Master's Degree Thesis
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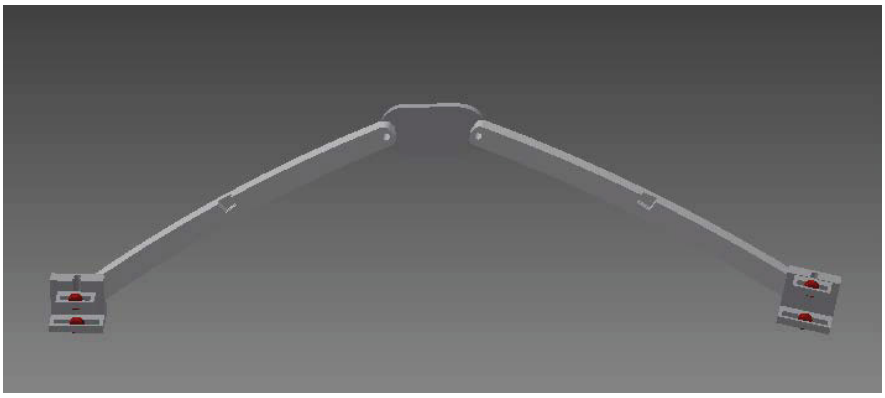
Development of asphalt removing tool

For a tandem roller



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Abstract

This master thesis have been done to come up with different concepts that could solve problems that is connected to vibrations in tandem rollers. The main problem is that the vibrations makes it harder to remove asphalt with the built in scraper, creating an uneven contact with the drum and the scraper. The new concepts should improve the machines ability to remove asphalt and decrease the amount of maintenance that is needed.

To understand what the new tool needs to do some functional analyses have been done. To create new concepts the triz method have been used. The different concept was evaluated with a pugh matrix and swot. In the final part the focus is on how the best concept could become better.
The final concept locks the scraper geometrically so it moves the same way as the drum. This makes it so it always are at the same distance to the drum.

Acknowledgements

I would like to thank Dynapac for the possibility to work with this project and for all the information and feedback I have got during projects time.

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Henrik Thorwaldsson

Notations

E	Elastic modulus
F	Force
I	Moment of inertia
N	Normal force
n	Safety factor
P	Pressure
Pa	Unit of pressure
$\mathbf{R_{eH}}$	Yield strength
τ	Shear stress
$\boldsymbol{\omega_c}$	Critical frequency
ρ	Density

Index

a	thickness
h	height
L	length
m	mass
r	radius

Content

1 Introduction

1.1 History of Dynapac

Dynapac AB was founded in 1934 in Stockholm as AB Vibro-Betong, When they began the development of their own idea to compact concrete with vibrating staffs. In 1953 they launched their first vibrating roller on the market, and after that road construction equipment such as the rollers and the pavers have been Dynapac primary products. In 1973 They changed their name to the current one. In 2008 Dynapac was acquired by Atlas Copco and is now part of their group Atlas Copco Road Construction Equipment**.** Dynapac sells their products to many different markets among them is India, England and others all who have different preferences which leads to that Dynapac offers a wide variety of models. (1)

The machines delivers a linear load which is used to compact the asphalt mix. The differences in their models are the weight of the drums which ranges from 1,5 Ton to 12 Ton, the lengths of the drums and that the machines could have one or two drums. Some model have drums that are able to vibrate so they can reduce internal friction in the mineral mix, they also requires less passes than static rollers to finish their work. They also have models with rubber drums

1.2 Tandem Vibrations rollers CC 2200

Figure 1,1 (1) An tandem roller with vibrations.

In figure 1.1 you can see the model that I have been looking on when I worked toward the solution. The weight it uses to deliver its pressure is 9 Ton and the drum have a length of 1,5m. (1). The drums are made of steel and the scraper is made of plastic. It is one of the models that have drum that can vibrate. The drum is suspended with rubber elements that is connected with the black frame than can be seen inside the drum.

To remove the asphalt mix that sticks to the drum there are two scrapers on each drum. There are two scrapers on the drums so it the roller can be used in two directions. To reduce the chance of asphalt sticking there is sprinkler system with several nozzles connected to the scraper.
Due to that the drum is not as dry as before it will have less asphalt stuck to it. To be able to clean the scraper and adjust its position to the drum, it is connected to spring that allows it to be moved.

1.3 Purpose

The purpose of this work is come up with a range of solutions that could solve some of the problems Dynapac have with their scrapers on their asphalt compaction machine. It also is to look for other problems or undiscovered customer value that could be found and used in the new concepts There also needs be an evaluation of the concepts where one is chosen to be further developed, where it's needed to take in account of the positive effects and what could go wrong with the concepts. I want to answer these question in my discussion.

- Does my solution improve the result of the scraper by removing more asphalt ?
- Does my solution need less maintenance than the original solution ?
- Is my solution economically viable ?

1.4 Definition of the problem

The main problem with this project is to find a solution that can ensure that tandem vibrators can make an even road. The problem with today solution is that the scrapper that is used does not vibrates while the drum does which makes it difficult to make an even contact. When there is not even contact between the objects it creates some problems. It will damage the scraper and the drum which will shorten their lifespan.

There will be contact problem when the machine make a turn because the drum does not follow through the motion the same ways as the scraper which leads to an uneven contact during the steering. When there is no contact there will be an increased risk of asphalt will continue to stick on the drum and then it can eventually leads to that the machine will make marks in the road. These marks will reduce the quality of road as it won't be an even road from the beginning

There are some additional problems with the scraper which will be described here, some of these are connected to the vibrations but not all. I will take these in consideration while trying to solve the problem.

- The drum could be damaged if the scraped is pressed to hard against it, and the scraper itself will be damaged in the process. So if the scraper is not correctly adjusted it will damage the system. As there is an vibrating system, it needs adjustments to have some distance to the drum or it would continually slam against it, tearing it down after some use.

- The scraper is not vibrating while the drum is which make it difficult to have an even contact between them.

- If the Scraper is misadjusted there will be noises, which could disturb the worker and lower their satisfaction using the machine.

- The scraper could be stuck during low temperatures and be frozen to the drum which adds work that will be needed to heat it up to continue with the work.

- When the machine turn the drum will not follow through the motion the same way as the frame does as because of the rubber elements.

- The scraped needs to be adjusted after the drum have been torn down from use. So it needs to be checked regularly if the current adjustment is acceptable.

- To be able to use water in the tanks optimally the scraper needs to have an even contact with the scraper so it could redistribute it evenly over the drum and there not use as much water to cover the same area.

2. Background

2.1 Asphalt mix

The asphalt mix that is used when making road can different from country to country and depending on the climate and how much traffic the road will be expected to have. The mix is made up from rocks which varies in sizes, there can be a bit of sand in the mix and then there is the binder bitumen that holds the mix together . Circa 6% of the weight of mix comes from bitumen and 14 % if you look on the volume. The mix is heated up to around 500 Celsius to let the different parts come together as a mass. When the mix are stored and during delivery it is stored with a temperature of circa 150 Celsius. The asphalt can also be reused to make new asphalt. (2)

As the bitumen is solid during room temperature it needs to be heated up to mix with the stone. But there exist cold asphalt mixes still as it is possible to create cold mixes thanks to emulsion where you mix two liquids that wont mix easily together by adding drops of one liquid to the other. The other liquid used for this solution is water where bitumen is dropped on to the water. mixing the liquids you get a lower smelting point and can be mixed with the rocks at lower temperature. (2)

2.1.1Properties of different mixes

Road with heavy traffic needs to have high deformation resistance. The mix for it have larger stones sizes, have more stones in the mix, needs to have more filler and less bitumen. The mix is very stabile and have high internal friction but is more difficult to compact. It is used in airstrips and highways and more places. (3)

For places like parking spaces and cycle ways there are another mix that is used. It have instead smaller stones, less filler, less stones and more bitumen. It is more easy to compact than the first mix but because it has less stability it can be sensitive to if machines are used to early in compaction process. This will cause material displacements which leads to that the asphalt in pressed up in front of the drum, which can be seen in figure 2.1(3). This is unwanted

because it makes it harder to compact and more asphalt will come in contact with the drum.

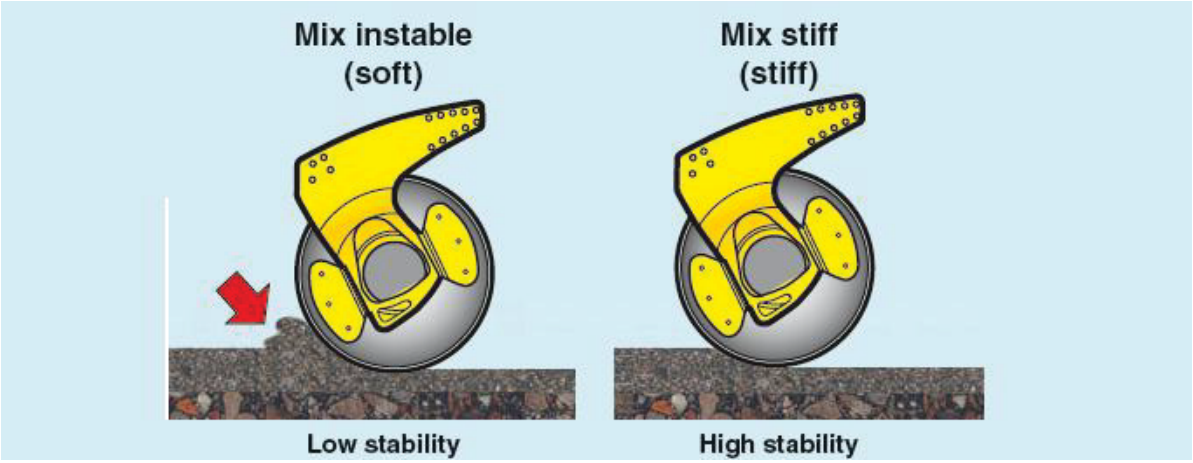

Figure 2.1 (3) One the left you can see how the asphalt react when the wrong type of machine is used.

2.3 Compaction

The compaction is done to increase the density of the asphalt layer or an reduction of porosity. If done correctly it will have more stability and have more resistance against deformation and be more resistant to wear so it last longer. The compaction is done by delivering pressure on the asphalt and compressing the different layers of the road.
The forces needed for compaction depends on the temperature of the mix. If the temperature is to high the compaction of the rollers is supported by the low viscosity of the bitumen.

The bitumen is used as lubrication and reduces the internal friction in the mix. As the bitumen will become more solid as the temperature goes down it will require more effort to as the temperature goes down. Therefore in most cases the compaction should start as soon as possible. The optimal temperature for compaction has been found to be around 100-140 Celsius for most bitumen types. The compaction should be completed when the temperature has went down to 80-100 Celsius. (3)

As the finisher which can be seen as the middle machine in figure 2,2 need constant speed and an constant material flow as if not there will more material on some parts in road leading it be uneven, there is often another truck in front of the finisher and unload its materials unto the conveyor belt on the finisher which takes it to the auger which is rotating screw that will leave

material in front of the screed to work with. The screed will make sure the asphalt will have the same height all over and do some light compaction.
As the asphalt finisher have finished laying out the asphalt and making it flat and given it some light compaction it is time to begin to use the roller. If the mix is with small stones it will needed to be compacted by a lighter roller, If vibration rollers are needed for this time they will run two passes without having vibrations on. If the finisher have made a heavier compaction by the beginning there will be less problem to use heavier machines and the temperature will be more favorable and because of this it will need less passes to complete the work. (3)
The rollers use their weight to do the compaction with an linear load (kg/cm) and rollers with vibrations can use it to reduce the internal friction in the mix, so it can be easier for the linear load to increase the density.

Figure 2.2 (3) Picture of the compaction can look like. To the left we have an roller which could be an tandem roller. Next in the middle we have the finisher who is laying out the asphalt and make some compaction. Last we have a truck that unloads an steady stream of material into the finisher.

2.4 Limitations of project

There exist different ways and scope of how the problem could possibly be solved. For example it could be that coming up with a new way material or ways to make roads that won't stick to the drum or change the mix of the asphalt. But to make it more manageable to do the project I have narrowed it down to look on the drum or the scrapper if something could be changed or replace to suit the same function. It should also be something that does work with the type of machines Dynapac have today.

To better understand when the asphalt that sticks becomes critical and how they appear, an interview with Ingmar Nordfelt was made. Ingmar Nordfelt work on Dynpac and is their practical expert on the machines. When the drum begins to pick up asphalt it only small parts firsts, where it is around 0,06mm in size and will increase for each passing lap. When the particles begin to become over 1 cm high then it will begin to influence on the quality of the road and leave stamp marks.

If the temperature difference between the drum and the asphalt is only around 20 degrees the drum will no longer have any problem with the asphalt as it won't pick up it anymore. The highest temperature that is used for the mixes is around 180 when they use the machines. When the machine do the first passes without vibrations the scraper will have no problem with keeping the drum clean as it won't move. The problems appear after the vibrations are turned on. The information in the text below have I got from my supervisor Linus Bilén on Dynapac.

As the drum is held up with rubber elements it will not only be the amplitude from the arms in the drum that affects the height maximal amplitude. If the drum is driving up on a sidewalk or hit something hard enough to withstand the weight of the drum then the rubber will make it go in the same height as the passed object. It can also move sideways the same ways. It has been estimated that it can move around 20 mm up and to the sides from its original point of origin.

The new solution cannot depend on that the drum is at some height specially as it would break then from the forces of the heavy drum. It can't be placed in the front of the drum either because if the roller would hit an obstacle it would also be crushed from being between the drum that movers and the object in the way.

The current scraper is cleaned one time per day to ensure that it works the next day.
The new design should not be large enough so it cover the drum from the driver perspective as then he cannot stop the machine if something has happened.

The asphalt that gets stuck does not sit there particulate tight. It's the stickiness of the bitumen in the asphalt mix that make it get on the drum.

2.5 Calculations theory

2.5.1 Eigen frequency

As the solution is going to be affected by the vibrations it needs to be checked if accidents can happen because of that's parts Eigen frequency are too close to the drums vibrations.

Resonance happen when the system have built up more energy from having a frequency that that is the same as the Eigen frequency of the system. This will result in that there will be large movements and deformations and displacements can occur.

The system will begin to move around more than usually and break. The equation needed to calculate the frequency can be seen below.

$\omega_c = \sqrt{\frac{k}{m}}$ where k is the beams flexural rigidity which has the properties $\frac{EI}{L}$ it also have some different constant depending on the element case. that describes the constraint of the case.

It would be more complicated if the system had a mass attached to that it needed to bear, but in my concepts there was only one big enough part that was interesting to look on.
I is the inertial resistance which is to be chosen from existing elemental cases cross section. and m is mass of the beam. If you want look on my calculation they are on chapter 4.9.2.1 page 48.
[4] pages 156.

2.5.2 Wheels

When two wheels are in contact with each other, there will be area that is deformed and flat between them than links them together. To calculate the pressure the formula below is used..

$$p_0 = 0{,}418\sqrt{\frac{F * E^2}{L}\left(\frac{1}{r_1} \pm \frac{1}{r_2}\right)}$$

this part $\left(\frac{1}{r_2} \pm \frac{1}{r_2}\right)$ is depending on if wheel is on an flat surface, convex or an concave.

