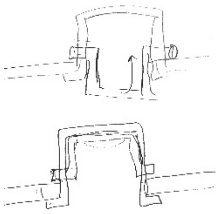
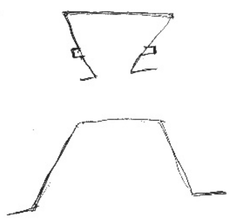
The lighter green is the planned time for each activity. The darker green is the added time the activity needed. The major changes were due to the given directions of which concept that should be selected that became clear a few weeks after the first selection of concept.

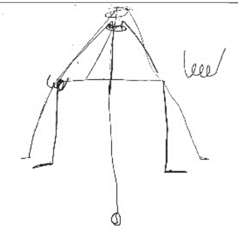
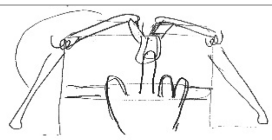
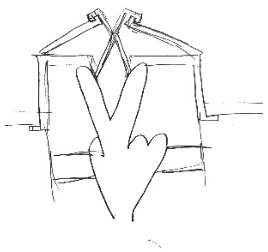


Appendix B Brainstorming

Ideas generated during the brainstorming session that was held 2017-02-22.

Picture	Description	Reason for discarding
	Two horizontal springs (instead of vertical) that is precipitated from the main body when relaxed. When mounting, the springs are forces in and secured by some mechanism. When pressed through the ceiling the mechanism is de-activated and the two springs are precipitated above the ceiling	Hard to adjust for different ceiling heights and many details including other material than plastics.
	A outer body with two arms attached. When the inner body is inserted it triggers something that is connected to the arms which makes them fold down. The more the inner body is inserted into the outer body, the more the arms are folded out.	*The idea is based on Idea 2 and not discarded.*
	Inner and outer body is attached and between them is a handle. Arms are connected to the outside which are connected to a spring. When relaxed, the arms points down. When the handle is pressed upwards, the arms are forced to point up. The mount can be inserted through the ceiling and when relaxing the handle the arms will fold down and clamp the ceiling.	Springs in metal is needed and the construction is advanced.

	A cylinder split in two halves which is enlarged when rotated. The friction between the walls in the mount and the ceiling makes the mount stay.	If the ceiling is very thin the support area will be too small to create a frictional force that can hold it in place. The solution will probably need two hands for installations.
	Flexible wings are placed on the outer body. These are pressed through the hole. After that part is above the ceiling an inner body is mounted inside the outer body which the camera can be attached to.	*The idea is based on Idea 1 and not discarded.*
	The body has a rod through it. When twisting the rod, it changes in length. When the body is inserted in the ceiling, the rod is the same length of the body's diameter. When the body is above the ceiling the rod can be twisted which makes the rod longer and will therefore keep the body above the ceiling.	The possibility to adjust where the rod should be inserted is making this solution hard to adjust for different ceiling thicknesses. It might be hard to only use one hand and the rod will probably be in the way for the camera unit.
	The body has a rod formed as the inside of the body. This rod gets longer when twisted. After the body is above the ceiling, the rod can be rotated 180° which makes mounting of the camera possible.	Hard to adjust for different ceiling heights and two hands might be needed.
	The body is made in a flexible material which makes it possible to be pressed together as in the upper picture. This makes it easy to insert into the ceiling and when it is done, the body relaxes and the walls of the body is pressed against the hole in the ceiling. A support can be used to ensure that the mount stays over the ceiling. The support should be able to adjust to the ceiling height before mounting.	Hard to adjust for different ceiling heights and the flexible material might cause trouble in a long-term-perspective.

	The body has torsion springs that can stand upright secured by a lace. When the lace is pulled down, the torsion springs will rotate downwards and make sure the mount is hold above the ceiling.	The risk of someone being hurted is big if the lace is pulled down too early. Metal is needed for the torsion springs. The lace must be thrown away after installation.
	The body has torsion springs that can stand upright secured by a protrusion with a hole. When the handle is pressed together with this protrusion, the torsion springs will rotate downwards and make sure the mount is hold above the ceiling.	Metal is needed for the torsion springs.
	The body has torsion springs that can stand upright secured by a scissor-like mechanism. When the scissor-like-legs are pressed together, the torsion springs will rotate downwards and make sure the mount is hold above the ceiling.	Metal is needed for the torsion springs and the movement needed to press the legs together might be hard and unnatural.

