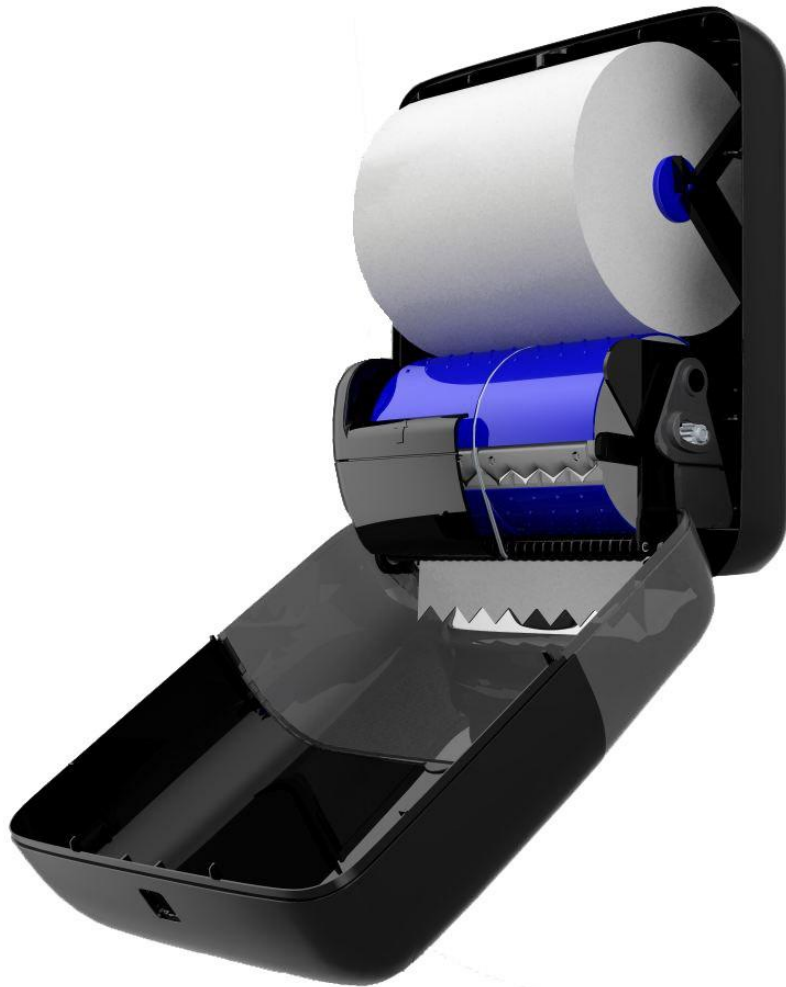


CHALMERS



Optimization of Tissue Dispensers

Master of Science Thesis

FILIP SAHLBERG

Department of Product and Production development

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden, 2010

Optimization of Tissue Dispensers

FILIP SAHLBERG

Department of Product and Production development
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2010

Optimization of Tissue Dispensers
FILIP SAHLBERG

©FILIP SAHLBERG 2010
Published and distributed by
Department of Product and Production development
CHALMERS UNIVERSITY OF TECHNOLOGY
SE-41296 Göteborg, Sweden
www.chalmers.se
Telephone: +46 (0)31-772 1000
Göteborg, Sweden, 2010

Preface

This report is the result of a Master thesis conducted from January to June 2010 which completes the master program in Product Development. The thesis was conducted at the Away From Home Tissue division at SCA Hygiene products in Mölndal. Knowledge acquired during the studies at Chalmers University of Technology has been very useful in this project and I have also gained a lot of new knowledge during the Master thesis. The project comprises 30 credits and is a product development project for the Department of Product and Production Development.

I specially want to thank my supervisor at SCA, Björn Larsson for his advice, support and encouragement.

A second word of thanks goes to Creator AB and the entire staff for helping me developing my prototype, especially Joonas Jokitalo, Per Möller and Stig XXXX.

Third, I would like to thank all students who also wrote their Master Thesis at SCA while I did it. I want to thank them for the help in my project, but even more for the fun lunch breaks we had and the pleasant after work activities.

I would also like to thank my examiner Göran Brännare at Chalmers University of Technology for guidance during the project.

Finally I want to thank my girlfriend, friends and family for your advice and support through this work.

Filip Sahlberg

Abstract

SCA, Svenska Cellulosa Aktiebolag, produces and markets personal care products which includes tissue, packaging, publication papers and solid-wood products. The tissue department is divided into two divisions, Consumer and Away From Home. The Consumer products are sold in grocery stores as Edet, Tempo and Zewa. The Away From Home products are marketed under the global brand Tork. Tork distributes dispenser system with belonging tissue products to workplaces, institutions, hospitality, and other public facilities.

The objective with the project was to optimize SCAs Tork H1 roll towel dispenser. Tork H1 is a paper dispenser for high traffic toilets where hygiene is an important factor. To secure good hygiene it is touch-free; by only touching the paper you use. The dispenser is ejecting one towel at the time to reduce consumption. The optimization was focused on performance; with the main target to reduce pull force and noise level. Another wish was to increase robustness, consistency and reliability.

An initial pre-study gave insight in how different factors affect the performance. A wide variety of affecting factors were studied to obtain complete understanding. Next phase was to generate ideas and new concepts which after the concept evaluation resulted in three remaining concepts. These concepts were made as functional mock-ups for further testing and evaluation. The winning concept was designed in detail and finally built as a fully functional prototype.

Table of Contents

1	Introduction	1
1.1	Background	1
1.2	Purpose	1
1.3	Objective	1
1.4	Scope	1
1.5	Limitations	2
2	Method.....	3
2.1	Research.....	3
2.1.1	Internal research	3
2.1.2	Functional analysis.....	3
2.1.3	Benchmarking	3
2.1.4	Specification of requirements	3
2.2	Concept development	4
2.2.1	Brainstorming	4
2.2.2	Scamper	4
2.2.3	Sketching	4
2.2.4	Morphological matrix.....	4
2.2.5	Elimination Matrix	4
2.2.6	Pugh Decision Matrix.....	5
2.2.7	Mock-ups	5
2.3	Detail design	5
2.4	Result	5
3	Research	7
3.1	Product analysis	7
3.1.1	Cutting mechanism.....	10
3.1.2	Eject mechanism	10
3.1.3	Brake mechanism	11
3.1.4	Paper quality	12
3.2	Market analysis	13
3.2.1	Cutting mechanism.....	13
3.2.2	Eject mechanism	22
3.2.3	Brake mechanism	23
3.3	Specification of Requirements	23
4	Concept development	25
4.1	Concept generation	25
4.1.1	Brainstorming	25
4.1.2	SCAMPER	26
4.1.3	External search	26
4.1.4	Morphological charting.....	27
4.1.5	Concepts.....	28

4.2	Concept Evaluation	30
4.2.1	Elimination Matrix	30
4.2.2	Pugh Decision Matrix.....	30
4.2.3	Concept description.....	31
4.2.4	Mock-ups.....	33
4.3	The chosen concept	34
5	Detail design	35
5.1	Dimensions.....	35
5.2	Dispenser features.....	36
5.2.1	Cutting mechanism.....	36
5.2.2	Eject mechanism	38
5.2.3	Brake mechanism	38
6	Result	41
6.1	Renderings.....	41
6.2	Prototype	43
6.3	Evaluation of concept	45
6.3.1	Performance.....	45
6.3.2	Manufacturing.....	45
6.3.3	Function	46
6.3.4	Product Environment.....	46
6.3.5	Dimensions	46
6.3.6	Safety	46
7	Discussion and Recommendations	47
7.1	Research.....	47
7.2	Concept development	47
7.3	Detail design	47
7.4	Result	48
7.5	Recommendations.....	48
8	References.....	49
9	Appendix	50

1 Introduction

This chapter presents the background, the purpose and the goals of the project.

1.1 Background

SCA develops, manufactures and markets personal care products, tissue, packaging and forest products in more than 90 countries. The main market is Europe, but SCA is also one of the biggest actors in North America, Latin America, Asia and Australasia. They have about 52 000 employees spread all over the world. The company consists out of four business areas; Personal care, Tissue, Packaging and Forest products.

The Tissue divisions are divided into two segments; Consumer and Away-From-Home products. The consumer segment consists of products which are sold in retail stores like kitchen rolls, toilet paper, facial tissue and napkins. SCA's Away-From-Home products offer a complete hygiene solution to bigger institutions and companies. This segment includes tissue products, such as dispensers, soap, paper and services which are marketed under the global Tork brand. (SCA , 2010)

This project will process the paper dispenser Tork H1 Hand Towel Roll. This is a paper dispenser for high traffic toilets where hygiene is an important factor. To secure good hygiene it is touch-free; by only touching the paper you use. The dispenser is ejecting one towel at the time to reduce consumption.

1.2 Purpose

The purpose of this project, which was initiated by SCA Hygiene Products AB, is to optimize and further develop the cutting mechanism for the tissue dispenser H1. SCA believe that there is a potential for optimization of the cutting mechanism. Possible improvements are, knife shape, knife movement, knife angle of attack and knife actuation.

1.3 Objective

The objective is to optimize the cutting mechanism in SCA's H1 dispenser and reaching the main targets:

- Low pull force.
- Low noise level.
- Robustness.
- Reliability and consistency.

1.4 Scope

- To understand the product and identify difficulties.
- To benchmark cutting mechanisms in competitor dispensers.
- To propose functional improvements.
- To verify the performance of the proposed cutting mechanism with a prototype.

1.5 Limitations

The dispenser that will be optimized is SCA's towel dispenser Tork H1. The optimization is only focused on performance and not any economical issues. The main focus has been improvement of the dispenser's interior and the changes shall not make any impact of the exterior design. Tests on the dispenser have only been performed with European paper qualities. A main limitation for this master thesis has been the limited amount of time. This project should be performed during 20 weeks which means about 800 hours of work.

2 Method

This project consists of a complete product development process. This includes a market analysis, concept generation and evaluation, detail design, prototype building and testing. The different phases have been done in series of activity that follow each other in a natural way. The first step was to gather information through analysis of SCA's H1 dispenser and benchmarking of its main competitors. The next step was to develop new cutting mechanisms. The following phase was to develop, build and test the chosen concept. The final stage was the evaluation of the result and to conclude the project. The time plan for this thesis with all activities can be seen in Appendix A. This chapter contains information about the different methods that have been used during the project. These methods have been used to organize and execute the project from initial research to the final concept.

2.1 Research

This chapter describes the research methods which are used to understand the product and the needs.

2.1.1 Internal research

Internal research is the use of knowledge and information about the problem within the company. The reuse of existing knowledge and experience can be of great help during projects. The information is mainly used during the initial phase when a wide range of information is gathered in a relatively short amount of time.

2.1.2 Functional analysis

Functional analysis is used to map and identify complex products. The purpose with the analysis is to divide the complex problem into smaller sub-groups and to give a good overview of the product. By breaking down the problem into sub-problems and solve them individually it makes it easier. (Johannesson, Persson, & Pettersson, 2004)

2.1.3 Benchmarking

The competitor analysis is used to get an overview of the market and existing products. A good understanding of competitive products is critical to get a successful product. The purpose with the analysis is to identify competitive solutions and can provide a rich source of ideas for the product design. (Ulrich & Eppinger, 2008)

2.1.4 Specification of requirements

The specification of requirements describes what the product has to do in measurable parameters. The specification is mostly a translation of customer needs into requirements that the development team aim to achieve. Specifications are often developed throughout projects due to increased knowledge about the problem. The specification is a list of constraints and limitations identified during the pre-study, and often trade-offs between cost and performance. (Johannesson, Persson, & Pettersson, 2004)

2.2 Concept development

The methods used during the concept development are presented in this chapter.

2.2.1 Brainstorming

Brainstorming is a creative idea generation method by gathering people with different skills and experience. During a brainstorming session the group members shall stimulate, combine and improve each other's ideas. Throughout the session it is prohibited with negative criticisms to not impede the creativity. The session should not be longer than 45-60 minutes and have a leader to stimulate the group with new thoughts, ideas and questions during the gathering.

2.2.2 Scamper

The SCAMPER method developed by Bob Eberle is a checklist that can be applied as stimulation in the concept generation phase. The list helps the user to think of changes that can be done with the existing product. The method leads to new thoughts and opportunities, but many of the ideas are unpractical or not possible to manufacture. (Mind Tools Ltd, 2010)

SCAMPER stands for:

- S - Substitute - substitute materials, components, parts, assemblies, shapes, and textures
- C – Combine – combine, mix and group parts, elements, features, processes, and methods
- A - Adapt - adapt functions and shapes
- M - Modify - modify shape, scale, multiply, and distort
- P - Put to another use - repurpose parts, materials, features, and assemblies
- E - Eliminate – simplify, eliminate parts and features
- R – Reverse/Rearrange - flip parts, reverse orders, inside-out, upside-down, use the negative

2.2.3 Sketching

Sketching is a fast and easy way to communicate ideas and concepts. The ability to quickly record impressions and thoughts through sketching is an advantage in discussions in the concept generation. (Ulrich & Eppinger, 2008)

2.2.4 Morphological matrix

The Morphological matrix is a technique for finding new combinations of sub-solutions for new concepts. The system is broken down into parts, and solved individually with different sub-solutions. These sub-solutions are then combined to build up different concepts.

2.2.5 Elimination Matrix

The Elimination Matrix is used as the first step in the concept elimination. The matrix eliminates the bad concepts by investigating if the concepts solve the main problem, meet all requirements and are realizable. Only the concepts that meet all criteria and those who need to be examined more are taken further into the next phase. The rating of each concept determines if it will be developed further is based on the rating for each criteria, pass (+), eliminate (-) or more information needed (?). (Johannesson, Persson, & Pettersson, 2004)

2.2.6 Pugh Decision Matrix

Pugh Decision Matrix is the second evaluation step. The method is evaluating the different concepts one by one versus the reference solution. The comparison is based on criteria often taken from the requirement list. The criteria shall cover all areas and be focused on the main problem. All concepts are rated individually for every criterion, based on whether that concept is better (+), equivalent (0) or worse (-) than the reference solution. The worst concepts are eliminated and some concepts can be combined to get new good solutions. These concepts are added to the others during the evaluation. Combinations and modification of concepts are done to strengthen weaknesses located in the matrix.

Decision matrices have the advantage that they refer to pre-defined criteria collected from the customer specification rather than personal opinions. (Johannesson, Persson, & Pettersson, 2004)

2.2.7 Mock-ups

Mock-ups are used to get feedback about the design ideas early in the design process. The mock-ups are scale or full-size models of a design to easily teach, demonstrate, discuss and evaluate the concept. There are two kinds of mock-ups, physical appearance models and working prototypes. The physical appearance model is a mock-up made to display form and appearance of concept. Physical models are often made of paperboard, wood or polymer foams and are often painted to look like real products. Some functionality can also be included into appearance models. The other kind of mock-up, working prototype is including more function than form and design. The working prototypes are useful in concept testing, with the possibility to easily evaluate different features and functions. (Ulrich & Eppinger, 2008)

2.3 Detail design

During this stage the chosen concept will be further developed to a fully functional product that fulfills all criteria in the requirements list. Product summaries consist of detailed information about all parts and how they are related. It could be drawings, CAD-models, material specifications, technical component specifications and some more that are needed to describe a product for manufacturing. (Johannesson, Persson, & Pettersson, 2004)

2.4 Result

The results are the outcome from testing the fully functional prototype and compare it with the existing solution. The testing will be based on performance in test machines and other test methods earlier used at SCA.

3 Research

A pre-study was used to get a better understanding about the requirements that will have an impact on the product.

3.1 Product analysis

Tork H1 is a hand towel roll dispenser for high traffic toilets. The dispenser belongs to the Elevation range of dispensers, launched in January 2009. SCA's Tork Elevation series consists of 16 dispenser models for soap, toilet paper, hand towels, air refresher and waste. All models in the series are following the same visual profile and are available in black and white, see Figure 1.



Figure 1: Some products in the Elevation series, (SCA , 2010)

From left: H1 system- Hand towel rolls, T1 system-Toilet paper, S1 system-Soap, H2 system-Folded towels.

The Tork H1 dispenser cuts rolled paper into towel sheets with an area of 210 x 245 mm. It has high capacity with 400-775 sheets per roll depending on paper quality. When the roll is nearly finished it can be placed in the stub roll position and a new roll can be refilled. This feature gives the possibility to take care of the stub rolls and finish them instead of throwing them away. To secure a good hygiene the customer is only touching the paper which is going to be used, and the dispenser is automatically feeding out a new sheet after every dispensation. The hygienic push lever which is used for ejecting paper is only visible when no paper is in reach or during refilling. The dispenser with its vital components can be seen in Figure 2

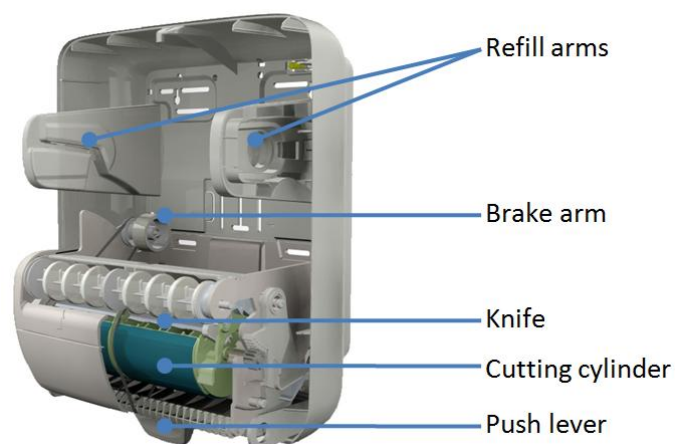


Figure 2: Tork H1 dispenser.

The existing product was fully taken apart to get a good understanding of how it is constructed. Contact with the staff at SCA gave further information about details in the design. To get a good overview of all functions they were placed into a functional analysis, see Figure 3. Every box in the analysis is realized by one or many components see Figure 4. Details during the penetration in box 7 can be seen in Figure 5.