If the two bodies if of different materials then E needs to be calculated trough this Formula below. This formula works if both materials have the same possions ratio v.

$$E = \frac{2E_1E_2}{(E_1E_2)}$$

In the material closet to surface of the contact of the two bodies there will compressive in 3 different directions. Because of this there will be higher pressure than it would have been if was only in one direction. The maximal pressure can be described like this

$$\tau_{3max} = 0{,}3 * p_0$$

The calculations is on 4.9.2.3 page 50. [5] page 35

2.5.3 Safety factor

The calculations needs to have an safety factor so it can withstand the loads for an longer lifetime, and to take in account of possible errors in the calculations and method. The formula looks like this.

$$\boldsymbol{n = \gamma_S * \gamma_{R1} * \gamma_{R2} * \gamma_{R3} * \gamma_{n1} * \gamma_{n2}}$$

The γs takes in account of how loads are affecting the part and depends on how large the risk for that it will go over the ultimate tensile strength of the material.

The γR1 takes in account of the different material data and how sure you are they are correct.

The γR2 takes in account of what methods you are using to calculate the stress.

The γR3 takes in account of you have the same loads or if the differ over time.
The γn1 depends on how big the chance there is that construction will break and how serious consequences it would have.
The yn2 depends on how big control you have over your calculations, the manufacturing, how the users will affect it and the material.
In each case the book have several different cases which be chosen to get a number.
The calculations is on chapter 4.9.2.3 page 49 [6] page 102-105

3. Methods

The general method I used for this project was the value model, where you begin to describes whose needs that are going to satisfied and what those needs are. Then you look on the different functions that is going to delivered to the customer. The next steps is to create solution based on the functions that have been found. I used this method because it takes many different perspectives in account when you look what is better to develop.
(7) page 128.

I will also follow this methods that first I plan what I needs to do, then do it and evaluate the result. If the result is not good enough, I will then do a new plan and continue this process until I have got satisfying result. So my development process will be iterative. The whole process can be seen in figure 3,1. In the following chapters I will explain each step more

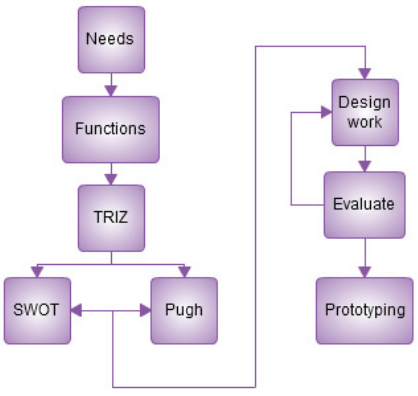

Figure 3.1 an summary of the process.

3.1 Information gathering

3.1.1 Interviews

When I needed more data for the project on for example how big the first asphalt particles would have and when it would have reached a critical height, I talked with different people at Dynapac who had expertise of the problem. I presented my concepts for some people at Dynapac to get some feedback to develop those ideas more. So I explained each concept briefly and what it would accomplish.

During the whole project I have discuses the problems with people that have expertise of machine and also those who does not have as much insight of the problem, to get more perspectives. When I did my brainstorming sessions I took help of some of these people to get more ideas where we used the triz method to come with ideas in structured way. It has also been very helpful to present my ideas for my different supervisors and get new feedback each week.

3.1.2 Books

All the books I have used for the work have been books I have had in courses in Blekinge institute of technology before this project. I did this because the problem with scraper is not described in books as it is a practical problem only found in the industry.

3.1.3 Internet

When I did my research for information on the internet I looked on different sources I looked on different sources so I did not use information that could be wrong. To better understand what alternative solutions exists today an of Dynapacs competitors where done. Different patents connected to asphalt and scrapers on the Swedish, American and European patent registers where also a part in more information.

3.2 Functions

To better understand the function that my concepts needed to fulfill some different techniques to analyze the currents solution was used. I did this because then I would not be focused on solution specific concepts when would begin with coming up with new concepts to solve the problem. The methods I have used are functional analysis system technique and main function analysis.

3.2.1 Fast

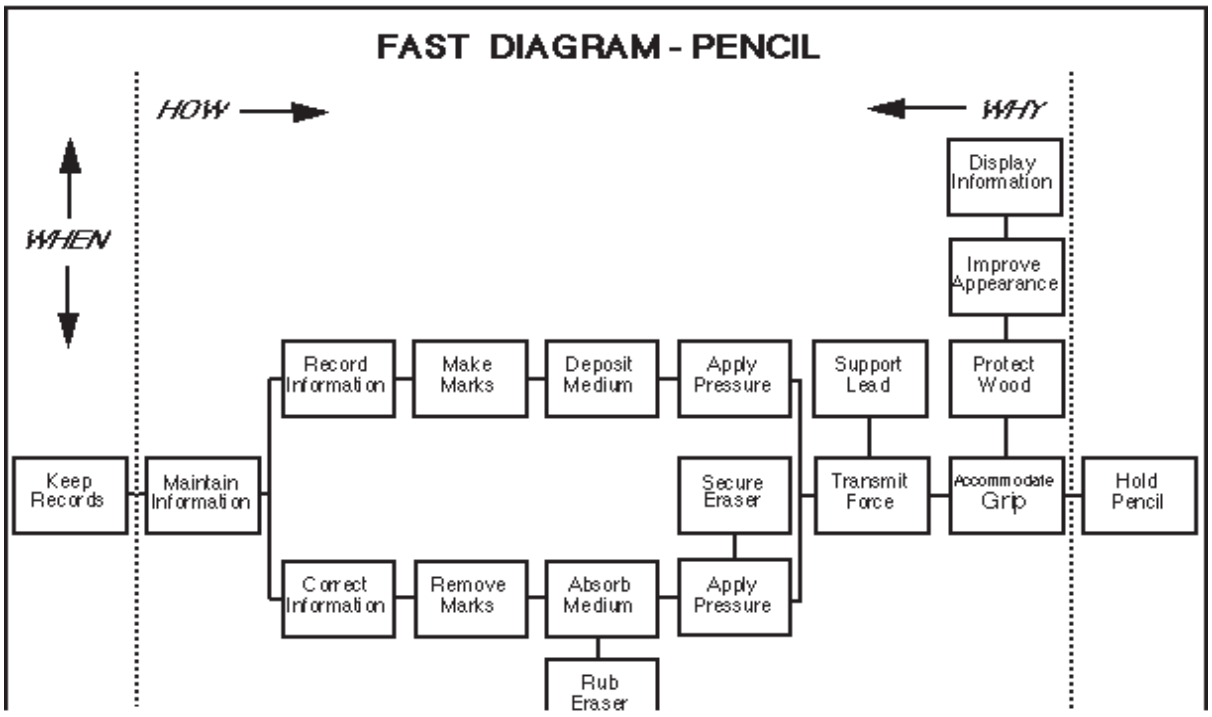

Figure 3.2 (8) example of an fast diagram

Fast is a method that can be used in two ways either you know how something works but doesn't know what's is purpose is in the first place, or you know the purpose but don't know how it works. If you want to understand how system of components works together this can be a tool to visualize the functions of the system. In the figure 3.2 you can see an example of how the method works.

I started with the goal of the system which in this case is to deliver an even road. Then I asked the question how it should be carried out to fulfill the need. I continued to ask the question till I had found all the functions that would affect the scraper. I could have continued to when driver needs to start the

machine, but what I wanted to get out of this method what was affecting the scraper, as I will only work with this subsystem and not the whole machine.

This method also takes in account of independent functions that are happening at the same time as one function, when this is done you go up and write a new function there. I also went from the left to right from where I stopped to ask the question why and see if could get new information from the independent functions that could affect. When you go down from a function this marks when a activity is connected to the function that must be done in order for it to operate. [8]

3.2.2 Main function analyses

If I want to improve the current solution, I needs to know what isn't necessary for the old solution and what annoys the users about the old solution. So I looked on what the main, additional, support and unwanted functions could be for the scraper. To describe the functions I need to have an subject that does an action to an object but it can be done another ways, for example a mobile phone deliver calls. (7)

It should only have a few or one main functions and if this function would be removed the purpose of the device would be lost. For the scraper it should be the scrapper keeps the drum even. The scraper system and the sprinkler is a support function to the drum as you don't really want a scraper you want compact asphalt. So it is something that is not really wanted but is required to let the main function perform its function. So if possible it would be better to remove the scraper.

An additional function is something that can increase the value of the product but it is not the main purpose of getting the product. It also must bring more value to the customer than it costs for the company to produce it, or else it becomes an unwanted function. In the scraper cases it is that the scraper distributes water evenly on the drum. So this additional function for the scraper becomes a support function for the sprinkler system.

Support functions are those function that are not wanted by the users but they are consequence of the chosen technology. They can't by removed because then the product would not function anymore without them. The support functions of the scraper is that it "needs to connected to frame" so it can be stable enough to remove asphalt .It is not wanted as the scraper will become

immovable from its position it will be less inclined to pick up asphalt from the vibrating drum. Another function would be that "the scraper needs an spring to be adjustable" as if scraper could not adjust to the drums new surface as it tears down it will no longer remove asphalt.

The unwanted functions are those functions that will cause problems, cost or inconvenience to the customer and are often a cause of the chosen technology for the concepts. It is often functions the use itself have an part in. For the scraper these should be "needs to be adjusted" and that it "needs to be cleaned" These functions are needed to be done continue which will take time from the workers that they could have used to something differently
[7]pages 76-78.

3.3 Needs

To better understand how I could improve the scraper and avoid creating a solution that theoretically works but won't be used because I had missed some critical points. These points could be that they expects that the machines to behave in certain way or for it to have features that if they would be removed would disappoint the user because it's not there.

So I began with doing a stakeholder analysis and drew a map of which people could be affected by this project. This can be seen in chapter 4,3 page 30. The users of the machine is the most important group because they are one that are going to spend the most time with it and they are doing the work that will affect my design. I do this because I don't want decrease the value for one of the stakeholders was looking trough one sides perspective. I would then have improve it in one way but decreased its value in another way. Which could have been avoided If I were aware of their perspective in the first place.

So I tried to see it from each perspective and figure out what each could want and how it could affect them. I used the value equation method to look on what the customers would get and what they would have to spend to get it. It have 6 different part I used the problem, the result, feelings, effort, time and money. [7] page15.

3.4 Concepts generation Triz

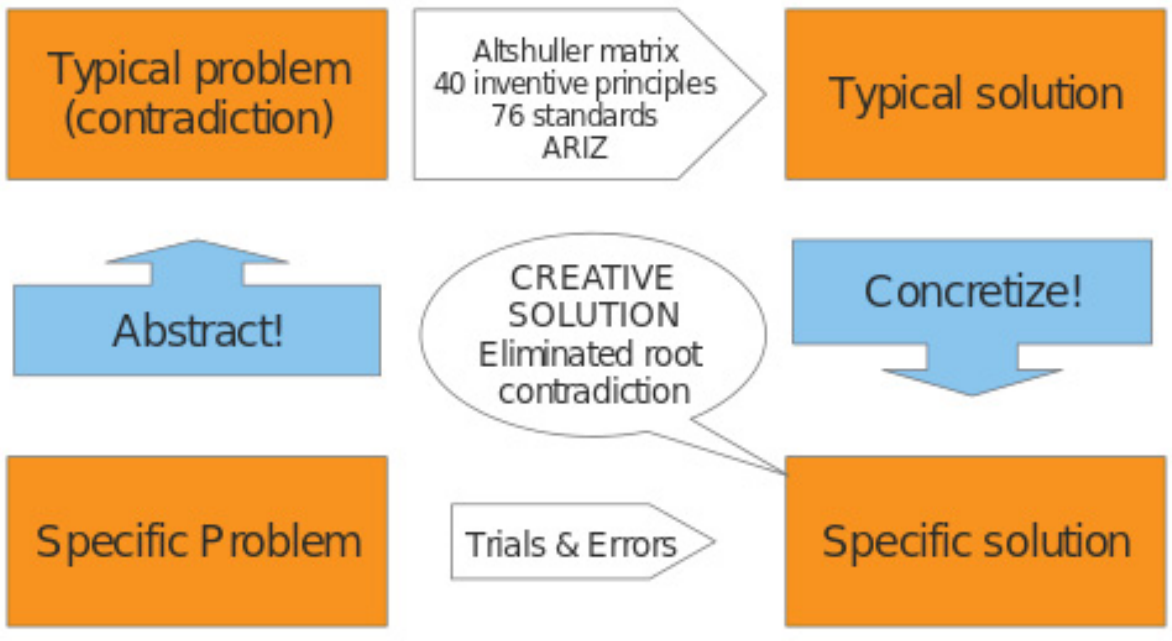

Figure 3.3 (9) example of the triz method.

Triz is a method where you takes your problem and tries to define it like a general problem that other have solved before. Then you look on triz databank on how that typical problem have been solved before. Then you takes the part that seem to make sense to your problem and makes a solution. The principles the data bank is made up of come from patents that have been sent in to different patent register. This 40 different solutions have been used to solve 90% of the patens. [9]
4
I chose to use Triz when I did the concepts generation because it gives a structured way to construct ideas and is not as unfocused as some brainstorming methods where everything is permitted.

It not really restraining method even if it only focus on one aspect at a time, as when you have finished making up ideas you can begin anew with a higher level in the system. So it have the advantage if you run out of ides you can begin with a new perspective. One drawback of this method could be that after you have got you list of ides after a while you could miss those ideas than can come up when have unrestrained mind.
The steps for this method can be seen below. In the figure 3.3 you can how an summary of the method work.

1. Describe at what level in the system the problem should be solved.

This is done because the number of available solutions depend on much you are willing to change. But higher the level the more it will cost to do the changes.

2. What resources does the current solution have that could be used to solve the problem ?

This Step is done too see if there is anything in the current solutions surrounding could be used to solve the problem and therefore have no need to make big changes.

3. Describe the problems trough a contradiction.

This is done to better understand how the problem appear and what the real problem is.

4. Try to get rid of the part the causes the problem.

Describe the part function and what the receiver of the function are. Then it look on if something else can do the original function instead and removing the problem.

5. Look if the contradiction could be separated from the part in some way. Possible by that it have an changing geometry or that it does its function in another time than when the problem occur.

6. Now when the problem have been defined I can go through Trizs 40 suggestions of how their typical problem could be solved.

[9]

3.5 Evaluations

I needed some way to evaluate my concepts, and I wanted some different ways to do it so I could look on the same concepts from different perspectives. So I chose to use the SWOT technique and the Pugh concepts selection matrix. I chose Pugh because there you rank the concepts from criteria you chose which link back to the function and needs that have been discovered before. One drawback of this method could that if you focus too

much criteria or make them wrong you could miss critical aspects that is not bound to the criteria that have been made. On the other hand it gives clear winners
SWOT was chosen to compliment the first method because here you describe what strengths and weaknesses each concepts have while not being limited to the criteria that has been chosen. It also take in account on what could threats would before the concepts, where I looked if there was any possibility for it to malfunction. In the Opportunities part I looked on it would be easy to add to the current solution as the less that would be needed to changed in currents machine the better. In its own the SWOT method doesn't necessary give any winner but in combination with the pugh I get more perspectives on the concepts.

3.5.1 Pugh's concepts selection matrix

		Concept				
Criteria	**Weight**	**1**	**2**	**3**	**4**	**5**
Safety	0.25	3	3	2	1	1
Cost Implementation	0.15	3	3	1	1	3
Final Packaging Floor Space	0.20	2	3	3	1	3
Material Handling Distance	0.10	2	3	4	4	4
Flow Between Cells	0.10	2	3	5	4	3
Worker Resistance to Change	0.05	4	3	4	3	3
Ease of Implementation	0.15	3	3	1	1	2
Weighted Score		**2.65**	**3**	**2.5**	**1.7**	**2.45**

1 – Much Worse than Datum
2 – Worse than Datum
3 – Same as Datum
4 – Better than Datum
5 – Much Better than Datum

Figure 1.4 (10) example of how a pugh matrix looks like.

