Pig Ear Tagger Concept

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MASTER THESIS

Pig ear tagger concept

Developing a specialized work tool concept using the Ulrich and Eppinger process

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Abstract

This thesis consists of the development of a concept for a new product, the primary purpose of which is to quickly and easily attach legally required tags to the ears of livestock pigs. The project was undertaken at Attention, a product development company based in Copenhagen.

For reasons of food safety, EU regulation stipulates that all pigs that are moved from their place of birth must be tagged with a permanent plastic tag on which the pigs country and farm of origin is marked. These tags consist of two elements, which when joined together form a tag. A large force is required to drive the male element tip through the ear tissue and make it stick in the female tag element socket. The common plier tool that is currently used is inexpensive, but strenuous and slow to use.

The existing automatic tagging machines are expensive, and force their users to adopt a specific and rigid work routine, which on many farms is impossible. This demonstrates the need for a tool that is as handy and flexible as the plier tagger, but that provides the high rate of tagging as the existing automatic taggers.

The Ulrich and Eppinger method for concept development was used as a basis for the structure of the project. This method bears great resemblance to the method employed by Attention design, which was being formalized into a revised written set of documents as this project was undertaken. The stages *Specification, Ideation* and *Concept Development* was included in the project.

In the *Specification* phase, the user needs were studied extensively. Study visits to Danish pig farms and agricultural trade shows were made. With the aid of online resources, subjects such as good pig handling practice, relevant regulations and the general state of the European pork industry has been studied.

In the *Ideation* phase product concepts that would satisfy the user needs were generated. Drafts for mechanical solutions to the problems inherent in these product concepts were drawn. The problems were broken down into smaller problems. The *Ideation* phase was concluded by choosing a combination of sub-concepts to become the basis of the concept. The chosen concept included a battery powered motor and a new shape for the plastic tag elements. Unlike existing tags, the concept tags are to be molded in strips of 20.

In the *Concept Development* phase, the concept was developed mainly by specifying the various mechanisms necessary for the function of the tagger.

Keywords: product development, agriculture, handheld power tool, ear tags, pig

Sammanfattning

Detta examensarbete består av utvecklingen av ett koncept för en ny produkt, vars främsta syfte är att på ett snabbt och bekvämt sätt fästa de öronmärken för grisar som krävs enligt lag. Projektet utfördes hos Attention, ett produktutvecklingsföretag baserat i Köpenhamn.

Av matsäkerhetsskäl stipulerar EU-regleringar att alla grisar som transporteras från sin födelseort måste öronmärkas med ett plastmärke med grisens nationalitet och födelseort. Märkena består av två delar, som bildar ett öronmärke först när de sammanfogats. En stor kraft krävs för att både driva den handelens spets genom öronvävnaden och därefter fästa handelen i hondelens hylsa. Tångverktyget som är i brukär billigt, men användningen är långsam och ansträngande.

Existerande automatiska öronmärkningsmasker är dyra, och de tvingar sina användare att använda en specifik och stel arbetsrutin, som på många gårdar inte fungerar. Detta synliggör behovet av ett verktyg som är lika behändigt och mångsidigt som tångverktyget, men som medger den höga arbetstakten som de automatiska öronmärkningsmaskinerna.

Ulrich och Eppingers metod för produktkonceptutveckling användes som grund för projektets struktur. Metoden har stora likheter med Attentions metod, som Attention formaliserade under projektets gång. Projektet rymde faserna *specificering, idéutformning* och *konceptutveckling* (*Specification, Ideation* och *Concept Development*).

I specificeringsfasen studerades användarbehoven utförligt. Det gjordes studiebesök till Danska grisbondgårdar och jordbruksmässor. Med hjälp av källor tillgängliga på nätet studerades gott grishandhavande, relevanta juridiska krav och den europeiska grisindustrin.

I idéutformningsfasen genererades produktkoncept som kunde tillfredsställa användarbehoven. Det togs fram utkast för mekaniska lösningar till de problem som var inneboende i dessa produktkoncept. Problemen bröts ned till mindre problem. Idéutformningsfasen avslutades genom att en kombination av underkoncept valdes. Dessa blev grunden för produktkonceptet. Det utvalda konceptet innehöll en batteridriven motor och en ny form för öronmärkena.

Till skillnad från de existerande öronmärkena så ska produktkonceptets öronmärken gjutas i remsor om tjugo märkesdelar.

I konceptutvecklingsfasen skedde utvecklingen i första hand genom specifikation av öronmärkarens de olika essentiella mekanismerna och funktionerna.

Nyckelord: produktutveckling, jordbruk, handhållet verktyg, öronmärken, gris

Acknowledgments

A great thank you is due to all of the charitable and helpful professionals that I have encountered during this project. Attention Design provided me with ample resources and support, while keeping me on a very long leash throughout the project. Thank you very much, the academic and administrative staff at LTH. Last, but not least, I am very grateful to all of the farm managers who let me come and visit, and to all of the farm workers who let me bother them with my cameras and silly questions.

Lund, September 2016

Axel Nordberg

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1 Introduction

1.1 Background

This project was conducted at Attention Group. Attention Group is a company that delivers product development services from their headquarters in Copenhagen. The company has design, engineering and production departments. The need for a new tool was expressed by a client of Attention's. The client retails tools for industrial pig farming.

1.2 Purpose

The purpose of this project has been to develop a new concept for a tool that applies tags to the ears of pigs, in accordance with European Union regulations. The concept tool will better suit the user than existing tools and related work processes.

1.3 Delimitations

Detailed technical analysis has only been done when necessary to confirm the viability of design choices.

It was assumed early on that radical changes to the geometry, function or materials of the penetrating part of the male tag element as well as the part of the female tag element which holds the tag together should be avoided. This hypothesis was later confirmed, see section 3.1.

1.4 Method

A blend of the *Attention Design Process* and the *Ulrich and Eppinger Product Design and Development* methods was applied in this project. The project spanned from the phases that in Attention terminology are called *Specification, Ideation* and *Concept development*. These phases roughly correspond to the following stages in the Ulrich and Eppinger method: *Concept Development, System Level Design* .The *Attention Design Process* phase *Specification* corresponds to the first half of the first Ulrich and Eppinger phase, while *Ideation* corresponds partly to the later stages of Ulrich's and Eppinger's *Concept Development* and *System Level Design* phases. The final phase of this project is *Concept Development,* which is concerned with refining the concept selected in the previous phase. See tables 1.1 and 1.2 for a visualization. It should be noted that, in this project, the purpose of the detailed work with the mechanism of the product was to demonstrate that the concept was theoretically viable, rather than purposefully produce a set of dimensions and other specifications that would be viable in the final iteration of the product. In the Attention Design Process, that work is undertaken in the subsequent *Detailing* phase. (Ulrich & Eppinger 2012; Attention Group 2016)

Table 1.1: Ulrich and Eppinger product development process. Phases 1-2

Phase	***Concept development***	***System level design***
Main activities and objectives	• Identify and customer needs and target specifications. • Generate, select and test concepts.	• Develop product architecture. • Define sub-systems. • Preliminary component engineering.

Table 1.2: Attention design process. Phases 1-3

Phase	***Specification***	***Ideation***	***Concept development***
Main activities and objectives	• Identify and customer needs and target specifications.	• Generate, select and test concepts. • Develop product architecture • Define sub-systems	• Preliminary component engineering.

During the *Specification* phase, an extensive pre study was made to gain knowledge of the requirements on the concept. Study visits to pig farms and agricultural trade shows were made. Through online resources, subjects such as good pig handling practice, relevant regulations and the general state of the European pork industry were studied. Existing products were studied, both the most commonly used simple plier tagger to the much more advanced and expensive products that aim to replace it, as well as similar products used on other types of livestock. Competing products were studied by examining them at trade shows, and their promotional videos by interviewing potential customers and by studying patent documents. A list of primary requirements for a concept for a new ear tagger was made.

In the *Ideation* phase product concepts that would satisfy the user needs were generated. Drafts for mechanical solutions to the problems inherent in these product concepts were drawn. This was done by breaking down the problem of developing a concept into three sub-problems, for which sub concepts were generated. These three sub-problems were: Tags and magazine, power source and power train, product architecture. The tags and magazine sub concept was chosen by concept scoring against a set of criteria.

The power source and power train sub concept was chosen by analyzing possible methods to generate linear force, and choosing the simplest and least expensive method that would meet the force and speed requirements.

The shape and product architecture sub concept was chosen by user testing. Three papier machié models with different shape, length and with different grip angles were tested by experienced pig farm workers in a pig sty in Skåne, Sweden.

During this process, secondary requirements, such as required compressing force and maximum time to finish the tagging cycle speed, were defined. The *Ideation* phase was concluded by choosing a combination of sub-concepts to become the basis of the concept for a new tagger product.

The chosen concept included an internal power source (battery) and a new shape for the plastic tag element molds. Unlike existing tags, the concept tags are to be molded in strips of 20

In the *Concept Development* phase, the concept was developed mainly by specifying the various mechanisms necessary for the function of the tagger. Solutions to problems that had previously been left unsolved were invented. Notably, the mechanism which feeds the strips of tag elements and holds them in place was designed. Further testing was made to confirm the choice of power train.

2 Specification

The specification phase could be described as a pre-study, the main task of which was to identify customer needs in order to set target specifications for the product.

2.1 Ear marking pigs

Owners of pigs and other feedstock animals in the EU are required to attach identification ear marks according to their respective national laws, which have been written in accordance with EU regulation No 1760/2000 of the European Parliament and of the Council.

In Denmark, these rules are applied by the Ministry of Environment and Food of Denmark. (BEK nr 303 af 27/03/2015) required by EU law, similar rules are applied in Sweden by the Swedish Board of Agriculture (SJVFS 2010:15).

The rules define both some technical qualities of the tags (such as their color and material properties), as well as the information that must be written on them. The Danish regulations specify that each pig that is transported from its place of birth must be marked with a number which is unique for that specific farm (CHR number), as well as a country code and logo (DK and a crown) (BEK nr 303 af 27/03/2015). See below for photograph of common ear tag. The diameter of the round flat part of the ear tag element is approximately 27 mm.

Figure 1: Common ear tag. Tracecompany A/S

In addition to the legally required CHR number, many farmers mark their pigs with an additional ear tag with a numberwhich is unique to that particular tag. This enables the farmers to keep track of individual animals, which provides useful information. This is used primarily by farmers that mainly produce breeding pigs, while farmers that focus on meat production use only the legally required CHR number tags.[2]

Best practice when applying ear tags is to be wary of their placement. The ear tag should be placed in the center of the ear, to make sure that it is securely fastened. If the tag is placed on the edge of the ear, there is a risk that something pulls the tag in a way that injures the pig. The ear tag should be placed in the center third of the ear. See below for an illustration on general guidelines for attaching ear tags to livestock.

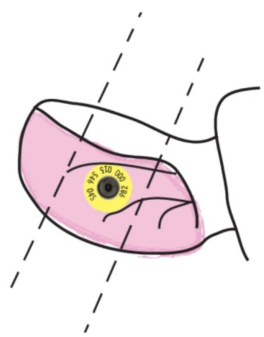

Figure 2: Proper placement of tag. (Oklahoma State University n.d.)

2.2 Current work routine[3]

The ear tagging method is similar when applying tags with just CHR and tags with both CHR and ID. However, ID tagging does of course add an extra level of complexity, as it requires a solution that gets each pig tagged with the correct ID number, whereas the CHR is the same for the entire pig farm.

Ear tagging is generally performed on pigs weighing 30 kg or less. Because of the rational organization of the work at the farm, several different procedures are

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[2] Mia Lind, manager at Tybjergaard farm for pigs for breeding. Conversation during study visit.(2016-02-02)

[3] This section is based on what was found when conducting study visits to Håstrupgård in Fredericia (2016-01-21), Tybjergaard in Herlufmagle (2016-02-02), Pedersen Multisite in Lejre (2016-02-11).

performed on the pigs in the same routine as the tagging. The combination and order of the various procedures varies from farm to farm. The importance of flexibility in this routine was apparent during the study visits. Often, the tools are modified by the user, for example by duct taping a paint marker to a syringe in order to be able to conveniently mark piglets who have been injected, using only one hand. In one of the farms visited, the timing of the ear tagging was dictated by the specific requirement of a medication, which, in order to be effective, must be distributed to the pigs between their third and fifth day of life. Consequentially, on that particular farm, all ear tags were applied to the pigs between their third and fifth day of life.

2.2.1 **User scenario 1: high volume tagging on a farm that exclusively exports piglets for slaughter**

This is the archetype user scenario that has created the interest in the product concept envisioned by the client. The source for this description is observation confirmed by interviewing. The pig farm produces almost exclusively piglets for slaughter, and 100 % of the piglets are exported to be put in stalls and slaughtered abroad. Since the farmers know that every piglet will be exported, they know that 100 % of the piglets must be ear tagged, and thus the ear tagging is included in the everyday routine.

It is performed by ideally two workers who walk down the aisles of the pigsty, performing procedures on those groups of piglets who are in the right age (during my study visit, this was 3-5 days). Each room with an aisle contains 16 small stalls each containing one litter: 13-15 piglets (and sow). The piglets receive a medicine injection, an iron supplement injection, castration (if male) and they are ear tagged. The approximate time for one litter is five minutes. The manager of the pig farm estimates that half of this time is ear tagging. Every piglet in one small stall is placed in one of two baskets on the cart. One worker does all tasks except for ear tagging, moving the piglets between the baskets to keep track of which piglets have been processed and which are still to go. The worker who applies ear tags can easily see which piglets are tagged, and which are not, and can therefore tag the piglets where they are, without moving them between the boxes. When all piglets in a small stall are processed, the cart moves on to the next stall, and the process repeats.

Approximately once every five stalls (i.e. once every 70 piglets), there is a short break to refill medicine injectors, clean the baskets on the service cart and so on. Hygiene routines are important to limit the spread of diseases.

If an ear tag or two is lost in user scenario 1 or user scenario 2, it is of little importance. A new one can be attached as soon as the problem is discovered.

