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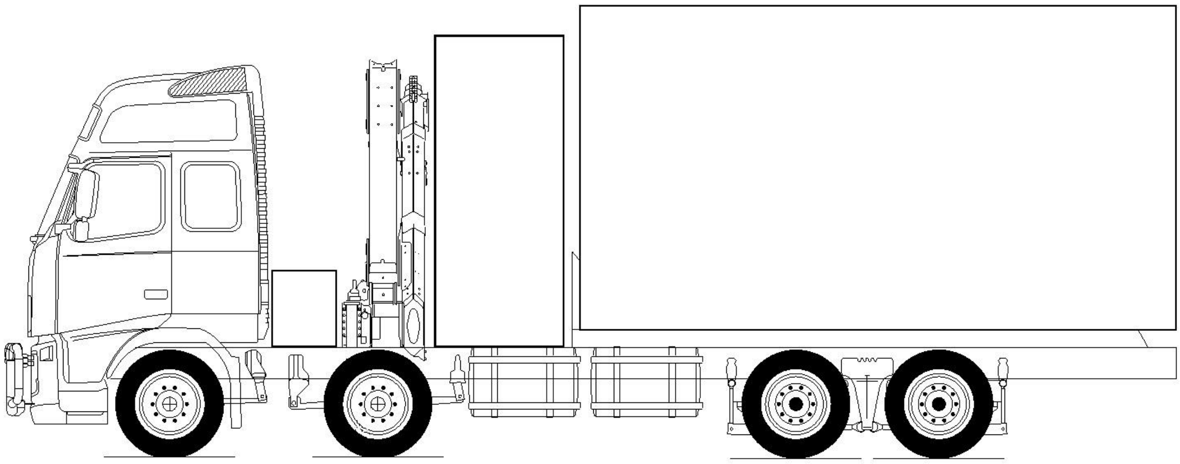

Packaging study of hydraulic pumps

Conceptual design of a pump installation for hydraulic front-wheel drive

Degree project in the Bachelor of Science in Mechanical Engineering

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PREFACE

This diploma work is the final work in our education in mechanical engineering (180 credits) at Chalmers University of Technology. The report comprises 15 credits and has been conducted at Epsilon AB and Volvo Group Trucks Technology in Gothenburg from February to June 2012.

We would like to especially thank our supervisor Alfred Johansson at Epsilon AB, Emil Pettersson at Epsilon AB and Lena Larsson at Volvo GTT. You have all been a great help and support during this work. We would also like to thank Göran Andersson at Rolf Eriksson Lastvagnar & Bussar AB and Ragnar Ek at Övermo Flis for your enthusiasm and help throughout the project.

Finally, thanks to our examiner Gert Persson, Senior Lecturer at Chalmers and all the rest of you who have contributed in various ways to our diploma work.

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Dennis Persson

ABSTRACT

This diploma work has been performed at Epsilon AB, located at Lindholmen in Gothenburg. Volvo Global Trucks Technology has, along with Epsilon AB, been working with an implementation of a hydraulic front-wheel drive system for trucks driving in terrain with low traction. The hydraulic motors are placed in the front wheel hubs and are powered by a hydraulic pump. The pump is in turn powered by the engine power take off, located at the rear end of the engine.

The whole hydraulic front-wheel drive system is meant to fit a broad variety of truck models, but due to the time limit this diploma work has focused on a single truck model. This was a chipper truck operating in rough environments, which made it a suitable target. The truck has several applications driven by different pumps. One of these pumps, as well as the hydraulic pump, needed to be driven by the engine power take off. This meant an overlook regarding the placement of the pumps was necessary. This diploma work has used the development process described in *Product Design and Development* presented by Ulrich & Eppinger to gain a structured work approach.

The work resulted in five different concepts, each presenting a different placement solution. Ultimately the solutions can be divided into two types, those who make use of a cardan shaft and those who do not. Those using a cardan shaft have the pumps placed on the chassis, behind the engine, with the cardan shaft connecting them to the power take off. The advantage of these solutions is that they do not interfere with any components surrounding them. However, having the pumps placed on the chassis is not desirable because this will cause relative motion between the pumps and the engine module and maybe lead to a reduced life length of the installation.