First I looked on my needs and tried to make them into categories that could be measured. I also included categories that took in account of what could be improve the concepts for Dynapac like cost, how easy it could be assembled or made at Dynapac. Then I looked at each concepts and gave them different

scores according to the different criteria. I used an scale of 1-5, where 3 would be same as the original solution and 5 would be much better than the original. I used the 1-5 scale because I had not enough data on each category to make an scale of 1-10 worthwhile as It would have to hard differentiate the scores then. An example of how the result of the method can be seen in figure 3.4

[11] pages 150-159.

When I had evaluated the concepts according to my criteria many concepts did not have any clear differences in scores, so I decided to give the different criteria different levels of importance. At the same time I had discussions with Dynapac about the criteria's and what they thought what was important to include.

The most important criteria should be cost as the machine will sell even if the problem is not fixed. So an expensive solution that solve the problems may decrease the value as the user accept the current solution to a degree. The next important one would that it is a trustworthy solution as if the solution breaks or malfunctions it will give bad brand recognition for Dynapac.
To deem how important the rest of the criteria where I compared each criteria pair wise I had till there where non left to compare. Next I divided up a value of 100 among the different criteria depending on how important those were where the more important one got more.

In version 2 of the pugh I split up some of the criteria into new sections so it would be easier to explain what each meant. I also included new criteria that seemed to be missing to make a fair assessment, like solve all problems which was changed into trustworthy solution and simple solution. So I shifted focus from trying to solve as many problems at once, to solving one well enough and thereby raise customer value by not adding to much complexity.
I also removed "can be made at Dynapac" where I looked on how easy it would be to add the concept to the current machine and if new suppliers would be needed.

After the version 2 of the pugh had been completed I had 4 concepts with high scores. The sponge concepts and the cloth concept who worked with similar principles but the sponge was a bit cheaper. I had the arm concept and the vegetable oil solution also. I looked on my SWOT analysis of these concepts

and disregard the oil solution as even if it solve the problem very well it would be too expensive.
As the sponge would be made of a softer material than the arm it can break more easily. The sponge concept also depends on that asphalt get stuck on it. It can be a possibility that asphalt get stuck under the sponge and begin to tear trough the sponge and thereby breaking it. So I chose the arm as my final concept that I would continue to develop.

3.6 Design work

When I began to do the design I begin with drawing a sketch of how I thought it should look like. The idea was at first to connect the scraper to an point in the middle of the drum so it would geometrically fixed to its movements and moving from the same origo.

But as it would have been needed to have an arm that is connected to an point that goes in trough the sides of the drum as it can be connected to the frame as it won't move. The idea was to have a wheel that moves inside the drum, but I deemed to be too complicated as it would need to connected to 4 different points on the both scrapers on each drum.

Under this whole phase I used an iterative process where I evaluated the concept and fixed its problems. I looked if new parts could solve the problems like springs and wheels. One part of the evaluation was to calculate the Eigen frequency to check if it could handle the drums vibrations.

When I began to draw version 2 I used inventor to make 3d models to visualize the concepts. I had gotten 3d models from Dynapac of the scraper, the frame and the drum to able to make measurements. After I had an overall design I did some calculations for some of the parts to see what measurements they should have according to what loads that would affected them.

4. Results

4.1 Function analysis

To better understand the current solution is looked on the different functions the current solution offer. I draw a FAST diagram to figure it out and it can be seen in appendix 1.

From this we can seen that the scrapers primary function is keep the drum even so it can in turn make an even road. It also is important that it can adjusted to an acceptable level of contact. And that it needs something more like a spring to ensure that it is kept against the drum,

4.1.1

To see what adds value to the solution and what is needed for it to work I did a main function analyses so I could get new ideas on how to improve it. The diagram can be seen in figure 4.1 below.

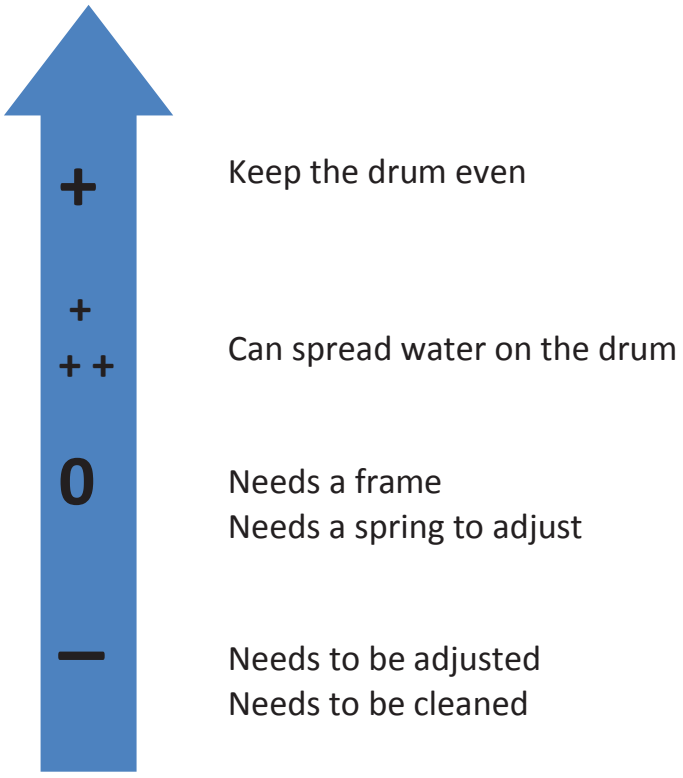

Figure 4.1 arrow of main function analysis

From this we can see that if want to improve the value of the function we can try come with a solution that don't needs to be adjusted or that is self cleaning. It could be have room to add some additional functions but it depends if they add any value in end, they could be features that won't be used. From this and the fast diagram we can also see that it must be able to be stiff at times and must be able to moved, so it can be more easily cleaned and adjusted when it is needed.

4.2 Value equation

The value equation is describing what perceived benefits the buyer could get out from their purchase and they have to spend to get those benefits. It have several parts. From perceived benefits you have the problem, result and feelings. In total expenditure you have time, money and effort. It can also be what is the function are you buying. it can also be used to describe what you want to change in each category. I have used some of this categories for my pugh which can seen in later chapters.

Problem. This is the main function of the product and is the reason why it should be bought. In the scrapers case it is ensure that the drum can produce an even road by removing as many unwanted particles from the surface of drum as possible.

Result is how to do the main function in a better way which for the scraper is ensure that no particles that is big enough to leave marks get trough or that no particles at all gets trough.

Feelings is what the user or customer feels when they think of the product or of using it. In this cause it could be to know that you can rely on the scraper, or feel how easy it is to adjust so it follow the drum after the drum have been torn down. It can also be that cleaning it doesn't require many operations when you need to finish for the day.

Time is all the time that it takes from the user to fulfill the function of the product. The time to learn how to use the machine the first time. The time to adjust the scraper each time it needs to be adjusted, how often it needs to be checked if new adjustments are needed. It can also be how much time is needed to clean the scraper each day. It also is the needed time to assembly it for production. The lead time it takes from suppliers to Dynapac.

Effort is how bothersome each of the task needed for the product is. The amount of knowledge that is needed to operate it. Which in this case is not so much. Use the different settings of how close it needs to be to the drum and to clean it after each time it is used. They also need remember to fold the scraper up during cold temperatures when they leave the machine for the night. As else it would frozen to the drum the next morning.

Money is the total cost of the product. How long it will take before it will need a replacement. How much the needed cleaning equipments cost. The cost for Dynapac to buy it from their manufactures. The end price of the scraper for the customers. The time is also part of the cost as the workers could have done other things if the operations wouldn't be needed so it would be more efficient.

4.3 Needs

4.3.1 Stakeholders

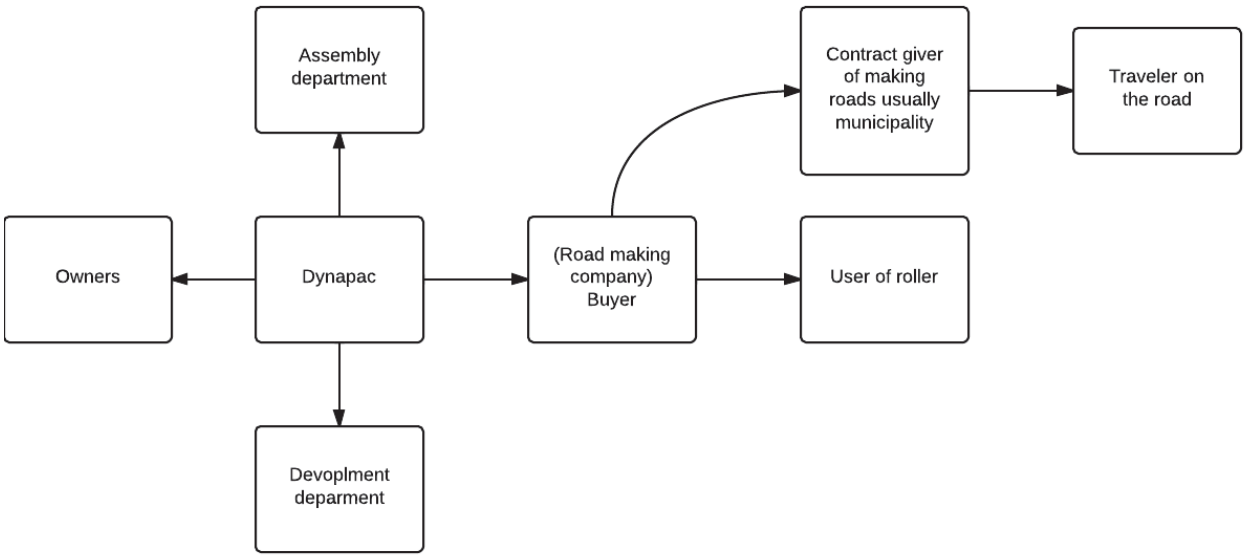

Figure 4.2 stakeholder map.

To understand which people is affected by this project I made up a map of different stakeholders so I knew whose needs I need to take in account of when developing new concepts. So we have assembly departments that can get less components to assembly and operations that don't take as much time. We have the development department who look on the new ideas I bring forward even then ones I don't chose to continue working with to get new angles.

There is the buyer of the machine who can chose a machine that gives a better result and can get less cost from using it as the employers need less time to prepare work. There is the user that can get simpler and fewer operations to the same amount of work that can take less time. Dynapac owners can possibly get new revenue as they market a new product with better result so more customer will be more interested in their products. Those who travels on the road will get more roads of higher quality, which will last longer.

4.3.2 Needs

I looked on the most important stakeholders and tried to figure out what their needs would be. These stakeholders would be the users and the buyers.
The user doesn't want to do any work that seem unnecessary or tiresome.

They would want a solution that works by itself and that does not require to be checked up regularly and the less maintains the solution needs the better as it could be risk that some user does not do the maintenance. Always leading to that the product will decrease in effectiveness. So the fewer operations the user needs to do in preparation and during work the better. If there is operations that can't be removed they should be simplified as much as possible.

The user should not get less control over situations that can spin out of control. As for an example the user should have the parts of the drum visible so he know if the system isn't working and have an chance to reduce the damage the asphalt can make.

If the solution is in need of cleaning it should placed well enough so it won't be difficult to reach and clean certain places of the solution.
When I looked on the assembly departments they are a part of the cost of the product as the solution will take different amount of time to assembly depending on how complex the solution is. So it would be positive to bring down the number of parts and the complicated form that cost more to produce and in the end to buy for Dynapac.

The buyer want to avoid buying new parts for the machine as it will be a new costs. So they will want to have an sturdy solution that doesn't break down. It can also be good to make an solution don't seem less sturdy as the rest of the machine to not remove customers that feels that it won't suffice. If it can be avoided they buyers should not have get the solution from different stores.

They also want an as low price as they can get. There also other segments that accepts a higher price for more value but then you get a lesser customer base.
Dynapac want to have machines that is more desired than their competitor to increase the same time. At the same time they don't want their machines to be associated with returning breakdowns or be associated with products that is unsustainable, as it can affect how customers see their company and can be a factor in that they will not buy their product.

4.3.3 Requirements list

- The solution should be able to durable enough to withstand the environments it are working in. which means it should handle these parameters.
- It should handle vibrations in the range of 50-70 Hz.
- It should handle the temperature from the asphalt in the range of 80-180 Celsius.
- It should be able to handle the amplitude of the vibrations(0.8mm) and the movements from the drum which can go in any direction (20mm)
- It should be able to be used on all the scraper on the machine(2 scrapers on each drum).
- It should be able to remove the particles before they make any harm to the road.(before they become 1 cm high and after they are beginning to gather more).
- It should be in the same price range as the previous solution.

4.4 Competitor analysis

To get more ideas and see how the industry looks today I have chosen to look on the competition and how they have solved the problem. Cat uses a similar system as Dynapac There is one difference though, they have placed their second scraper much lower than their first on some models. This could be due some restrictions in form so they didn't have enough space for it. It can also be that they believe that the scraper could be more efficient if they remove asphalt from different angles. They also have different models that also have the second scraper in the same place as Dynapac. An pictue of a cat machine can been seen in figure 4,3

Another competitor use an spring to press down the scrapper against the drum. Because of this they don't have to worry about that the scrapper doesn't have enough contact but it will affect the life length of the drum and scrapper for the worse.

Hamms machines doesn't have any way to reconfigure its scraper as it only depends on its own weight to keep an even contact with the drum. This way it will be more cheaper but less reliable. An picture of a Hamm machine can be seen on the next page in figure 4,4.

So all who works in the industry is currently offering the same solution with some variations on the concept. So we can say that customers accepts the solution for now but it could be potential to buy a new machine from Dynapac if it solve the problem better, but you can also say that it is a conservative market.

Figur 4.3 picture of Cat tandem roller. The lower scraper can be seen on both wheels.(12)

Figure 4,4 picture of an Hamm machine.(13)

4.5 Triz problem solving process

Step 1. Define the system level at which the problem is to be solved.

We will begin with trying to look on how we can change the scraper itself to solve the problem and then look if we could change the drum. The next iteration would be to change materials for making roads or changing the whole machine which I believe would be too big.

Step 2 List all resources.

. With the machine we have several resources available to draw use of too possible solve the problem. There is vibrations from the drum, heat from the asphalt, movement from the wheel, there is fuel that can be used and a limited supply of water. We also have a driver in the cabin and possible other humans who is in the surrounding working.

Step 3. Formulate a system conflict.

There is a solution today but it is not effective enough. The scraper must have contact to remove unwanted particles to have an even drum, but it can't always have an even contact due to that the drum must vibrate to increase the density of the asphalt layer.

Step 4. Get rid of the "troublemaker".

The scraper keeps the drum even.
A. Eliminate the need for the function.
B. Let the receiver of the function perform the function. The drum keeps itself even.
C. Have an already existing component perform the function. Use only the water system to keep the drum even.
D. Carry out the function in a different way. Use an coating to protects the layer of the drum from asphalt sticking.

Step 5. Educate the "troublemaker"

The scraper should have contact with the drum but it shouldn't be pressed to hard against the drum due to that it could damage the drum and itself.

4.6 Ideas

These are the ideas I have come up with during the triz method and other times. The list in this chapter is the ones I believe could potentially solve the problem. There was more ideas but I eliminated those for reason that can be read in the next chapter. These first 7 ideas are the one I evaluated more.

Sponge that is pressed against the drum and is regularly changed and washed. Or have an object that easier get asphalt stuck on it than the drum. it is hold down at the sides with arm that can move sideways to able to handle the motion from rubber elements.

Use an adaptive steering system that is used in cars today to steer the drum before you turn. The idea is that the system have sensors so it know when you begin to turn it activate an dampening effect on the scrapper so it keeps an even contact.

Several individual scrapers that is pressed against the drum on different locations. So if one scraper miss a piece another one can make up for it.