2.2.2 **User scenario 2. Hasted tagging on a farm that only exports excess piglets for slaughter.**

This scenario was described by the manager of the farm described in user scenario 1, stating that he had previously worked in the manner described below. Farms that keep mainly piglets for slaughter within Denmark often commit to a hygiene and food security arrangement which is sanctioned by the authorities as an exempt from the ear tagging requirement. Many farms in Denmark are arranged in this way, with a small number of farms in each arrangement. For a farm producing piglets that are to be matured in another farm within the same arrangement, it is unnecessary to ear tag each piglet, so this procedure is omitted from the daily routine. If however, there is a surplus of piglets that can not be housed by the other farms in the arrangement, the surplus piglets must be sold on the open market, and then they must be ear marked. Because of the timing of these events, the piglets may weigh over 25 kg, and they must be marked in quite a haste. They may be marked while kept tightly packed in small stalls. During this tedious procedure, one worker gets the pigs in place, while the other operates the ear tagging pliers. Ear tags are kept either in pants pockets or in baskets that can be hanged on the edge of a nearby stall. The baskets with tags can not be kept in the same stall as the pigs getting ear tagged, as they are likely to tip the basket over, spilling all the ear tags down on the floor of the stall. In this scenario, hundreds of pigs must be tagged in a short period of time. The current process is generally costly in manpower and quite exhausting for the workers.

2.2.3 **User scenario 3: ID tagging on a farm producing breeding pigs**

The source of this description is observation confirmed by interview. In a farm where breeding pigs are produced, the procedure is similar to the one described in scenario 1. Regardless of wether or not the piglets are being exported, they will be marked for practical reasons. In breeding, and trading with breeding animals, is important to know which pig is which. The legality is not what prompts the ear marking, unlike in scenario 1 and 2. Also unlike scenario 1 and 2, the ear marks are not simply printed with the CHR number of the farm, but also with a unique ID number. Sometimes the tags contain an RFID tag which interacts with various modern farming technologies. The piglets that are being ear tagged in this process have already been assigned their ID number, which can be read from a simple kind of temporary ear mark in the shape of a clamp, which is attached when the piglets are very young. The reason for the temporary ear mark is that in the breeding pig industry, it could be a serious problem if it becomes impossible to identify a pig. The permanent tags have a high risk of being lost later in the life of the pig, if the tags are attached when the pig is very small.

When the pigs are old enough (6-10 kg) the temporary ear mark is removed and replaced with one or two proper ear tags with the same appearance as the ones in user scenario 1 and 2, but with the ID and possibly RFID. The worker has with him a basket with sheets of cardboard, each holding a range of male ID ear marks. As the worker is processing the piglets, he browses through his stack of cardboard sheets looking for the ear mark with the same number as the piglet he is currently processing. The female part of the tag is unmarked. For piglets that received both a tag with the CHR number and a tag with ID+RFID, the female tags were not the same for both kinds of tags. This was apparently without any technical reason, and added complexity to the work.

It should be noted that breeding pigs are only roughly 10 % of the total population. Satisfying the need to give correct ID to the piglets numbers might eventually prove to be too costly in other features of the product, thereby excluding the user needs from this scenario from the final concept.

2.3 Existing solution: Manual Plier

The most common way to attach two-part ear tags to livestock animals is the manual plier (see figure 3). The plier consists of two arms and a central joint. Before tagging, a male and a female tag element are mounted in the plier. The male tag element is mounted on a steel pin, which provides rididity as the tag penetrates the ear. The female tag element is mounted in a slot in the opposite arm. The slot is open in the direction straight away from the central joint of the plier. When an ear is tagged, the arms are rotated around the joint so that the male tag element penetrates firstly the pigs ear, secondly the female tag element. When the penetration is complete, the operator relaxes his or her grip, and spring pressure causes the arms to rotate back to their original position. As the tag elements are joined, the steel pin is retracted from the male tag. At this moment, the female tag element slides out of its slot, and thus, the pig is separated from the pliers.

The compression force required just to join the tag elements has been determined to be approximately 350 N, and roughly 50 % more when an ear is penetrated. This is described in detail in the appendices test 1,2 and 3. This force is generated by the gripping action of the operator. If used one-handed, the pliers do not offer much leverage, as positioning the hand far enough out on the handles to gain leverage makes it impossible to reach around both the handles. When the compression is partially complete, and the handles are closer to each other, the user may grip the handles with his or her other hand, far from the joint, to provide great leverage and finish the tagging.

As the tagging cycle restarts, the user must mount new male and female tag elements on the pliers. If the situation is best likened to user scenario 1 or user scenario 3, both described above, the tag elements are typically retrieved from plastic bags with tag elements (one bag for each gender) placed in the cart. If the user finds him- or herself in a scenario better described by user scenario 2, the tags are typically placed in pants pockets or another container that is more portable than the cart.

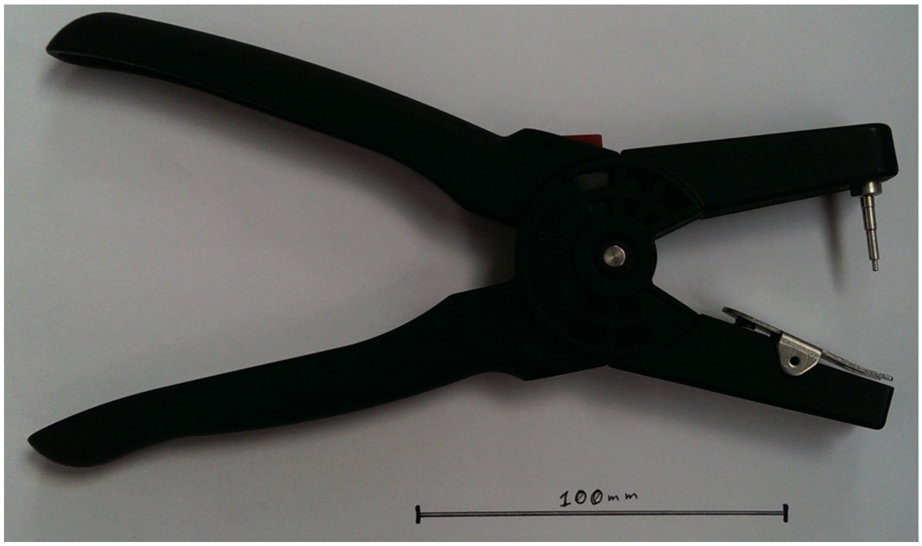

Figure 3: Manual plier tagger

2.3.1 Manual plier:conclusion

The manual pliers, while inexpensive and easy to implement in different work routines, are also slow and strenuous to use, especially when large quantities of ear tags are to be applied.

2.4 Existing solution: Automatic tagger

Two products that significantly increase the rate of the CHR tagging exists. They are marketed by MS Schippers and Merko, and they are both very similar to each other. They consist of a specially made treatment trolley to which automated equipment is mounted. This includes a machine for needleless injection of iron supplements, a machine for oral injection of medication, a tail cutter, and a large, automated ear tagging machine. The ear tagging machine is either gravity fed with stiff strips of 25 ear tag elements per strip (Merko) or fed by the trolley's power supply and long belts of ear tags mounted on large rolls (MS Schippers). Below is a screenshot from a promotional video published online by MS Schippers.


Figure 4: MS Schippers automatic tagger. A red strip of female tag elements is visible, as well as a smaller section of yellow male tag elements. (MS Schippers)

The method of use of these products, as perceived from looking at their marketing videos (MS Schippers 2013; Merko NV 2014) is similar, with a few differences. The Merko trolley has a basket which permits the worker to load up all the piglets in the basket and then process them one by one, without having to go fetch each piglet in the small stall, every time one of them has been processed. The MS Schippers trolley does not have baskets, and is rather supposed to be operated by one worker collecting piglets, one by one, and handing them to the other, who process them with the trolley (holding the processed piglet with both hands during the whole process) and puts them back into the stall. This setup would make it very time consuming to do the work alone, if only one worker is availible. The reason for omitting baskets from the design is to reduce the spread of disease from piglet to piglet. Indeed, the MS Schippers trolley is also equipped with a desinfectant pump to be used on the farm worker's hands (which, in the marketing video, are covered with single use rubber gloves).

The MS Schippers product is powered by an air compressor, likely in the 5-10 Bar class, which provides air pressure to power the mechanism. Both of the automatic tagger products must be connected to an electric power outlet by a power cord which is contained on a roller inside the cart. From the patents for the MS Schippers product, it is evident that the invention was originally intended to be fixed in a wall mount. The author of the patent states that this would greatly increase the rate of tagging, but omits that this would require a substantial rearrangement of the facilities where the product is to be used. For a graphic description of the interior of this machine, see figure 5. (Claessens A.W. J. 2010) Interview with managing staff at a pig production site where the tagging work can be likened to user scenario 1 stated that although the existing automatic taggers had potential, they had drawbacks which prevented them from becoming universally accepted. These are a combination of inflexibility and cost. If the management of a pig sty chooses to implement either of the automatic taggers described above in their operation, the management must implement the entire system marketed by the companies that sell the automatic taggers. These are, for example, injection systems for medicine and diet supplement equipment that are used to orally distribute iron supplement to the piglets. Each of these replacements are substantially more expensive than the conventional methods in use at most pig production sites. Once they have been implemented in the work process, the pig production site becomes dependent on the consumable parts, medicines and iron diet supplements that are provided by the company that sold them the equipment. In addition to this inflexibility, if any component of the system should break down, the entire work process is halted until this component has been replaced. It is economically unfeasible to keep, for example, a spare needleless injection gun on a shelf in the pig production site, to be ready if the main injection gun fails. As a comparison, one interview subject said that the conventional and inexpensive needle injectors where regarded as consumable material, and purchased in large quantities. If a conventional needle injector fails, it can be replaced instantly, without hampering the work.

The third aspect of inflexibility of the existing automatic tagging systems is that they can only be used on piglets. In order to tag the pig, it has to be lifted to the tagger, which is fixed on top of the cart. This makes it completely impossible to use any of these products in user scenario 2, or any other situation where a large number or pigs older than a few weeks must be tagged. (MS Schippers 2013; Merko NV 2014)

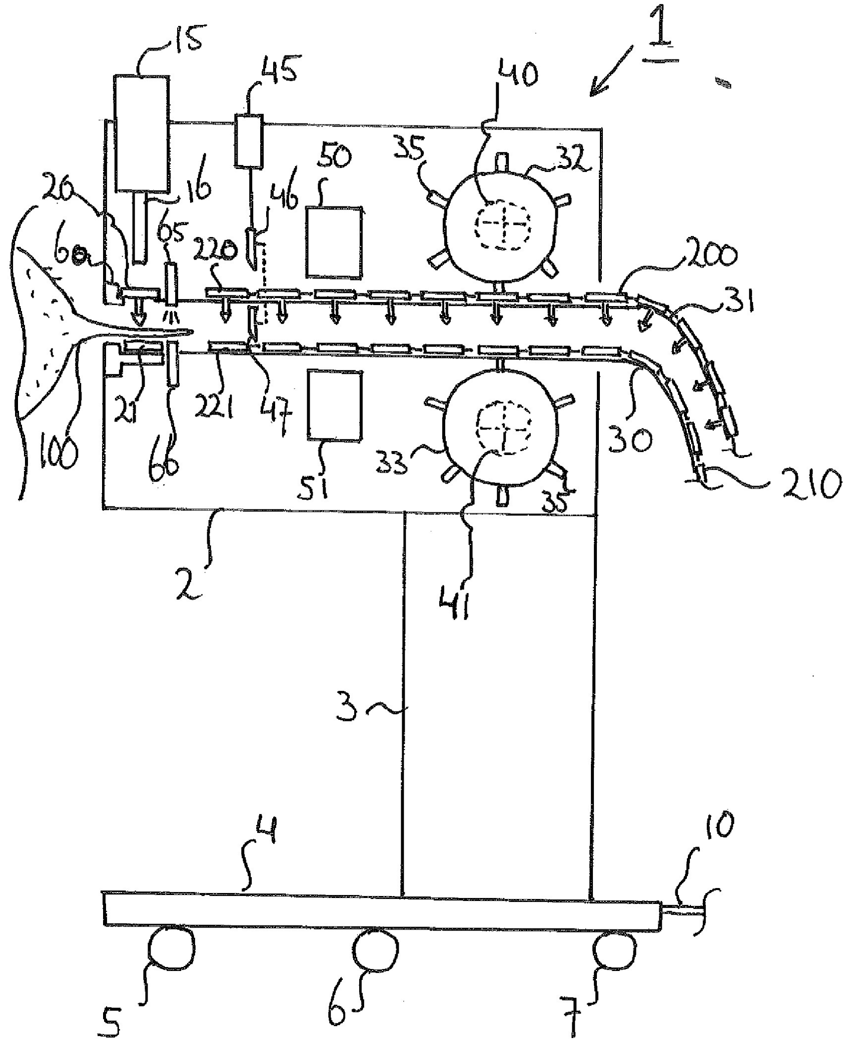

Figure 5: Patent illustration

2.4.1 **Existing automatic taggers: conclusion**

The existing automatic taggers offer greatly increased rate of tagging, and when combined with the proprietary additional equipment, such as the injection guns and oral dispensers, can greatly increase the speed of related work processes as well. Their downside is their high cost and their inflexibility.

2.5 Product specifications

The following are the requirements that are deduced from the pre-study. Further technical requirements are discussed in later sections.

2.5.1 **Primary requirements**

The new product must provide for a high rate of tagging. The new product must be more comfortable to use than the manual pliers. The new product must be more flexible than existing automatic taggers. The result of these basic requirements is that the product must be handheld, cordless and it must contain tag elements in an internal magazine. The new product must be easily integrated into the existing work routine.

2.5.2 **Secondary requirements**

The internal power source must last long enough to tag at least 100 pigs before resupplying it in the maintenance room. The internal magazine must have a capacity of at least 10 tags before refill. It must be possible to refill the tagger with one hand, while holding it with the other.

3 Ideation

This chapter is an account of the concept generation and selection. The product concept is divided into three sub concept categories. These are: "Tags and magazines", "Power source and power train" and "Architecture, layout and shape". Concepts for each category have been generated and evaluated.

3.1 Sub concepts: Tags and magazines

A large number of iterations of tag shapes and concepts have been considered. Presented here are the most viable ideas and combinations of ideas.

As mentioned in the delimitations section, one significant design decision limitation was made: It is assumed that any concept with a radically different method of attaching to the ears would be too costly to develop fully, including testing. The viability of this strategy was supported by an interview with an official of the International Committee for Animal Recording (ICAR). ICAR is the body responsible for type-approving ear tags for use on pigs in several EU countries, including Denmark. (BEK nr 303 af 27/03/2015). According to ICAR, there is currently no concrete list of requirements for ear tags specifically for pigs, and their type-approval of such ear tags is based on the requirements for ear tags meant for sheep. The key requirements in this list regard the material used and that the tag can withstand a constant 200 N force under certain conditions without separating. According to Jonas Persson of ICAR, a pig specific set of requirements is being developed, and it is likely that it will be similar the sheep ear tag requirements, with some differences to accommodate for the greater tendencies of pigs to gnaw. [4]While testing, it became apparent that the existing pig ear tags probably outperform the 200 N requirement set for sheep ear tags by a large margin. Several times during the project, people knowledgeable in the field of ear tagging pigs stated that the durability and thus reliability were important features of the ear tags. Because of these circumstances, rather than to try and optimize the joining of the ear tag elements to minimize the force required (which would lower the requirements on the tagger product), during this project, one delimitation is the assumption that the geometry and material properties of the joining parts of the tag elements are functionally identical to those of the existing ear tags sold by Attention's client.