Appendix C Meeting Notes

Notes from the meeting with Andreas Sjunnesson and Magnus Klügel at Axis 2017-02-28. They are polymer specialists and have a great knowledge in plastic design, design for manufacturing among other areas. Main learnings from the meeting are summarized below and were used when selecting between the 12 different concepts.

- The living hinge should be avoided if possible since it is difficult to injection mould. Another kind of hinge is recommended.
- Three load points are better than two for stability.
- Three load points are better than four for stability.
- If some flexibility is wanted relaxation will be a fact that might lead to deformations.
- Design the "arms" so that they are thicker in the bottom and thinner in the top. This will lead to an even stress distribution.
- Relaxation and the time effect during constant load is important when designing in plastic.

Appendix D Test Setup

Test Setup on Living Hinges

Short Time Tests of Living Hinge

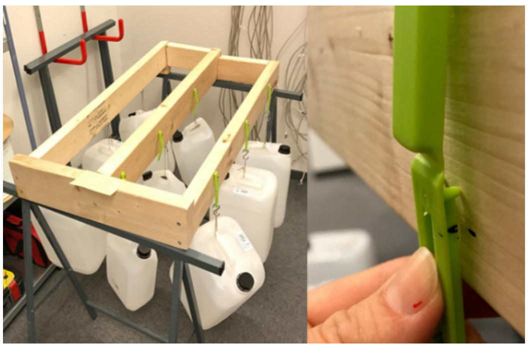
The following steps were performed in the short time test:

1. Holes were drilled in the samples.
2. The sample was fastened in the Zwick using a hook and a bolt.
3. The Zwick was set to pull with the velocity of 80mm/min
4. Step 2 and 3 was repeated for all the samples.
5. Results of force and displacement was summarized in the test software.

Time Dependency Tests of Living Hinges

The following steps were performed in the time dependency tests:

- A test rig was built with wooden planks in a framework.
- The sealing clips were prepared as in the short time test.
- The sealing clips were mounted to the wooden framework by screws.
- Water carriers were filled with water until reaching the correct weights of 10, 6, 4 and 1.5 kilos.
- The water carries were hung in the sealing clips by strings and hooks.
- A mark was made on the sealing clip as well as the wooden framework besides each clip to be able to determine whether creep has occurred or not.



D 1 Test setup of time dependency test.

Appendix E Result Time Dependency Tests

A selection of the living hinges before load and after three weeks of being loaded with different weights.

E 1 - 6 kg

E 2 - 10 kg

E 3 - 4 kg

E 4 – 1.5 kg

Appendix F Polypropylene

Technical Data of Polypropylene TAIRIPRO K1011

TAIRIPRO K1011

Polypropylene Homopolymer

Formosa Plastics Corporation

PROSPECTOR®
www.ulprospector.com

Technical Data

Product Description	
FCFC PP resin K1011 meets the requirements of UL, FDA, RoHS and the certificates of environmental protection.	
General	
Material Status	• Commercial: Active
Literature [1]	• Processing (English) • Technical Datasheet (English)
UL Yellow Card [2]	• E162823-224734
Search for UL Yellow Card	• Formosa Plastics Corporation • TAIRIPRO
Availability	• Asia Pacific • Europe • North America
Features	• Homopolymer
Agency Ratings	• EC 1907/2006 (REACH) • FDA 21 CFR 177.1520
RoHS Compliance	• RoHS Compliant
UL File Number	• E162823
Forms	• Pellets
Processing Method	• Injection Molding

Physical	Nominal Value Unit	Test Method
Specific Gravity	0.900 g/cm³	ASTM D792
Melt Mass-Flow Rate (MFR) (230°C/2.16 kg)	15 g/10 min	ASTM D1238
Molding Shrinkage - Flow (23°C)	1.4 to 1.8 %	Internal Method
Mechanical	**Nominal Value Unit**	**Test Method**
Tensile Strength (Yield, 23°C)	34.3 MPa	ASTM D638
Tensile Elongation (Break, 23°C)	> 200 %	ASTM D638
Flexural Modulus (23°C)	1420 MPa	ASTM D790A
Impact	**Nominal Value Unit**	**Test Method**
Unnotched Izod Impact (23°C, 3.18 mm)	27 J/m	ASTM D256
Hardness	**Nominal Value Unit**	**Test Method**
Rockwell Hardness (R-Scale, 23°C)	100	ASTM D785
Thermal	**Nominal Value Unit**	**Test Method**
Deflection Temperature Under Load		ASTM D648
0.45 MPa, Unannealed, 6.35 mm	110 °C	
Flammability	**Nominal Value Unit**	**Test Method**
Flame Rating (1.50 mm, All Colors)	HB	UL 94