Use a piece of cloth that is pressed against the drum to collect asphalt pieces by making asphalt stick to the cloth instead of the drum.

Use an protecting layer on the drum that makes it difficult to stick (vegetable oil solution). Diesel is today in same way as this solution but it are not environmentally friendly. I got this idea from a patent which used this to relapse asphalt from shovels. It would have an sprinkler system that sprays continually the oil over the drum.

Fixate the scraper with the drum vibrations with an arm that goes from the center of the drum to the scraper. As the scraper have the same movements as its geometrical fixated to the drum it is less likely to skip asphalt due to that there no longer is a distance between the drum and the scraper. To support the scraper it would need another arm linked to the frame to prevent that it falls of or roll around the drum.

Heat up the drum before rolling on the asphalt. By doing this the asphalt is much less likely to stick to the drum.

I have not included the next two ideas in my evaluations. They are not included because I came up with them after I did my evaluations and had already begun further development with my chosen concept. They seemed to have more potential than the ideas described in the next chapter so I left them here.

Replace the edge of the blade with a soft part so it can be pressed against the drum without damaging both the blade and the drum. As this soft piece will be grinded down after a time of use it will need to be replace with a new one.

Use an brush instead. This can be rolling one like in a car wash where at the top you collect the asphalt that sticks so it won't go back to the drum again. It would probably some kind of box at top that the asphalt runs down into, so it won't get stuck on the drum on again when it passes trough.

4.6.1 Solutions that probably won't work.

I had a discussion with Dynapac where we discussed my ideas. From the discussions I could eliminate some of my ideas as they would not be effective enough or making the problem worse than it were before.

Press down the asphalt on the drum so it will become flat and not leave any marks and thereby avoiding the problem.

Have several smaller drums that quicker get warm and therefore is less likely to stick due to that it will be less change of temperature between the drums and the asphalt.

Use only water to cut away the other layer with asphalt.

Fill the whole drum with asphalt so it can no longer stick to the drum. And keep the layer even as it continue to pick it up.

Use an layer on the drum, with a material that asphalt won't stick to..

Have an toilet roll approach where the drum have an outmost layer that can be removed after it been damaged too much and be replaced whit a new one.

These ideas have been discarded of different reasons. The first even though it would at first keep an even road , the asphalt that was pressed down would still pick up more asphalt and thereby making the problem worse.

The second one is discarded because you need a certain weight and radius to pack the asphalt.

The third idea was made before we knew how big the particles was as it would be troublesome to cut away 1mm particles with water cutting and it could be dangerous for workers around the machine if something went wrong.

The idea I had at first was to have an layer of ceramic but that would probably break due to the drums weight. But it is an good idea as you only need the drum to fix it.

The fifth would just continue to pick up asphalt more and more till the machine could run anymore. Also as this is a conservative business it could be hard to motivate the operators to not stop the machine when there is asphalt all over the drum

The sixth idea. It would probably be hard to put on the other layers as it would need to cover the whole drum and therefore you would need to lift up the drum to place it, or run over the layer and the drum would pick it up as it would go around the drum.

4.7 Strengths, Weakness, opportunities and threats.

Sponge

The strength of this solution is that is simple and it is made of a flexible material so it doesn't matter that the drum vibrates as it still will cover the drum. It also can target a bigger area than the scraper could. You could possible work it out so it can cover the sides when the drum turn.

Weakness could be damaged more easily than the scraper due to that is made of softer material, but it shouldn't give any damages to the drum if it is pressed to hard against the drum.

The Threat could be that asphalt could possible get stuck under the sponge and begin to make marks on the drum and tear trough the sponge

Adaptive steering

Strength
It can solve the turning problem as it can adjust the movement of the scraper as you turn.

Weakness. it can be expensive to solve and it only solve one of the problems.
Threats. It will need a complimentary solution to solve the vibrating problem, and it can be expensive.

Several smaller scrapers
Strengths They could get the particles that on scraper have missed. And it you have them at different places it is more likely to pick up the particles due to that is in different places of amplitude.

Weaknesses. It will be more expensive and you will get more scraper that will need to be adjusted and cleaned.

Threats it will need more time in assembly as it have more parts.

Fabric that is strapped on the front

Strength. It will cover a wider area than the scraper and could be pressed against without damaging as the cloth will dampen the impact.

Weakness. It will probably need to be changed pretty often as the rocks may break the fabric down.

Threats. There is a possibility that asphalt will get stuck under the piece of cloth and then it can lay there and damage the drum and the cloth.

Vegetable oil coating

Strength. It is a simple solution that will solve the problem. It also is a environmental friendly solution compared to other asphalt release agent such as diesel.

Weaknesses. You need gain a provider for the oil and it doesn't exist everywhere for all customers. You also trade a cost for a physical object that needs to be replaced after a while for a service
that can be possible be more expensive in the long run.

Threats. Not all customers will have same chance to get the solution. Will need to get a new value chain to get the vegetable oil.

Fix the scraper to the drum

Strength. By using an arm that connected the center of the drum and the scrapper. It will need to be connect to the foundation also so it won't go of.

Weakness. Added costs from the original solution.

Pre heat the rollers

Strength. The drum will be much less likely to pick up asphalt. Could change routines to skip vibrations for a time till the temperature change is small enough so it don't matter if it vibrates.

Weakness. It will take time to heat up the drums and therefore the customer would lose money due to that work will take longer time. on the other side they can get lower down time as the machine doesn't need as much repairs.

Threats. It will not be as effective for all as different operators use their machines differently. Some only use their machine for a short amount of time to patch some holes while others will use it for hours.

4.8 Pugh

	A	B	C	D	E	F	G	H	I	J	K
1		rank	Sponge	Scraper with arm	Piece of cloth	Vegtable oil solution	Several scrapers	Pre heat the drum	adaptive steering	original solution	
2	Costs	30	4	2	4	1	1	1	1	3	
3	Enviroment	5	3	3	3	3	3	2	3	3	
4	Can be made at Dynapac	15	2	3	2	2	3	1	3	3	
5	Life length	10	2	4	2	1	3	1	3	3	
6	Solve all problems	10	5	5	5	5	4	5	4	3	
7	Time for service	15	3	3	3	5	2	2	3	3	
8	user Friendly	15	3	3	3	5	3	5	3	3	
9	total	100	22	23	22	22	19	17	20	21	

Figure 4,5 my first Pugh,I did another version when the first didn't suffice

	A	B	C	D	E	F	G	H	I	J
1		weight	Sponge	Piece of cloth	Vegtable oil solution	Scraper with arm	Several scrapers	Pre heat the drum	adaptive steering	original solution
2	Costs	25	3	3	1	2	1	1	1	3
3	Trustworthy solution	17	5	5	5	5	3	5	3	3
4	Life length	14	2	2	1	4	3	1	3	3
5	Robustness	14	2	2	4	4	3	4	3	3
6	Time for service	10	3	3	5	3	2	2	3	3
7	User Friendly	10	3	3	5	3	3	2	3	3
8	Simple solution	6	4	4	4	2	2	4	2	3
9	Enviroment	4	3	3	5	3	3	1	3	3
10	total	100	312	312	324	331	234	248	247	300
11	rank		3	3	2	1	7	6	5	4

Figure 4,6 the second and final version

15	Costs	1
16	Trustworthy solution	2
17	Life length	3
18	Robustness	3
19	Time for service	4
20	User Friendly	4
21	Simple solution	5
22	Enviroment	6

Figure 4,7 the weighting of the criteria

I evaluated the concepts with another method so I had more perspectives to work with. the method I used was Pugh's concepts selection matrix, where you give score to different concepts with regard to different criteria. I did come up with the criteria's from looking on the needs for the project and by

talking to different people at Dynapac I got more perspectives on what is important for the company.

I also used the value equation from the value model to understand what would give value to the customer and not only focus on costs. I also knew from my competitor analyze that most have a similar solution as Dynapac have now.
So it is important that the solution solves the function better that the old one as it today works well. But I can't chose a solution that will cost much more, due to that then you will increase the price for the machine to solve a problem that industry accept for now. So a more expensive solution would decrease the value for the customer as they would still accept the old solution. I looked on how expensive the parts of the concepts would be to buy for Dynapac as I had their internal price for the scrappers to compare with.

Then in some criteria's for customer value such a life length where I look on how long time it will take before they will need to buy in new replacements or materials needed to do necessary service which will prolong its life.

Another was how user friendly the concept where I looked on how difficult the steps were to make the machine operational, like if it was needed to reach places that would be reach hard to reach so they would need to stand in a positions that is not ergonomically correct. This point is also important because if it requires too much effort then it may happen that the operators may skip them and thereby decreasing the life length of the machine or need to do the operation the next day.

Time for service was another criteria as if it is lowered they will get more time to use the machine efficiently and they does not need to as much work to have the machine running before they can start to do the work they are there to do. If it need to do it every day and even more.

That the concept would be a simple solution was another criteria and looked on how much work would be needed to assembly the tool.
That the solution should be trustworthy was another important criteria, if it am a unreliable solution then customers would spread the word about the quality and Dynapac would lose customers due to that the buyers would be unsatisfied.

last I also included environmental issues, because if the product get negative environmental impact that could have been avoided it could hurt the value of

the brand. It has the lowest score because if you make a really products that really environmental friendly but it doesn't fulfill the main function well then the product is pointless and contradict that you want to save material and energy while still making a product that don't fulfill its purpose. I looked on how much energy would be need to manufacture and use the product and if any not suitable materials was used in harmful way

I did an evaluation with these criteria on the concepts that sounded reasonable. But in the end there was many who had similar scores. So I decided to weight the different criteria. And after a discussion with Dynapac changed some criteria they wanted.

4.8.1Costs

Concepts	Cost(kr)
Sponge	288
Fabric	195
Vegetable oil	870
Orginal solution (2 blades)	760

I looked up on some places what some parts of the concepts could cost. I compared them with the price of the blade for the current solution which I got from Dynapac. As the concept was not developed enough to make detailed calculations I looked on the parts that would be different. The scraper would be replaced and some of the solutions would use similar parts the original solution had. 2 blade are included in this table because each drum have two different scraper. For the other concepts I made some assumptions which can be found in next chapter. It is likely that the sponge and the fabric is needed to be replaced more often than the original solution. So they should cost more than the comparison here.
(14) (15) (16)

4.8.2 Explaining the scores

Sponge

The sponge is cheaper to manufacture as it only require a wall behind it to support it, but as it should only need to be geometrically fixed it doesn't need to be made of a expensive material. The sponge is made from cellousa that could be extracted from when you make paper. When the sponge is to be recycled it will need to be burned to get energy from it. This would be less good as the plastic and steel from the original which can be reused up to a point. But due to that the sponge is made from that is very common and you get from another process that is already made in the first place it will not have an negative impact compared to the original solution.

The sponge may last longer as even if it pressed against the drum it won't be damaged from being miss adjusted, but as it is made of a soft material it have a chance to break as hard particles may get stuck and rip through the sponge. If it is cleaned it should hold for a while. The sponge will solve all the problems that has been found, as it always will have even contact with the drum. The sponge is going to be cleaned regularly every day probably, the same as the original solution. it still need to be taken of and cleaned like the original solution so no difference there.

Fix the scraper to the drum

A this concept included the original scraper it will cost more. It will take some material and energy to make it, but it can be reused so it doesn't have worse impact then original solution. It can have longer life length due to that it will no longer be slammed against the drum sometimes as will follow the drums movement now. It will also solve the problems that has been found. It will need the same time for service as the original as the blade will still need to be cleaned. And there is the same amount of work need to do it.

Fabric that is strapped on the front

It will be cheaper than the original solution. The fabric will need to be burned to be recycled but it is made from common material so it has the same environmental impact. If the chemicals that is used during the process is not handled properly it will have a impact, but used correctly there is no issue.

It can be strapped in with a construction that allows it go with drum when it turn so it will still have contact then. It will probably need to cleaned each day to be able to functions so no improvement there. When it needs cleaning they will need to take it off the machine and flush the asphalt out.

Vegetable oil coating

It will need a tank and some nozzles to spray the coating over the drum. 5 gallons of the coating cost as much as buying a new scraper. And if you compare how long the scraper with how much you will need to buy in won't be economically viable. As it only made from vegetable oil and water it won't have an impact on the environment.

It may have the problem that it will be competing with food producers to get the necessary oil. As you have a continued service instead of one cost you will need run in new supplies when it run out. As the oil prevents asphalt from sticking it will have little need to be cleaned. As it no longer needs to be cleaned as often the operator needs to do less work before begin the work. There will be a need to refill the oil

Several smaller scrapers

Because there is twice as many components the price will be doubled a least. There also is increased cost for assembling the concept. There is more material we use but it can be recycled so it won't have an impact. it will have same life length as the original as it will still have the same movements.
It will need more time for service as more that needs to be cleansed. The same goes for how many operations that will be needed.

Pre heat the rollers

A high temperature change is needed for this concept to work. And it can be quite expensive to use so much energy that would be needed to do so. There is no way to recycle the heat from this operation so it is a waste of energy. There will be a need to do this every time they run machine perhaps even after lunch breaks. So there will a need to always buy new supplies. There will probably take some time to heat the drums in safe way so it will have longer service time and because they have handle hot equipment it will increase the chance that accidents happen.

Adaptive steering

This concept need electronics that is connected to when the machine turn it hinders the movement of the scrapper so it match the drum movements. This will need a system that is expensive. The electronics can be reused so it won't have an impact on the environment. The vibrations from the drum may damage the electronics but otherwise it should manage. It will have the same need for service as the scrape still needs to be cleaned and it still is the same sorts of cleaning.

4.8.2 Conclusion Evaluation

I continued with 3 concepts when the pugh was finished and I took the 3 ones with the highest score excluding the oil solution as it would have been too expensive. In appendix 3 you can see some early sketches of the concepts.
The scraper with an arm goes into the drum and is connect to the base of the frame it is not directly connected to drum but is affected by its vibrations. As the arm needs to move it connected with another arm that is connected to the frame. The arm has an hole that is loose enough for axel from the first arm to able to move according to the amplitude. At the end the first arm it mounted to the scraper.

The sponge concepts have an sponge that is pressed against the drum. This is done by having it pressed down with springs. These spring have an outer setting so you can clean or replace the sponge easily. The sponge brackets can move sideways to be able handle the drums movements

The cloth concepts would have an piece of cloth that had good tear resistance or could be wire wool. It would be strapped on two different points and those would be connected to the inside of the machine. This concept like the sponge will have an larger area where it can remove the asphalt from. Due to this it doesn't matter that it miss it at one point as it can pick the asphalt up later and still do it before the asphalt have done a turn.

4.8.2.1 Final evaluation

looking back at the concepts I chose to continue working with the scraper with an arm concept. this is because it got the highest score from the Pugh and it got not many weaknesses outside form the higher cost. The sponge concept would not be suitable for the environment it should be working in as it have

an risk that asphalt will get stuck underneath it and begin to tear holes in it leading to that it would need to be replaced with a new one quite often.

4.9 Design

4.9.1 version 1

When I looked on the sketch again I thought it would be too complicated to do it that way and it may not be as effective to place it at the inside base of the drum. So I changed the design but still kept the same principle that it should be geometrically fix the scraper to the drums movements. So instead I did an concepts that locked itself to the edge of the drum. It would have space between itself and the drum so it would go and up and down from it. In Figure 4,8 you can see some sketches of the design.