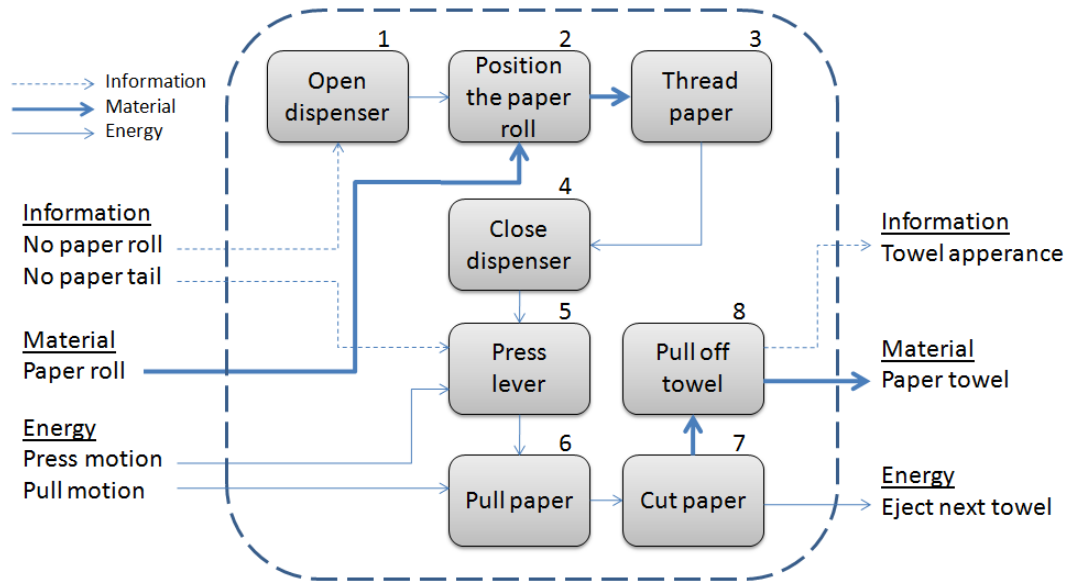


Figure 3: Functional analysis of Tork H1 dispenser.

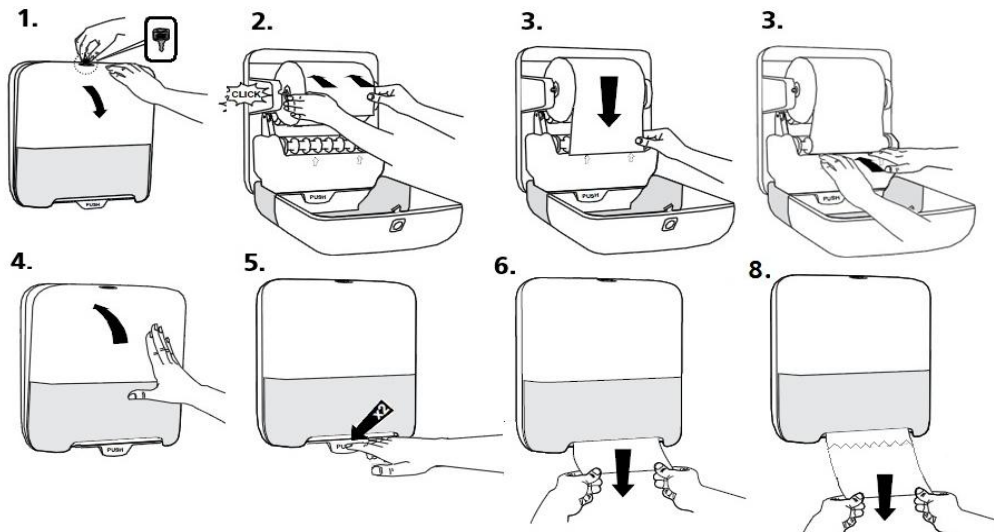


Figure 4: Filling and use of Tork H1 (SCA, 2010).

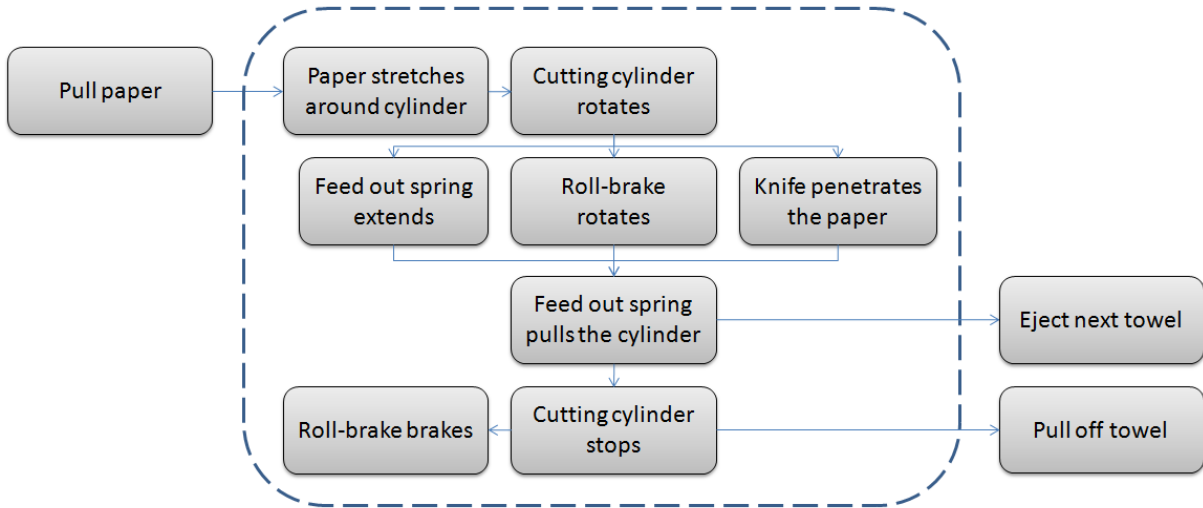


Figure 5: Details during the penetration.

The H1 dispenser consists of 74 parts, most of them manufactured in plastic except some screws, bearings, cranks, springs in metal and a few components in TPE. Most of the dispenser’s parts are located in the cassette. The cassette is a separate unit which is easy to mount in the console due to demands on short assembly time and possibility to replace it, see Figure 6.

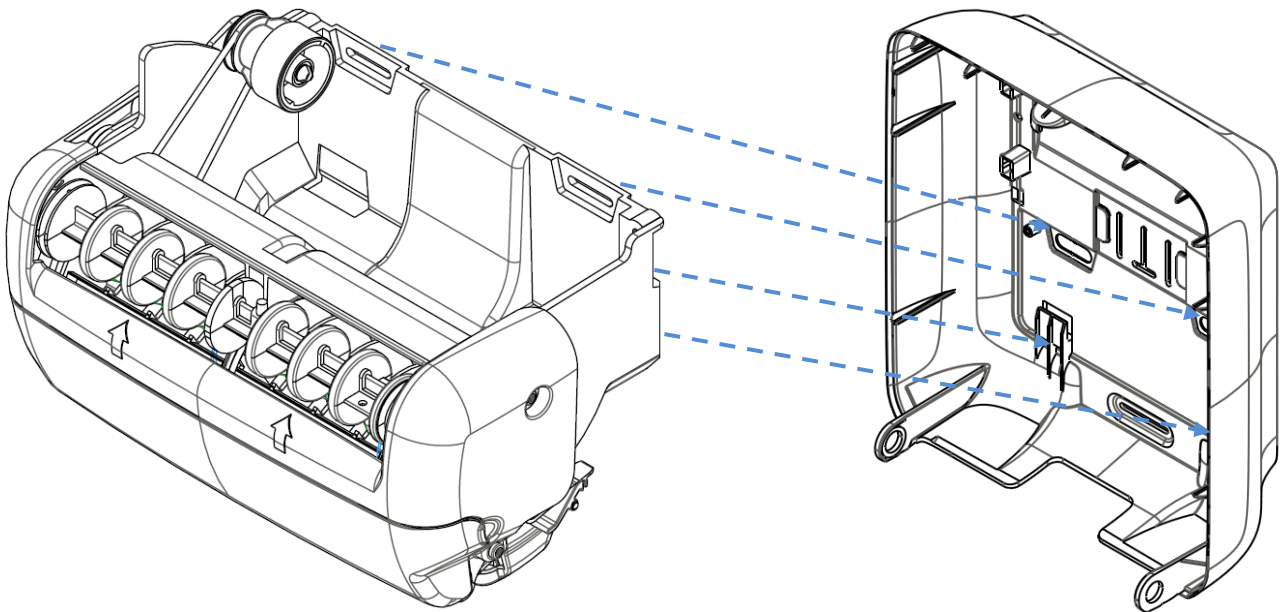


Figure 6: Cassette and console.

The cassette is the core of the dispenser which contains the cutting-, eject- and brake mechanism. These mechanisms are of big importance throughout every dispensation. If any of them malfunctions it causes a non successful dispensation and in some cases the paper can get jammed and occasionally components in the dispenser break.

3.1.1 Cutting mechanism

The cutting mechanism is located on the cutting cylinders right side and is driven by a cog segment, see Figure 7. During one revolution the knife is penetrating the paper by turning out the knife from the cylinder when the cog segments meets.

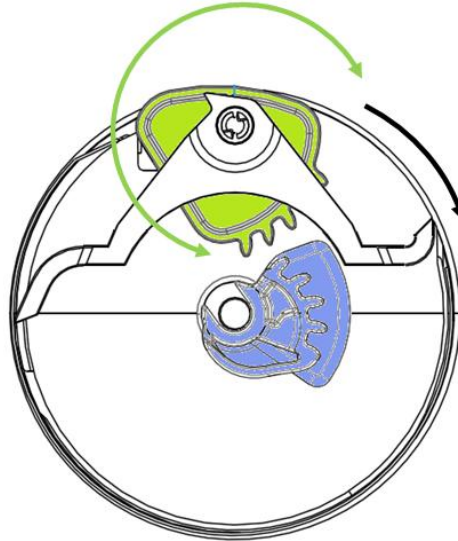


Figure 7: Cutting mechanism.

The knife consists of a knife holder and two separate knife blades; each blade with four bended teeth, see Figure 8. The cog segment is placed on the right hand side of the knife holder.



Figure 8: The knife with knife blades.

3.1.2 Eject mechanism

The tail is ejected after every dispensation to make it possible for the next user to get a sheet without touching the dispenser. Touch free dispensation is of great interest because of high demands on hygiene. If the mechanism does not work and no paper tail is presented, the user is forced to press push lever which is not appreciated for hygienic reasons. The mechanism consists of a crankshaft and a tension spring which is placed on the cutting cylinders left side. In the state of equilibrium the crankshaft is positioned to the left, see red position in Figure 9. When the user pulls the paper the spring will distend during the first 180° and then bringing with the cutting cylinder through the rest of the revolution, see black and green position in Figure 9. The penetration takes place during the tension of the spring and the tail is ejected along the last half rotation.

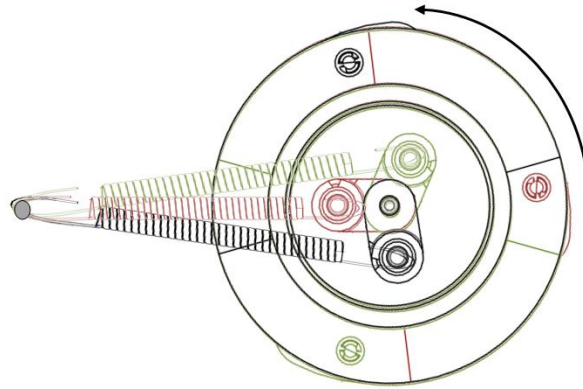


Figure 9: Tail ejection mechanism.

3.1.3 Brake mechanism

The brake mechanism is used to avoid paper loops created by over spin of the paper roll. Loops emerge if the roll is big and the user pulls the paper too fast. This leads to large kinetic energy in the roll, which does not stop as fast as the cutting cylinder and a loop is then formed due to different speeds. By using the brake arm which is lying on to the paper roll and connected to the cylinder with an O-ring the dispenser does not form any loops, see Figure 10. The brake arm is also used as a help to feed out the tail by transferring the kinetic energy in the paper roll to the cutting cylinder.

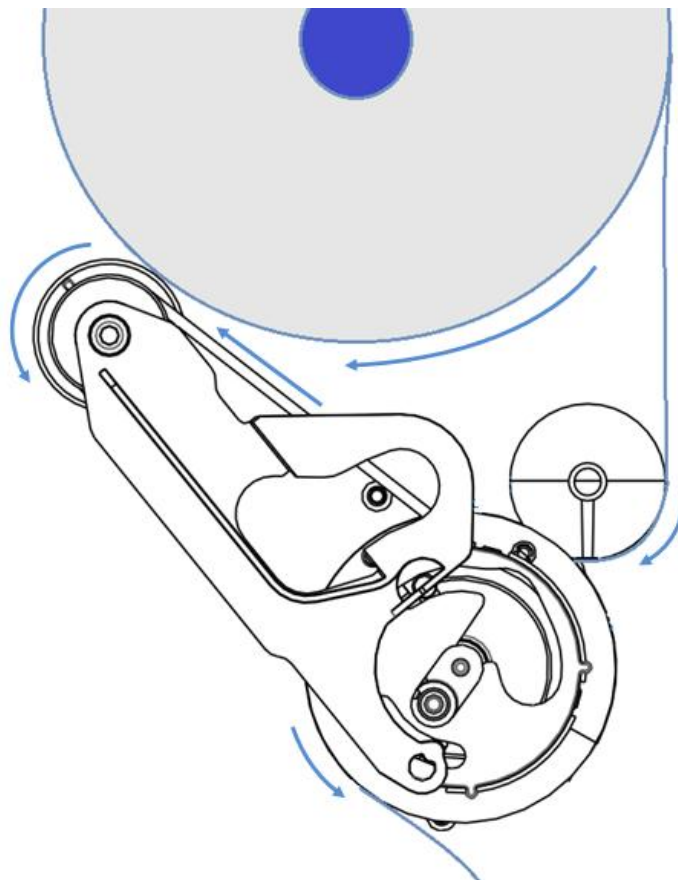


Figure 10: Brake mechanism.

3.1.4 Paper quality





An important variable factor in the dispensers is the different paper qualities. The dispensers need to manage the wide variety of paper qualities with different properties. Some of the differences are manufacturing methods, number of layers and paper density. Variations in the manufacturing is how the paper is dried, the two most common methods are TAD (Through Air Drying) and DC (Dry Creped). The major difference is that the TAD process replaces the pressing operation in the conventional dry creped process with a through-air-drying step. This results in a thicker tissue which is softer, stronger and better absorbency than the DC paper. (Atkins, 2004) Most of the tissue papers have multiple layers for better absorption and some has only one layer. The single layered paper gives more meters per roll which is requested from the market. Another variable factor is the paper density, expressed in grams per square meter (g/m^2) also known as grammage.

The various paper qualities give different demands on the dispenser:

- Strong paper requires a robust knife.
- Stretchy paper requires a good grip surface on the cutting cylinder to ensure fulfilled penetration.
- Soft paper requires a low pulling force to not tear apart when it is pulled.

To ensure that the new developed dispenser will handle this and some other demands it has been tested with four different paper qualities, see Table 1 for details.

Table 1: Detailed information about the paper qualities used in the project.

	290016 Premium	290067 Advanced	290076 Green Adv	290057 Universal
				
Roll length [m]	100	150	150	190
Material	TAD	TAD/DC	DC	TAD
Layers	2	2	2	1
Grammage [g/m^2]	2x20,5	18/23,5	2x24,5	26
Other	<ul style="list-style-type: none"> • Highly absorbent • Very soft and strong 	<ul style="list-style-type: none"> • Efficient absorption • Wet-strong hybrid TAD quality 	<ul style="list-style-type: none"> • Efficient absorption • Wet-strong quality 	<ul style="list-style-type: none"> • Soft quality

3.2 Market analysis

The analysis of competing dispensers was made as a technological benchmark with focus on cutting-, eject- and brake mechanism. The market analysis was important to get a grasp of what demands the mechanism should achieve.

Torks main competitors are Kimberly-Clark, Georgia Pacific, Metsä Tissue and Global Plastic. These companies offer a wide variety of paper tissue products and dispensers. The analyzed dispensers in this project have been the equivalent competitor products to Tork H1. Most of them works the same way and looks nearly the same from the outside, see Figure 11.



Figure 11: Competitor dispensers.

3.2.1 Cutting mechanism

The major differences which distinguish the dispensers are how the cutting mechanism works. All analyzed dispensers except one is using a penetrating knife to cut the paper, that one is using cylinder cutting mechanism. It has a rotating cylinder with cutting blades which cuts against a set of fixed metal pieces; the mechanism has similarities to a cylinder lawnmowers. A driving mechanism is used in all dispensers to penetrate the knife through the paper. Two kinds of knife actuation exist on the market; one of them is driven by a cog segment as in Tork H1 and the other by a cam mechanism. A cam mechanism transmits movement from a rotating roll by direct-contact to another mechanical part which allows controlled timing, speed and motion. The mechanism transforms a rotational motion into a linear reciprocating motion; see Figure 12. (DAEDONG FA Co, 2005)

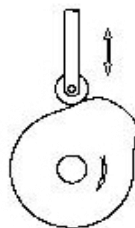


Figure 12: Cam curve mechanism (DAEDONG FA Co, 2005).

The design of knives is something that is very different between the analyzed products. Various elements are number of teeth, knife thickness, teeth angle and height. Some competitors are combining big and small teeth to spread the penetration force over time. A test rig was developed to evaluate different knife designs based on penetration force, see Figure 13.

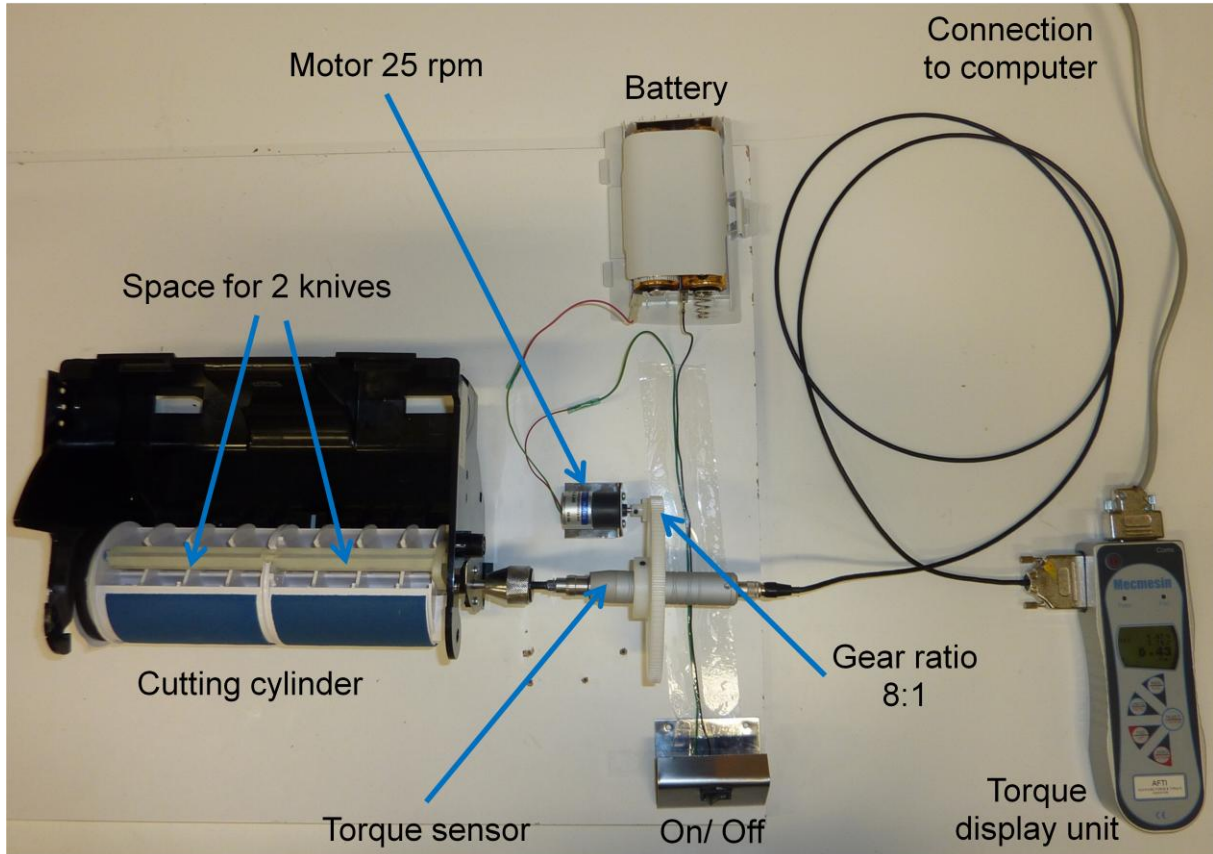


Figure 13: Testing equipment.