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[4]Jonas Persson of ICAR, telephone interview on the 3rd of November, 2016

3.1.1 **Existing tags in existing plier**

The existing tags are very well suited for the context in which they are used. Because they are rotationally symmetric, it is easy to correctly put them into the tagging pliers. When they are attached to a pigs ear, they have no protruding sharp edges. They are also sufficiently strong to be retained in a pigs ear throughout the life of the pig, without separating. Because the plier is loaded with one tag at a time, the subconcept scores zero in the category "tag capacity per load".

3.1.2 **Spring loaded box magazine loaded with separate tag**

The tags are kept in under spring pressure in a linear stack. The tag which is the farthest from the spring is presented so that it may be used in the next tagging. After each tagging, the spring pushes the stack forwards so that a new tag is presented for tagging. The male and female tags are kept in separate stacks, although possible driven by the same spring. The box magazine is detachable from the tagger, and it is possible for the user to keep multiple box magazines loaded with tags and change them out whilst working in the aisles of the sty. Once the magazines have been depleted, it would be necessary to refill them, one tag at a time.

The strength of the box magazine concept is that it is potentially compatible with existing tags, while providing the capability of tagging at least ten pigs in quick succession (A box magazine containing ten tags would be approximately 250 mm long, a circular box magazine with a 250 mm diameter would have a capacity of approximately 25 tags).

The weaknesses of the box magazine concept is firstly that it could prove difficult to construct a reliable magazine that is compatible with the existing tags. If the tags would be redesigned for more reliable feeding, this could be mitigated, but that would eliminate one of the strong points of the box magazine concept. Secondly, if the box magazine is loaded one tag at a time, it will require the user to invest just as much time per tag as the legacy product. Figure 6 is a rendering of the spring loaded box magazine with separate tags sub concept.

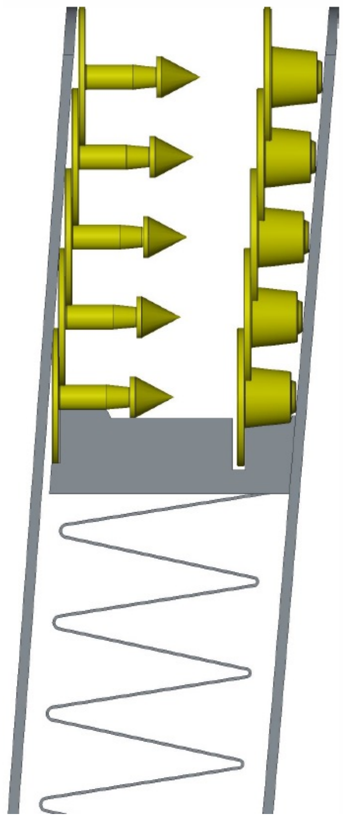


Figure 6: Spring loaded box magazine

3.1.3 **Individual slots in a detachable bar**

A bar containing two rows of corresponding slots for both male and female tags holds the tags in position. The slots are similar to those on the existing pliers. The male tags are not kept on individual pins, but in a position which allows the pin to penetrate the male tag and force it through the ear and into the male tag. After each tagging, the slot moves one position. The user experience of this concept is in many ways similar to the spring loaded box magazine loaded with separate tags: this tag and magazine concept permits tagging at least ten pigs in quick succession, but after those ten pigs, the user would have to load each slot with a male and a female tag. Even if the bar magazine would be detachable, and the user could keep several bars loaded with tags, the amount of time invested in each tag would not be much lower than if the user would have used the existing plier tagger. It should be noted that this concept would be significantly simpler to develop into a functional prototype, compared to the box magazine concept, and that it would probably be compatible with a manually powered tagger. Figure 7 is a rendering of this sub concept.

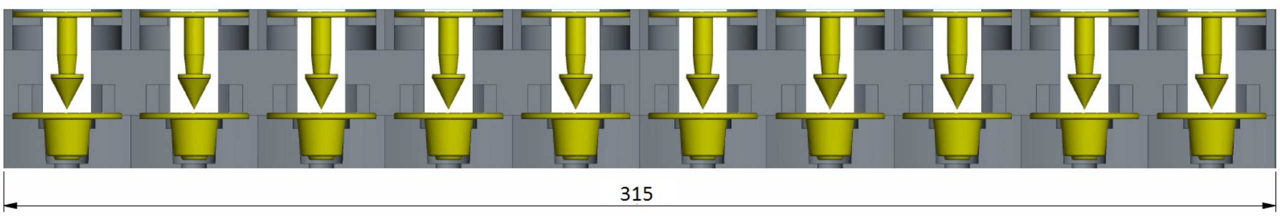


Figure 7: Individual tag elements in detachable bar

3.1.4 **Individual slots in a drum**

Similar to the concept with individual slots in a bar, but the ability to detach the bar and replace it with a loaded one is forsaken for a permanently fixed magazine with a less protruding profile. See figure 8 for reference.

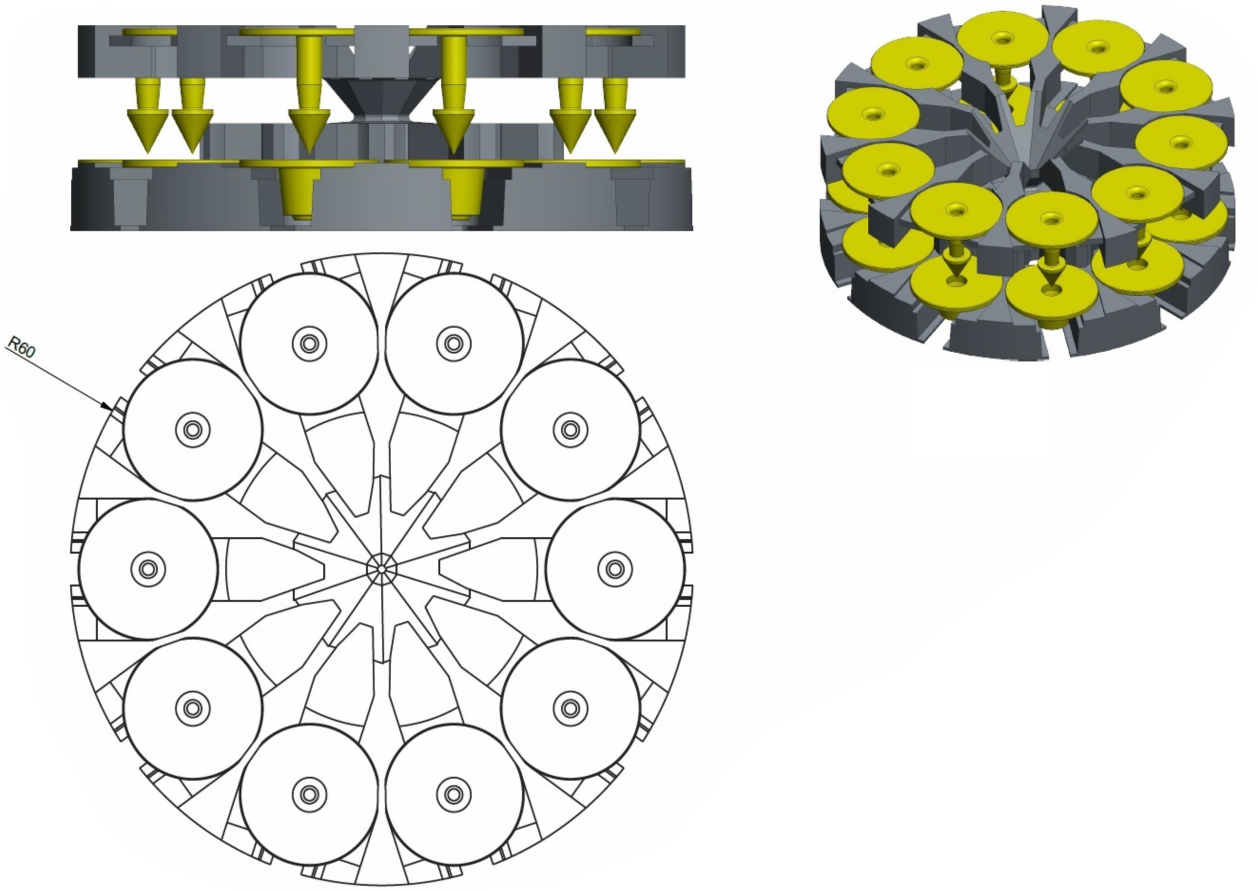


Figure 8: Individual tag elements in slots in a drum

3.1.5 **Slanted strip of tags in screw formation**

This concept is much like #5, but the separating indentation between each strip is slightly slanted, so that when the strip is bent, it forms a screw. See figure 6 for reference. This screw can fit in a tubular magazine with a diameter of 10-15 cm and a length of about 30 cm. Such a tube, the size of a small thermos, could hold up to 100 tags without making the base plate much smaller than the tags that are currently in use. Two tubes would be required – one for each sex of tag. If the strips run in a track inside the tube, there is little risk of a jam to occur. This concept does however demand that a good method of loading the strips into the tagger is deviced. It should be noted that the 100 tag strip would be roughly two and a halv meters long, and probably quite ungainly to handle while in the aisles of the sty. As the reloads would not be frequent, this might be an acceptable tradeoff. It could also be possible to develop a feeding system which would be based on the strip of tags being welded together and delivered already in a screw formation. The tagger would have to incorporate a mechanism for separating the next tag not only from the tag behind it, but also the first row of tags from the second, as the screw rotates.

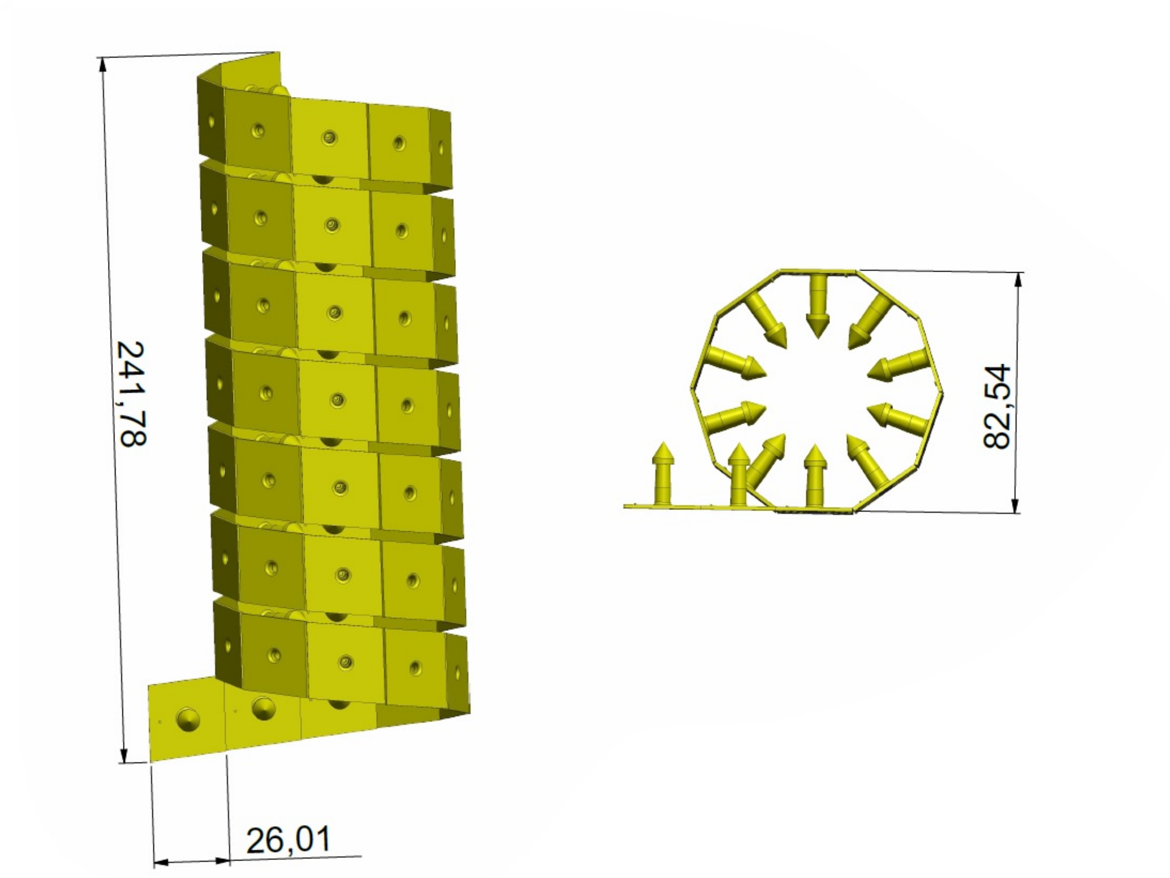


Figure 9: Slant strip of male tag elements in screw formation. An additional strip is required for the female tag elements.

3.1.6 **Straight strip of tags molded together**

To make it possible to load more than one tag at a time, multiple tags are made in the same mold. The tags are similar to existing tags, but their base plate is shaped like a rectangle with rounded corners. The tags are joined to each other at the base plate and form a straight strip of tags. The rectangular base plate is as wide or wider than the existing tags (with a diameter of 27 mm), but the side of the base plate which is parallel with the direction of the strip is shorter, to make more tags fit in a shorter package. The entire strip of ten to thirty tags can be loaded into the tagger at once, saving the user a lot of time. The tagger would have to contain a pulling mechanism to pull the next tag into place after each tagging, and in the tagging procedure, the tagger would have to separate the foremost tag from the strip of remaining tags. Figure 10 depicts this sub concept.