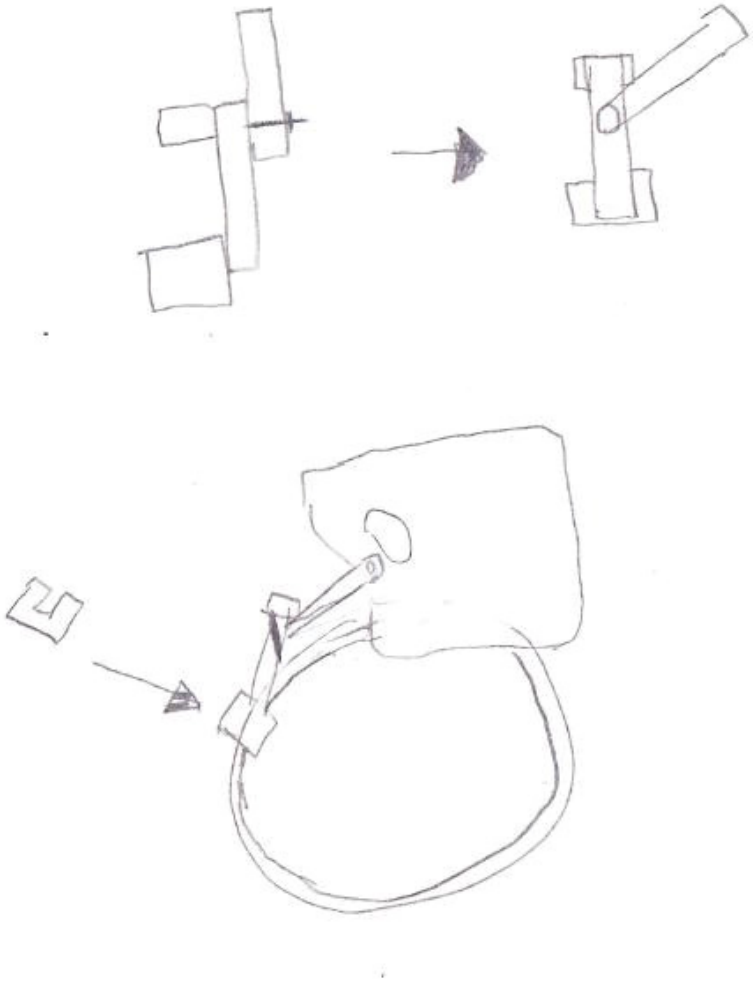

Figure 4,8 sketch of the design

It is still held in place with the arm that goes from the frame otherwise it would fall out on the sides. It still also have the hole with extra space to deal the with amplitude from the drum. With this solution the spring the scraper may be removed as it can hinder the scraper form moving. One negative

aspect of this solution is that it would become harder to clean as it can no longer be folded up as it is connected to the arm. I had the idea that it could be removed when it needed to be cleaned by removing the nuts that held's the griping part in place and the connection between the scraper and arm. But it will still take a longer time than just folding up the scraper with springs. The griping part will also tear down after some use as it will constantly slam against the drum because of space. It must also have space as else it would act like an brake to the drum and probably break down momentarily.

4.9.2 version 2

So with the issues in mind I began to draw a new version with the program 3d drawing program inventor.

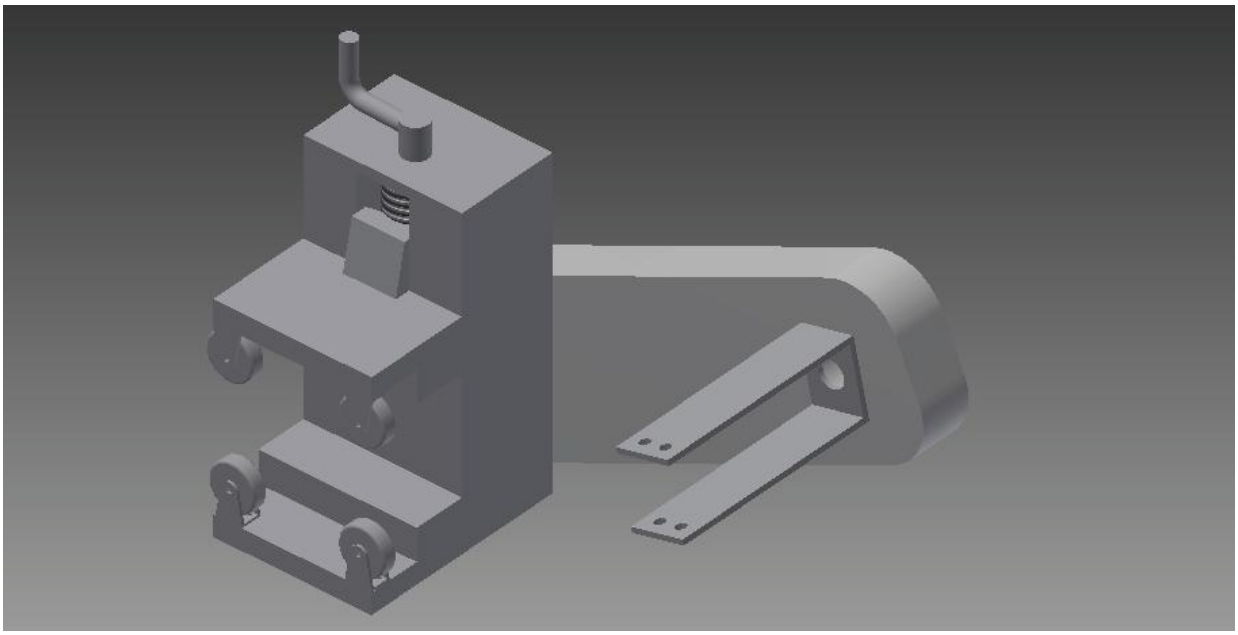

Figure 4,9 cad model of version 2

I removed the issues with it having contact with the drum by adding wheels on both sides so it would roll on the drum and not do any damage. The wheels will roll on the other edge of the drum. It also will constantly be fixed to drum even as the drum will begin tear and become less thick. But it will need some adjustment to do so. So I added a handle on the top of the griping part. I got the idea from an wrench so it can be adjusted without any tools. I thought of having the same with connection the arm to scraper but I thought it would be to many parts.

When I evaluated this version I found that having 4 wheels where unnecessary regarding for it to stable enough so it could be follow the drum. Which is good because the less the parts the cheaper solution would be. Another matter was that the handle should have some sort of locking mechanism because or else the screw should begin turn around due to the vibrations and thereby making it useless as it would lose its grip. I also want to check if the length and cross section of the arm is ok according to the

vibrations. And I need to some calculations to how big the wheels need to be so it can withstand the contact with the drum.

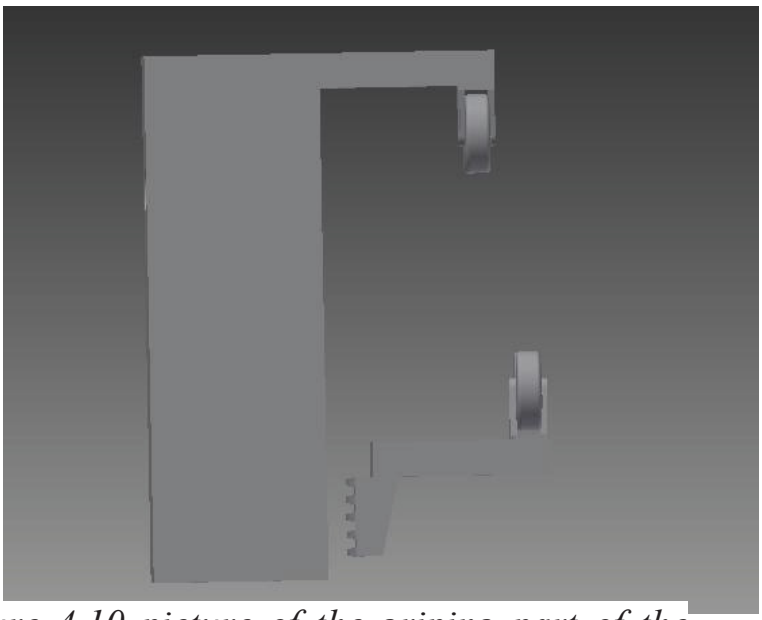

Figure 4.10 picture of the griping part of the design.

4.9.2.1 Eigen frequency

The part I am looking at is the beamlike structure which connects the different parts in version 2. We want avoid that the arms frequency are near to the drums. If that were the case the system would get large movements and it could break.
So we got have formula from the theory.
$\omega_c = \sqrt{\frac{k}{m}}$ I chose an elemental case where $k = \frac{48EI}{L^3}$ because it can look like this. Where the left side can roll sideways and the right side does not move as much.

The beams inertia resistances should be $I = \frac{bh^3}{12}$ and now I have all formulas I need to solve it.
The mass was measured to be 0,942 kg from cad, the length is 0.1m. The material is steel so the E modul 210 is Gpa and b is 0,01m and h is 0,02m. With these data we get that $\omega_c = 4597HZ$ so this beam is ok as the vibrations of the drum is around 50-70 Hz

4.9.2.2 Safety factor

So I have the formula for calculating the safety factor. I use this factor for the wheels the will be calculated in the next chapter. The different cases that is used can be found in the book. (6)

$$n = \gamma_S * \gamma_{R1} * \gamma_{R2} * \gamma_{R3} * \gamma_{n1} * \gamma_{n2}$$

$\gamma_S = 1 + kv$ where v is variation in the material and I believe it will not go higher than 30% so I will use v = 0,3 the k is depending on how high the chance there is that it will break. I deem it to be a small chance as the wheels will be locked against the wheel. So I got the value 2.2 from the table in the formula sheet for k.

γ_{R1} will be 1,7 because I don't know of the spread in the material data and I don't know if material data is normalized, but the value I chose was the highest that could be chosen.

γ_{R2} will be 1,05 because an handbook method have been used to calculate the pressure on the wheels.

γ_{R3} will be 1 as I believe it will be affected by the same load as it are affect by the its own mass.

γ_{n1} should become 1 as if the solution break I don't believe any human will be injured because of it and the scraper can still remove asphalt to a certain degree.

γ_{n2} should 1.1 as I believe there may be some errors in calculations and there can be thing affecting the solution when it are used which I may have missed.
When I add the parts together I get safety factor to be 3,45

4.9.2.3 Wheels

I needed to calculate how big the wheels needed to be. They are important to look on as they are the part that are in direct contact with the drum. If they break my design will no longer fulfill its functions. When the two wheels come in contact with another there will be an area of contact where it arise pressure. (5)
I will need to do 2 different case, one for the wheels on outside of the drum and one for the wheel on the inside as expression changes depending on which case it is.

$$p_0 = 0{,}418\sqrt{\frac{N * E^2}{L}\left(\frac{1}{r_1} \pm \frac{1}{r_2}\right)}$$

Both the drums and my wheels are made of steel. Therefore the E module is 210 Gpa. The yield strength is $R_{eH} = 355\ Mpa$. I need to calculate what the allowed sheer stress is.

The allowed sheers stress is calculated by this formula $\tau_{allowed} = \frac{\sigma_t}{n} * 0.6$
$\tau_{3max} = 0{,}3 * p_0$ (5) page 25.

if we then say that $\tau_{allowed} = \tau_{3max}$ we can get expression $p_0 = \frac{\sigma_t}{n*0{,}3} * 0.6$ which gives that $p_{0allowed} = 205{,}7Mpa$

The force in this formula is the normal force and it depend on the mass.
The force will come from the weight of the wheel that is pressed against the bigger wheel in this case. And as the wheel will not be directly on top of the bigger wheel it will be an part of weight that is affecting depending on the angle it is faced the drum. I looked on my model and deemed it to be 35 degrees. An picture can be seen in figure 4.11.

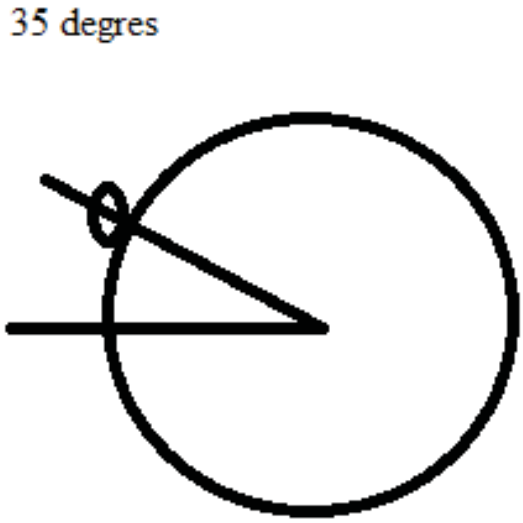

Figure 4.11 Position of the two wheels.

As the weight depends will deepened on the dimensions I will to add the volume and the density to N

$$N = \rho\pi r_1{}^2 L * \sin 35$$

Where $\rho = 7850\ kg/m^3$

I begin with case when the wheel is on the outside of the drum. Then expression is like this.

$$p_0 = 0{,}418\sqrt{\frac{7850\pi r_1{}^2 L * \sin 35 * E^2}{L}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)}$$

r_2 is 0,575m and I are going to test with L = 0,05 and r_1 = 0,015m. This gives p_0 the value 22,4 Mpa which is lower than 205,7Mpa so it is ok. I wanted to make the wheel smaller so tested with some new number. L = 0,01m and r_1 = 0,01m, now i got the value 17,2Mpa. Which is ok.
The case when it is on the inside looks like this.

$$p_0 = 0{,}418\sqrt{\frac{7850\pi r_1{}^2 L * 2 * \sin 35 * E^2}{L}\left(\frac{1}{r_1}-\frac{1}{r_2}\right)}$$

I use the same numbers as last time and multiple the force by 2 as there were two wheels holding up the same force on the other side. r_2 is changed to

0,555as this it is the inside of the wheel. I got the value 10 Mpa this time which is ok.

4.9.3 Version 3

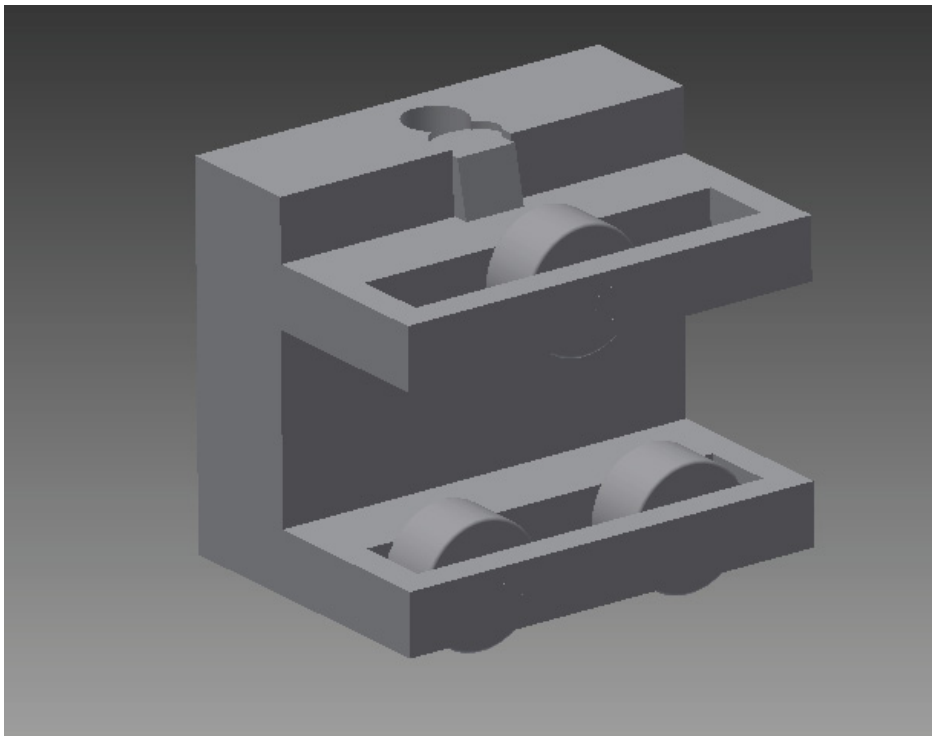

Figure 4.12 the new design for the griping part.