In the solutions without a cardan shaft, both pumps are a part of the engine module, creating a compact and reliable installation. The disadvantage is that it requires reconstruction of some of the components surrounding the power take off, which takes both time and an increased cost. Thus, the problem can be solved in two main ways. Either go for a quick solution with a cardan shaft and save time and cost, by not having to reconstruct any components, or reconstruct the affected components and obtain a compact and reliable solution.

An important conclusion drawn from this work is that the available space around the power take off is no way near large enough the desirable, there is barely space for just one pump. It would also be much desirable to have more than one power take off on the engine, to allow power to several applications at the same time.

SAMMANFATTNING

Detta examensarbete har utförts hos Epsilon AB, vid Lindholmen i Göteborg. Volvo Lastvagnar har, tillsammans med Epsilon AB, arbetat med att implementera ett hydrauliskt framhjulsdriftssystem för lastbilar som kör i terräng med dåligt underlag. Hydraulmotorerna är placerade i de främre hjulnaven och är drivna av en hydraulpump. Pumpen är i sin tur driven av motorkraftuttaget som finns på den bakre delen av motorn.

Hela systemet för den hydrauliska framhjulsdriften är tänkt att passa till en stor variation av lastbilsmodeller, men på grund av tidsbegränsningen har detta examensarbete fokuserat på en enda modell. Denna modell var en flistuggsbil som arbetar i svår terräng vilket gjorde den till en lämplig målvagn. Lastbilen har flera applikationer som är drivna av olika pumpar. En av dessa pumpar behövde vara driven av motorkraftuttaget, vilket också hydraulpumpen behövde vara. Detta innebar att det behövde utföras en studie över hur de båda pumparna skulle placeras. Detta examensarbete har använt den utvecklingsprocess som beskrivs i *Product Design and Development* skriven av Ulrich & Eppinger för att få ett strukturerat upplägg på arbetet.

Arbetet resulterade i fem olika koncept som presenterar olika lösningar genom olika placeringar på pumparna. Lösningarna kan delas in i två sorter, de som använder sig av en kardanaxel samt de som inte gör det. De som använder en kardanaxel har pumparna placerade på chassit, bakom motorn, med kardanaxeln kopplad mellan dem och motorkraftuttaget. Fördelen med dessa är att de inte interferar med några av de kringliggande komponenterna. Dock är det ej önskvärt att ha pumparna placerade på chassit eftersom detta leder till relativa rörelser mellan pumparna och motormodulen, och detta kan leda till en minskad livslängd av hela installationen.

I de lösningar som ej använder sig av kardanaxel är båda pumparna en del av motormodulen, vilket ger en kompakt och pålitlig installation. Nackdelen är dock att detta kräver att de kringliggande komponenterna vid motorkraftuttaget behöver konstrueras om, vilket kräver både tid och leder till en ökad kostnad. Alltså kan problemet lösas på två huvudsakliga sätt. Antingen kan man lösa det snabbt genom att använda sig av en kardanaxel och på så vis spara både tid och kostnad eftersom det inte behövs några omkonstrueringar. Eller så konstruerar man om de komponenter som krävs och kan då få en mer kompakt och pålitlig lösning.

En viktig slutsats av detta arbete är att det inte finns tillräckligt med utrymme kring motorkraftuttaget. Det finns nätt och jämt plats för endast en pump. Det skulle också vara önskvärt att ha fler än ett kraftuttag på motorn. Detta skulle ge möjlighet till att driva flera applikationer på samma gång.

Contents

NOMENCLATURE

Body builder – An entrepreneur who buys a truck, adds different features and equipment to it and resells it to the final customer.

CC – Cubic centimetre

D11, D13, D16 – Engine sizes. D stands for diesel and 11, 13 and 16 for the engine size, in litres.