The testing equipment gave the possibility to compare various knives without the influence of other factors than the knife. The device made it possible to measure the required penetration torque during one penetration with high samples frequency. Tests were performed by attaching one piece of paper around the cutting cylinder, run the test which penetrated the paper and log the result on the computer. Each penetration test takes about 6-7 seconds. The tests were repeated ten times for every knife to get good repeatability and to give a mean curve with small variations, see Figure 14 .

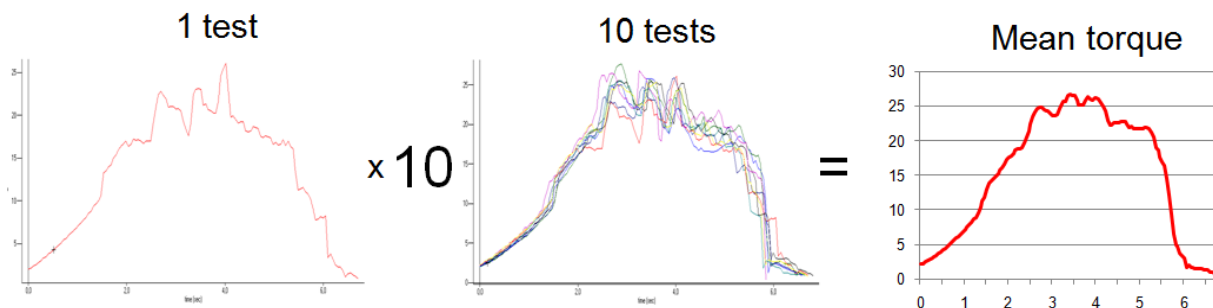


Figure 14: Testing of one knife.

These results could then be analyzed to see peak locations and torque curve characteristics. The curves for different knives could also be compared to determine which one that works best. This comparison of the torque curves were not ultimate, instead was the total work calculated with the formula:

$$W = \int_{\theta_1}^{\theta_2} \tau \, d\theta$$

W is total work, τ is torque and θ_1 and θ_2 the initial and final angular positions of the cutting cylinder.

The method is calculating the total area under the torque curve. By using this method an exact value of the required total work was given which was much easier to compare than the different curves.

First test reviewed how the number of teeth influences the torque. Every test was performed with double knives mounted in the knife holder which sits in the cutting cylinder. This test was done in four different types of paper to get a good reliability. As can be seen in Table 2 have nearly all knives the same curve except the knife with one tooth. The calculated total work can be seen in Table 3 and in the summarizing Table 7. The existing knife in Tork H1 has four teeth, only the triple teethed knife was performing better.

Table 2: Mean torque- Varying number of teeth.

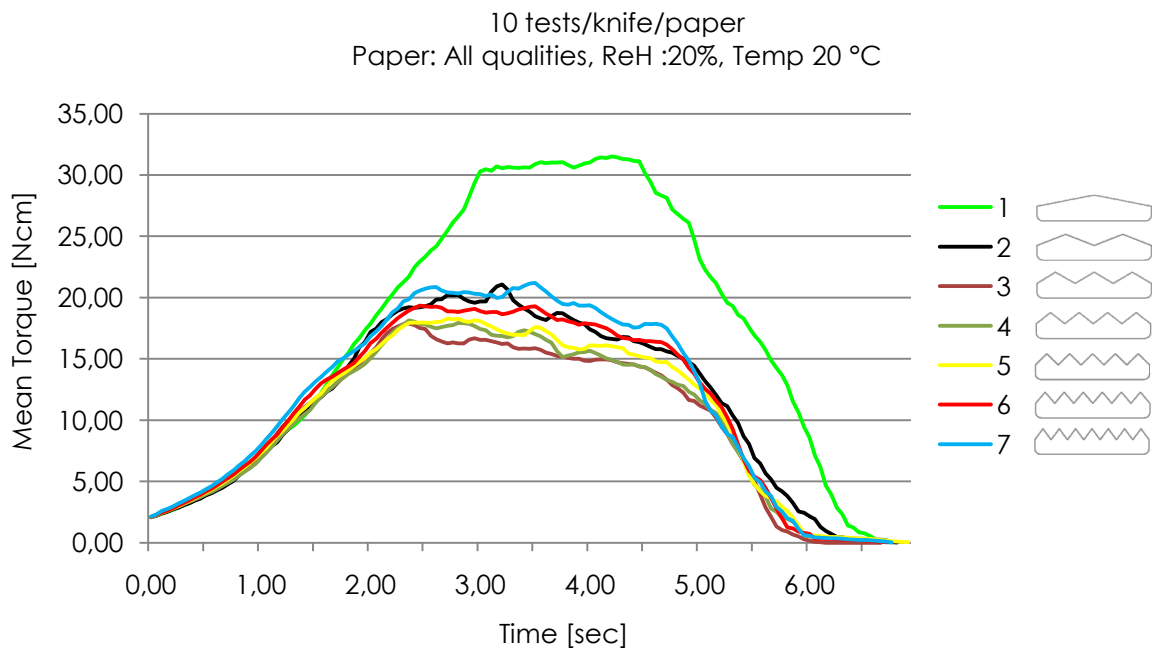
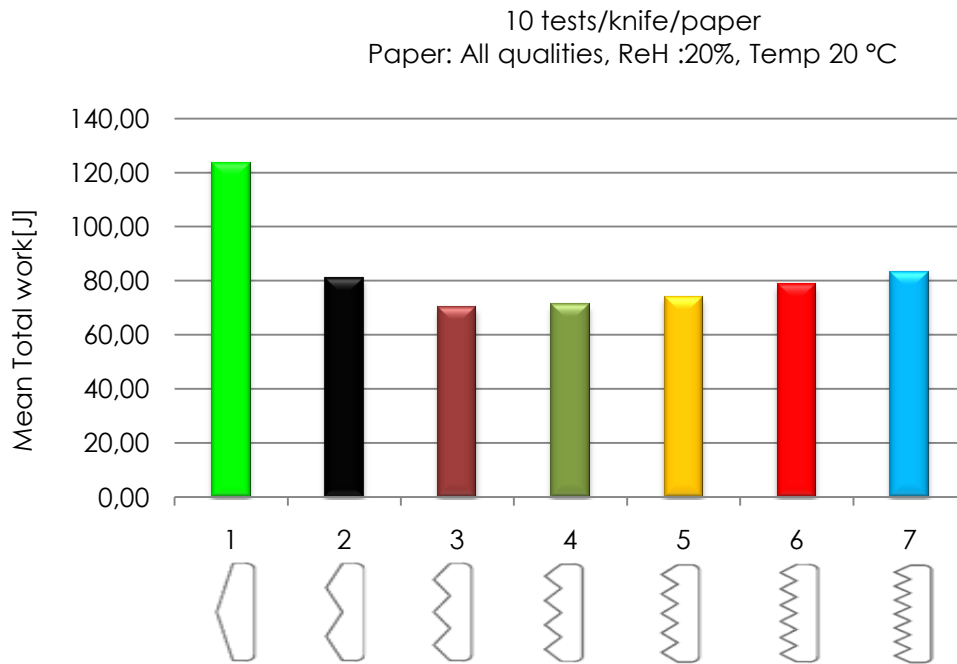


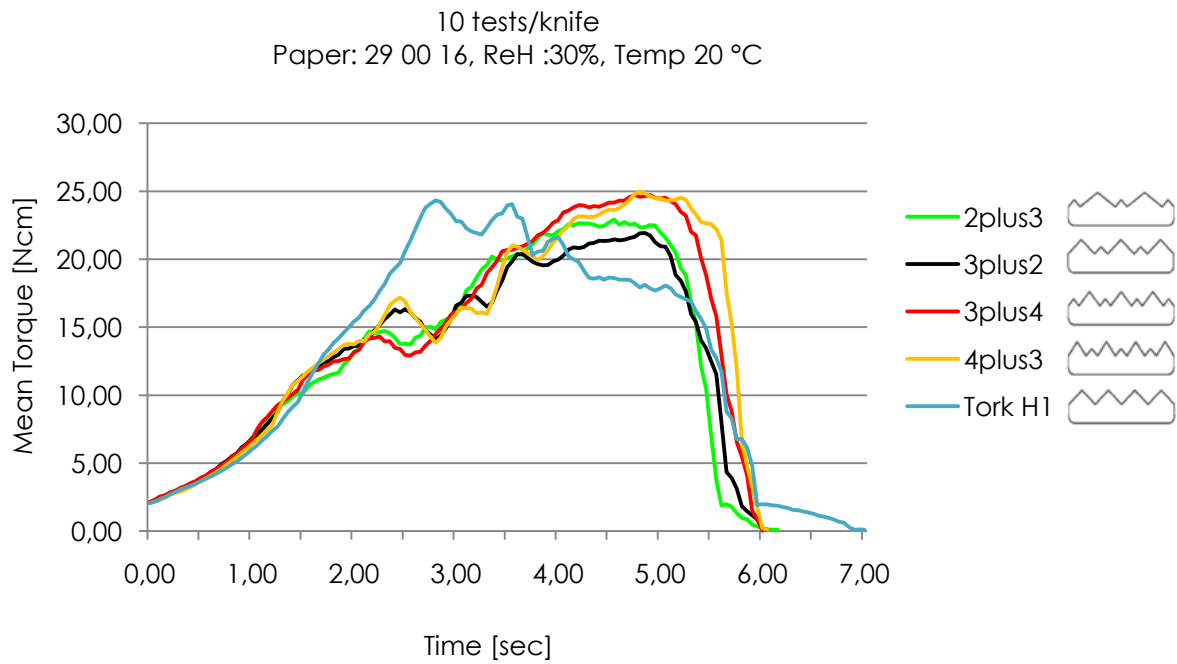
Table 3: Mean total work- Varying number of teeth.



For the remaining tests one paper quality was considered as enough because the first tests showed that curves were similar for all qualities. The chosen paper quality was Premium due to that it was the toughest.

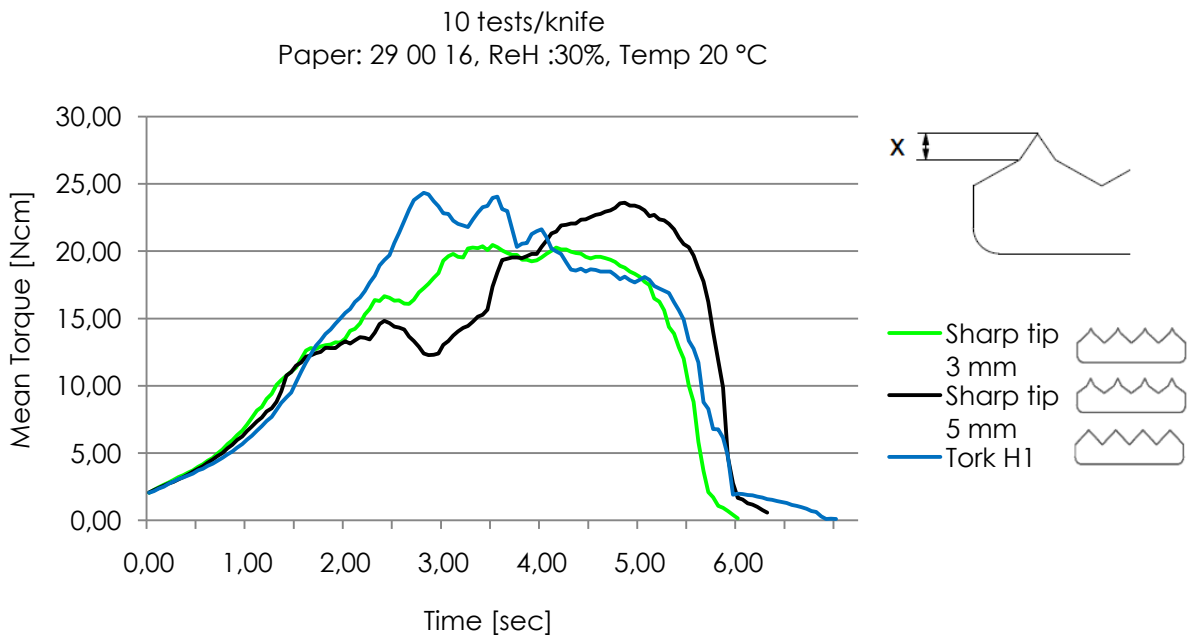
As could be seen in Table 2 the torque increased until the knife came through the paper, than it had a decreasing trend. The majority of the top peaks were located during the initial penetration. To avoid this some ideas were born; by combining short and long teeth as competitors do to spread out the force over time or by having a small tip on the tooth top to minimize the penetration peak. Results of combining short and long teeth can be seen in Table 4. The theory was right; the front end loaded curves disappeared and the curve peaks was delayed. Two of the tested knives were also consuming less work than Tork H1, see Table 7.

Table 4: Mean Torque- Varying number of teeth and teeth length.



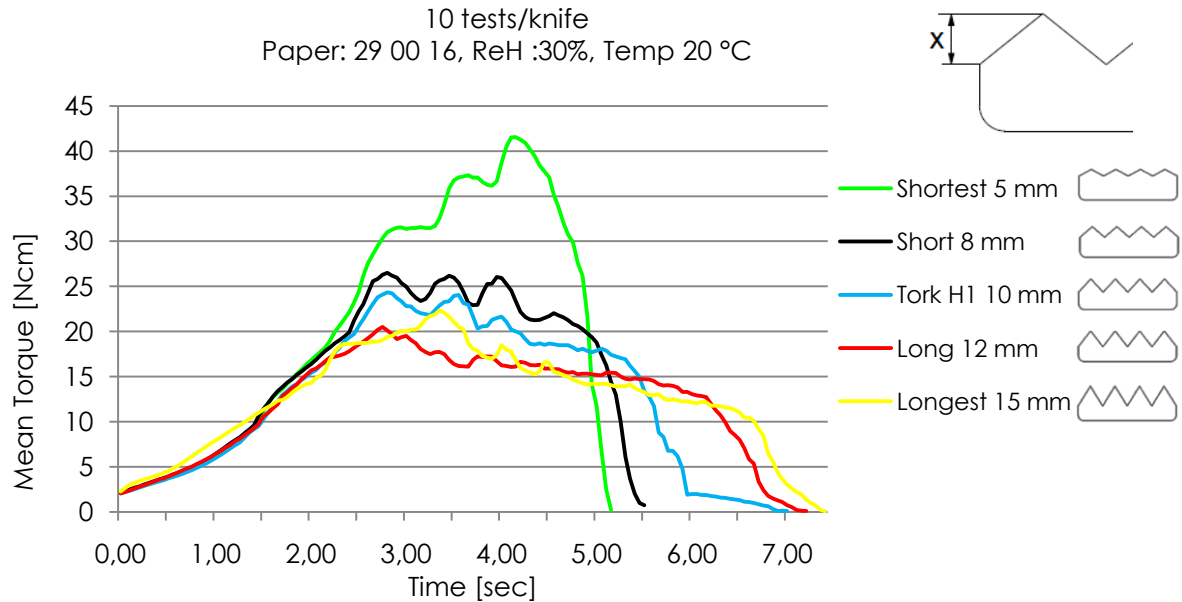
The second idea, to have a sharp tooth top was also tested, see Table 5. The sharp tip concept was also changing the front loaded curvature. The short 3 mm tip had the ultimate design which gave an arc shaped curve and the longer 5 mm tip resulted in a back end loaded curve similar to the knives with various teeth height.

Table 5: Mean Torque- Varying tip length.



Tests with changed teeth length was done without any significant advantages, the knives were performing similar or worse than Tork H1 in total work, see Table 7. The individual torque curves for these knives can be seen in Table 6.

Table 6: Mean Torque- Varying teeth length.



Tests on knives with rounded valleys were also performed, see Figure 15. The idea came from the sharp tipped knives which had a lower initial penetration force. But the knives were not able to cut through the paper because the knives were too flat in the valleys.



Figure 15: Knives with rounded teeth valleys.

A summarizing table of the total work was done to give a good overview of all knives performance, see Table 7. An additional table with max torque was also taking into consideration when evaluating the knives, due to wish of a torque curve without high peaks, see Table 8.

Table 7: Mean total work- Varying teeth design.