I changed the griping part so that it could hold the wheel instead so I could save some space and use less parts. I also now have one less wheel. Which can been seen in figure 4.12 above.

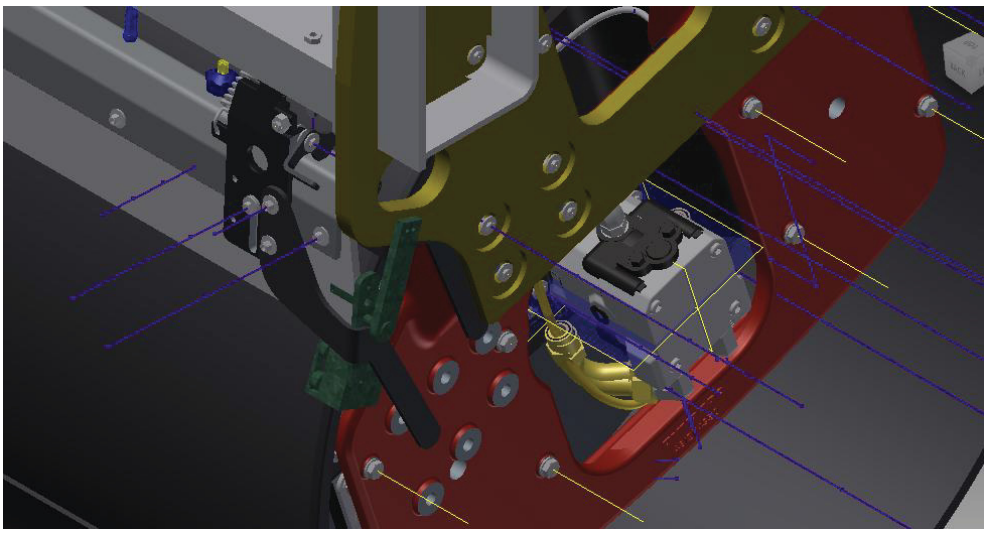

Figure 4.13 the new parts is marked in green.

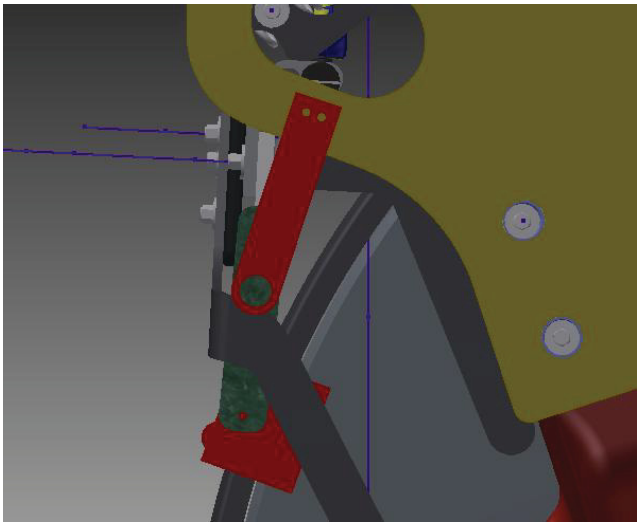

Figure 4.14 an close up from another angle.

Here is another picture where you see how my design is placed according to the drum. The parts I have made is marked in green.

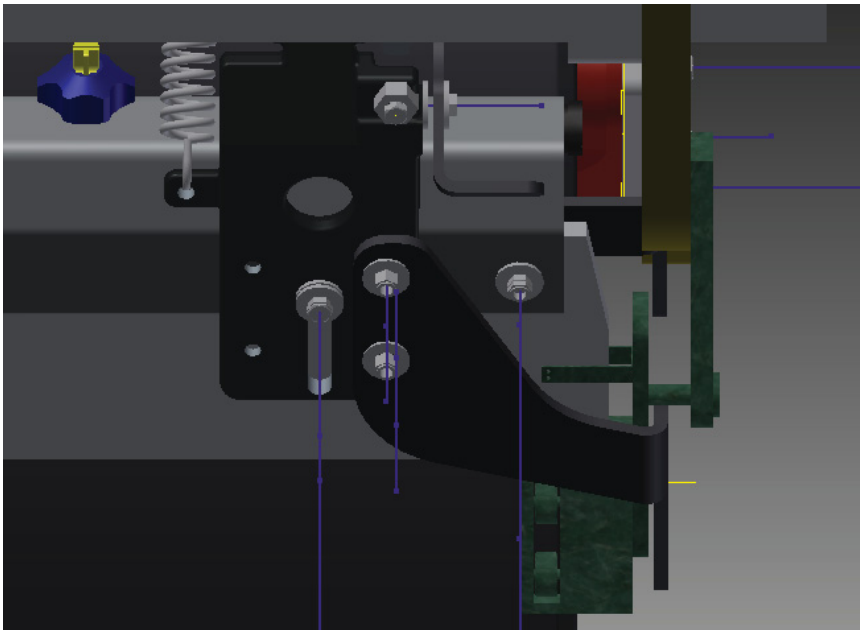

Figure 4.15 here you can see how the parts are connected to the frame.

Some other perspectives of the concepts I changed the color in one to so it won't blend together. I also added the other arm and did changed the arm so it was longer than before so the griping part would not run into the scraper. I also need to change the thickness of the arm so it could fit in under the handle from the scraper. So I need to check again if the arm is ok according to Eigen frequency.

So here is formulae I used before . The changed parameters are L, b and h.
L = 0.12m, b = 0,007m and h = 0,03 m,

$$\omega_c = \sqrt{\frac{48 * E * \frac{b * h^3}{12}}{m * L^3}}$$

It will then become 822 Hz, which is bigger than the range of 70-50 Hz so this design is still ok.

So when I evaluated this version I thought the griping part should be on the on the other side of the scraper as it will be cleaner there and have less risk of something getting stuck on the wheels. Another thing was that it would probably not be good idea to directly mount my construction on the blade itself as it is made of plastic and fairly flexible.
It would probably break the scraper from the movements. Therefore I should attach my construction to the holder of the scraper and change that construction so it can move.

I also thought of removing the stick that connect the two arms that can move in the loose hole, and replacing it with a rubber element so it can move in different directions still and not tear on the arm. At this point I had also misjudged the amplitude that the drum could reach as I had only thought of amplitude from vibrations.
Because of the rubber elements that the drum is held up by it can move in any direction about 20mm. So with this new data my construction should break pretty easily as it can withstand the mass of the drum and it does no longer fulfill its function. So I redraw this concepts yet again.

4.9.4 Proposed final concept

So I got two ideas on how solve the problems with the amplitude. An early sketch of both can be seen in appendix 3. One idea was to instead of using an arm was that the griping part should have an spring on the top of it that is connected to the scraper holder. Then the spring can push back the scraper to

the drum. This idea also is connected to the frame with a big rubber elements that have an radius of 20mm.

The other idea was that scraper itself should be removed from the frame and instead be held up with two arms that is connected to my griping devices. This will make scraper roll on the drum and always have same distance to the drum as the drum will tear down it will roll accordingly to the surface. If the surface tears rather evenly. This idea will also be held up with an rubber element similar to the other idea. The griping part uses an mechanical spring to press down one of the wheels to drum so the system become stable.

At first I thought it should only be used for one scraper but then I realized it could be connected to both scraper on the drum with one arm connected to each. This will also lead to that some wheels can be removed so that there is only 2 wheels on each griping device. In this way many parts can be removed . The second concepts seemed much better than the first so I continued to make an model of it in Inventor.

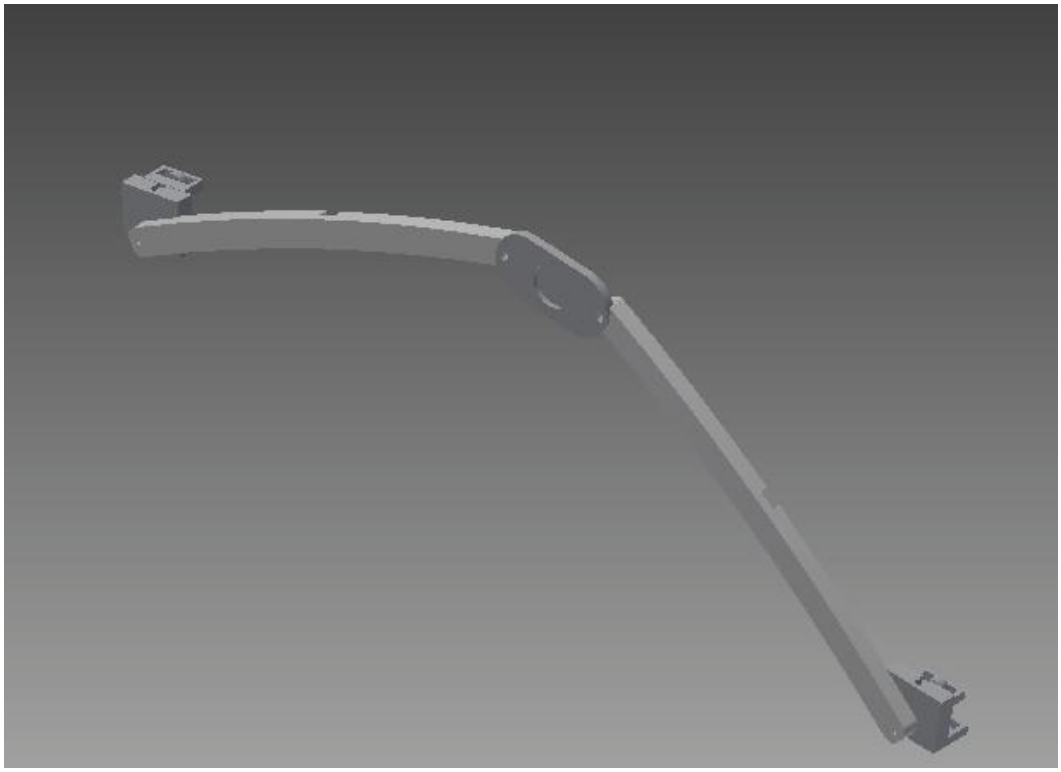

Figure 16 overview of the last concept.

It needed a place holder for the scraper where it can be held up. So I cut away a area in the arm to make space for that. This concepts should solve the

problems with the vibrations and there will not be any more trouble from this concept to clean the scraper as I will keep the scraper in an form. In this version I have not look as closely on the dimensions as only I wanted better pictures to visually it than my hand drawn sketches.

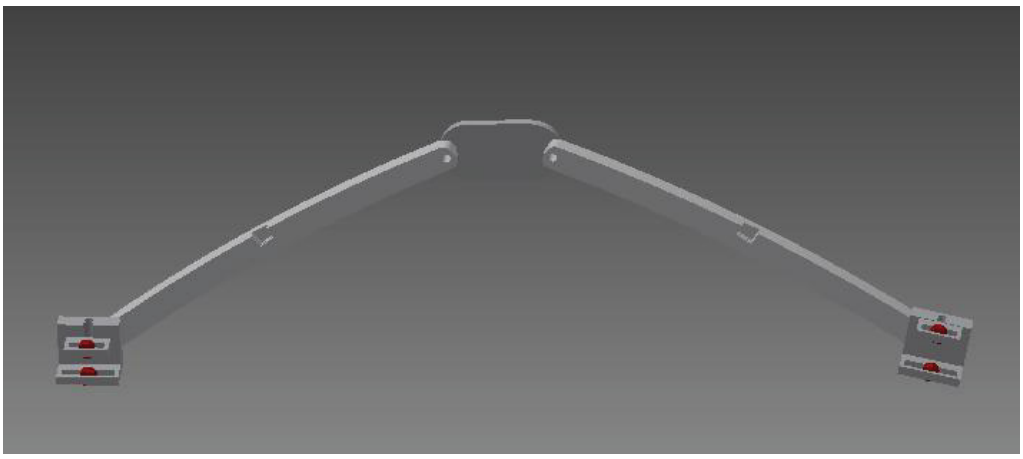

Figure 17 Backside of the concept.

This concept should be able to solve the problem as it can lock the scraper to an position that is constables at the same difference from the drum. by making the whole system and its end point move the vibrations will no longer be an problem. It could be an issue when asphalt get stuck on wheels. They could possible affect the system, so tests would be needed to how much of an impact they could have
More drawing of each part can be seen in appendix 4.

5. Discussion

5.1 Method and result

Using the triz method to generate concepts worked fairly well. It gave much insight of how the problem could be1 solved.
There was a problem during the evolution with that the concepts with the highest scores, that there were no clear winner. I could have chosen to change the importance of the criteria to see if it would change to the better. But instead of changing the criteria I used another method to compliment the first.
To compliment the score driven method, the SWOT method gave more insight of what could go wrong with each concept.
The different functions analysis gave an better understanding of what the new solution should deliver and what could possibly annoy the user.

My design would need to be optimized according to the new loads that would affect the design. It would now need to bear the weight from the scraper as it no longer get any support from the frame. It would also be needed to make an prototype to test how the asphalt that get stuck on the wheels affects the design. If the impact is low enough so that it can be run using a whole day, then the asphalt can be removed the same time as when the scraper is cleaned.

5.2 Final solution

Now I look back on the questions I wanted to answer in beginning see how my final concept look according to them.

- Does my solution improve the result of the scraper by removing more asphalt ?
- Does my solution need less maintenance than the original solution ?
- Is my solution economically viable ?

My solution should be able to remove more asphalt as the scraper is always at the same distance to drum now . The wheels that is rolling both on the inside and the surface drum and the rubber elements on the frame should be sufficient to keep. If this concept would be worked further upon the springs that press down one of the wheels to the drum could be important. If the spring would begin to get fatigue it could mean that it would no longer be able keep system in place.

The solution would need to be cleaned as often the original solution as asphalt still get stuck on the scraper. But there should no longer be an contact problem with the scraper and the drum. So it should be less maintenance problems from that the scraper and the drum get damages.
As for economical part, there have not been any calculations on how expensive the solution would be. It should be more expensive than the original solution as more parts have been added.

The solution does not work with all of Dynpac vibrating rollers because there will not be enough space on some model. But it could be solved by having two rubber elements at two different places and separating the two arm.

5.3 Conclusion

In the beginning of the project I had planned to do an prototype to see how effective my solution would be. But as time was a limiting factor and that some part took longer than I had expected I had to make some boundaries on where I would stop.

I wanted also do more calculations for the loads of the final concepts and how much it would have cost. But as I had made a wrong assumption about the movement of the drum which I discovered when I had made version 3 , there were not much time left on the project.

So from this I have learn that to ensure an successful development process, the data should be double-checked and discussed with many people to avoid problems that will come up later.
There also exist potential in some of the earlier concepts which I did not continued with. They can be used for inspiration if some else would continue this process.