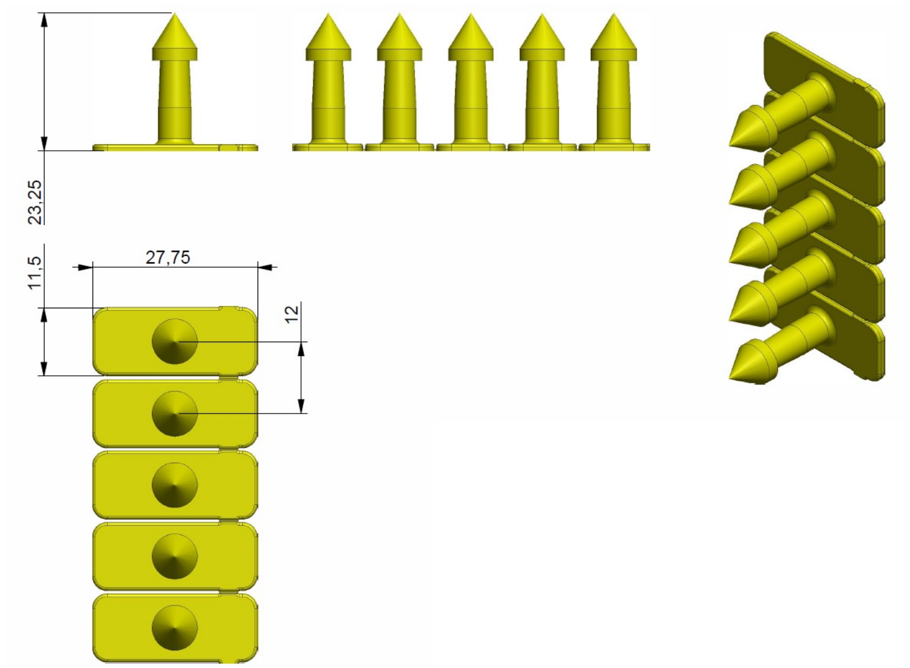


Figure 10: Straight strip of male tag elements

3.1.7 **Androgynous sheep style tag in straight strip**

This concept is based on an existing style of tags used for ear tagging sheep. Before tagging, the tag is a U-shaped piece of plastic with male and female parts of each end of the U. When tagging, the ends of the U are joined. See figure 11 for reference. If tags of this style would be delivered in strips, they could be administered from a simple and effective tagger with a large magazine capacity. In fact, there is an excellent product (The Roxan Tag-Faster) used for tagging sheep, which is inexpensive, fast to fill up, and easy to use. The fact that the female and male tags are fed by a single magazine greatly reduces the complexity and size of the tagger. There are two main reasons why this concept is not readily transferrable to the pig ear tagging business.

Firstly, the attached sheep tag forms a loop around the ear. As the ear grows, this might become to small, causing health issues for the pig. User interviews have exposed concerns that, if attached to a pigs ear, the loop could also get caught on something, which would be very painful for the pig wearing it.

Secondly, the joint between the female and the male parts of the tags used by the tag-faster is a lot weaker than would be necessary for tag that is meant to last a pigs lifetime in a sty. In fact, the Roxan Tag-Faster (see figure 11) is in limited use tagging breeding newborn piglets with individual ID tags, to ensure proper record-keeping from the start. Because of the weakness and frailty of these tags, they are replaced with proper pig tags when the piglets are a few weeks old. There might be remedies for these issues:

-Designing the tagger so that it places the tag on the ear so that it doesn't hinder the growing of the ear.

-Refuting the concerns that the loop would cause injuries, by testing.

- Providing a more potent power-source than manual power.

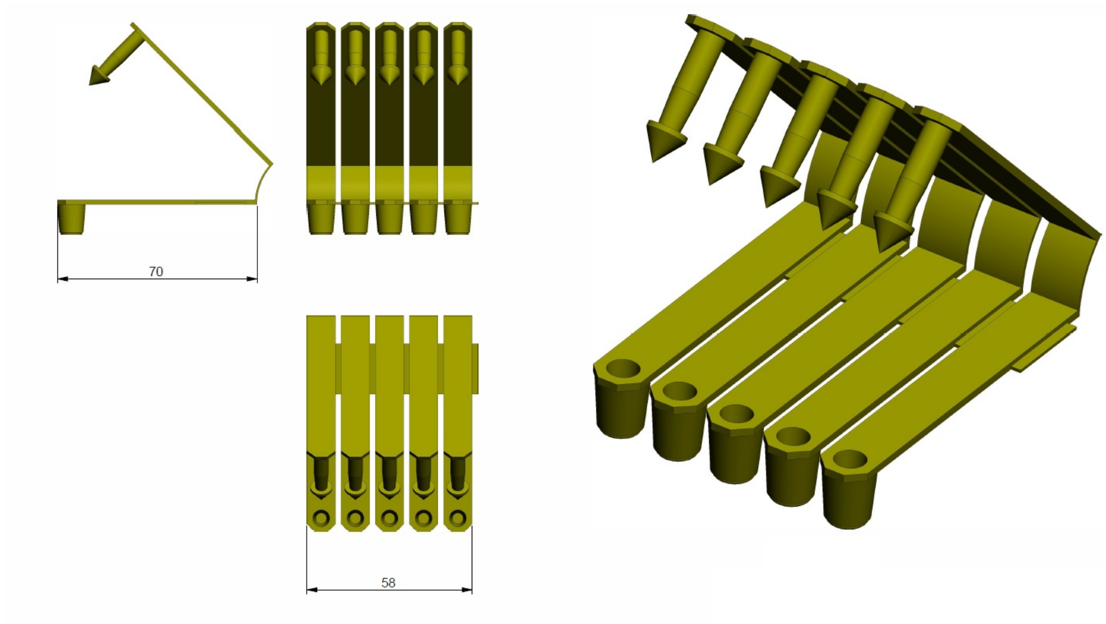


Figure 11: Strip of androgynous tag element

Figure 12: Roxan Tagfaster for sheep (4c Design n.d.)

3.1.8 **Androgynous double tag element in strip**

One way of overcoming the loop issue but retaining the advantage of only having one magazine is to separate the tag into two pieces as it is attached to the pig's ear. The validity of this concept depends on the relative cost of an extra magazine compared to the separating mechanism. Combining this concept with the slanted strip, which has a large magazine capacity but a somewhat cumbersome magazine, could produce a product with excellent features.

3.1.9 **Androgynous tag elements in tubular magazine**

The female and male parts are put on the same tag. See figure 13. When the tags are in the magazine of the tagger, the tip of one tag rests on the outside of the hollow end of the next tag. When they are attached to a pig's ear, these two are forced together. The benefit of this tag concept is that only one magazine is required, and that the logistics are simplified on every level from the factory to the end user, when any two tags are everything you need to tag a pig’s ear. The downsides are that the tubular magazine does not hold a lot of tags for its size, and that feeding the androgynous tags to both sides of the ear makes for a complex mechanism. Also, the tip of the tag which isused as a female tag is left exposed and may harm the pig wearing the tag.

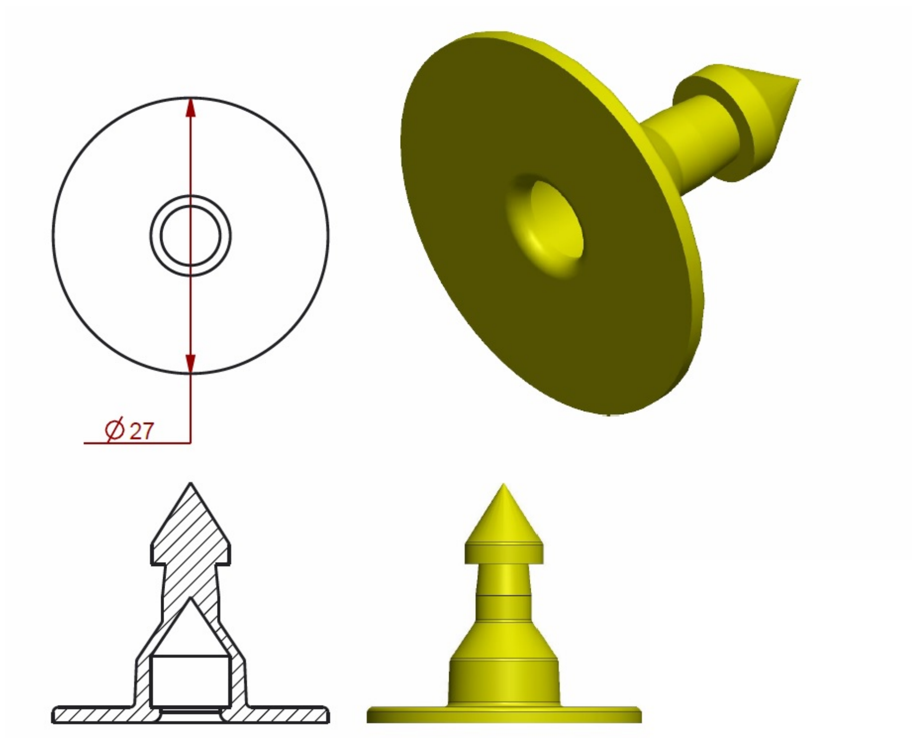


Figure 13 Androgynous tag elements

3.1.10 **Concept scoring**

Concepts are scored on a scale from 0-3, where 0 is insufficient, 1 is poor, 2 is decent and 3 is excellent. See table 3.1 on the following page.

Rate of tagging: This score describes the concepts potential to contribute to a high rate of ear tagging, in accordance with the core of the user needs. It represents a prediction of the amount of time and effort the user must invest per tagged ear. This is a combination of both the tag capacity per refilling of tags and the ease of filling the tagger up with more tags. This is the most important criteria. A high rate of tagging gives a high score.

Complexity: A tag concept which requires a lot of small parts in the tagger will drive costs, weight, difficulty of development and potentially the reliability and durability of the tagger. High complexity gives a low score.

Legacy tag compatibility: A tag concept which is fully compatible with existing tags scores high. A completely new design scores low.

Animal welfare: A tag concept which potentially causes unnecessary pain or stress for the pig will score low. As a benchmark, the existing tags are given the score of 2.

Table 3.1: Concept Scoring

Selection criteria	*Weight*	*Loose tags in tag plier (existing solution)*	*Spring loaded magazine*	*Individual slots in bar*	*Individual slots in drum*	*Slanted strips in screw formation*	*Straight strips*	*Androgynous sheep style tag in straight strip*	*Androgynous double tag in slanted screw strip*	*Androgynous tags in tube magazine*
Rate of tagging	0,5	0	1	1	1	2	3	3	2	1
Complexity	0,2	3	1	3	3	1	2	1	1	2
Legacy tag compatibility	0,1	3	2	3	3	1	1	1	1	1
Animal welfare	0,2	2	2	2	2	2	2	0	2	1
Total Score	**1,0**	**1,3**	**1,3**	**1,8**	**1,8**	**1,7**	**2,4**	**1,8**	**1,7**	**1,2**

3.1.11 **Prevailing tag and magazine concepts**

The highest scoring concept is the straight strip of tags molded together. If implemented into a tagger, that tagger could hold so many tags that the user would not have to refill more often than once every second batch of ten to fifteen pigs. Unlike the slanted strips that are stored in a screw formation, the strips are not ungainly and the refill could be a quick procedure done while the user is standing in the aisle of the sty with no special refilling tools. There is no reason to be concerned with its effects on the welfare of the pigs, unlike the sheep style tag and the androgynous tags. The simple straight strip of tags molded together should be the primary tag and magazine concept during the concept development phase. The slanted strip in screw formation style of tag would make for a larger capacity magazine, but its magazine would also be more cumbersome and its feeding mechanism would be more complex, as it would require certain design features to prevent jamming and facilitate loading.

Either of the individual slot tag and magazine concepts could easily be realized into a working tagger, and it is very likely that a tagger using such a tag and magazine system could be manually powered. It would make for an inexpensive product compatible with all existing tags, and thus could make for a viable solution. However, the slow loading means that this concept only barely passes the user requirements. This concept should be developed further. Remaining tag and magazine concepts should be discarded, as they offer no advantages over the superior concepts mentioned above.

3.2 Sub concepts: Power source and power train

3.2.1 **Detachable electric battery powered motor and gearbox**

The tagger is powered by an internal, detachable battery. The batteries are charged and exchanged in the maintenance room after 100-200 taggings. The battery could also power any electronic extra features such as an RFID tag reader or screen.

3.2.2 **Detachable electric battery powered, motor compressed spring.**

The tagger is powered by a battery, which powers a motor, which compresses a spring. The spring is mounted to a weight, which holds the pin that stabilizes the male tag as it penetrates the ear and lodges into the female tag. The spring increases the velocity of the pin, and the weight gives it inertia. The inertia must be such that it never fails to penetrate the pigs ear. The batteries are charged and exchanged in the maintenance room after 100-200 taggings. The battery also powers any electronic extra features such as an RFID tag reader or screen.

3.2.3 **Pressurized air powered tagger**

The tagger is powered by an internal tank of pressurized air. The tank must have enough pressure to be recharged with a compressor in the maintenance room after 100-200 taggings. The mechanism is driven by a piston which is actuated in a chamber that is temporarily pressurized with pressure from the tank, when the user presses a button on the tagger. A standard battery (AAA, AA or smaller) is used for any electronic extra features such as an RFID tag reader or screen. A rough estimate shows that a reasonably sized tank might have issuesmeeting the capacity requirement.

3.2.4 **Prevailing power source and power train concept**

To base the tagger on the simplest concept is feasible. In test 3 it was found that the compression force should be at least 450 N for reliable penetration. This can be achieved with an electric motor with an integrated planetary gear, supplemented by a couple of gears to power a rack and pinion mechanism, to which the penetrating pin is mounted.

If a Transmotec PDS4377 24V motor, with an integrated factor 24 reduction, is used, and the output torque is increased with a factor of four by a simple gear transmission, a compression force of 513,3N is achieved. (Transmotec).

3.3 Sub concepts: Architecture, layout, shape

The overall external shape of the tagger was determined by user testing three inert models with different shape and external features.

The models were all compatible with the sub concepts previously chosen, i.e. an electric battery powered motor and gearbox powered and strip magazine fed tagger. The main objective of the test was to determine what grip angle the tagger should have in order to enable the user to have his or her wrist in an ergonomically viable angle while ear tagging. This is one of several properties of a handheld tool that reduce unnecessary strain and risk of injury (Helander 2005). Because of this, the models differed from each other mainly in grip angle, but also in regard to the distance between the slot for the pigs ear and the hand.

3.3.1 **Models**

The models were of realistic shape, but completely inert and with very low mass. Three models were used. The firsts one “parallel” has the grip angled parallel to the ear of the pig, when it is about to be tagged. It has a distance of 15 centimeters from the index finger to the point where the tag penetrates the hear. The second model, “perpendicular”, has the grip angled perpendicularly to the ear, when it is about to be tagged. It has a distance of about 15 centimeters from the index finger to the point where the tag penetrates the ear. The third model, “long”, has the grip angled 45 degrees from the ear, when it is about to be tagged. It has a distance of about 35 centimeters from the index finger to the point where the tag penetrates the ear. This extra reach could possibly come in handy in some situations. See figures 14-16 for photographs of the inert models.