Injection	Nominal Value Unit
Mold Temperature	30.0 to 50.0 °C
Injection Pressure	7.85 to 11.8 MPa
Injection Notes	
Screw Temp 200-290°C	

Notes

[1] These links provide you with access to supplier literature. We work hard to keep them up to date; however you may find the most current literature from the supplier.

[2] A UL Yellow Card contains UL-verified flammability and electrical characteristics. UL Prospector continually works to link Yellow Cards to individual plastic materials in Prospector, however this list may not include all of the appropriate links. It is important that you verify the association between these Yellow Cards and the plastic material found in Prospector. For a complete listing of Yellow Cards, visit the UL Yellow Card Search.

[3] Typical properties: these are not to be construed as specifications.

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Document Created: Wednesday, October 08, 2014
Added to Prospector: April, 2008
Last Updated: 9/2/2014

Where to Buy

Supplier

Formosa Plastics Corporation
Taipei, Taiwan
Telephone: +886-2-2712-2211
Web: http://www.fpc.com.tw/

Distributor

Please contact the supplier to find a distributor for TAIRIPRO K1011

Document Created: Wednesday, October 08, 2014
Added to Prospector: April, 2008
Last Updated: 9/2/2014

Appendix G Polyketone

Technical Data of Polyketone

A. Schulman

SCHULAKETON NV

Polyketone, Aliphatic
Engineering Plastics

Product Description			
Low viscosity aliphatic Polyketon			
General			
Material Status	• Commercial: Active		
Availability	• Africa & Middle East • Asia Pacific	• Europe • Latin America	• North America
Processing Method	• Injection Molding		
Resin ID (ISO 1043)	• PK		

Physical	Nominal Value (English)	Nominal Value (SI)	Test Method
Density	1.24 g/cm³	1.24 g/cm³	ISO 1183/A
Melt Volume-Flow Rate (MVR) (240°C/2.16 kg)	3.66 in³/10min	60.0 cm³/10min	ISO 1133
Mechanical	**Nominal Value (English)**	**Nominal Value (SI)**	**Test Method**
Tensile Modulus	210000 psi	1450 MPa	ISO 527-2/1A/1
Tensile Stress (Yield)	9430 psi	65.0 MPa	ISO 527-2/1A/50
Tensile Strain (Yield)	18 %	18 %	ISO 527-2/1A/50
Flexural Modulus [1]	218000 psi	1500 MPa	ISO 178
Flexural Stress [1]			ISO 178
9.0% Strain	7980 psi	55.0 MPa	
3.5% Strain	5800 psi	40.0 MPa	
Impact	**Nominal Value (English)**	**Nominal Value (SI)**	**Test Method**
Charpy Notched Impact Strength			ISO 179/1eA
-40°F (-40°C)	2.4 ft·lb/in²	5.0 kJ/m²	
73°F (23°C)	7.1 ft·lb/in²	15 kJ/m²	
Charpy Unnotched Impact Strength			
-40°F (-40°C)	No Break	No Break	ISO 179
73°F (23°C)	No Break	No Break	ISO 179/1eU
Thermal	**Nominal Value (English)**	**Nominal Value (SI)**	**Test Method**
Heat Deflection Temperature			ISO 75-2/Af
264 psi (1.8 MPa), Unannealed	212 °F	100 °C	
Vicat Softening Temperature	376 °F	191 °C	ISO 306/B50
Flammability	**Nominal Value (English)**	**Nominal Value (SI)**	**Test Method**
Burning Rate (0.0787 in (2.00 mm))	< 3.9 in/min	< 100 mm/min	ISO 3795
Flame Rating			UL 94
0.06 in (1.6 mm)	HB	HB	IEC 60695-11-10, -20
0.13 in (3.2 mm)	HB	HB	
Glow Wire Flammability Index			IEC 60695-2-12
0.06 in (1.5 mm)	1290 °F	700 °C	
0.12 in (3.0 mm)	1290 °F	700 °C	

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Publish Date: 2017-05-04