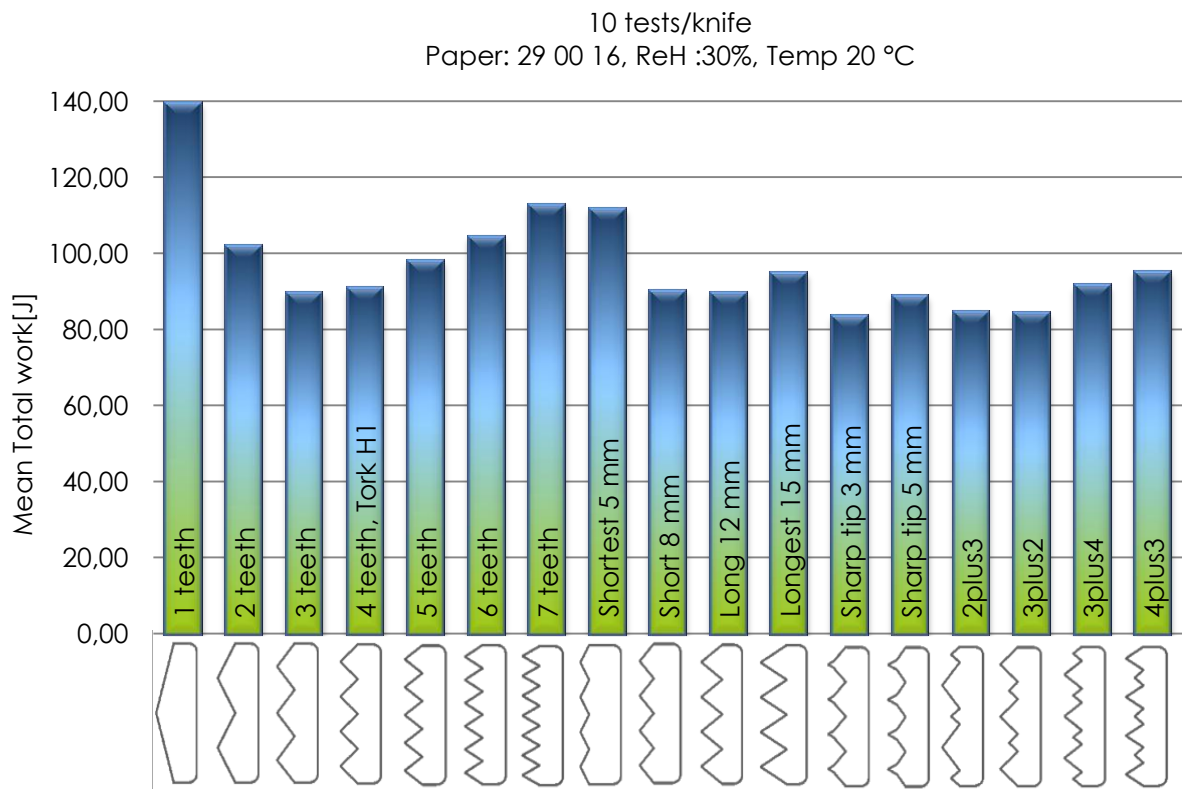
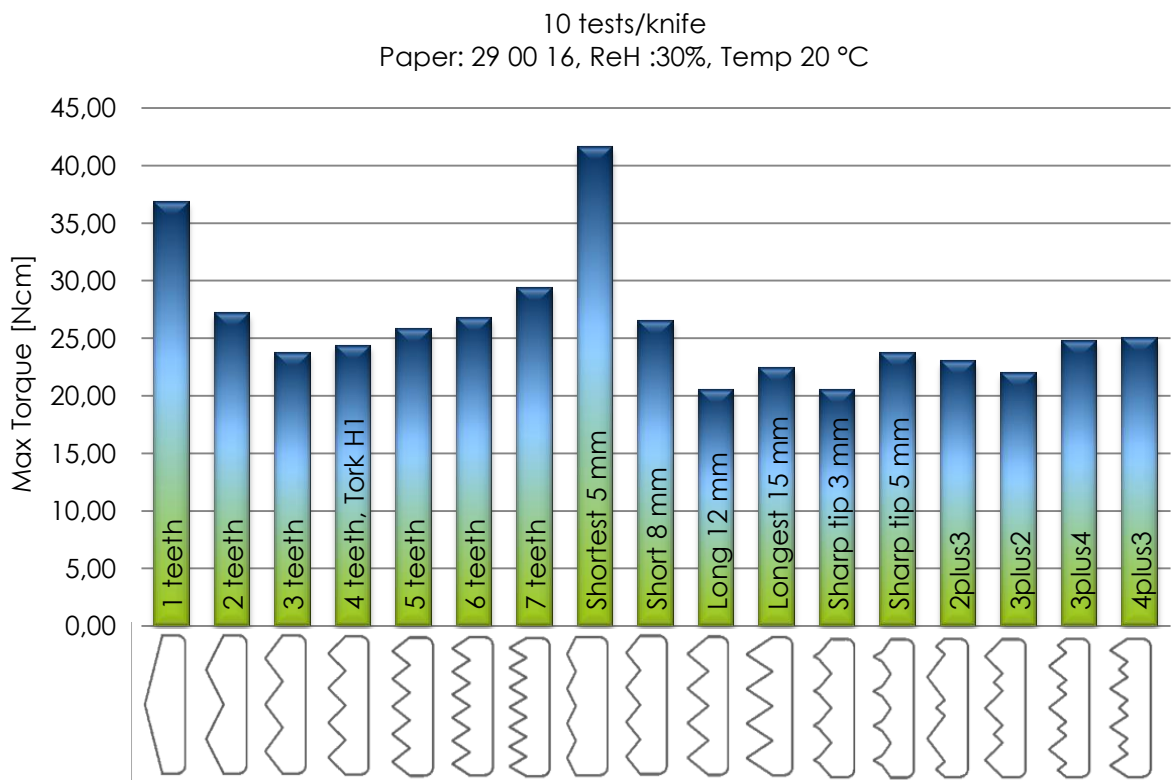


Table 8: Max Torque- Varying teeth design.



Another variable element in the knife design is the knife angle. By increasing the angle, the knife's lever will be shorter, measured from the centre of the knife rotation to the teeth tip, which decreases the torque, seen in Table 9 and Table 10. Tests were also performed with larger angles but they were not feasible due to that the knife was not able to penetrate the paper.

Table 9: Mean Torque- Varying teeth angle.

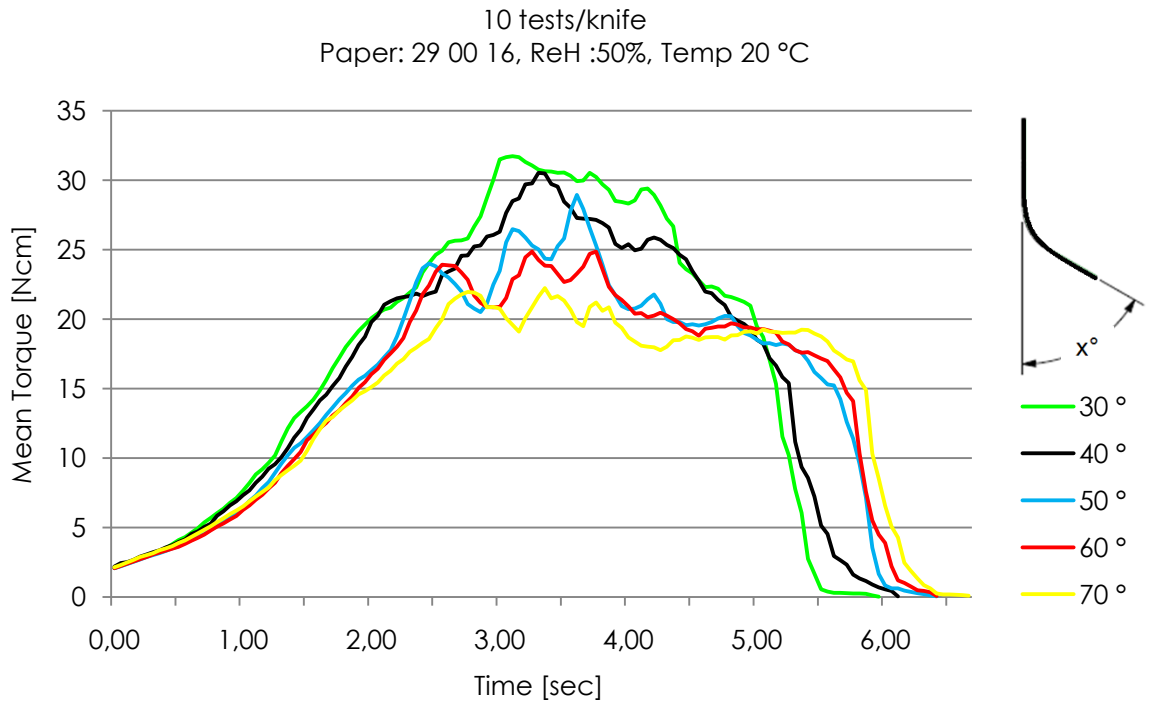
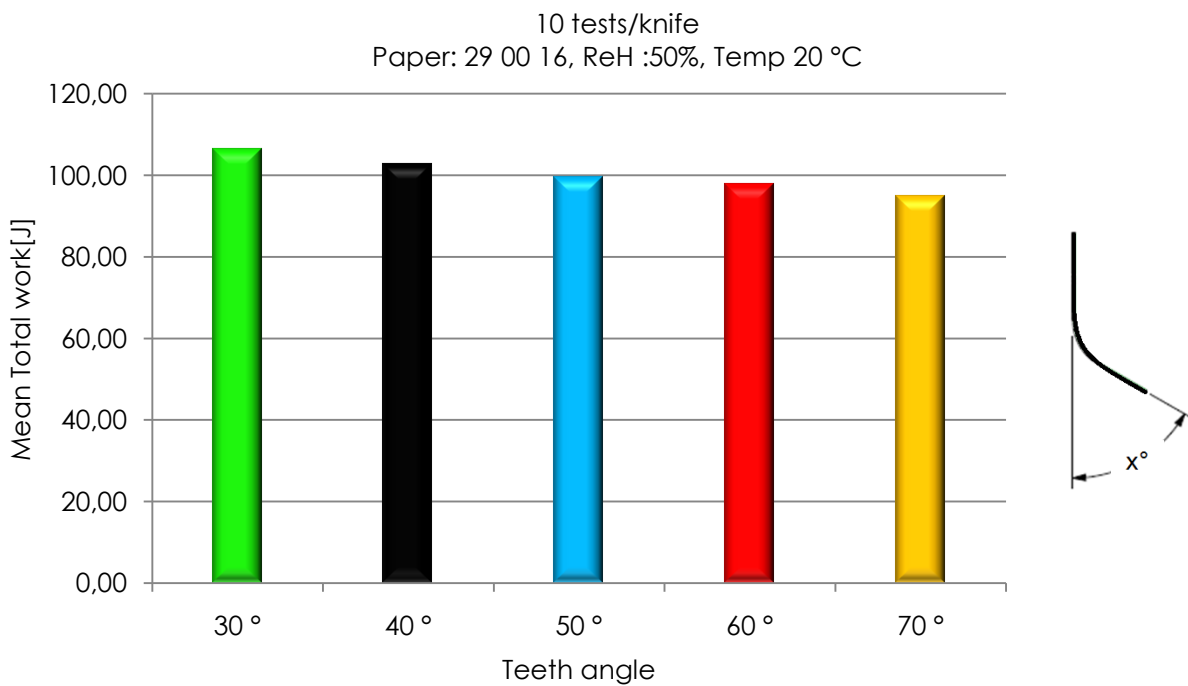


Table 10: Mean total work- Varying teeth angle.



The best performing knife during all tests was the sharp tipped knife with 3 mm tip, see Figure 16. To verify the test results the knife was mounted in a fully functional dispenser and tested in the dispensation robot. The dispensation robot is a pneumatic driven claw which pulls the paper meanwhile it measures the pulling force, see Figure 17. The claw is connected to a load cell which logs the peak force during every penetration to a computer.

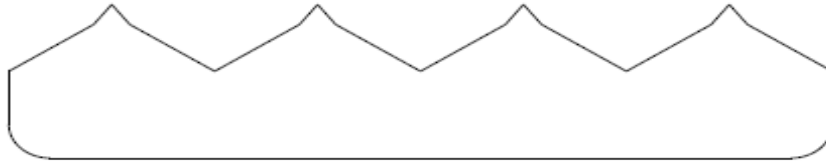


Figure 16: Knife with 3 mm tip.

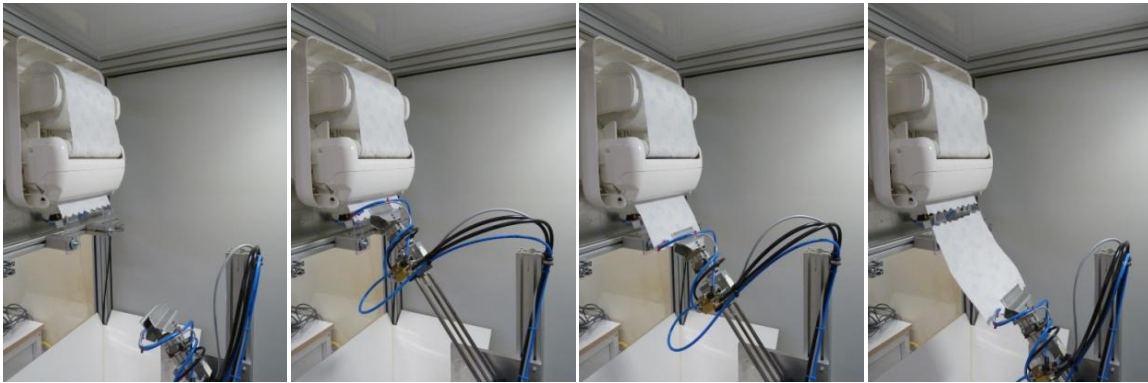


Figure 17: Dispensation robot, one dispensation cycle from left to right.

The test was performed throughout four different paper qualities rolls to provide fair evaluation between the new knife and the existing Tork H1 knife, see Table 11. The tests showed that the new knife was decreasing the pulling force with nearly 9 % for the two high qualitative papers. For the other two was it a smaller improvement, around 1 %. The difference is mainly because of the paper structure. In “bad” paper qualities is the required initial penetration force lower which means that the difference is getting smaller with the new knife compared to the old one.

Table 11: Data from tests in the dispensation robot

	290016 - Premium		290067 -Advanced		290076 - Green Adv		290057 -Universal	
	Tork H1	New Knife	Tork H1	New Knife	Tork H1	New Knife	Tork H1	New Knife
Roll length [m]	100		150		150		190	
Tests	378	371	579	581	582	575	751	758
Mean pull force [N]	13,58	12,39	13,57	12,34	12,47	12,33	11,85	11,78
Difference [N]	1,19		1,23		0,14		0,07	
Difference %	8,76		9,04		1,10		0,60	

3.2.2 Eject mechanism

The eject mechanism looks nearly the same in all competing dispensers. The mechanisms consist of a crankshaft and a tension spring similar to the mechanism in Tork H1. The only difference is that some competitors are using double springs instead of one, see Figure 18.



Figure 18: Dispensers with double springs, Left: Kimberly-Clark, Right: Metsä Tissue.

The test equipment used during the first knife test was used even here to verify how double springs performed compared to single spring, see Figure 19. With the test rig was it possible to measure the torque continuously during 360 degrees of rotation. With the received data was possible to calculate the total work to extend the spring and the regenerated energy during contraction of the spring. With the test rig it is possible to measure the spring force without influence of any other factors, and the only varying factor during the tests was the spring position. The test did not show any beneficial differences between different spring positions and varying number of springs.



Figure 19: Test rig for springs, possible to vary spring position.

3.2.3 Brake mechanism

None of the competitors are using a brake arm similar to the one used in Tork H1. Many of the competitors do not even have any brake device. This problem is in some dispensers instead solved by ensuring that no paper loops get jammed by covering all vital parts. Metsä Tissue has another solution, by having a feathering brake block against the side of the paper roll, see Figure 20. The brake block has a larger contact surface against the roll when it is full compare to when it is nearly empty. This gives a higher brake force when the roll has large kinetic energy during the rotations. Some other competitors has the paper roll placed direct onto the cutting cylinder to avoid over-spin, see Figure 20. By having it placed direct onto the cylinder it has always the same speed as the cutting cylinder and no paper loops are generated.



Figure 20: Brake mechanisms, Left: brake block, Right: roll direct onto cutting cylinder.

3.3 Specification of Requirements

The requirements criteria's were defined from the product analysis, market analysis and SCA's Tork H1 requirement list. On a meeting with Björn Larsson the list was reviewed and discussed, which resulted in some justifications. The weighting of the criteria were also discussed and completed together with Björn. The Specification of Requirements can be seen in Appendix B.

The requirement criteria were divided into sub-groups; performance, manufacturing, function, product environment, dimension and safety.

4 Concept development

The purpose of the concept development was to develop a number of concepts that could meet the requirements. The development process was screening the great variety of ideas down to a couple of well developed concepts. The development process includes idea generation, concept generation, concept evaluation and mock-up testing.

4.1 Concept generation

The concept generation was the initial part of the concept development, where all ideas were gathered and organized. A wide variety of ideas was desirable to raise the chances for good innovations.

4.1.1 Brainstorming

The brainstorming session was performed with other master thesis students and staff at SCA. The session was basically a short presentation of the problem followed by free form sketching without any limitations. The focus of the idea generation was on alternative solutions to cut the paper. The objective in this stage was to generate many ideas with different mechanical solutions and details and exact proportions were not of large importance.

The session resulted in a number of ideas, some more useable than others, and a few of them were taken further in the concept generation. Several of the ideas and thoughts that were put on paper can be seen in Figure 21.

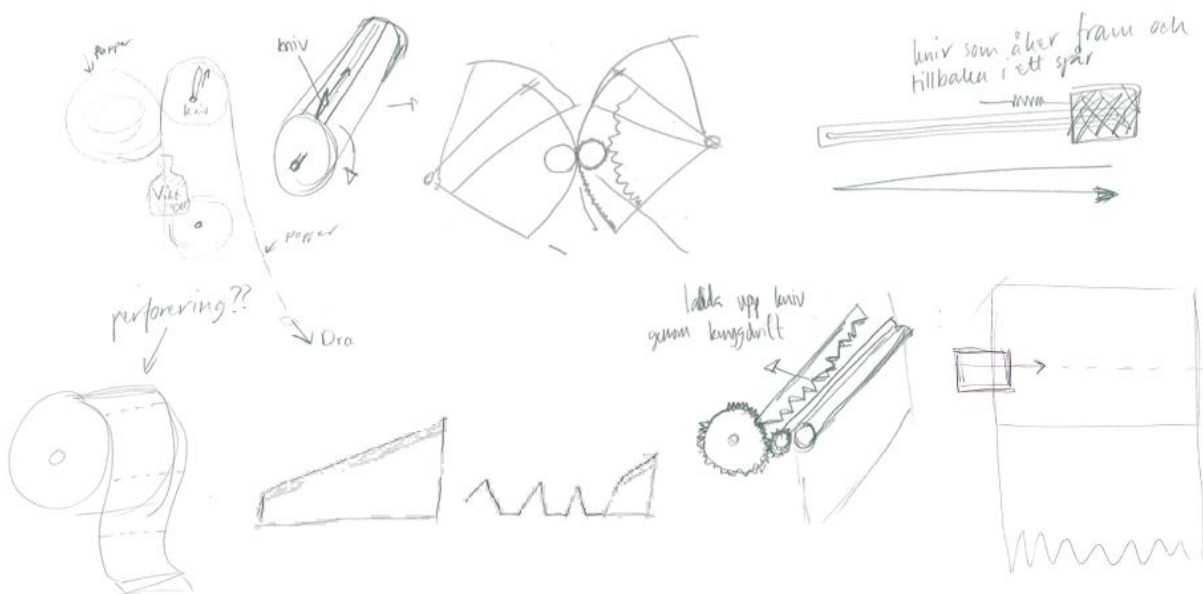


Figure 21: Brainstorming sketches.

4.1.2 SCAMPER

Lots of ideas were generated by using SCAMPER and the methodical way of reviewing individual parts one by one gives a different perspective. The method stimulates new ways of thinking and generated many ideas; a short summary can be seen below and the full list of ideas is shown in appendix B. Many of the ideas were taken further into concepts.

S - Substitute - substitute material, component, parts, assemblies, shapes and textures.