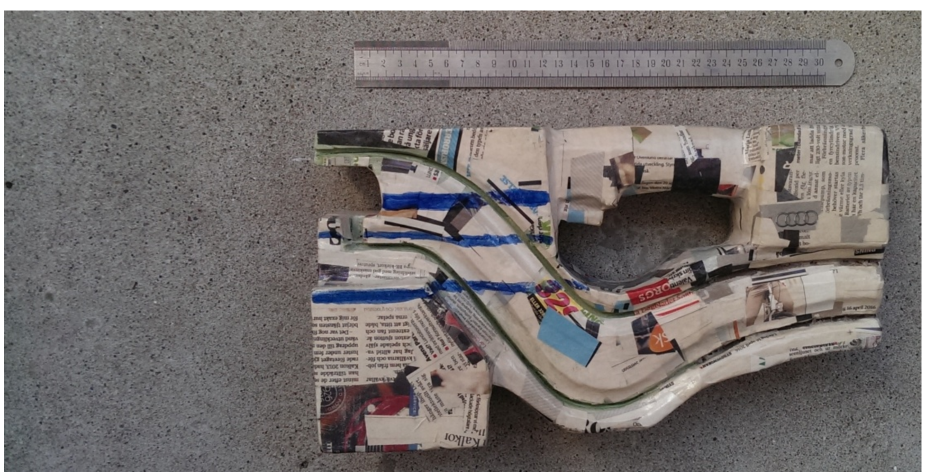


Figure 14: Parallel

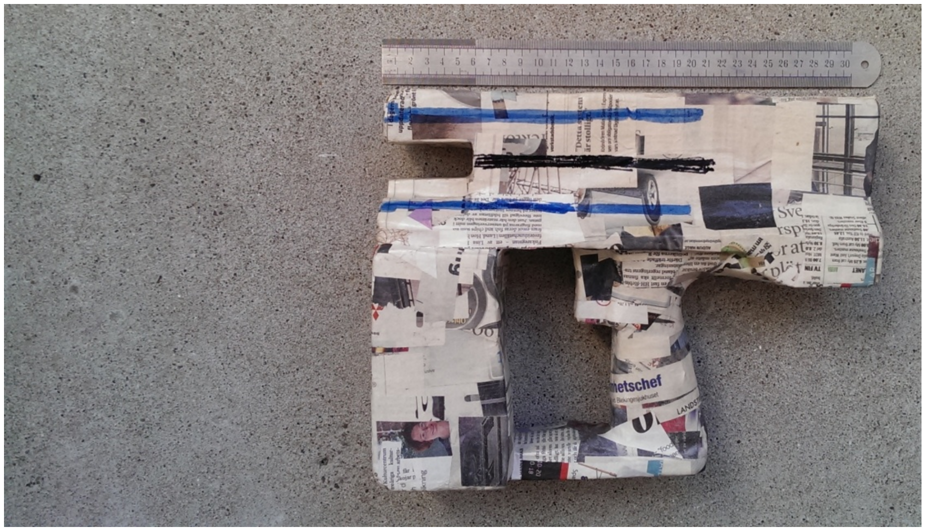


Figure 15: Perpendicular

Figure 16: Long

3.3.2 **User testing**

The user testing took place in the pig facility at Bollerup agricultural high school. The users, who were all experienced pig farm workers, were informed on how the new automatic tagger would function. They were instructed to interact with pigs and the inert models, as if they had been real taggers. The test was documented with video recordings, and the users were asked of their opinions and observations. See figure 17 for photographs of testing.

Figure 17: User testing

3.3.3 **Results**

The users stated preference varied. Two of the users stated that they preferred "perpendicular", and the other that she preferred the parallel, but specifically because of its smaller grip. The wrist angle for all users was notable more relaxed when using the perpendicular. All users raised their tagging arm (the right arm of the user, in all cases) to about 40 degrees from being horizontal.

The result of the test strongly indicated that the grip should be perpendicular to the ear, i.e. similar to the common handheld drill layout. All users rejected the "long" model, because it was cumbersome and the extra length made it difficult to use. If a piglet is to be tagged, the farm worker generally picks it up and either holds it with his or her left arm and tags it with his or her right arm. The benefit of being able to stand up straight when tagging larger pigs did not outweigh the downside of a design which creates a distance between the users hands and the pigs.

3.3.4 **Conclusions**

The new tagger product should have an architecture that is compatible with a grip which is angled so that it is perpendicular to the ear (parallel to the movement of the penetrating pin). When using the tagger, the ear of the pig should be close to the hand of the user.

4 Concept Development

The main task of the concept development phase was to unify the chosen subconcepts into a feasible complete product concept. In order to do this, it was necessary to specify the mechanical details of the feeding mechanism, the tagging mechanism, and the power supply.

4.1 Development of the feeding mechanism and tag element strips

The prevailing tag element concept was the straight strip of tag elements molded together. Attempts were made to design a mechanism that during its cycle could feed the strip forwards, separate the forwardmost tag element from the strip and hold the strip and the forwardmost tag in place. As was mentioned in the section beta sub concepts, it is assumed that a mechanism that relies on putting the entire strip under spring tension would be problematic, as the soft tag elements could easily deform and bind from the tension. Thus, a mechanism that pulled the strip forwards one step per cycle was required. The mechanism must also fixate both the forwardmost pair of tag elements and the pair of tag elements that are second in line to be applied to an ear.

One could think that the forwardmost tag element could be held in place by its joint to the second tag element in line, which in turn is held in place by the feeding arm that, when it is time, will push the second tag element in line to the forwardmost position. This mechanism layout would, however, not suffice, because when all tag elements of the strip but the very last have been expended, there will be no second tag element in line for the forwardmost tag element to hold on to.

As the machine is to be used in a dirty environment, in conjunction with live and lively animals, these functions must be performed with great reliability. After attempts of designing a mechanism that would perform these tasks as described in the table had failed, a modification of the tag element strip was made. This modification of the tag element strip design enabled the use of a relatively simple mechanism to position the tag elements in the tagger.

4.1.1 **Tag element strip with rack**

Instead of having the tag elements attach to each other directly, the original sub concept is modified so that they are attached to a plastic strip of rack, that runs parallel to the row of tag elements. This greatly simplifies the mechanism, as the only thing that must be fixed is the pair of racks, rather than both the first tag element in line and the second tag element in line to be tagged. The feeding pinions feed the strips of tag elements forward in synchronization. The tag element is kept in place by its joint to the rack. The breaking of the joint is completed as late as possible in the cycle, in conjunction with the penetration of the ear. This sheet is partially cut as the foremost tag element is fed to its position, and the sheet is completely sheared off when the penetrating pin rips the tag off the rack. As tag elements are expended, the rack is redirected 180 degrees and fed out small openings in the back of the tagger. When it is time to refill the tagger, the empty racks are under tension, and will not fall out to litter the floor unless pulled out and dumped as the user retrieves new strips of tag elements. If the spent racks are left in place, they will be pushed out as the tagging continues. The tag element strip with rack is depicted in figure 18.

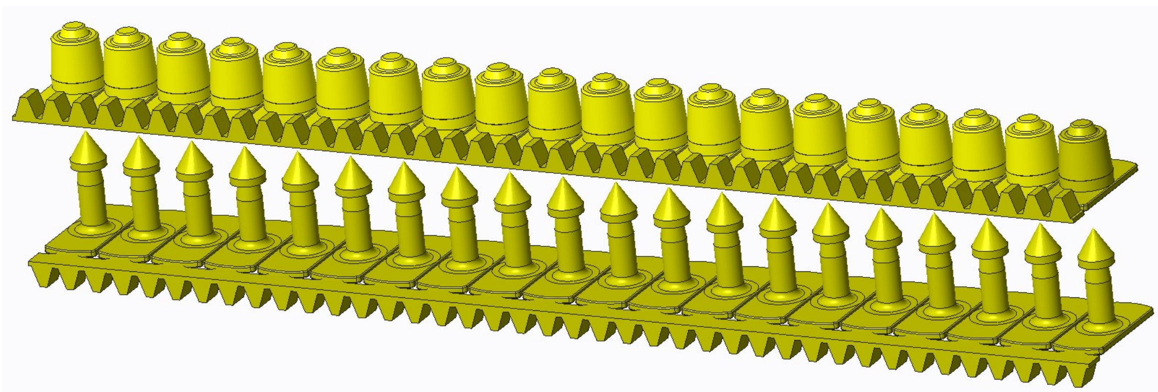


Figure 1Tag element strips with racks

4.1.2 **Feeding mechanism**

The male and female tag element strips are both held in place and fed forward by feed pinions that interact with the racks of the tag element strips. Mounted to the male feed pinion drive shaft is the driven wheel of a Geneva mechanism. The drive wheel of the Geneva mechanism is mounted to the same shaft as the pinion A, which is described in detail in the sections *Development of the power drive* and *Details on cycle*. Once during each cycle, the Geneva mechanism drives the male feed pinion so that it feeds the male tag element strip forwards enough to put the next tag element in line for the next tagging cycle. The female feed pinion is synchronized with and connected to the male feed pinion by way of three shafts. These shafts transmit the rotational movement of the male feed pinion around the space for the pigs ear, which is directly between the feed pinions. The feeding mechanism is illustrated in figure 19.

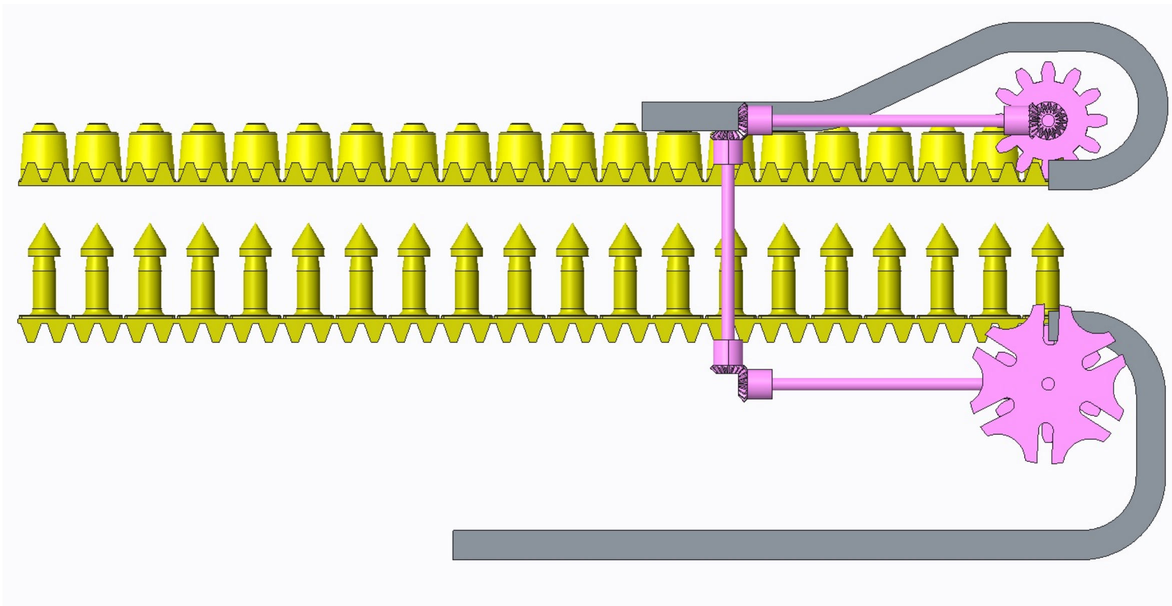


Figure 2Feeding mechanism. The grey parts are the chutes through which the expended rack is fed. The male feed pinion is covered by the driven wheel of the Geneva mechanism.

4.2 Development of the power drive

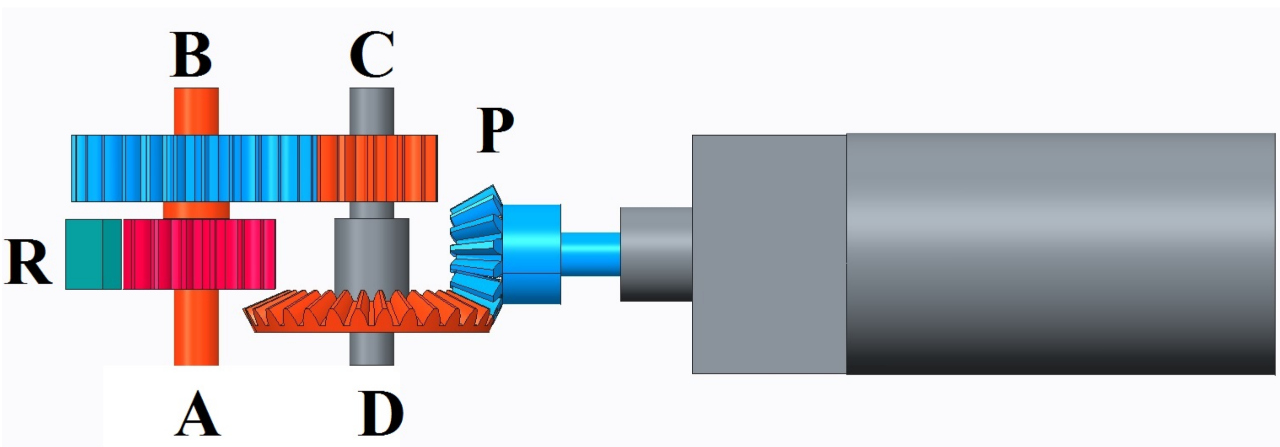
The components and dimensions of the power drive were selected to be compact and to be of sufficient strength. The motor and gears were arranged to fit inside a cuboid extrusion with the outer profile of the motor, and the gears fitted inside the extension of the motor.

The motor was chosen because it had favorable price, mass, torque and speed properties. It is also available in less expensive variants with lower voltages, if the higher voltage motor would be found to be unnecessarily powerful. References to the motor are intended to mean the motor and the integrated planetary gear.

The gears chosen were the largest that would fit inside the profile dictated by the external profile of the motor.

There are three gear transmissions in the gearbox. See figure 20 for reference. The first consists of the bevel gears P and D. The bevel gear P is the pinion. They are bevel gears with 15 and 30 teeth respectively. Mounted co-axially to the bevel gear D, is the gear C, which is mounted to transfer the torque to gear B. The gears C and B have 14 and 28 teeth respectively. Mounted co-axially to the gear B is the gear A, which has 20 teeth and a pitch diameter of 30 mm. The gear A acts as a pinion impinging on the drive rack. All gears are of module 1,5 mm and have a width of 12,6 mm. This gives sufficient strength for present loads, although optimization would likely yield a more compact mechanism (HPC Gears 2013).