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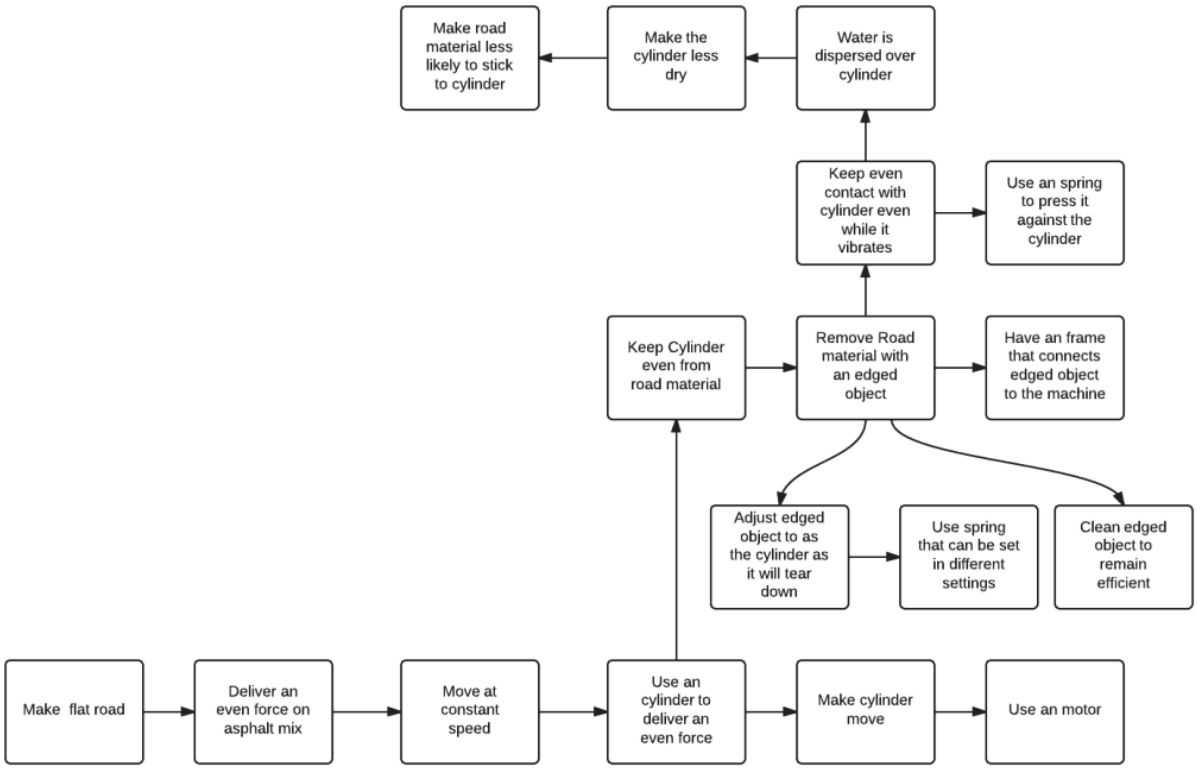
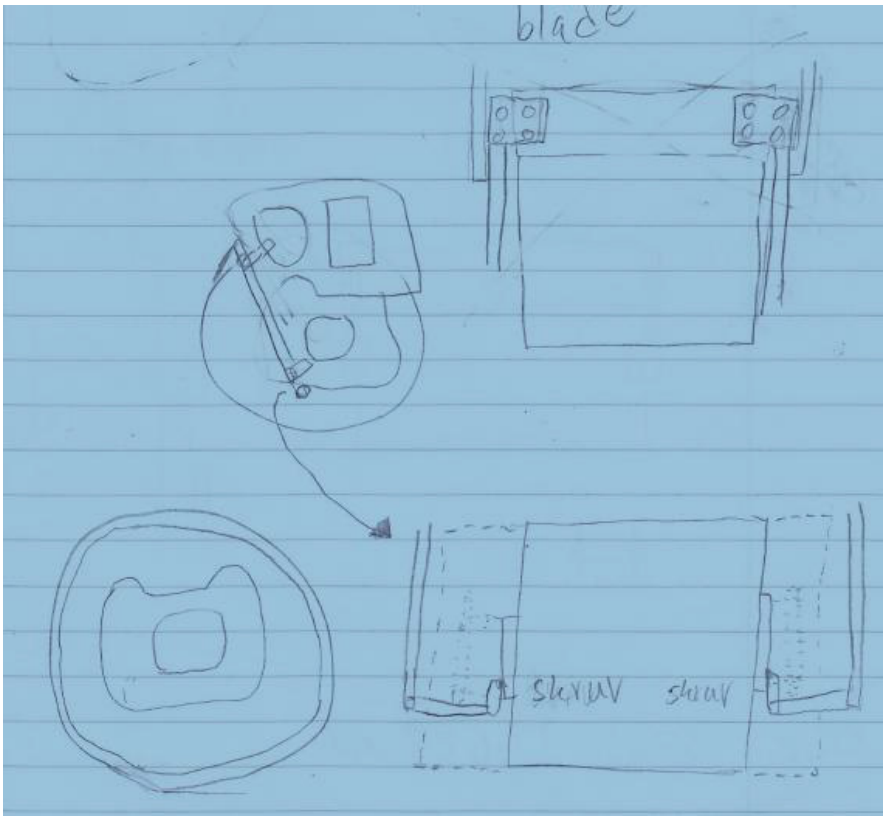
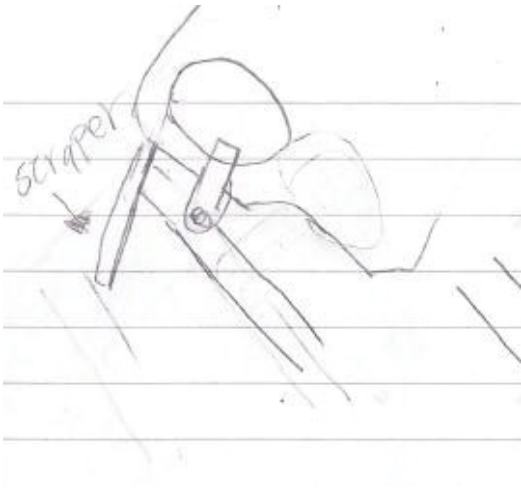
Appendix 1 Fast Diagram