- Replace sandpaper with another material
- Replace cog segment with a rubber grip surface

C – Combine – combine, mix parts, elements, features, processes and methods.

- Combine bearings with rolls
- Combine sandpaper with cutting cylinder

A - Adapt - adapt functions and shapes.

- Replace cutting mechanism with a mechanism for perforated paper
- Adapt mechanism for toilet paper

M - Modify - modify shape, scale, multiply and distort.

- Bigger cutting cylinder
- Double knives

P - Put to Other Uses - repurpose parts, materials, features and assemblies.

- Perforated paper
- Earlier cutting, direct after paper roll

E - Eliminate – simplify, eliminate parts and features.

- Eliminate pressure roll
- Eliminate brake arm

R – Reverse/Rearrange - flip parts, reverse orders, inside-out, upside-down and use the negative.

- Reverse rotation direction of cylinder
- Penetrate the paper from the outside

4.1.3 External search

A more systematic and rational thinking were also used to generate ideas. One method used was to analyze cutting mechanisms used in other industries; like metal cutting and gardening tools. The result of these ideas became inspiration for new concepts; see Figure 22 for some of these ideas.



Figure 22: Examples of cutting mechanisms.

An external literature search provided detailed solutions, especially for mechanical mechanisms. These mechanisms could be used as actuators and motion control of the knife during penetration, see example in Figure 23.

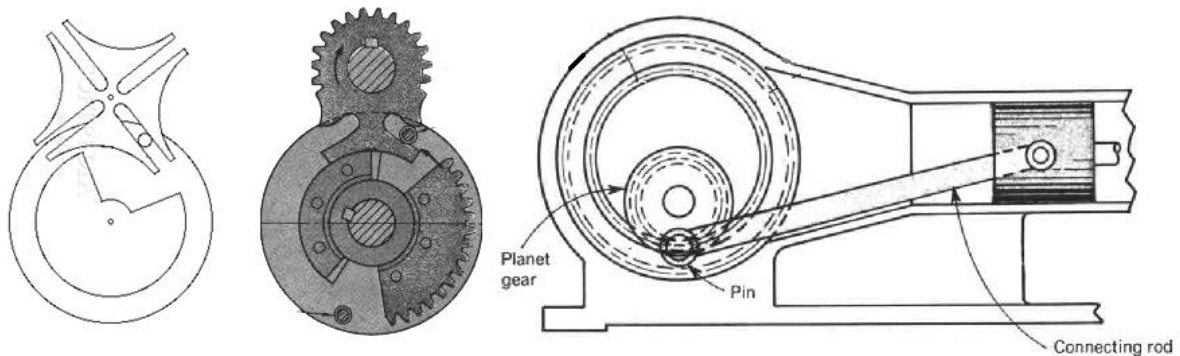


Figure 23: Examples of rotation mechanisms, (SCLATER & CHIRONIS, 2001)

Left: Geneva mechanism. Middle: Star wheel mechanism. Right: Cycloid gear mechanism.

4.1.4 Morphological charting

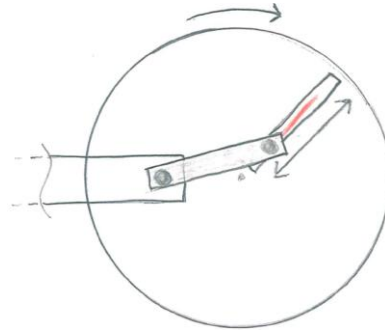
After the concept generation a large number of ideas and solutions were generated. They were screened and divided into sub-groups, to easily overview all ideas. The sub-groups were based on different sub-problems in the product; knife actuation, penetration type, penetration direction, tail ejection and brake mechanism. These sub-problems were placed in a morphological charting sheet together with sub-solutions to every problem. In the chart the organized solutions were combined to create different concepts. Theoretically thousands of concepts could have been created by using all the morphological charting combinations, but 10 concepts were considered enough to cover the most interesting realizable solutions, see appendix C.

4.1.5 Concepts

This chapter will shortly explain each concept one by one with focus on knife actuation to give a better understanding through the concept evaluation.

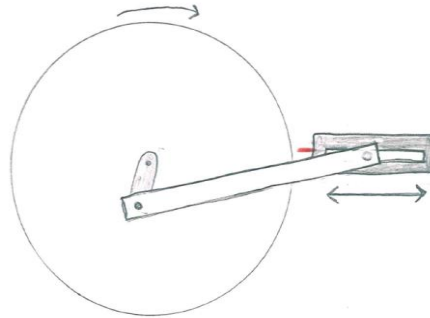
Concept A- The motor crank

The knife has a linear reciprocating movement in the slot that is controlled by a fixed rod.



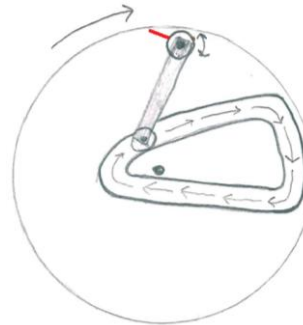
Concept B- The train

"The train" mechanism converts the rotary motion in the cutting cylinder through the rods to a linear reciprocating movement for the knife.



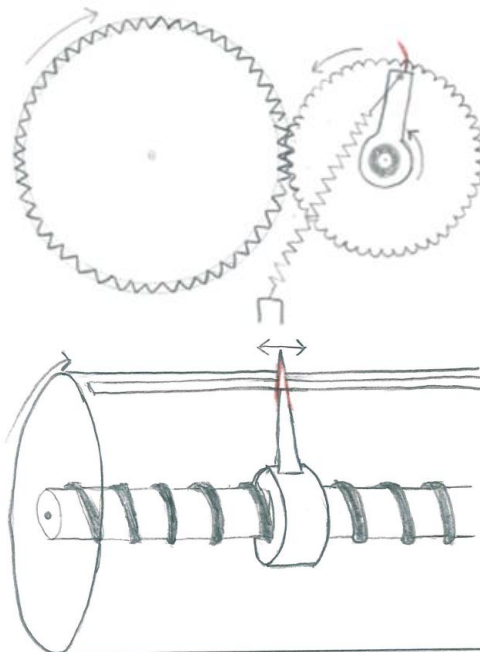
Concept C- The smooth cam

"The smooth cam" controls the knife-motion with a lever arm which is following a curved slot during the rotation, the same solution as can be seen among other competitors.



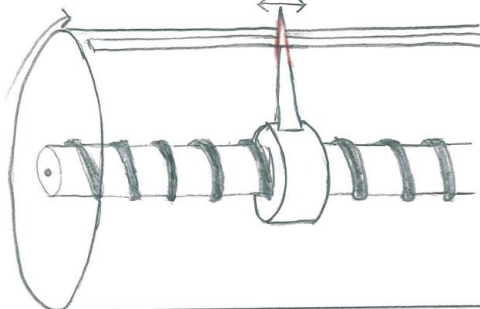
Concept D- The stinger

"The stinger" tightens up the spring connected to the knife until it flips over and hits the paper. The one way bearing gives the knife-arm free rotation in one direction to make it possible to strike the paper.



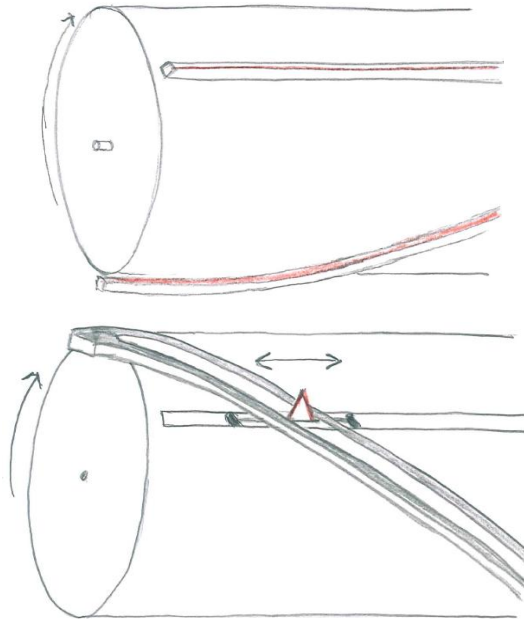
Concept E- The screw

"The screw" has a vertical transferring knife which shears the paper sideways. The knife runs by a threaded rod in the centre.



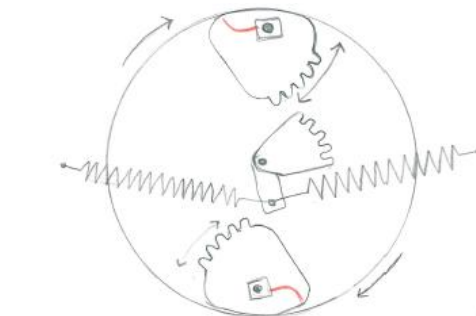
Concept F- The lawnmower

“The lawnmower” works just like cylinder lawnmower. The paper is cut between two sharp pieces of metal.



Concept G- The slide

“The slide” has a vertical sliding knife which shears the paper sideways. The knife runs in a guidance slot.

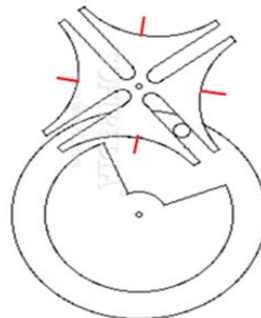


Concept H- Double Tork

“Double Tork” is basically the same as the existing Tork H1 except that it is equipped with two knives and have double circumference to get the same sheet length.

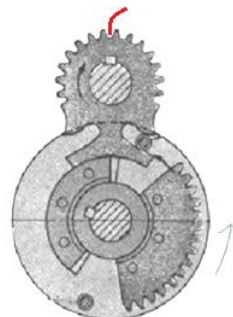
Concept I- Multiple knife

“Multiple knife” is having an intermittent gear where the driving cutting cylinder has a pin that reaches into a slot of the knife wheel and thereby shifts one step



Concept J- The cogwheel

“The cogwheel” is similar to the Tork H1. The difference is that the curved surface severely guides the knife throughout the rotation.



4.2 Concept Evaluation

At this stage of the project ten concepts existed which should be screened down to one. Three methods were used to evaluate and judge the different concepts; elimination matrix, decision matrix and mock-up testing.

4.2.1 Elimination Matrix

The Elimination Matrix was the first screening, which reviewed if the concepts meet the three criteria's. Seven concepts were taken further in the process, two of them needed to be studied more and three out of ten concepts were eliminated directly. See Appendix D for Elimination Matrix.

Eliminated concepts:

Concept A- *The motor crank* was not possible to realizable due to intersection between crankshaft and centre axis.

Concept E-*The screw* and Concept G- *The slide* did not solve the main problem because it is not possible to shear paper sideways

4.2.2 Pugh Decision Matrix

The second elimination used the Pugh Decision Matrix based on a comparison between the existing Tork H1 and different concepts. The weighting criteria's were taken from the requirement list to reflect the main problems.

The Pugh Decision Matrix was completed by scoring the concepts based on whether the alternative was better, equivalent, or worse than that the reference. The scoring showed which concepts that were the most suitable and which could be eliminated. All concepts with inferior performance than the today's dispenser were eliminated. Four concepts were now remaining for further investigation and development. Two of them were combined to get the best out from two ideas. This Decision Matrix can be seen in Appendix E.

Eliminated concepts

Concept D- *The stinger* was too complex with many moving parts and the solution can cause high noise levels when the knife arm flips over to hit the paper.

Concept F- *The lawnmower* does not give a customer satisfied cut shape and the reliability is low when the two cutting blades get dull because of wear.

Concept J- *The cogwheel* is a concept with high tolerance demands on cog segments and cogs can often cause high noise levels.

4.2.3 Concept description

Detailed description of the remaining concepts:

“Double cam” was from the beginning two individual concepts with interesting features and by combining them it got the most advantageous properties from each concept. The concept origins from “Double Tork” and “The smooth cam” see Figure 24. By combining the concepts a smooth noiseless cutting motion is obtained due to the cam curve and a low pulling force because of the larger cutting cylinder, see Figure 25. Double reversed springs are used in the concept to establish two equilibrium states for tail ejection after every dispensation. The paper roll is placed direct onto the cutting cylinder to get rid of paper loops and to avoid unnecessary brake mechanisms.

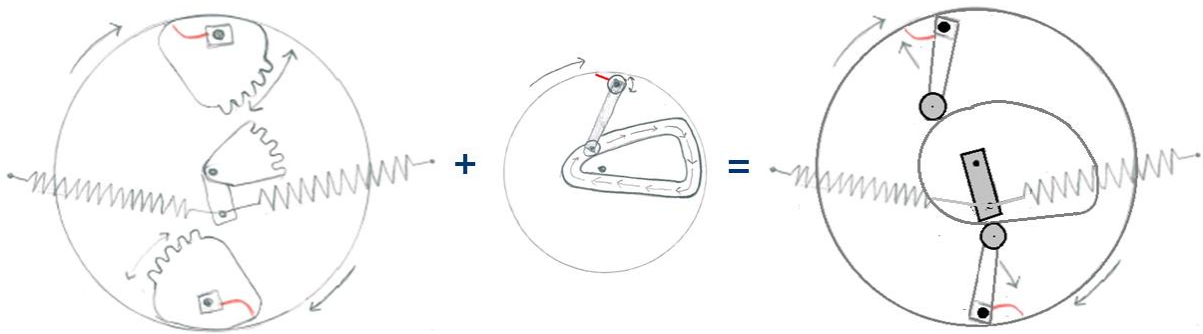


Figure 24: Combination of “Double Tork” and “The smooth cam” results in “Double cam”.

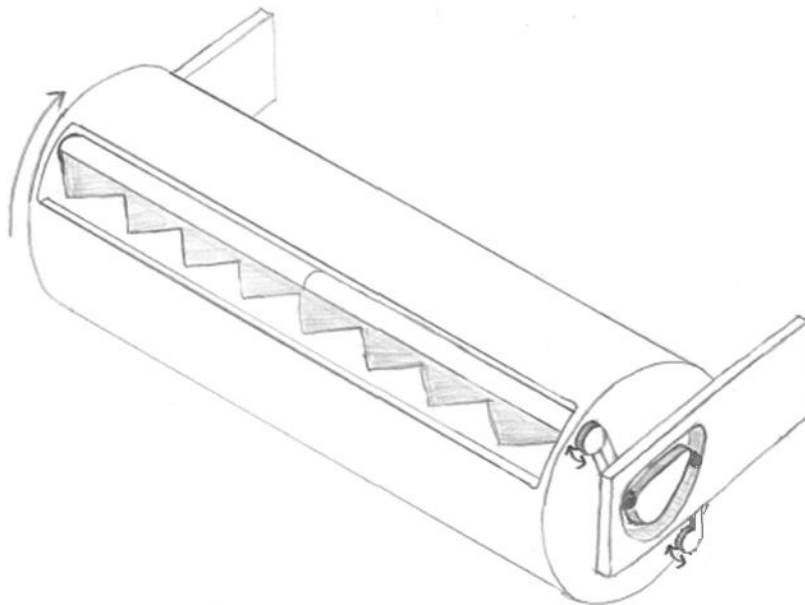


Figure 25: “Double cam”.

“The train” got its name from the similarities to the rotating motion which runs a train wheel. “The train” mechanism converts the rotary motion in the cutting cylinder through the rods to a linear reciprocating movement for the knife, see Figure 26. The knife will then penetrate through the paper from the outside once per revolution. The spring is attached to the knife-bar to generate tail ejection after penetration and the Tork H1 brake arm is used to avoid loops.

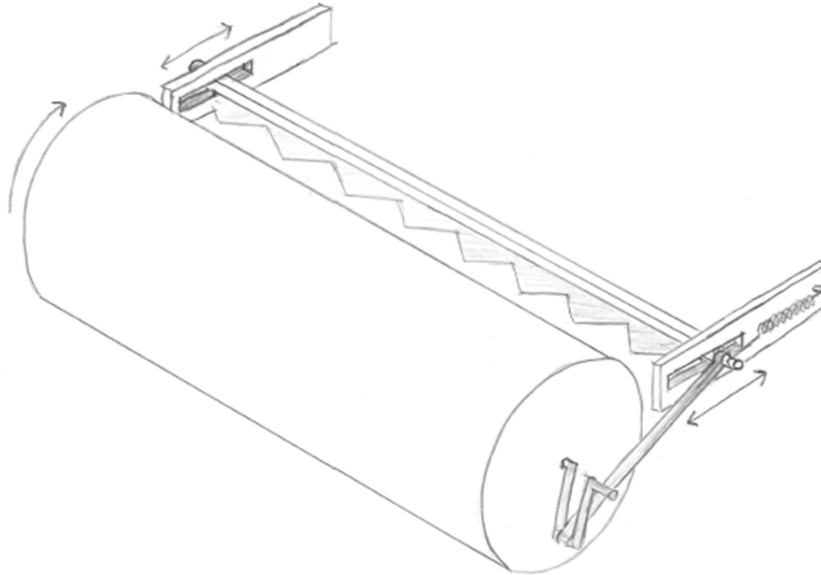


Figure 26: “The train”.

“Multiple knives” arises from the Geneva mechanism which converts a continuous rotation into an intermittent rotary motion. The Geneva drive is an intermittent gear where the driving cutting cylinder has a pin that reaches into a slot of the knife wheel and thereby shifts one step, see Figure 27. This concept gives the opportunity to choose how often the paper shall be penetrated by changing number of knives on the knife holder. With four knives it dispenses one sheet every time, two knives gives double sheet length and one knife gives four times sheet length. Tail ejection mechanism is solved with a lever and a spring similar to Tork H1. Even the brake mechanism is the same as in the existing dispenser.

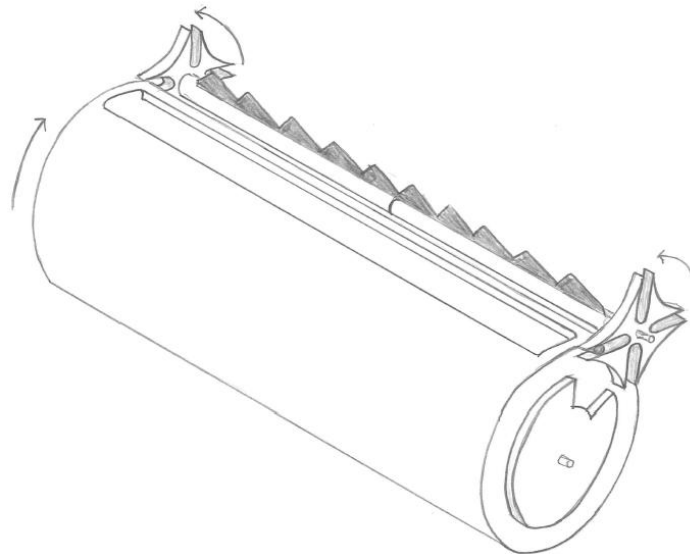


Figure 27: “Multiple knives”.