The motor (and integrated planetary gearbox) provides, according to the specifications published by its Swedish retailer, 1,93 Nm of torque at a nominal speed of 133 rpm. This gives the gear A a torque of 7,72 Nm and a speed of 0,55 turns per second. The pitch diameter of the gear A is 30 mm, for a circumference of 94,25 mm. The resulting nominal velocity of the drive rack is 51,8 mm /s. It will keep this velocity until meeting a maximum resistance of 7,72 Nm/ 0,015m= 514,67 N. When a lower resistance is encountered (which always should be the case, lest the tagger fails to penetrate), a slightly higher drive rack velocity should be achieved. The mechanism is not dependent on a high initial velocity or a high initial torque to function properly. As specified in the *Details on cycle* section, after the trigger is pulled by the user, the drive rack is pushed 25 mm upwards before the ear is penetrated, tagged and released from the tagger. To complete the 25 mm push with the nominal velocity takes 0,48



seconds. With nominal speed, the cycle takes 1,82 seconds (Transmotec).

Figure 20: Power train viewed from below.

4.3 Development of architecture

In order to minimize the strain and risk of injury of the users wrist, the tagger should not only have a beneficial grip angle, which was determined in the previous phase, but also a centre of mass which minimizes torque on the wrist.

A suitable layout of the internal components was chosen, which puts the centre of mass close to the palm of the users hand, while also being rational in respect to the functioning of the tagger. While the layout is tall, the upper portion containing the tag element strips and their feeding mechanism is not very heavy. The two objects with the most mass are the power train and the battery. The chosen layout puts these two objects close to the hand. See figure 21: for an illustration of the architecture.

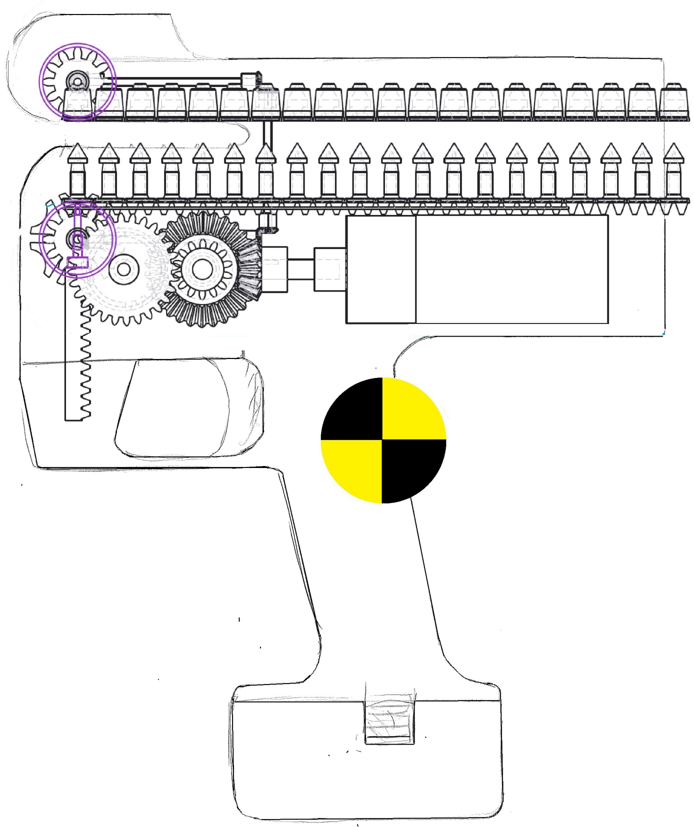


Figure 3Architecture. Approximate center of mass marked with black and yellow symbol.

5 Final Concept

After integrating the sub concepts and refining them, an end result has been reached.The suggested concept tagger would satisfy the user needs. It would have a much higher rate of tagging than the existing plier tagger. Unlike the plier tagger, an operator of the concept tagger could tag 20 pigs in succession, without having to retrieve loose tag elements from the pockets of the users pants between each pig. Operating the concept tagger would also be much less physically strenuous than operating the plier tagger. The concept tagger would be in the same weight class as a handheld screw driver, making it much heavier than the plier tagger. The concept tagger is, however, much lighter than the existing automatic taggers. The lower mass and smaller size makes the concept tagger much more portable and flexible. It can be used in any location on the farm, even inside a truck. Unlike the existing automatic taggers, it does not require a power cord. Also unlike the existing automatic taggers, the concept tagger would not force the users to radically change their work routine: it does not replace the existing trolleys or force the users to adopt a new method for distributing food supplement or medication. The existing automatic taggers are impossible to use with any pig too heavy to be comfortably picked up by the farm worker, but the concept tagger is hand held and is powerful enough to be used on a pig of any age. Figures 22-26 are renderings of the tagger concept.

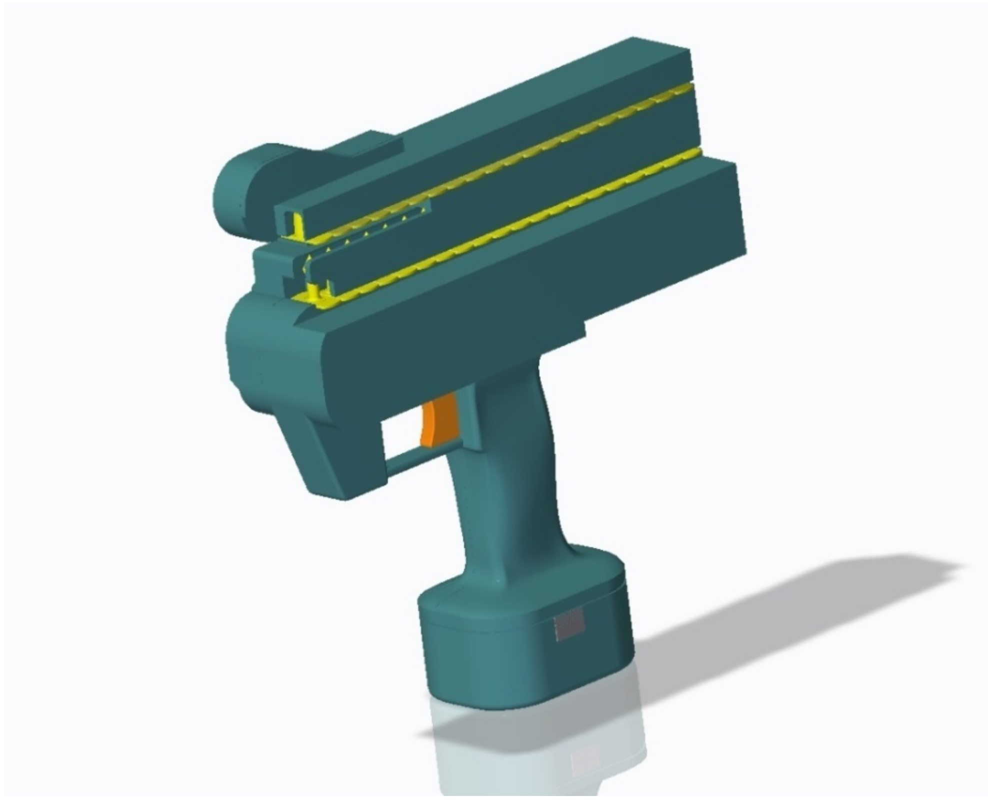


Figure 22: External shape of tagger

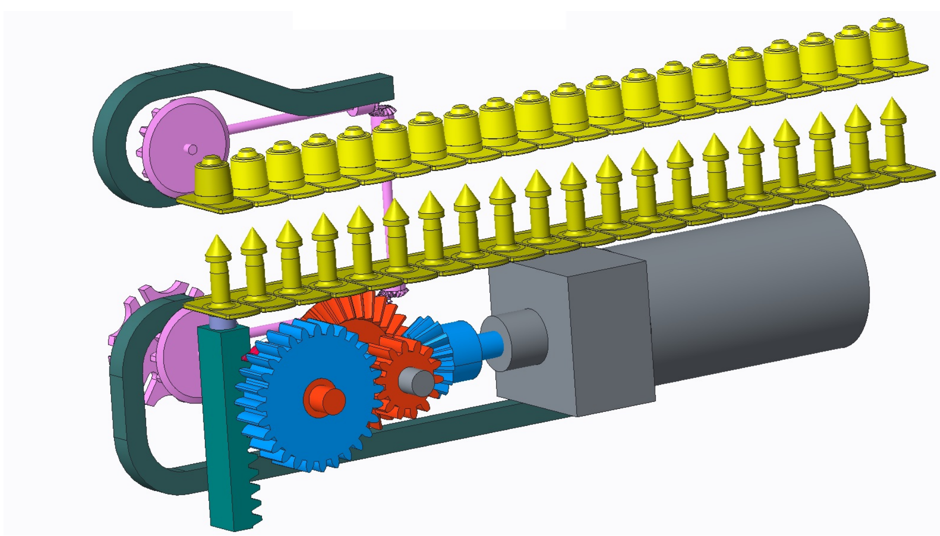


Figure 23: Major mechanical components of the final concept. Functioning described in details in other sections.

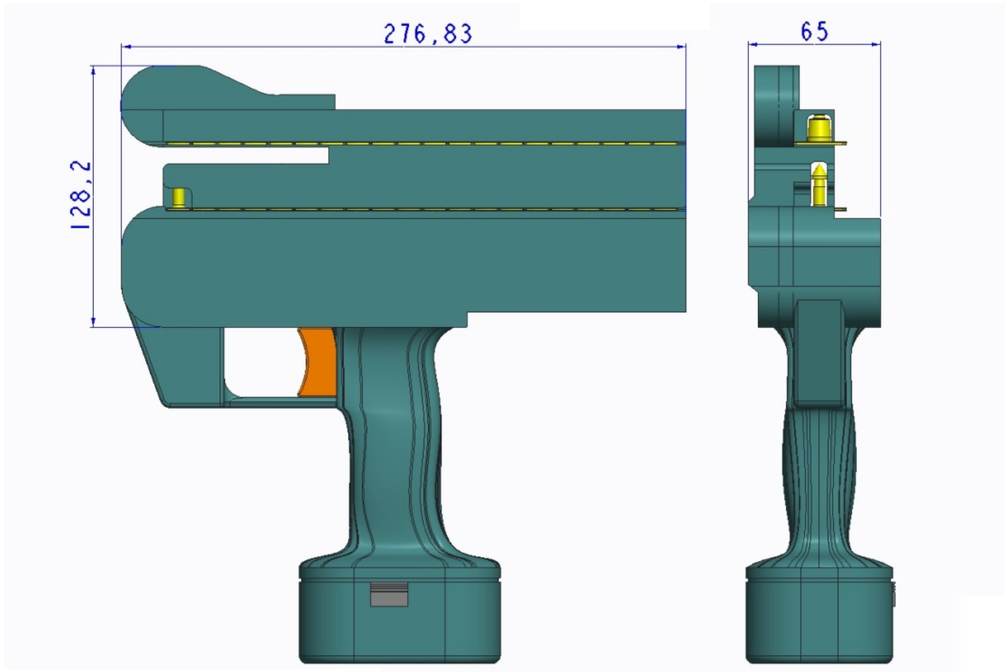


Figure 4Left and front view of the tagger, with some external dimensions.

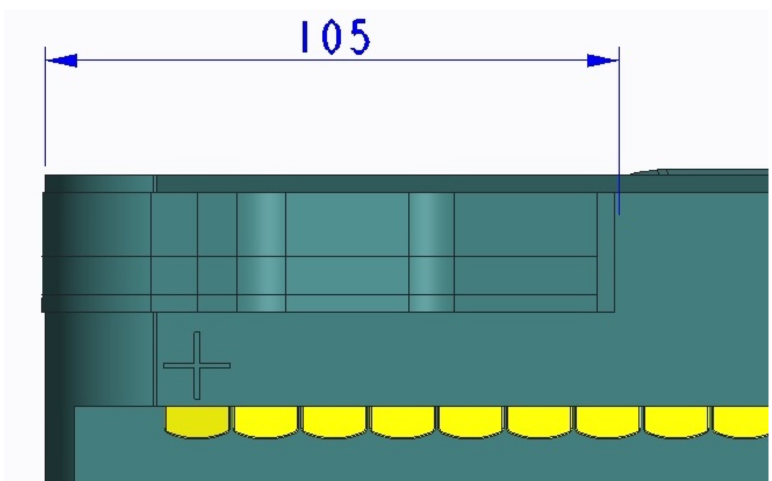


Figure 5Top view of tagger, showing approximately what the user sees when positioning the tagger before attaching the ear tag. The dimension indicates the depth of the slot for the ear. Note the cross which indicates the position of the tag.

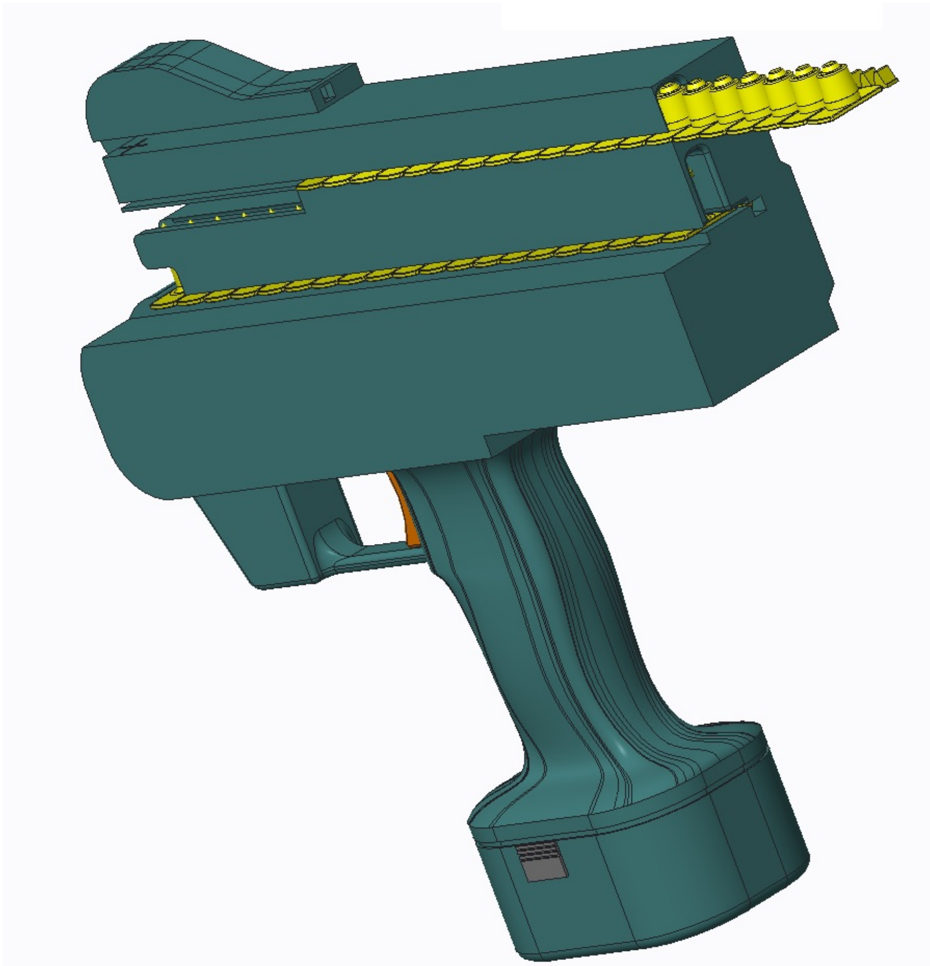


Figure 6To refill the tagger, the strips are inserted from the rear, one at a time. When both strips are inserted, the trigger is activated once, which will put the first couple of tag elements in position.