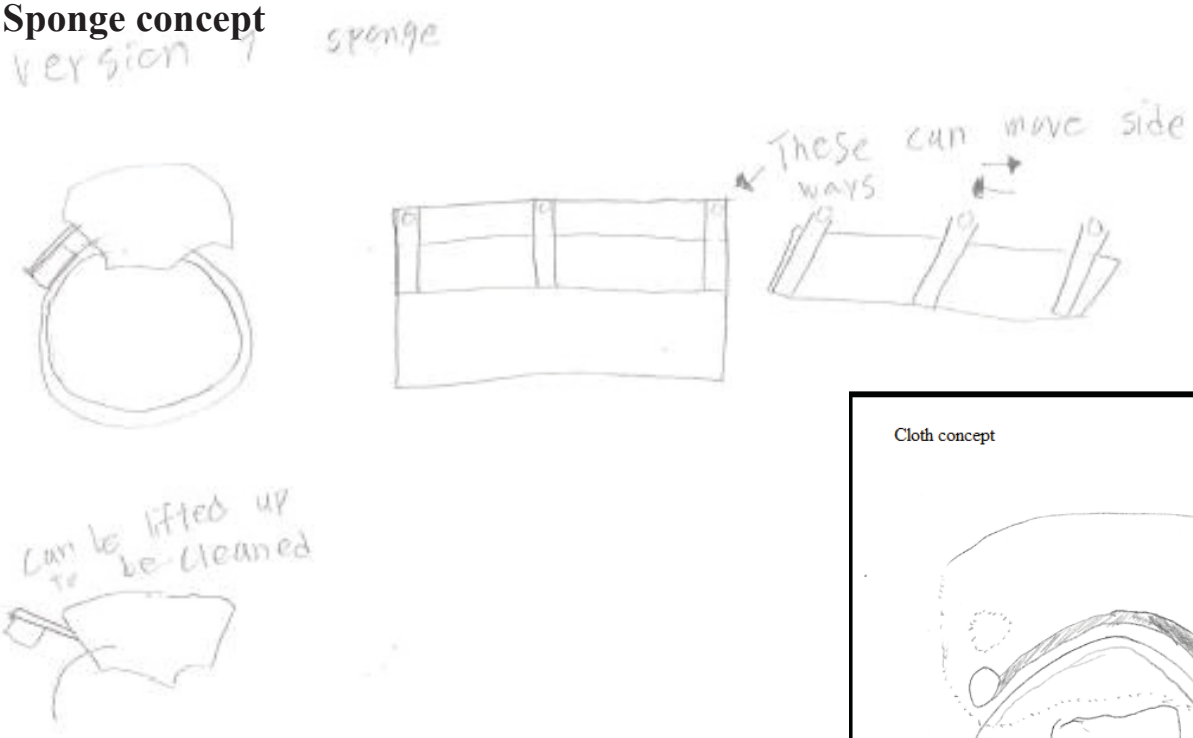
Appendix 2 concept sketches

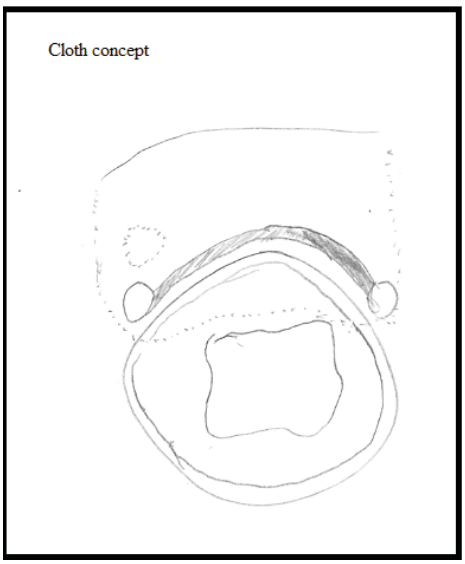
Arm concepts



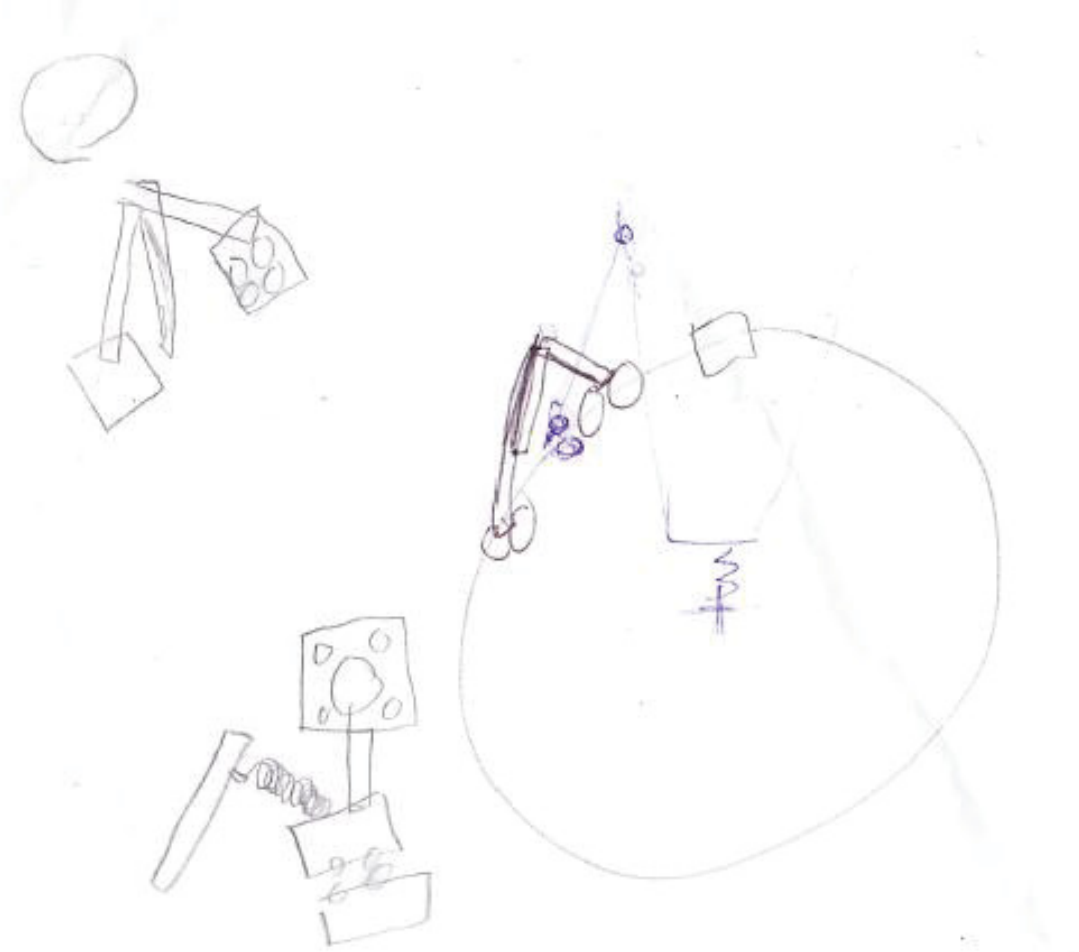


Sponge concept

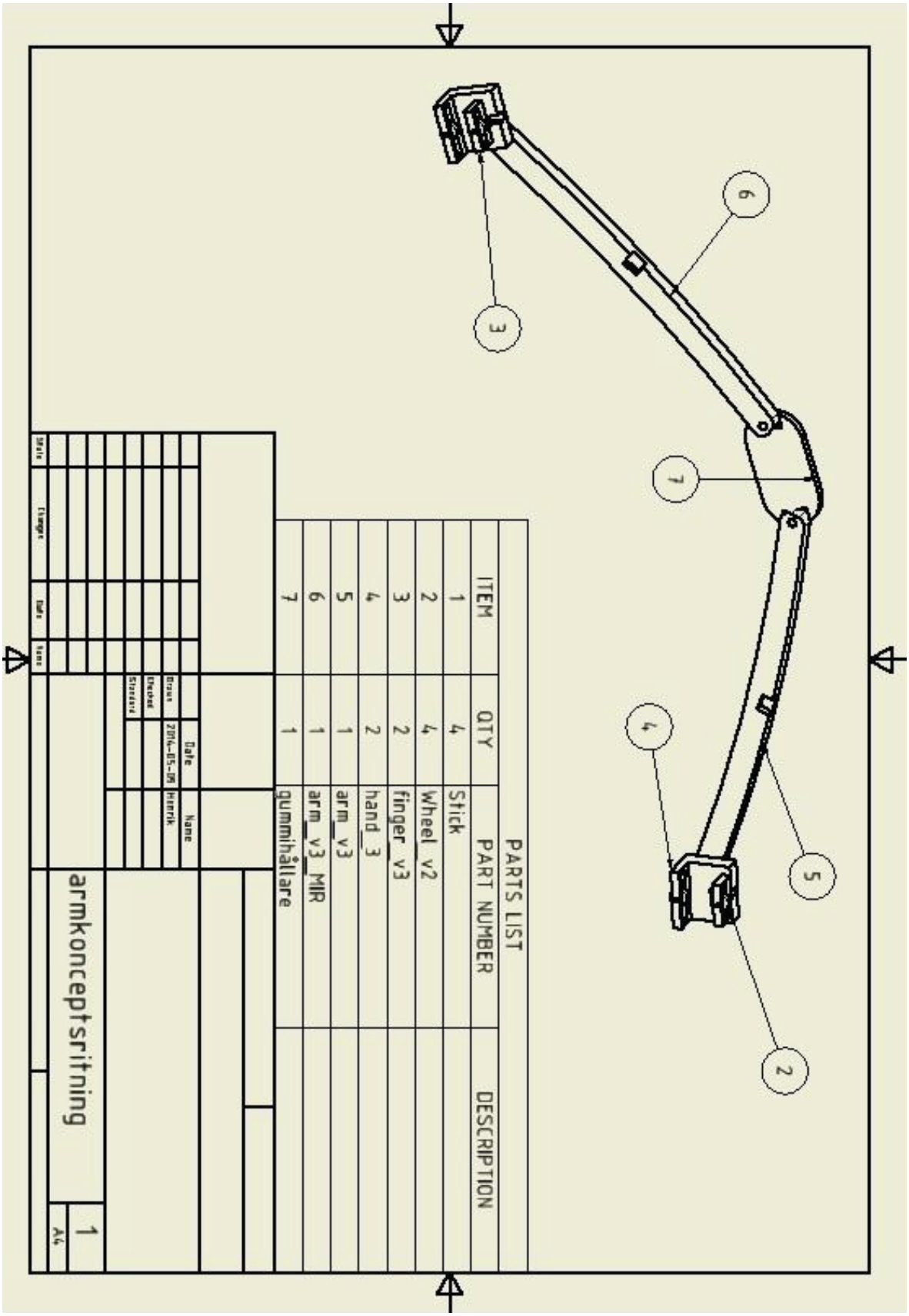


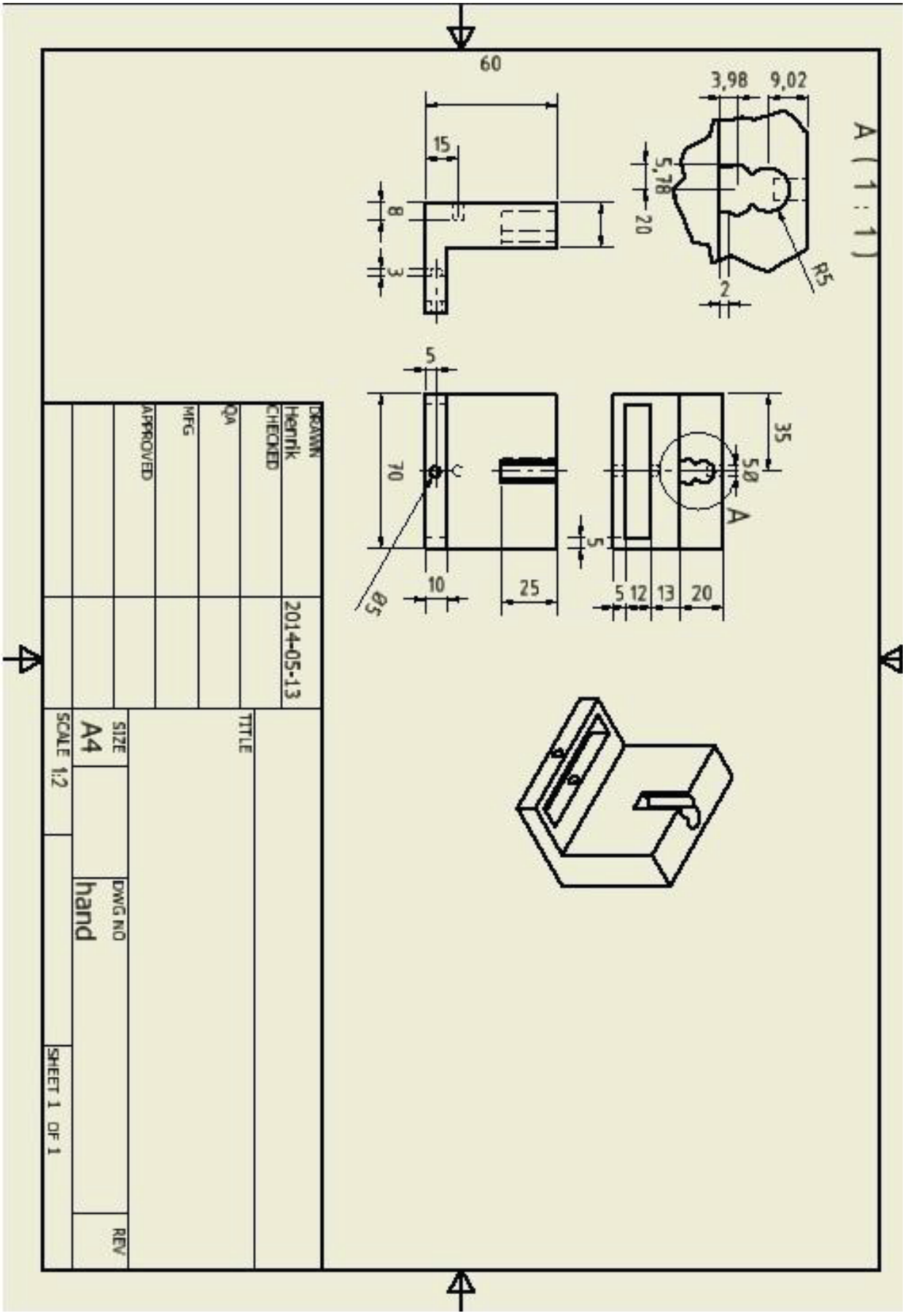


Appendix 3 Last new sketch



Appendix 4 Drawings

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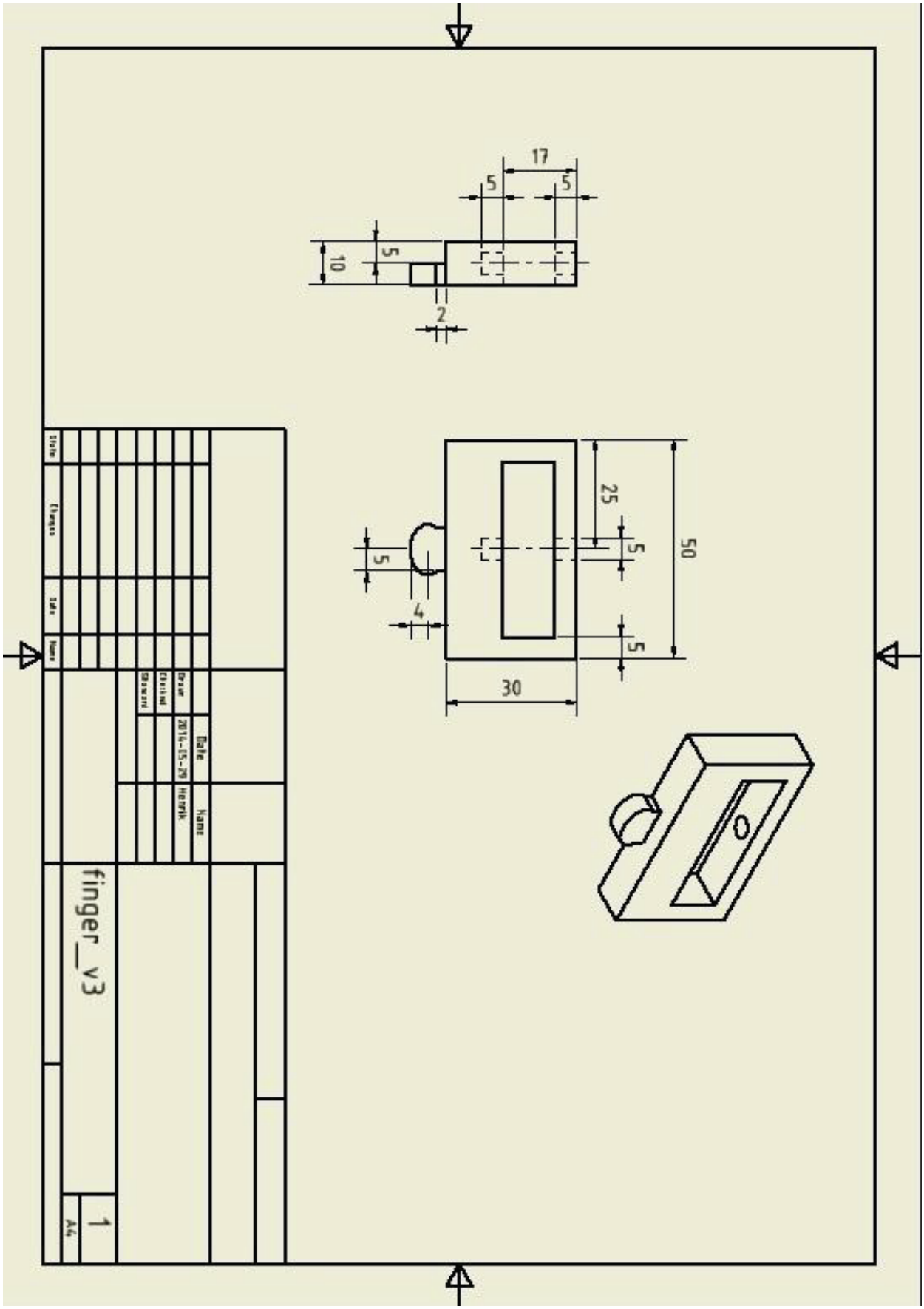
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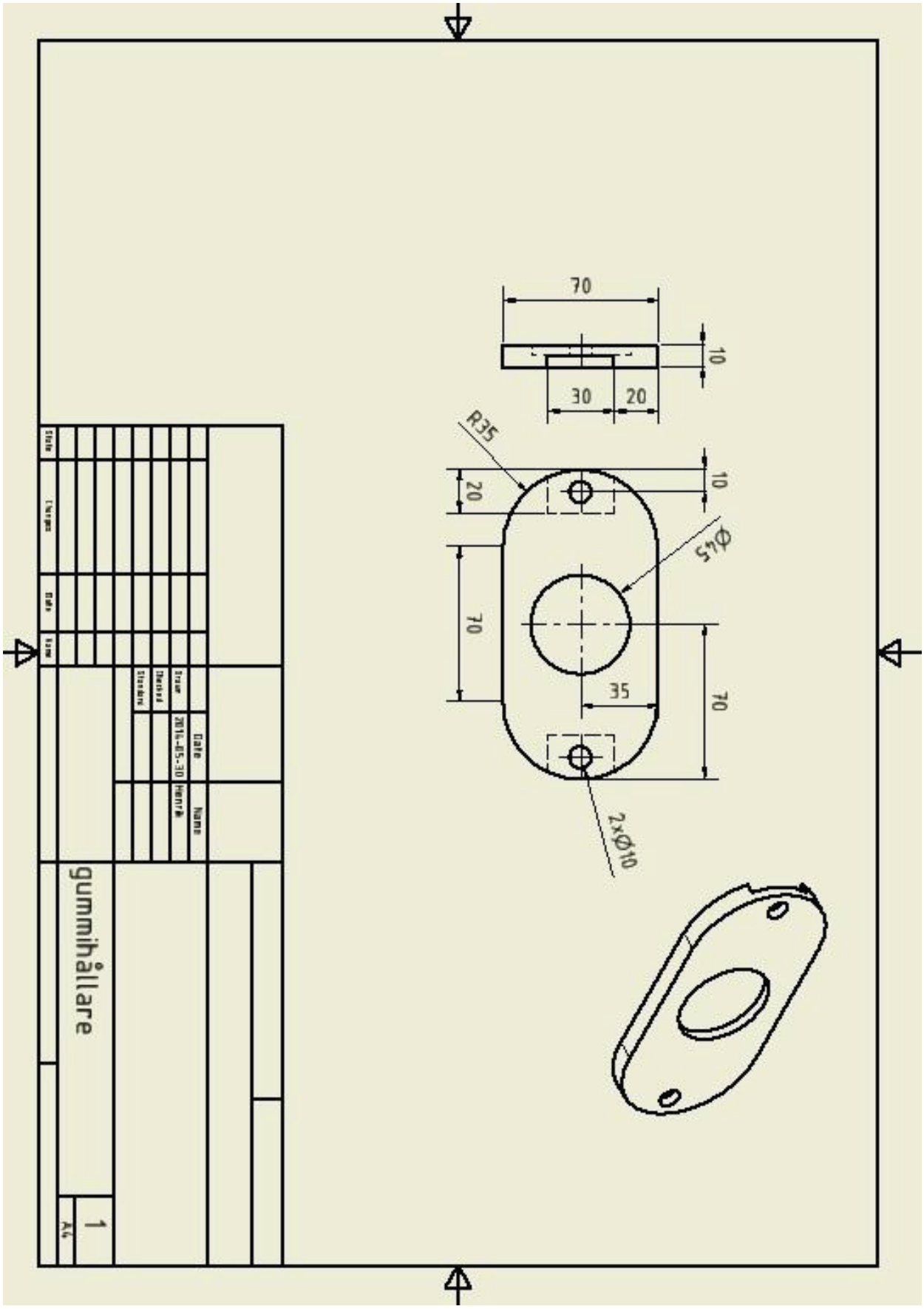
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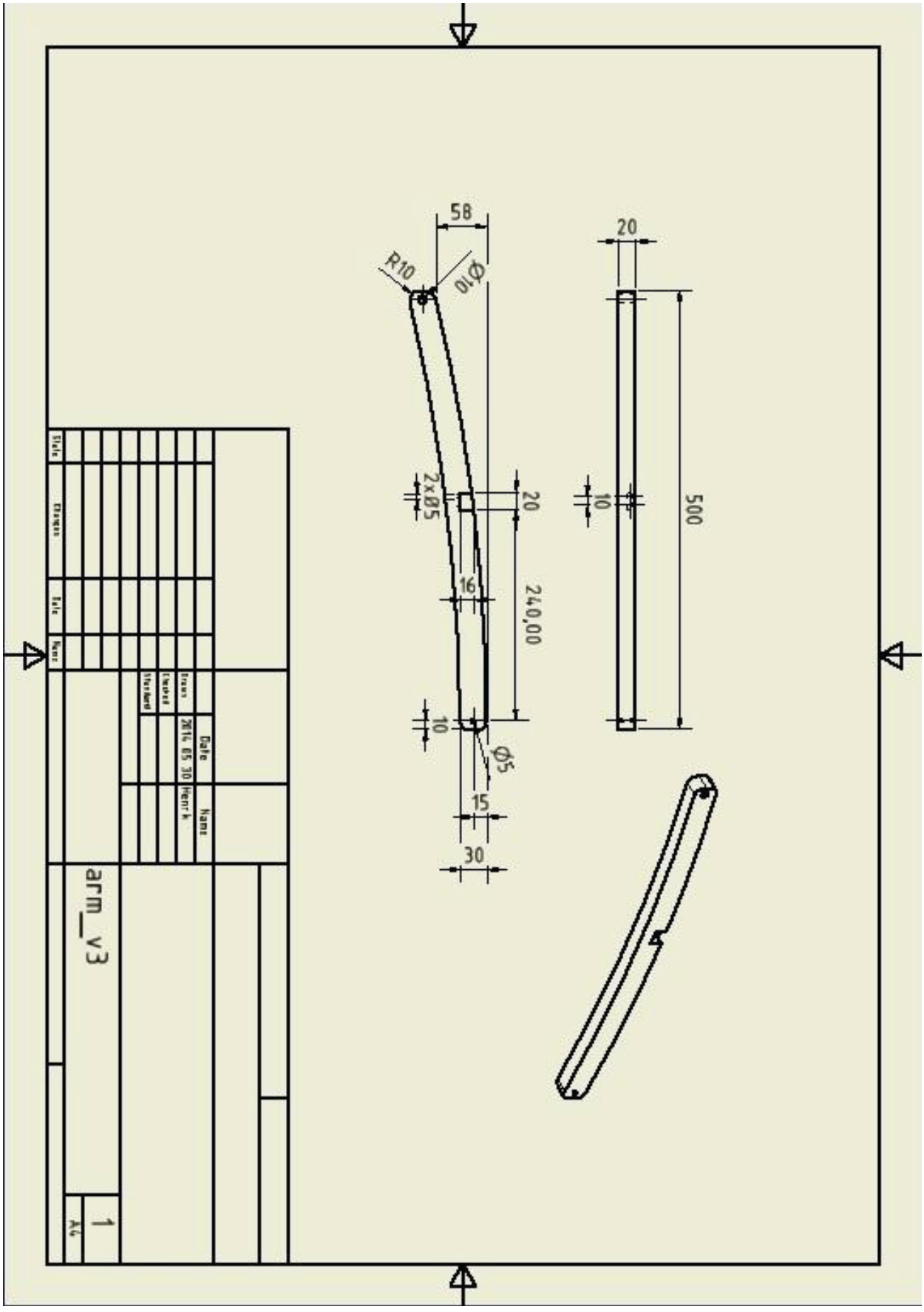
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Henrik
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