4.2.4 Mock-ups

The final stage of the concept evaluation was to build functional mock-ups of the remaining concepts to distinguish them from each other. With the mock-ups it was possible to test and compare the different concepts. Conclusions and properties of each concept can be seen below.

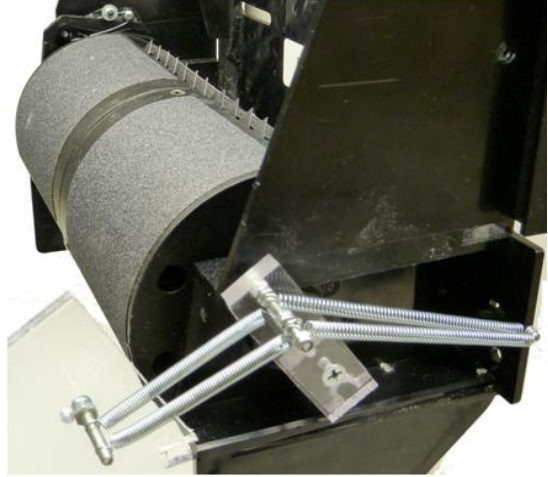
Double cam

Benefits

- Lower pull force, due to larger cutting cylinder
- Lower cutting force, due to more room for long lever arm on knife
- Shorter sheet length is possible with double knives, due to more room for the mechanism
- No paper loops(roll lies direct onto the cylinder)
- Easy threading

Drawbacks

- Space-demanding- no space for stub roll



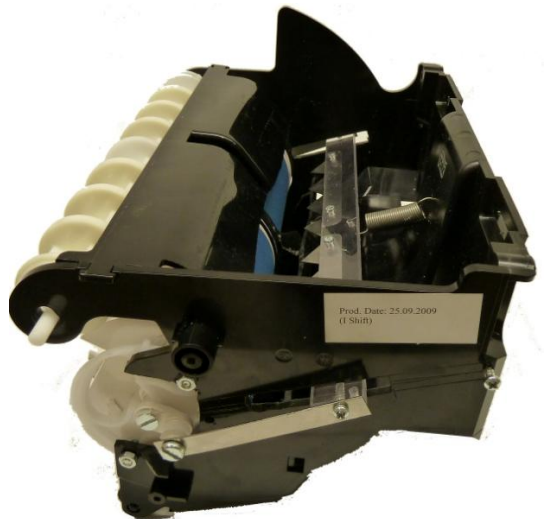
The train

Benefits

- Dynamic cutting motion

Drawbacks

- Long tear marks on paper(slow penetration)
- Not possible to dispense paper



Multiple knives

Benefits

- Secured knife position between cuts
- Dynamic cutting motion
- Possible to change sheet length(choose 1-2-4 knives)

Drawbacks

- Multiple knives(cost issue)
- Fast penetration(high cutting force)



4.3 The chosen concept

The concept that was chosen for further development was “Double cam”. This concept had the most advantages compared to the other two, seen in the decision matrix and tests. The concepts were also presented to Björn Larsson and Per Möller in a meeting at SCA to get an opinion from SCA. Their thoughts were that “Double cam” were new thinking and could probably decrease the cutting force quite much. “The train” was also interesting due to a new kind of mechanism but it did not have sufficient advantages. “The train” was not even considered after testing the mock-up which showed that it did not manage to cut the paper.

A physical appearance model was build to verify that the concept was realizable. The mock-up displays the form and appearance of concept, see Figure 28. The physical model was mainly build of existing parts from the Tork H1 dispenser with the purpose to reuse as many parts as possible in the new prototype. Other parts were made of paper, tape and plastic which are easy to form. The mock-up showed that the existing cassette front covers could be used. Even the push lever and the one way bearing could also be used in the same way as in Tork H1 with some small modifications. The O-ring together with the existing paper guide roll could be used to feed out the paper. Details in the mock-up can be seen in Figure 28.



Figure 28: Physical appearance model, the brown taped paper roll visualizes the cutting cylinder

Left: Dispenser, Right: Cutting Cassette without front covers.

5 Detail design

Even if the concept was chosen and a functional mock-up was tested it was still lots of work to do, to actually transform the concept to a physical product. The concept needed to be further developed in detail and this chapter will describe this development process.

5.1 Dimensions

The size of the cutting mechanism is affected by several parameters. One of the most important was that the cutting mechanism shall fit into the existing console, see Figure 29. The cutting mechanism should be placed in a cassette which is easy to mount in the console and use the same interface as in the existing cassette. Another important aspect was to give room for a full paper roll, with a diameter of 190 ± 3 mm and a width of either 210 ± 3 mm in Europe or 198 ± 3 mm in USA, see the blue circle in Figure 29.

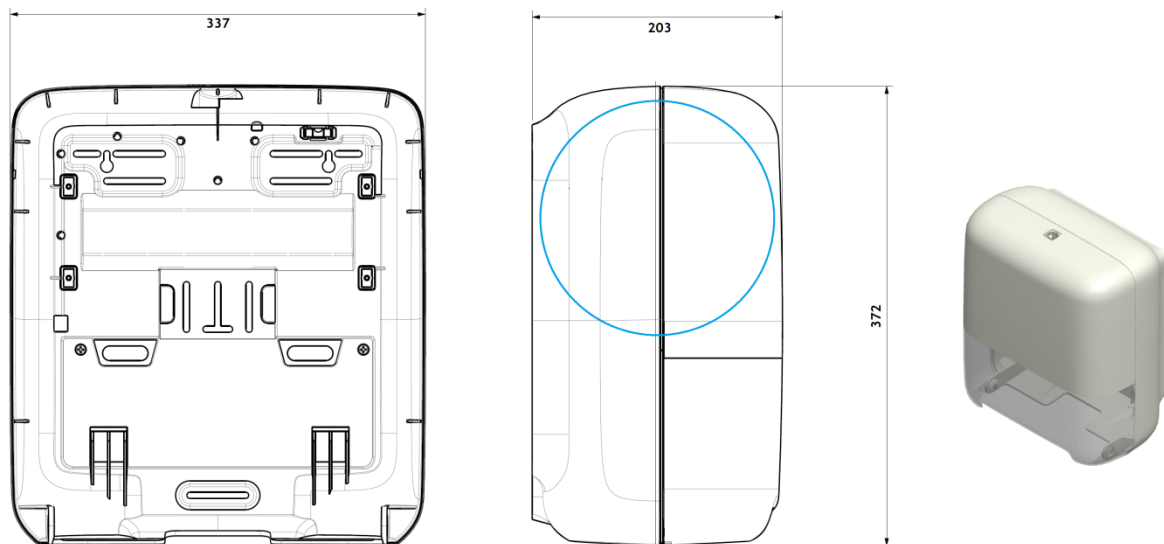


Figure 29: The approximate dimensions of Tork H1 Console with paper roll.

These given dimensions delimited the cutting cassettes size which was most problematic for the cutting cylinder. The largest cylinder that could fit into the console was 140 mm but the target diameter was 156 mm which gives the same sheet length as the existing dispensers. The target dimension was then omitted and set down to 140 mm which gave a sheet length of 220 mm compared with previously 245 mm. The delimiting factors were the push lever that should have room under the cassette and the overlying paper roll.

The mechanical work that is done during the dispensation is pulling the paper. This work depends on the required cutting torque and the length of the moment arm which in this is the radius of the cylinder, see Figure 30. Therefore was an increased cylinder radius of great interest when it leads to a decreased pulling force. By changing the diameter from existing 78 mm to 140 mm the lever length is increased with nearly 80 %.

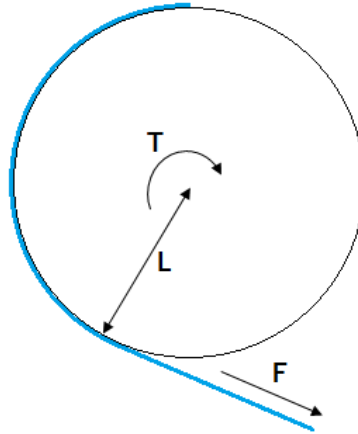


Figure 30: Cutting cylinder, $T = (L \times F)$, T =cutting torque, L = Cylinder radius, F =Pulling force.

5.2 Dispenser features

The detailed design for all features in the dispenser is presented in this section.

5.2.1 Cutting mechanism

The cutting mechanism is the main feature in the dispenser. The chosen concept was using double knives driven by a cam curve as cutting mechanism. The detailed design was mostly based on the cutting cylinders measures, when it were determined all other dimensions could be set. The knife is designed to lie in the periphery of the cylinder to prevent the bumping effect when the paper roll rolls over the knife, see Figure 31. The cylinder is also equipped with extra support between teeth to ensure that the paper roll can pass the knife without falling into the gap. This gives a noiseless and smooth rotation.

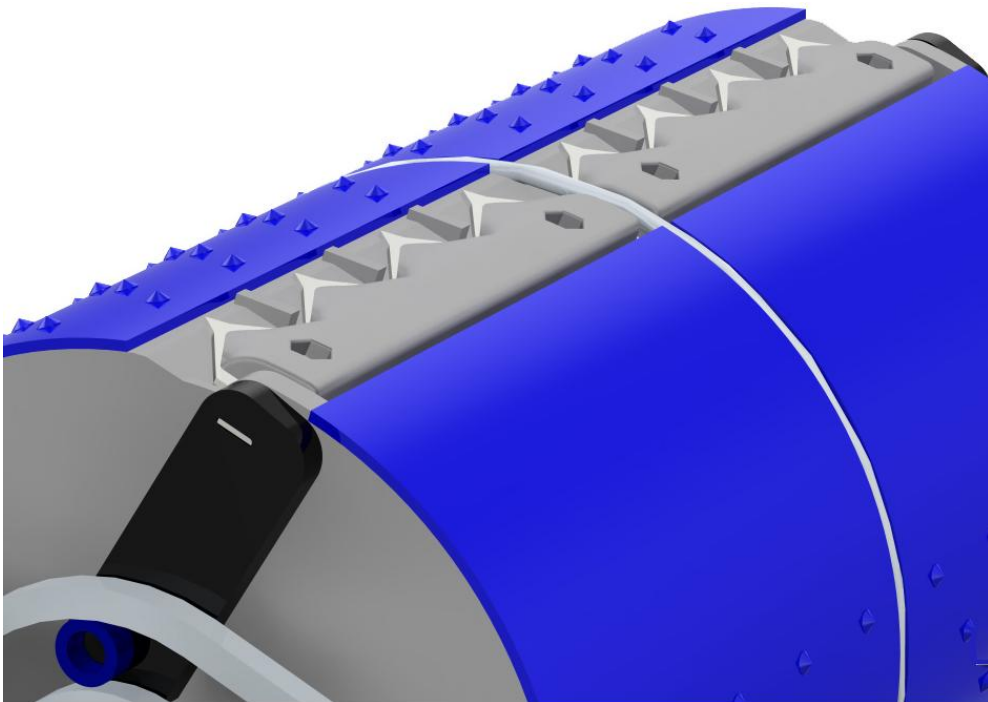


Figure 31: Knife position in the cutting cylinder.

The knife design is partly based on the results from the pre-study. There the most advantageous feature was the sharp tip teeth. The new knife is sharp tipped and the number of teeth is still four because the only better performing knife was not good enough that it would be worth to change. To avoid that the knife should twist as in Tork H1 the knife thickness have been increased. The knife is designed in one piece to make it stiffer and to decrease the number of parts.

The actuation of the knife is controlled by a lever arm which is following a curved slot during the rotation, see Figure 32. To get a smooth and soundless rotation is free rotating wheel mounted on the arms axis. The shape of the slot was designed by first establishing how the knife should be positioned during one rotation. This together with the given lever arm length generated the cam curve, see Figure 33. The increased cylinder diameter gave room for a longer moment arm on the knife which resulted in a lower turning force. To prevent that the knife should be twisted it is controlled by one curved slot on each side of the cylinder.

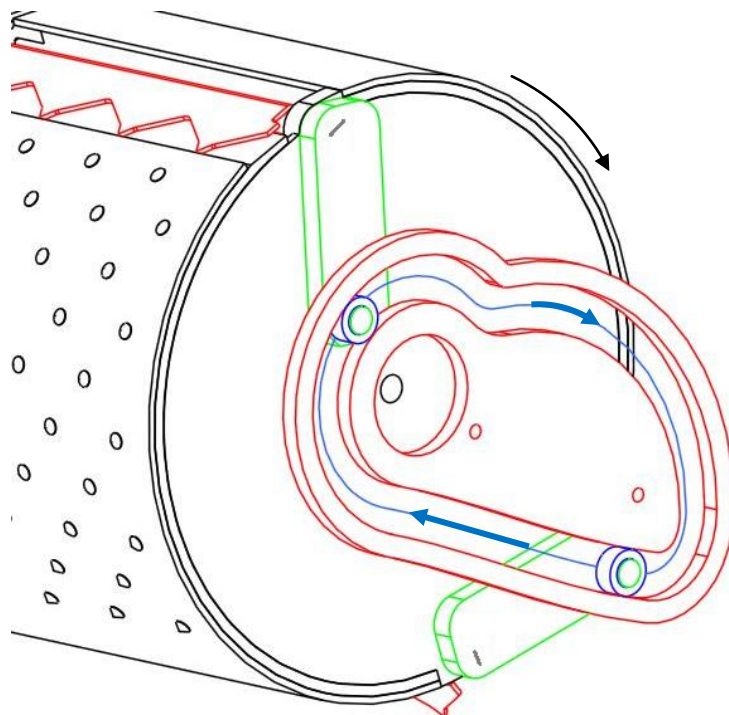


Figure 32: Cam curve.

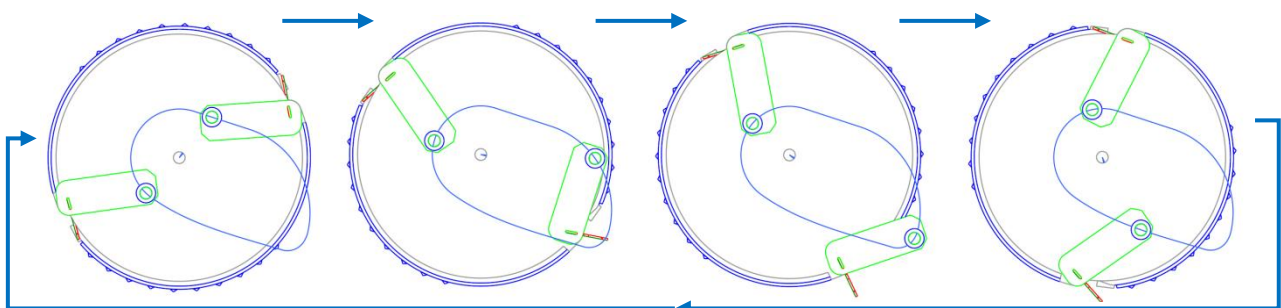


Figure 33: Knife position during rotation.

5.2.2 Eject mechanism

The tail is ejected by using a crank in the end of the cylinder connected to two reversed springs. These springs maintain two equilibrium states per rotation. The equilibriums are located to feed out the tail 60 mm every dispensation, see Figure 34. To get the mechanisms to work ideally, the crank and the springs have been tested out by varying crank length and spring properties. The emergency push lever is used when the tail is not presented for the user, similar to the existing solution in Tork H1.

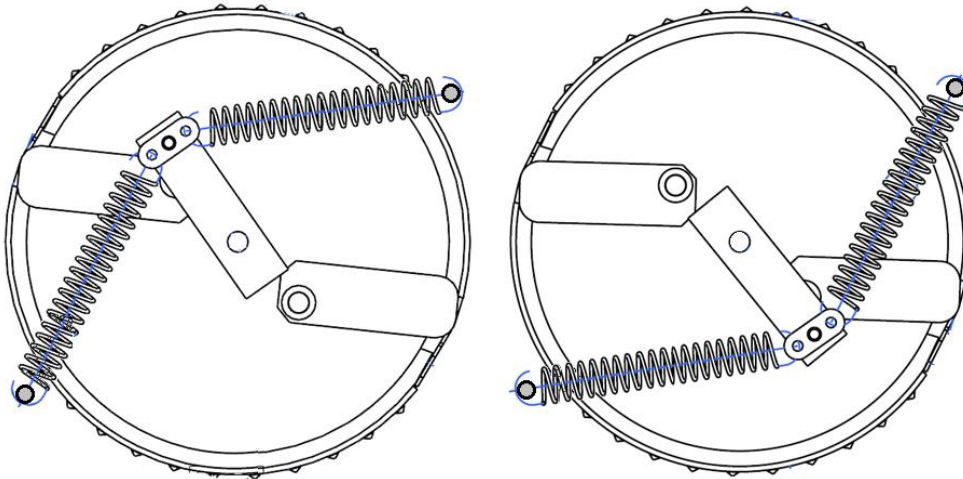


Figure 34: Equilibrium states.

5.2.3 Brake mechanism

The complex brake system in Tork H1 is eliminated and instead replaced with a system where the paper roll lies direct onto the cutting cylinder, see Figure 35. The surface of the cutting cylinder has spikes that bores into the paper and holds together the layers in the paper. This stops the paper roll and the cutting cylinder simultaneously and no loops are generated.

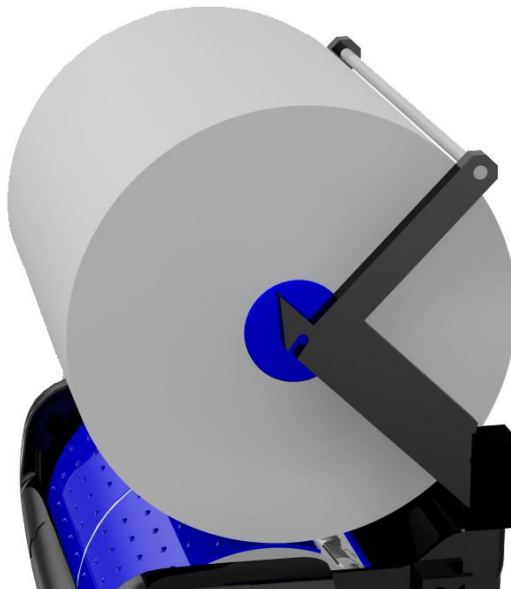


Figure 35: Brake mechanism.

To ensure a successful cutting it is important to keep the paper stretched around the cylinder. This is ensured by having a constant pressure between the roll and the cylinder. The gravity of a full roll gives enough pressure but with less weight a tension spring is attached to the refill arm as a support. The spring is attached in a way which makes the moment arm longer when the roll gets smaller and comes further down, see Figure 36. Even if the spring is getting shorter and the spring force is decreasing the extending moment arm gives a gradually higher pressure.