6 Discussion

6.1 Afterthoughts

In the tag and magazine sub concept chosen in the ideation phase, the tag elements were attached directly to each other. In the concept development phase, attempts to design a mechanism that would feed the tag elements, and positively keep them in the correct position, led to the perception that such a mechanism would be unnecessarily complex and possibly unreliable. Because of this, the strip of tag elements was changed by adding a gear rack to which the tag elements are attached. The gear rack makes for a simple mechanism to keep the tag elements in the right place at the right time. The rack and pinion feeding mechanism does, however, make the concept tagger taller, wider and asymmetric. It is possible that the best solution would be to keep the rack and pinion mechanism, but to replace the mechanism that synchronizes the translational movement of the male and female tag element strips with a separate servo motor to feed and position the male tag element strip.

One reason why the setup suggested in this report, with synchronizing shafts, bevel gears and a Geneva mechanism was chosen, was the original ambition to make a functional prototype. Because of the skill set and equipment available to the author of this report, it would have been easier to make a prototype with relatively simple electronics and relatively complex mechanics, than the other way around. This may have skewed design choices.

It is necessary to recognize the issue of balancing on the one hand ambitiously suggesting creative features and on the other trying to specify the mechanisms and technical inventions that are necessary to realize the aforementioned features. This project has been an endeavor to invent a new class of product, and the singular person working on it was responsible for both creation and realization. This author believes it to be beneficial to separate these functions. In this project it was done by placing them in different phases, but it would have been even better to separate them further by assigning responsibility for them to two different people in a team.

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Appendix A

A.1 Protocol test 1 – constant speed compression

A.1.1 Abstract

Male and female tag elements were tested in a constant speed press. The force required to maintain constant speed while joining the tag elements was recorded. Several tests with different constant speeds showed that a peak force of 300-400 N is required to join the tag elements. Note that no earlike tissue was placed between the tag elements prior to pressing.

A.1.2 Background

The test was performed in order to gather information on the characteristics of the task of joining the male and female elements of the ear tag. Knowing the peak forces, the total energy work expended, and how these values vary with the compression speed, is essential for choosing the method of generating compression force in the tagger.

6.1.1 **Procedure**

The tag elements were placed in a two piece wooden jig, and before compression, the elements were placed so that the tip of the male element was in the hole of the female element, although with no force applied other than the relatively small weight of one half of the jig and one element. The machine was set to a specific compression velocity and distance. After each cycle, new tags were mounted. Note that no earlike tissue was placed between the elements during this test.

6.1.2 **Results**

Velocity [mm/s]	Maximum force [N]
1	280
5	330
10	300
20	350
100	390
2000	390

6.1.3 **Conclusion**

Joining the male element to the female element requires, at velocities relevant to this project, a maximum force between 300 and 400 Newtons. This is true with no tissue for the tip to penetrate.

How this changes when an ear is placed between the tag elements is unknown. It is possible that the fluid and greasy substances of the ear lubricates the contacting surfaces of the tag elements, lowering the maximum force required. It is likely that this effect is smaller than the added resistance of the tearing and shearing required to penetrate the ear.

6.1.4 **Tables**

The results can be read in the tables in figures 27-32. The vertical axis displays force, measured in kiloNewtons, while the horizontal axis displays movement, in millimeters.

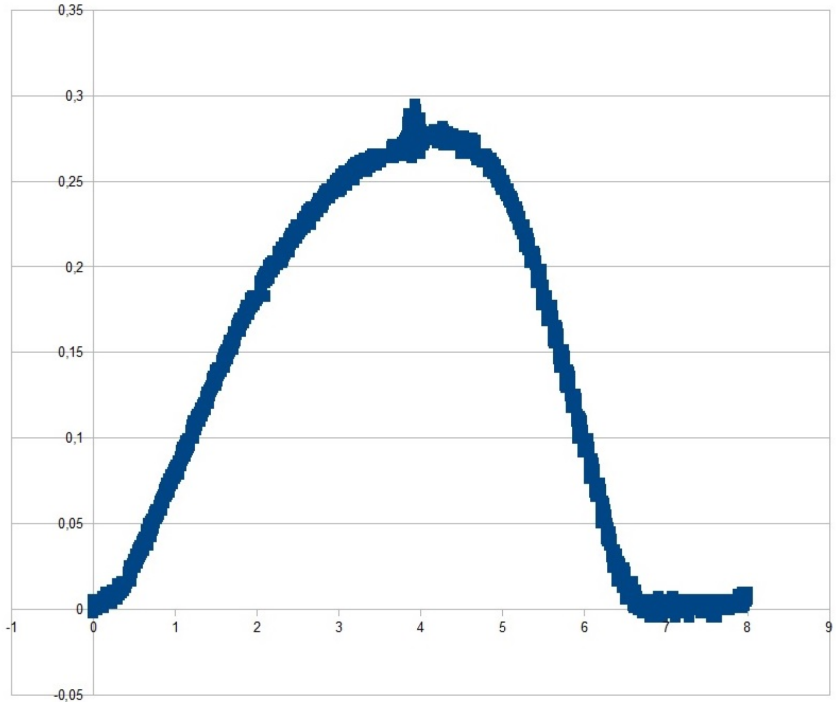

Figure 27: Constant velocity 1 mm per second

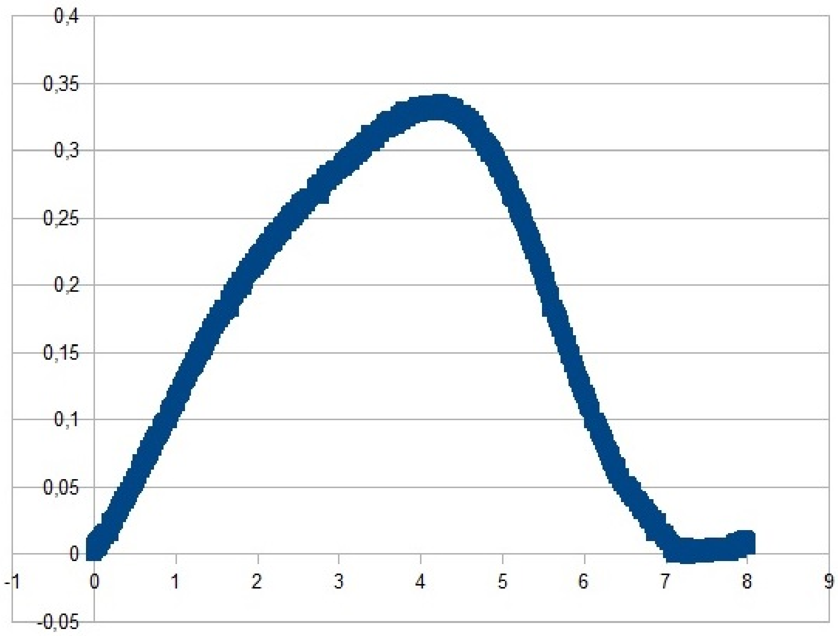

Figure 7 Constant velocity 5 mm per second

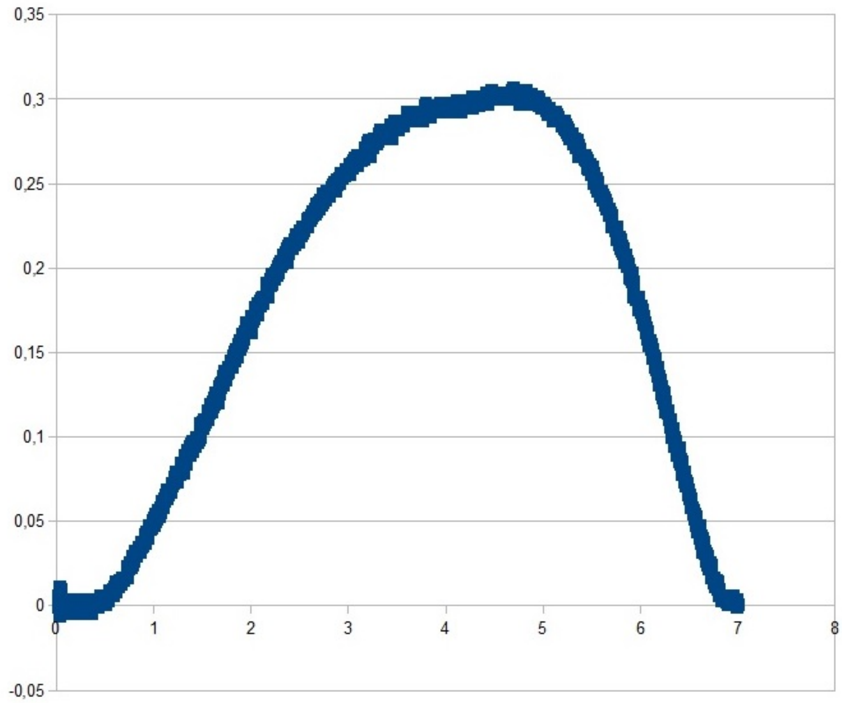

Figure 8Constant velocity 10 mm per second

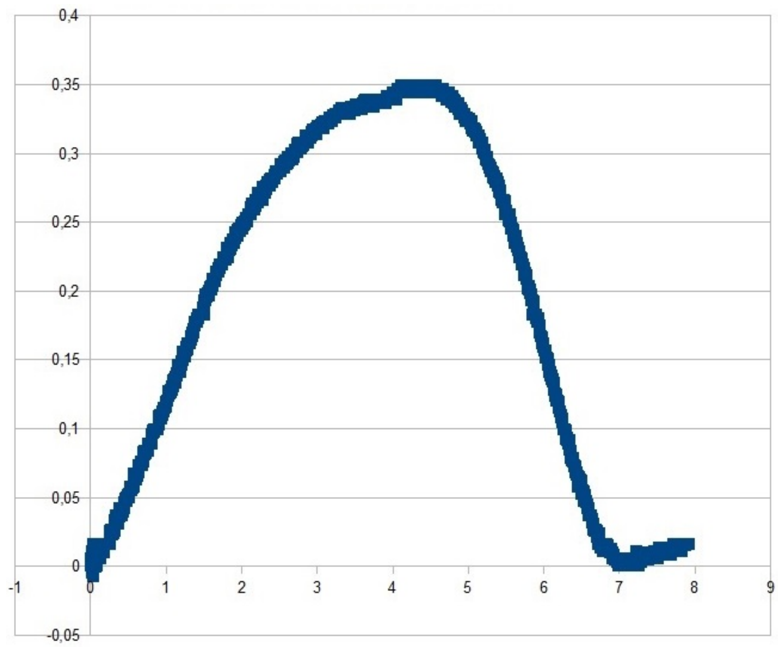

Figure 30: Constant velocity 20 mm per second

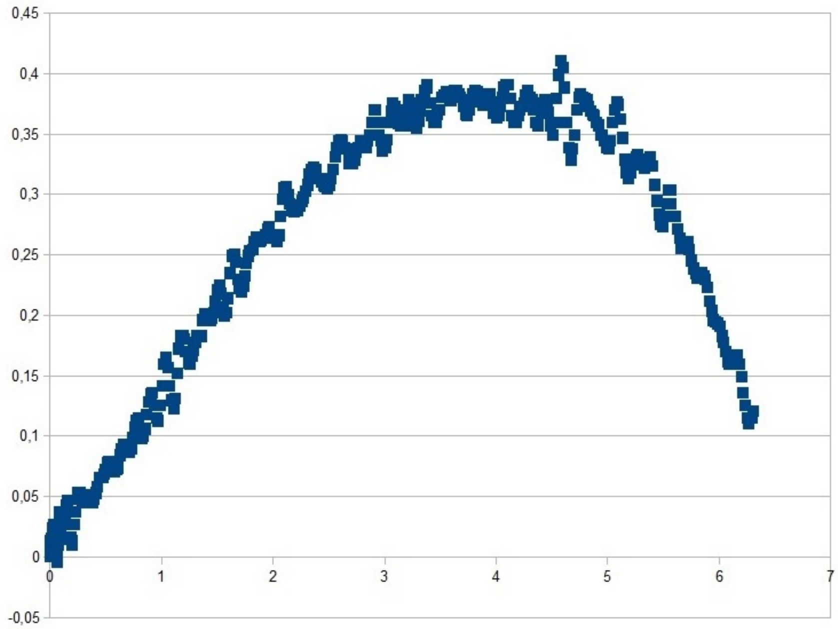

Figure 31: Constant velocity 100 mm per second

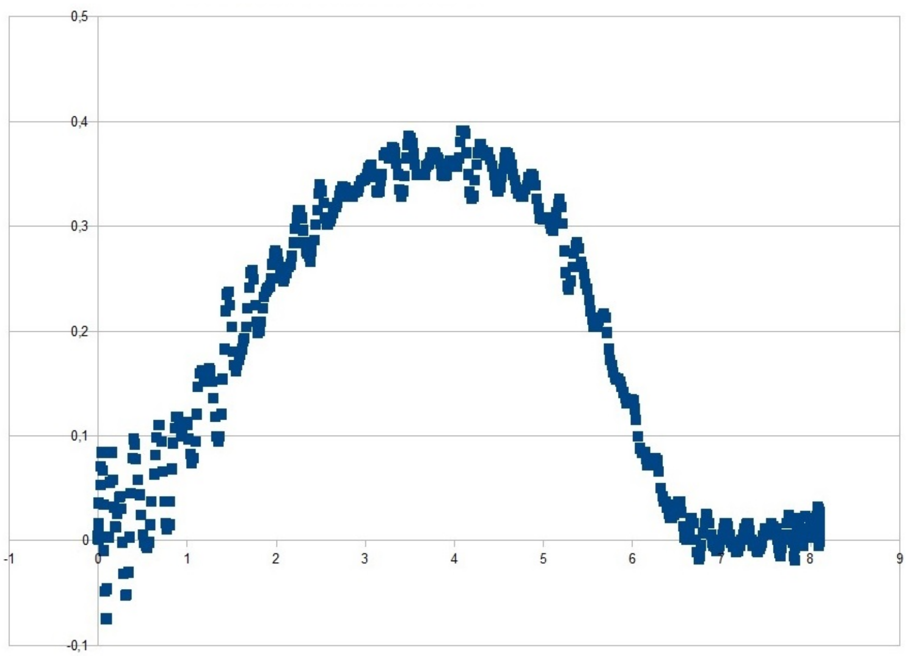

Figure 32: Constant velocity 2000 mm per second

6.2 Protocol test 2 – kinetic energy compression with ear

6.2.1 **Abstract**

In order to explore less expensive mechanical solutions, tests were conducted to establish what would be required of a mechanism that performed the tagging function by means of propelling a mass to hammer the male tag element through the ear and joining the tag elements together. It was found that the toughness of the ear meant that a rather high kinetic energy would be necessary to perform the tagging function, and that this would have several disadvantages compared to a mechanism that performed this function with a pushing action.