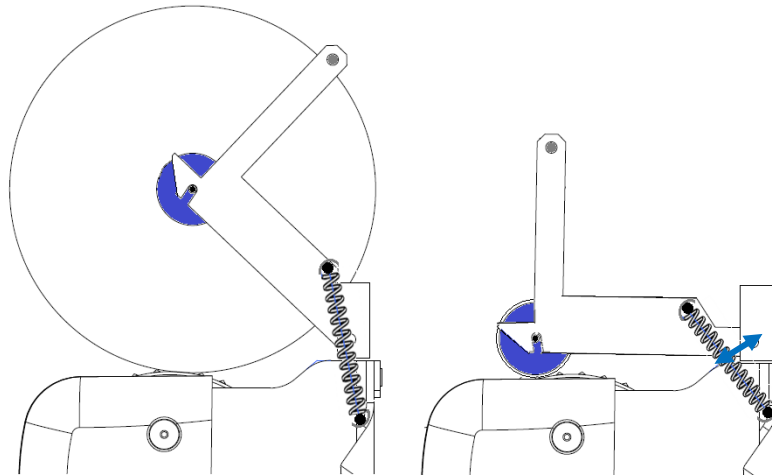


Figure 36: Spring location, the moment arm is the distance between the spring and the centre of rotation for the arm. With a full roll it is no moment arm because the distance is zero.

The refill arm is also designed for easy refilling by having a connecting bar between the arms. This is used to lift up the arms when a full paper roll should be refilled. The roll is then pressing against the bar which lifts the arms until centre pin slides into the slot, see Figure 37. By having the paper roll direct onto the cylinder the threading is done automatically when pressing the push lever.

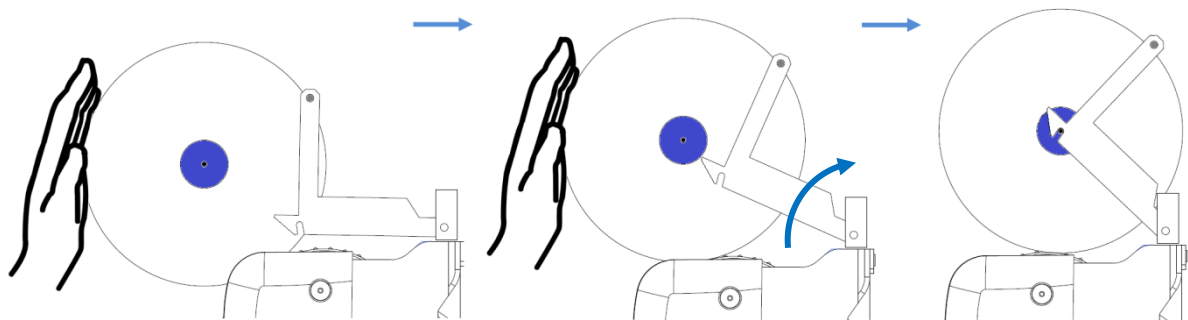


Figure 37: Refilling of dispenser.

6 Result

The Thesis resulted in a final design concept for the Tork H1 dispenser. The result is presented as renderings from the 3D-modell and images of the final prototype. The evaluation is mainly based on tests of the prototype.

6.1 Renderings

Renderings of the concept can be seen in Figure 38 -Figure 40. The renderings are made in Pro/engineer.

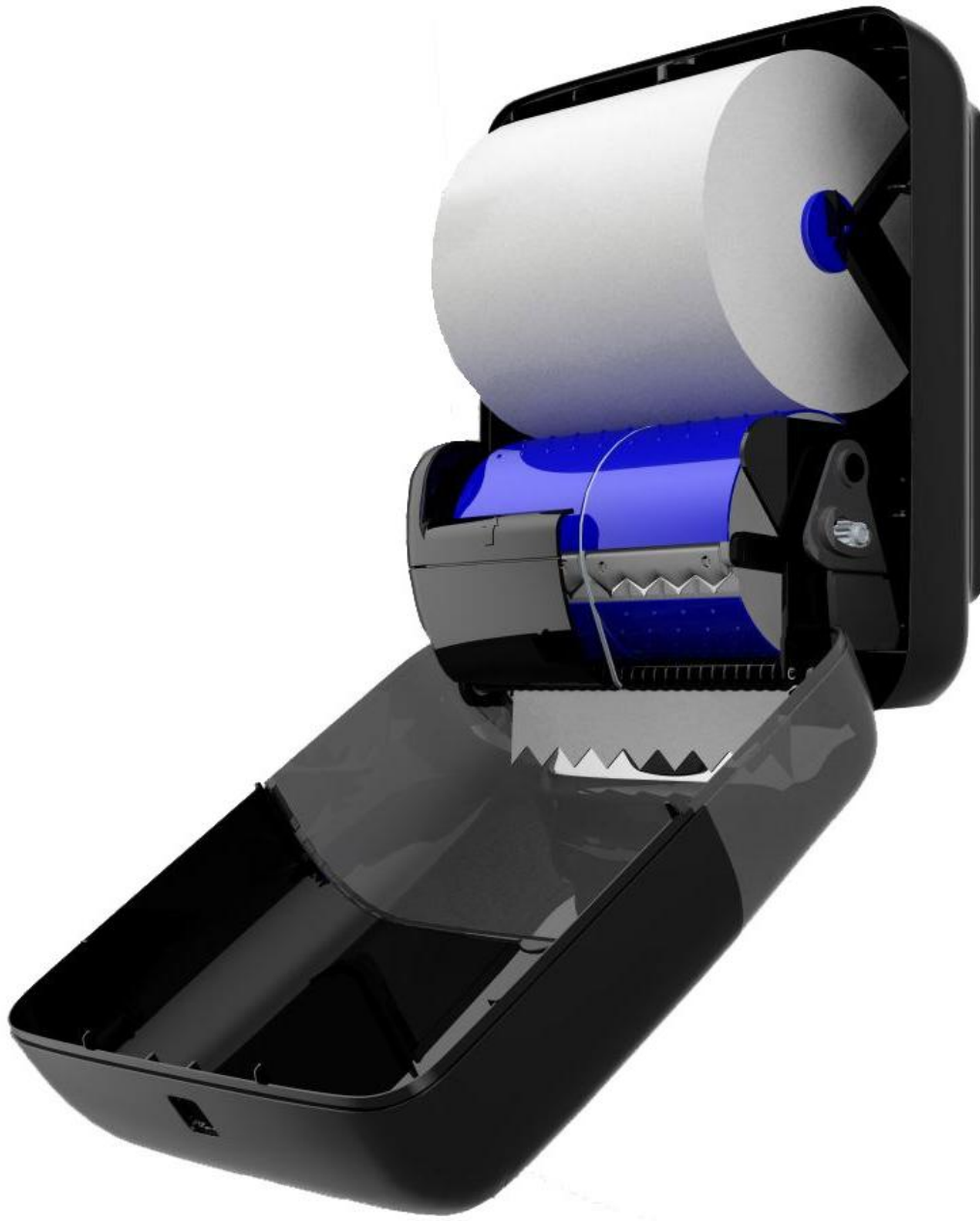


Figure 38: Rendering of the new concept loaded with paper, the front cover is partly hidden to show the cutting cylinder.

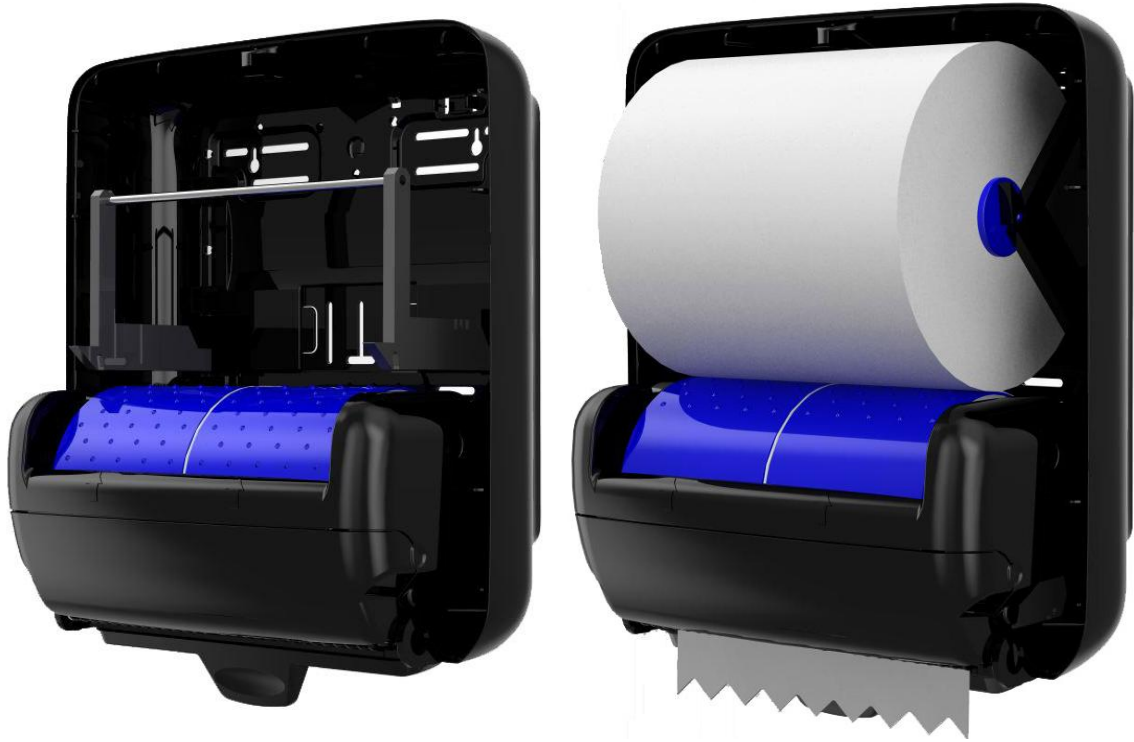


Figure 39: Rendering of unloaded and loaded dispenser.



Figure 40: Rendering of the cassette without front covers. The cassette side is transparent to show the cam curve and cam follower.

6.2 Prototype

A wish from SCA was to build a fully functional prototype and to design something for a prototype sometimes differs from designing for commercial production. In this project most parts have been designed with the thought to be manufactured in the future, but some components have been divided into smaller parts for easier manufacturing. The prototype was mostly made in a rapid prototyping machine which doesn't give the components the same durability properties as if they should have been injected molded. The rest of the parts were milled out from Plexiglas which gives a rougher surface than injected molded parts. Many parts from Tork H1 have been reused with small modifications such as the console, front cover, push lever and some more. See Figure 41-Figure 43 for images of the prototype.

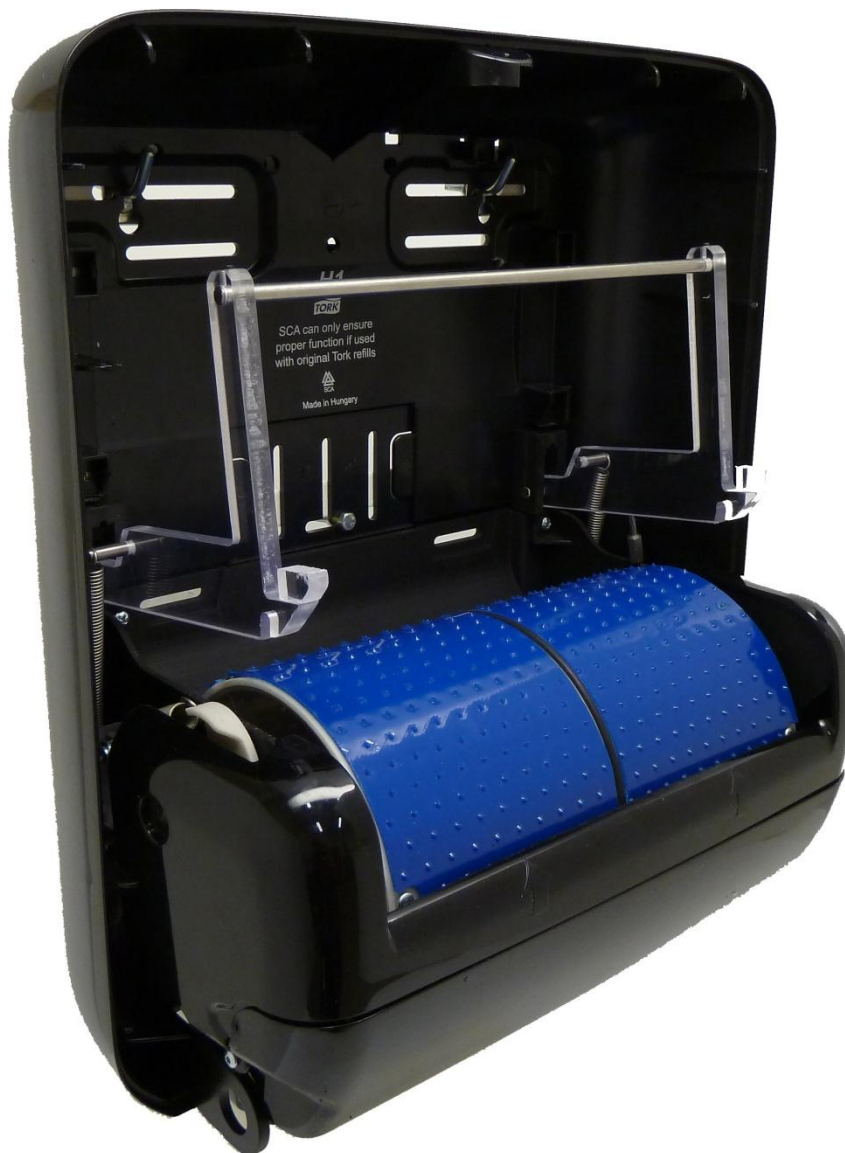


Figure 41: Prototype, unloaded dispenser.

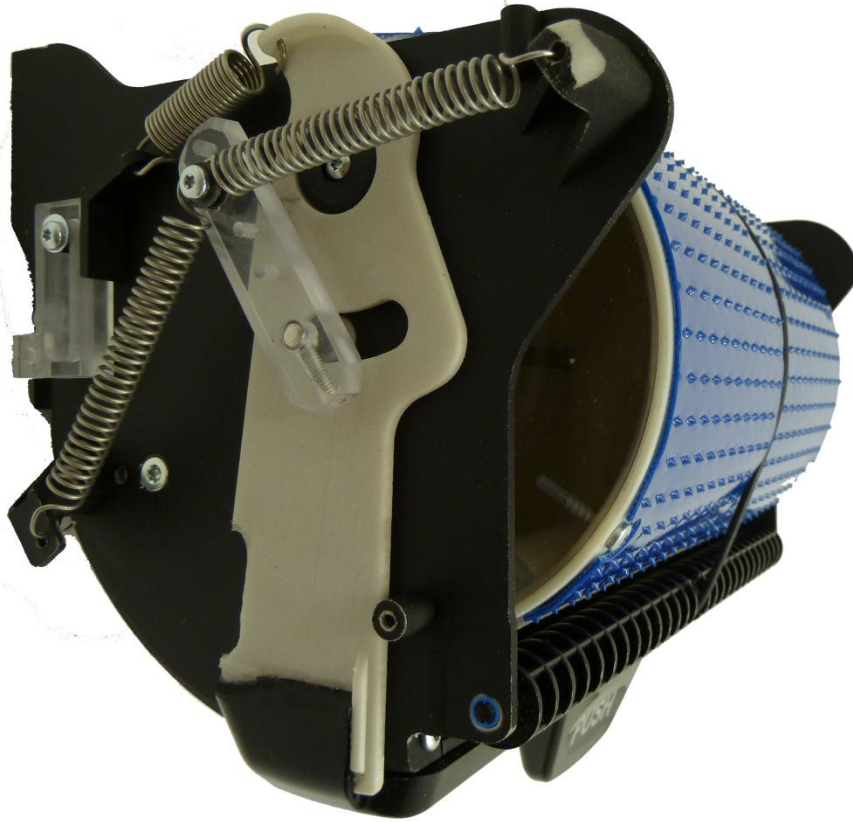


Figure 42: Prototype without front covers, the eject mechanism is in one of the equilibrium states.



Figure 43: Prototype without front covers, the emergency push lever with the cogwheel and the knife are visible.

6.3 Evaluation of concept

The evaluation was based upon the criteria's from the Specification of Requirements, set early in the project, see Appendix B. The evaluation was done to verify how successful the project has been.

6.3.1 Performance

The variations due to the manufacturing methods made it difficult to build a prototype that works perfect and to compare the prototype with the Tork H1 could be an unfair evaluation. Unfortunately could not the dispenser be tested in the dispensation robot due to that it was not available at the time of evaluation. The dispenser was instead tested with a handheld force gauge meter which only gave rough measurement due to that it is affected by the pulling speed and the pulling angle. Thereby was not any exact number of pull force and noise level considered as important. Instead was the focus on the overall performance and to investigate the possibilities with the system.

The rough measurements showed that the pulling force were between 11-14 Newton which is equivalent to Tork H1. The relatively poor result was mainly because of high friction between parts.

The new cutting mechanism was really smooth and noiseless. It was able to dispense a whole roll without any problems and the refill arm spring gave enough pressure to ensure stretched paper throughout the roll, see Figure 44.



Figure 44: Testing of prototype, Left: Full roll, Middle: Half full roll, Right: Nearly empty roll.

The robustness and reliability tests were not performed due to that those prototypes does normally not withstand strength and endurance tests.

With the new refill mechanism was the problematic threading eliminated and done automatically by pressing the push lever which feeds out the paper around the cylinder.

6.3.2 Manufacturing

The manufacturing and assembly cost are hard to estimate at this stage of the product development process but approximations could be done based on the prototype. The prototype is mainly manufactured in rapid prototyping and many parts are screwed or glued together which in real manufacturing will be made as one part. However the new concept has nearly the same amount of

components as Tork H1 and is also mounted in a cassette for easy assembly. Many of the components are reused from Tork H1 to decrease cost in prospective manufacturing.

The main difference between Tork H1 and the new concept is that the new concept does not have the complex brake arm system which includes some extra parts. On the other hand does the new concept have some additional parts due to double knives, even if these parts can be made as duplicates it is an extra cost. Another difference is the larger cutting cylinder in the new concept. In the end when the costs are summarized the new concept will probably be a little bit more expensive.

6.3.3 Function

For the user the new concept functionally is the same with identical features as Tork H1. The push lever sits in the same position and the towels are distributed at the same location. The differences are when the console is opened to be refilled; the refill mechanism is different and the stub roll position is removed. The dispenser can easily be reloaded by pressing the full roll into the dispensation position with one hand. The papers unwind direction is the same to avoid confusion for user that are used to refill Tork H1.

6.3.4 Product Environment

The new concept withstands the same environment demands as Tork H1. The only difference is the cylinder mat with spikes which replaces the less hygienic sandpaper in Tork H1 as grip surface. The sandpaper is not seen as hygienic in some service areas due to that grain of sand can detach from the sandpaper.

6.3.5 Dimensions

The new cutting mechanism fits into the existing console with some small modifications in the bottom of the console which is not visible from the outside. The cassette looks nearly the same with the front covers and has the same interface as Tork H1 to fit into the console. With the new cutting cylinder the sheet length is decreased to 220 mm. A decreased towel length is of great interests for many customers to reduce paper consumption. The dispenser works for both European and American rolls by changing the width of the refill arms or by having extra long plugs in the end of the roll.

6.3.6 Safety

The new concept is really safe due to that the knife position is controlled during the whole rotation. The location where the penetration of paper takes places is neither reachable from the outside or the inside of the dispenser.

7 Discussion and Recommendations

This chapter concludes the Thesis and mine reflections together with recommendations for further work.

7.1 Research

The initial product research was performed thoroughly and gave a large amount of knowledge about the product. The functional analysis gathered the information which resulted in a good overview map of the quite complex dispenser.

The market analysis resulted in a detailed benchmarking of the competitive dispensers and generated lots of ideas in the concept development. The analysis could have included more information about the competitors, such as pulling force and noise level, but I believe that sufficient time was spent on this in relation to the time schedule.

The own developed test rig was a great tool to find the best performing knife. Earlier used test methods at SCA are not that accurate. Another big advantage with the new method is the possibility to measure only the penetration torque without influence of other factors in the dispenser.

The results from the pre-study were a useful guidance throughout the rest of the project.

7.2 Concept development

The concept generation methods used during the project were good and resulted in lot of innovative ideas and interesting concepts. The brainstorming session was occasionally not so creative and could have been better if the group should have been stimulated with ideas; maybe by using the keywords from the SCAMPER method.

A concept evaluation based on theoretical methods is not always the best choice, especially not when the technical performance are of greatest interest. The Elimination Matrix and Pugh Decision Matrix were good as a first screening but with these methods it is often hard to estimate different concepts performance capacity. The mock-up testing was then the naturally choice of method to distinguish the remaining concepts and the outcome from it was satisfying.

A big advantage during the concept development was the accessibility to the workshop which made it possible to test ideas and rebuild unlimited numbers of dispensers. The possibility to verify thoughts by building small mock-ups gave fast feedback and the project could proceed without delayed external prototyping. The functional mock-ups were during discussions a great support to explain functions and details.

7.3 Detail design

The concept was designed in detail together with the consulting firm Creator AB. The mock-up was in the initial detailed design a great guidance for the CAD-modeling and many measures could be taken from it. Creator was very helpful throughout the development and their knowledge about dispensers is an invaluable resource when problems arise.

The final outcome from the detail design was satisfying but the process could have been done in a more iterative way. Nearly all parts were designed and manufactured at the same time and no parts were tested until the whole prototype was finished. This caused late changes in the detailed design due to problems in the prototype and it could not be tuned as much as expected.

7.4 Result

The objective with this Thesis was to optimize the Tork H1 dispenser. I have found a couple possible modifications in the design that I consider as improvements. The three main improvements that I believe in most are:

- Increased cylinder diameter with double knives to decrease the pulling force
- Sharp tipped teeth on the knife to decrease the required cutting force
- The paper roll is placed direct onto the cutting cylinder to avoid paper loops and force waste due to poor brake systems.

The prototype showed in a good way how these improvements could be implemented in the dispenser.

Even if the prototype not were performing perfect am I very satisfied with it, and I believe that it can be modified and tuned to work really good. The late changes in the design process were time consuming and delayed the prototype which did not give any room for tuning. I know that the pull force can be decreased quite much with a tuned dispenser.

7.5 Recommendations

I believe that there is a future market demand to decrease the towel length and with this system it is possible without increasing the pull force.

With the new system where the paper roll lies direct onto the cylinder gives also the possibility to have stacked rolls on top of each other for higher capacity.

The prototype needs to be modified and adjusted to work perfect. With the modified prototype is it possible to do a fair evaluation compared to Tork H1, and if it shows out to work as good as we thought it would be a well worth investment.

Next step could be to get feedback from customers to see if it is a market demand of shorter sheet length. It is also recommended to have a pilot study to see how cleaners and users experience the new prototype.

8 References

Atkins, J. (2004, 11 01). *A beginner's guide to towel and tissue*. Retrieved May 14, 2010
<http://www.allbusiness.com/specialty-businesses/258290-1.html>

DAEDONG FA Co. (2005). *Cam Indexing Technology World*. Retrieved April 28, 2010
<http://www.ddfa.co.kr/english/tech1.html>

Johannesson, H., Persson, J.-G., & Pettersson, D. (2004). *Produkt utveckling*. Stockholm: Liber AB.

Lietz, H. W. (2010, May 15). *Lietz Betriebshygiene GmbH*. Retrieved May 18, 2010
<http://www.betriebshygieneservice.de/Aktuell.htm>

Mind Tools Ltd. (2010). *Mind Tools Ltd*. Retrieved April 4, 2010
www.mindtools.com/pages/article/newCT_02.htm

SCA . (2010, 05 05). *Svenska Cellulosa Aktiebolaget SCA*. Retrieved 05 07, 2010
www.sca.com

SCA. (2010). *Assembly instructions*. Retrieved April 21, 2010
<http://www.sca-tork.com/product/551000/>

SCLATER, N., & CHIRONIS, N. P. (2001). *MECHANISMS & MECHANICAL DEVICES SOURCEBOOK*. New York: Mc Graw-Hill.

Ulrich, K. T., & Eppinger, S. D. (2008). *Product Design an Development*. New York: McGraw-Hill Companies.

9 Appendix

Appendix A - Gant Schedule

Appendix B - Specification of Requirements

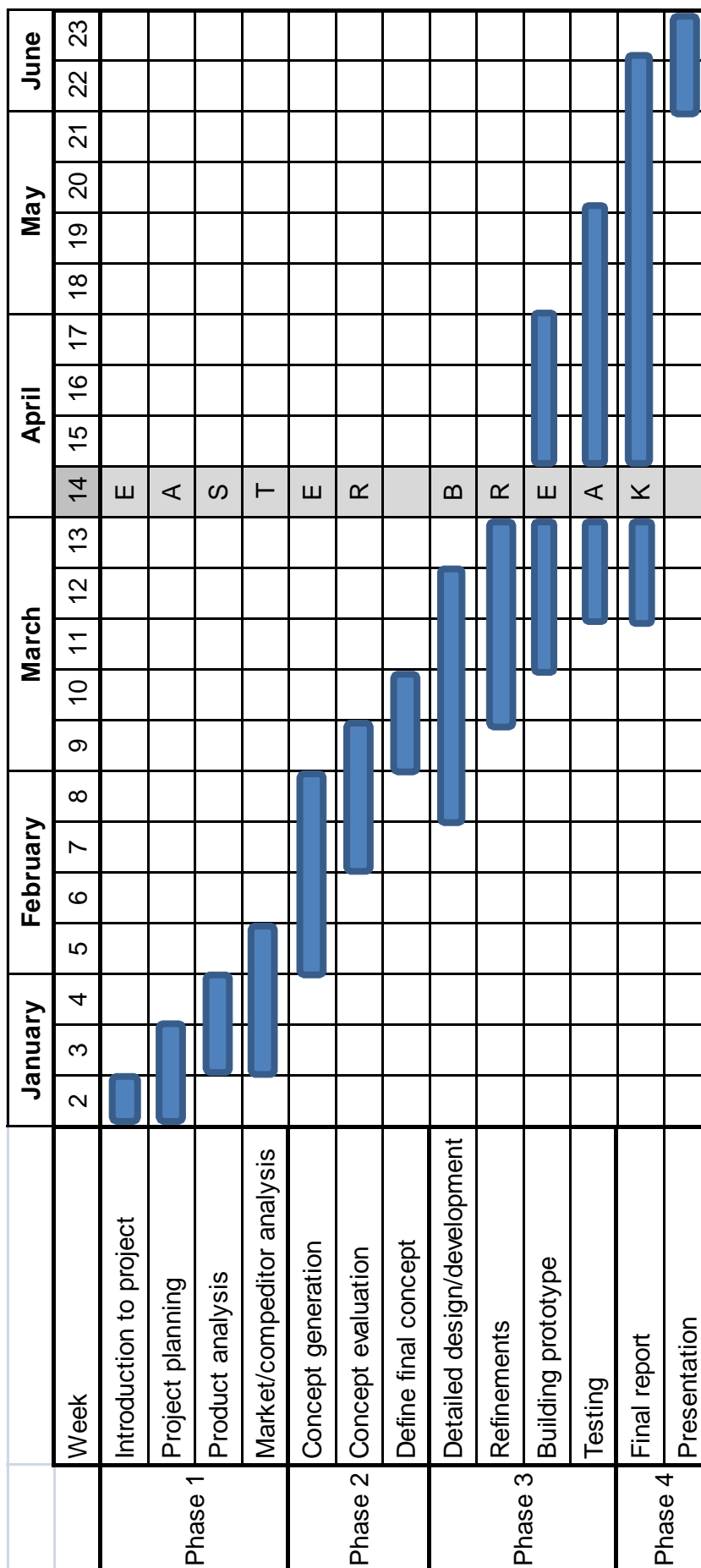
Appendix C - SCAMPER

Appendix D - Morphological charting

Appendix E - Elimination matrix

Appendix F - Pugh Decision Matrix

Appendix A - Gant Schedule



Appendix B - Specification of Requirements

Category	Nr.	Criteria	Demand/Wishes	Measurements	Imp.
Performance	1.1	Design of cutting mechanism shall facilitate low noise.	W	Not higher than existing solution, < 80 dB	4
	1.2	Pull force	W	Not higher than existing solution, < 12 N	4
	1.3	Robustness	W	Drop test from 1500 mm	3
	1.4	Reliability	D	Endure 5000 rolls / 10 years	5
	1.5	Easy to thread the paper	W	Thread time < 30 sec	4
Manufacturing	2.1	The manufacturing cost	W	The cutting cassette shall cost less than existing model < XX Euro	2
	2.2	Cassette shall be easy to mount in dispenser	W	Similar or easier than existing solution, 2 clip fastener and 2 screws	3
	2.3	The cutting mechanism shall be easy to assembly	W	Assembly time < XX sec	1
	2.4	The cassette shall have less parts than existing solution	W	Number of parts < 41 pcs	2
Function	3.1	Papers unwind direction as in Europe. Feed from front of roll.	W	Pass/Fail	3
	3.2	The cutting mechanism shall be driven of the pulling energy	D	Pass/Fail	5
	3.3	The dispenser shall distribute one paper towel at the time	D	Pass/Fail	5
	3.4	The mechanism shall eject a paper tail for next user	D	Pass/Fail	5
	3.5	Possible to eject paper when no towel is visible	D	Pass/Fail	5
Product environment	4.1	Temperature Normal use:	D	+0°C – 40°C	5
	4.2	Temperature Storage and transport:	D	-20°C - +50°C	5
	4.3	Humidity Normal use:	D	15% - 95% ReH	5
	4.4	Humidity Storage and transport:	D	15% - 95% ReH	5
Dimensions	5.1	The cutting cassette shall fit into the existing H1 dispenser	D	Width: 337 mm Height: 372 mm Depth: 203 mm	5
	5.2	Cutting cassette weight	W	Max 1500 g (existing 1240 g)	3
	5.3	The mechanism shall manage both European and American rolls	D	Paper width EU 210 ±3 mm Paper width USA 198 ± 3 mm Diameter 190±3 mm	5
	5.4	Sheet length	W	Sheet length 245± 10 mm	3
	3.6	Tail length	D	Tail length 55-80mm	3
Safety	6.1	No burrs or sharp edges accessible for the users or service personnel in order to minimize the risk of injuries	D	Pass/Fail	5

Appendix C - SCAMPER

S - Substitute - substitute material, component, parts, assemblies, shapes, and textures

- Replace sandpaper with another material
- Replace the material in the knife, to make it stiffer
- Replace cog segment with rubber a grip surface
- Replace cylinder with driving bands
- Replace knife with a scissor
- Replace knife with a cylinder knife (cylinder mower)
- Replace spring with hanging plumb
- Replace knife with stinging guillotine

C – Combine – combine, mix and group parts, elements, features, processes, and methods

- Combine bearings with rolls
- Combine sandpaper with cutting cylinder

A - Adapt - adapt functions and shapes

- Replace cutting mechanism with a mechanism for perforated paper
- Adapt mechanism for toilet paper
- Adapt the dispenser to be sensor controlled
- Adapt the dispenser to be motorized
- Adapt the dispenser for cling film

M - Modify - modify shape, scale, multiply, and distort

- Bigger cutting cylinder
- Thicker knife
- Double knives
- Number of teeth
- Teeth height
- Double retraction springs
- Longer/shorter crank
- Double action knives

P - Put to Other Uses - repurpose parts, materials, features, and assemblies

- Perforated paper
- Earlier cutting, direct after paper roll

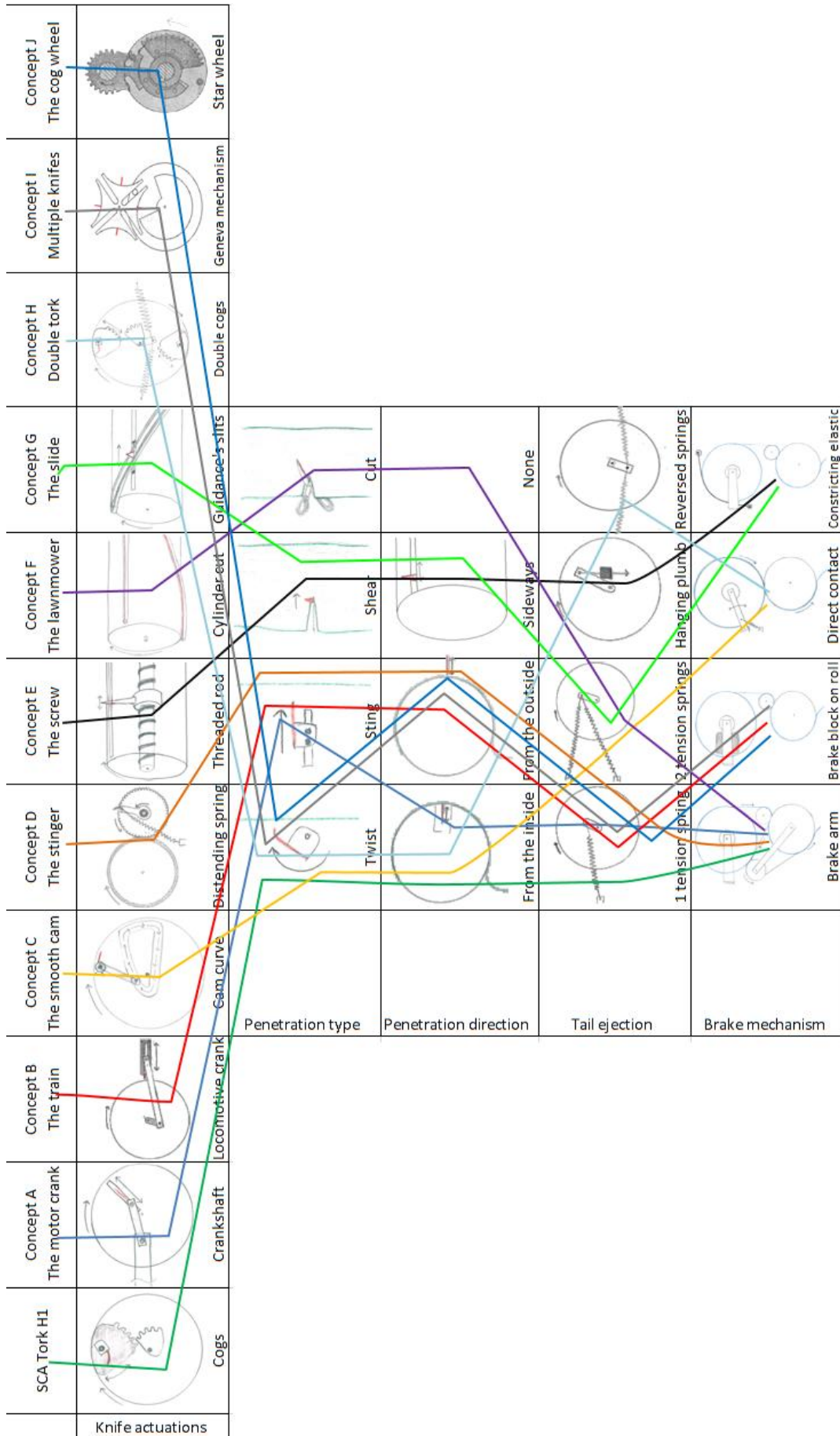
E - Eliminate – simplify, eliminate parts and features

- Eliminate pressure roll
- Eliminate brake arm
- Eliminate knife (perforated paper)

R – Reverse/Rearrange - flip parts, reverse orders, inside-out, upside-down, use the negative

- Reverse rotation direction of cylinder
- Reverse rotation direction of paper roll
- Reverse rotation direction of the turning knife
- Penetrate the paper from the outside

Appendix D - Morphological charting



Appendix E - Elimination Matrix

Concept	Solves the main problem	Meets all requirements	Realizable	Elimination Criteria (+) Yes (-) No (?) More information needed	
				Comments	Decision
Concept A The motor crank	+	+	-	Intersection between crankshaft and centre axis	-
Concept B The train	+	+	+		+
Concept C The smooth cam	+	+	+		+
Concept D The stinger	?	+	+		?
Concept E The screw	-	+	-	Not possible to shear the paper sideways	-
Concept F The lawnmower	+	+	+		+
Concept G The slide	-	-	+	Not possible to shear the paper sideways	-
Concept H Double Tork	+	+	+		+
Concept I Multiple knives	?	+	+		?
Concept J The cogwheel	+	+	+		+

Appendix F - Pugh Decision Matrix

		Datum	1	2	3	4	5	6	7
	Concept	Tork H1	Concept B The train	Concept C The smooth cam	Concept D The stinger	Concept F The lawnmower	Concept H Double Tork	Concept I Multiple knives	Concept J The cog wheel
Main criteria	Sub- criteria								
	Noise level	0	1	1	-1	-1	1	1	-1
	Pull force	0	0	1	-1	1	1	0	0
	Reliability	0	1	1	0	-1	1	1	1
	Easy to thread	0	0	0	0	0	1	0	0
Manufacturing	Manufacturing cost	0	0	0	-1	0	-1	0	-1
	Assembly cost	0	0	0	-1	0	0	0	-1
Design	Cut shape	0	0	0	1	-1	0	0	0
Environment	Endure surroundings	0	0	0	0	0	0	0	0
Dimension	Space demanding	0	0	0	-1	0	-1	0	0
Safety	Safe for users and service personnel	0	-1	0	-1	1	0	-1	0
	Number better Σ+	0	2	3	1	2	4	2	1
	Number worse Σ-	0	1	0	6	3	2	1	3
	Number same Σ0	10	7	7	3	5	4	7	6
	Sum	0	1	3	-5	-1	2	1	-2
	Rank	5	3	1	8	6	2	3	7