6.2.2 **Background**

The selection of the power source and power train, was to be determined by picking the simplest solution that would work, acting on the assumption that the simplest one would also be the easiest to develop and the least expensive to manufacture. That simplest solution turned out to be having an electric motor power a rack, to which the penetrating pin is mounted. This does, however, require a motor that can provide all the energy that is necessary for the penetration in a short period of time (less than a second) . Such a motor is expensive, and it is prudent to explore alternatives. If the penetration energy is provided by a spring, which quickly releases all its energy, but could be compressed slowly, then perhaps a less expensive motor could be used. The motor would have up to five seconds to compress the spring.

A discussion of the problem with professor Per Lidström introduced a hypothesis that a low mass and high velocity striker would be the most cost efficient setup to achieve reliable penetration. A fast, light projectile is generally considered a better choice than a slow and heavy projectile in kinetic energy based weapon systems that are used to penetrate armor.

6.2.3 **Procedure**

A wooden jig that ensured correct alignment of the ear tag elements was used. The jig was placed on the ground, and directly above it, a long brass pipe with an outer diameter of DIAMETER was suspended, perpendicular to the ground. To strike the wooden jig, a section of steel pipe was used. The steel pipe section had a somewhat larger inner diameter than the brass pipe. When the steel pipe was put around the brass pipe, it slid along the brass pipe without binding or visibly apparent friction.

The steel pipe was dropped on top of the jig from varying heights. The test was performed both with just tag elements, and with a small piece of pig ear between the tag elements. Three steel pipe sections of different masses were used.

For each combination the test was repeated until the information gathered was deemed sufficient.

6.2.4 **Results**

Mass [kg]	Height [m]	Velocity [m/s]	KE [J]	Ear	pass/fail TAG	pass/fail EAR
0,625	0,80	3,96	4,91	no	p	N/A
0,625	0,60	3,43	3,68	no	p,p	N/A
0,625	0,40	2,80	2,46	no	f,f	N/A
0,15	2,00	6,27	2,95	no	f,f	N/A
0,25	1,50	5,43	3,68	no	p,f,f	N/A
0,25	2,00	6,27	4,91	no	p,p	N/A
0,25	1,75	5,86	4,30	no	f,f	N/A
0,25	2,00	6,27	4,91	1 layer	f	p
0,25	2,10	6,42	5,16	1 layer	f	p
0,25	3,30	8,05	8,10	1 layer	p,f,f	p,f,p
0,4	3,30	8,05	12,96	1 layer	p	p
0,4	2,30	6,72	9,03	1 layer	p	p
0,4	1,80	5,95	7,07	1 layer	f,p,p	f,p,p
0,4	1,50	5,43	5,89	1 layer	p,p	p,p
0,4	1,00	4,43	3,93	1 layer	f	f

Table of results from test 2

6.2.5 **Conclusions**

Comparing the results with and without pig ear tissue present with the 0,25 kg drops shows the difference in kinetic energy required for a pass result. With no ear to penetrate, the drop from 1,5 meter resulted in one pass and two fails. Increasing the height to 2,0 meters, the result was two passes. As dropping from 1,75 meters resulted in failures, the threshold can be assumed to be at roughly 2,0 meters. With 1 layer of ear to penetrate, a height of 3,3 meters was required to achieve only a sporadic pass result. This increase in height represents a 28 % increase in impact velocity and a 65 % increase in impact energy. The 0,25 kg section of steel pipe required 8,1 Joules for sporadic penetraion.

It should be noted that although it failed once at 1,8 meters, the heavier section of steel pipe passed twice at that height, and twice more at 1,5 meters. Falling from 1,5 meters, the heavier section of steel pipe had a kinetic energy at impact of only 5,9 Joules. This disproves the theory that a light and fast striker would be the most efficient setup to achieve reliability. It also suggests that the dynamics involved are unlike those of a projectile penetrating armor. The results seem to rather be suggesting that the task of penetrating the pig ear and compressing the tag elements is, to preserve the firearms analogy, more similar to the task of a slow and heavy rifle bullet penetrating deeply into a moose. The pig ear is tough and flexible.

In either case, it is also noteworthy that the energy required for reliable penetration with the kinetic energy approach, roughly 7-8 joules, is much more than the energy necessary when using a push approach. If the results from tests 1 and 2 are combined, and the peak force requirement of 450 N from test 3 is applied to the general appearance of the force/distance curves from test 1, it can be roughly estimated that the total energy required with the push approach is close to 2 Joules or less.

These results support a rejection of the concept that penetration is to be achieved with the method of compressing a coil spring and releasing that spring to accelerate a 0,25-0,40 kg striker to achieve the penetration and compression of the tag elements. It was hoped that this alternative concept would allow the use of a motor which produced roughly the same energy in a longer period of time, by letting the motor perform its task immediatly after the tagging, rather than having to perform its task in the short time frame of the actual tagging. As a much higher amount of energy would be required for that approach, it is likely that the economic benefit of a less powerful motor would be low or non-existent. Having the mechanism powered by a compressed coil spring also presents issues. If the penetration fails, there are no good ways of providing additional energy to complete the penetration. Each cycle that the tagger is used, the coil spring would cause an impact inside the tool, which could cause wear and parts breakage. The coil spring releases the same amount of energy regardless of the resistant met. There is a large difference between penetrating a thin section of a pig that is only a few weeks old and penetrating a thicker section of the ear of a fully grown sow. The competing subconcept with the rack and pinion does have the capability to produce a large push force, but this only happens when great resistance is met, and the increase in push force is, from a parts endurance perspective, slow. If the tagging does not require a large push force, the rack and pinion concept tagger will just perform its cycle at a slightly higher speed, as the electric motor that powers it spins faster with a low workload.

6.3 Protocol test 3 – constant force compression with ear

6.3.1 **Abstract**

This test was conducted to establish what compression force is required when piercing a pigs ear and joining the tag elements together. The force was measured by placing an jig containing the tag elements and pig ear tissue on top of a scale. It was found that the penetration of the ear adds about 20 % to the force required to join the tag elements together.

6.3.2 **Background**

It is crucial to know how much force is required to pierce the pigs ear and join the tag elements together. Previously, in test 1, the force required to just join the tag elements together was measured. In this test, the force required to both penetrate a pigs ear and join the elements together was measured. Before the test, it was unknown wether the pigs ear would increase of decrease the required force. The theory that suggested that the ear would decrease the required force was based on the idea that the ear itself would act as a lube that decreased the friction between the male and female tag elements. The counter-argument to this is of course that the force required to penetrate the ear tissue would be greater than the lube effect, if such an effect even existed.

6.3.3 **Procedure**

Unfortunately, the high precision equipment used for test 1 was unavailible when test 3 was performed. For test 3, the tag elements and the ear were placed in a jig, which ensured that the tip of the male tag element would hit the hole in the female tag element, after penetrating the ear.

The jig was placed on top of a scale, and pressure was manually applied to the top of the jig, noting the reading on the scale.

Because the thickness of the ear varies, and because of the differences of the mechanical properties of the ears used and the ears of live pigs, and because the objective of the test was to determine the minimum required force for reliable penetration, two ears were stacked so that two layers of ear tissue were penetrated each time.

6.3.4 **Possible sources of errors**

The force applied varied with time by approximately 1-3 kilograms, as it is difficult to apply even force. It was also difficult to get precise readings from the scale, and it can be assumed that the results are wrong up to 1 kg. The ears used were drained of blood and scolded (all pig carcasses are scolded when they first arrive at the slaughterhouse, primarily to remove hair), which altered their mechanical properties.

6.3.5 **Results**

Applied mass [kg]	Force [N]	Pass/Fail
40	393	Pass
35	344	Fail
30	295	Fail
40	393	Pass
47	462	Pass
45	442	Pass
42	412	Pass
40	393	Fail
43	422	Pass

Table of recorded results of test 3

393 Newtons sometimes passed, sometimes failed. 412 Newtons or more always passed.

6.3.6 **Conclusions**

Adding an ear to the tagging process does not decrease the force required to join the tag elements together. To have some margin, a compression force of at least 450 N is required.

6.4 Project planning

6.4.1 **Initial time plan**

As thoroughly described in the method section, the project was divided in three phases. Time intervals for each phase were set up, and activities were assigned to each phase in accordance with the Attention design process and the Ulrich and Eppinger product development method.

Phase	Specification
Planned activites	Research workshops, User interviews, Technical research. Requirement specification, Study trips, Trend research
Interval	2016-01-05 // 2016-03-03

Phase	Ideation
Planned activites	Sketching/brainstorming, visual models, concept generation, concept selection, research to verify, user testing
Interval	2016-03-04// 2016-04-20

Phase	Concept development
Planned activites	Develop concept to specify, mechanical calculation, CAD, model building
Interval	2016-04-21// 2016-06-17

6.4.2 **Actual use of time**

The actual use of time generally followed the time plan, with the following major exceptions:

- Study trips were conducted in every phase. Sometimes this happened because questions arose that required a field study or an interview to be answered. It also happened because the early study visits were not completely satisfactory from a research perspective, as they were to farms that did not use the work routine that was the most relevant to study. If the differences and relative relevance of the work routines would have been known beforehand (by more thorough communication with the client), this could have been avoided.
- Initially in the project, there were expectations that the end result would be a full power functional model. By the middle of the *Concept Development* phase, preparations for making a functional model was made (in accordance

with the time plan), but it was soon realized that it would be impossible to make a functional model within the available time scope.

- User testing in the *Ideation* phase was abandoned in favor of user testing in the *Concept Development* phase. The concepts available by the end of the ideation phase were much too diverse and unfinished to be suitable for user testing. In thethe *Concept Development* phase, user testing of inert papier machié models was performed with success.

6.5 Details on cycle

6.5.1 **Components and interfaces**

In this appendix, the operating cycle of the mechanism is described.

A full cycle is defined as a full revolution of the pinion A. The zero position is defined as when the pin has penetrated the male tag element so deeply that any additional upward movement of the pin will move also the male tag elements upward. Note that after each cycle, the pinion A stops before the pin reaches zero. This ensures that the tag elements are not cut off from their racks prematurely. The pinion A drives the drive rack, on which the drive pin is mounted. The drive rack is connected to a coil spring, which compresses as the drive rack is driven upwards by the rotation of the pinion A. The pinion A does not have teeth on its entire circumference. Rather, the teeth have been removed on approximately half the pinion, so that when the drive rack reaches its maximum position, it looses its connection to pinion A, and the rack is pushed down to its lowest position, - 21,9 mm. The coil spring is strong enough to resist the slight friction that can occur between the pin on the drive rack and the inside of the male tag element, but the force generated by the coil spring is too weak to slow the drive rack down by a substantial amount while the drive rack is being driven by the pinion A.

Mounted to the same axis as the pinion A is the Geneva drive wheel. It is connected to the Geneva driven wheel which in turn is coaxially mounted with the female feed pinion. The Geneva mechanism performs two tasks. Firstly, it keeps the female feed pinion fixed while the female tag element strip must be fixed in position. Secondly, it drives the female feed pinion exactly 1/6 of a turn for every complete rotation of the pinion A.

Via three bevel gear connections and three shafts, the male feed pinion is synchronized with the female feed pinion.

6.5.2 **Walkthrough of standard cycle**

The cycle starts when the user pulls the trigger with his or her index finger.

The first segment of rotation is from the starting position, which is an unknown but low negative value, to zero. At this time, the gap between the tip of the male tag element and the flat surface on the bottom of the female tag element is 8,75 mm.

Immediately after passing zero, the pin starts impinging on the bottom and inside of the male tag element, which is ripped off its feed rack within less than a couple of millimeters of translative movement of the drive rack.

At some point between zero and 8,75 mm, the tip of the male tag element makes contact with the pigs ear. A pigs ear is typically less than 5 mm thick, and quite flexible. The part of the travel of the male tag element which meets the greatest reaction force is probably from about 8 mm above zero, when it is expected that resistance is begun to be met by the ear, to about 19,35 mm above zero. The latter is derived from a geometric calculation as well as test results from Test 1. In Test 1, position zero was defined as where the female tag element can rest on the tip of the male tag element without stretching (where it would be if the male element would be put on a table and the female tag element would be balanced on top of it). In this state, the tip of the male tag element protrudes 5,6 mm past the plane surface on the bottom of the female tag element. Further, in test 1, the peak of the resistive force happened just before 5 mm past zero. In test 1, the resistive force measured is the resistive force generated when joining the tag elements together. The ear is most likely completely penetrated before this happens. Thus it can be concluded that most resistive force is exerted before the pin is 8,75+5,6+5=19,35 mm above zero.
The pin will continue to lift the male tag element until the pin has raised 25 mm above zero. Because the tip of male tag element bottoms out the cap on the female tag element, it is impossible for the female tag element to remain in its original position when the pin rises this high. The female tag element will be lifted approximately at least 3 mm. This assists the separation from the female feeding rack. The movement is so small that it will not cause the tip of the male tag element to miss the hole in the female tag element.

Just before the pin reaches its maximum height of 25 mm above zero, the tag elements are joined together, and they are completely separated from their feed racks. The pin is, however still inside the male tag element, which limits the movement of the now complete tag.

When the pin reaches its maximum height, the teeth on the pinion A move out of range of the teeth on the drive rack. When this happens, the drive rack is pushed down from 25 mm above zero to 21,9 mm below zero, where it remains static.

As the pinion A continues to rotate, the Geneva mechanism is activated, and the female strip of tag elements is moved forwards, so that the next tag element is in position to be tagged. The male strip of tag elements is, by way of the bevel gear connections, simultaneously moved forward.

Thus the tagger is ready for another tagging, and the cycle is complete.