Engine module – Single name for the components attached to the engine, such as the gearbox.

ETT – One More Pile (in Swedish **E**n **T**rave **T**ill), a project for making timber transports more efficient.

FH – Front High. A type of truck which has the cab placed at the front with a high cab height. The truck is mostly used for long and heavy transports.

FM – Front Medium. A type of truck which has the cab placed at the front with a medium cab height. It is mostly used for regional transports.

FMX – Same as FM, but the truck is designed for heavy construction duties and has an increased chassis height.

FWD – Front-Wheel Drive.

Hooklift – Device on the truck for loading and unloading portable containers.

MaxTrack – A prototype truck used in the ETT-project which uses a hydraulic front-wheel drive system.

PTO - Power Take Off. A socket used to transmit power from the engine to different applications.

REPTO – Rear Engine Power Take Off. A coupling independent socket on the back of the engine. Used by, for example, customers for powering their own equipment.

Koblam – Extra equipment placed just before the gearbox. Adds an extra engine power take off.

1 INTRODUCTION

This diploma work treats a repackaging issue of two hydraulic pumps. The work has been performed at Epsilon AB, in corporation with Volvo Global Truck Technology (Volvo GTT).

1.1 Background

Front-wheel drive is very helpful when driving on roads with low traction, such as snow, gravel and mud, i.e. the friction is low between the ground and the tires. This is especially the case when the truck is unloaded since the weight distribution is larger at the front, because of the weight of the engine and cab etc. A body builder with this problem, whom this report will focus on, builds chipper equipment for trucks.

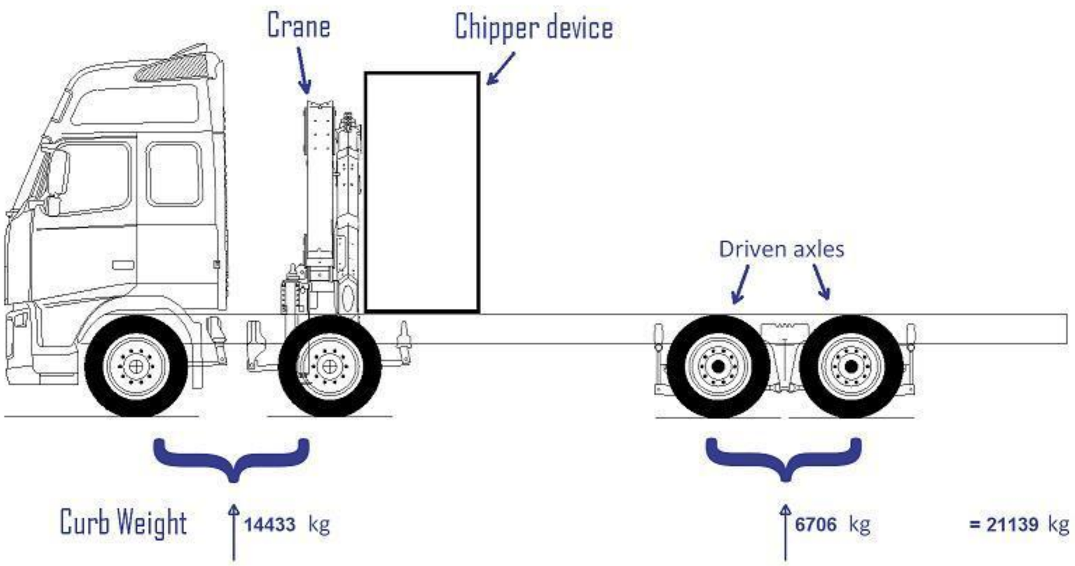

Figure 1.1 - A schematic picture of an unloaded truck with two driven axles at the back, and two steering axles in the front.

The chipper truck has a very high percentage of the distributed weight on the front axles when unloaded, about 68 percent. Both the crane installation and the chipper equipment are placed almost directly over the front axles, the total weight from these are about nine tones. Having front-wheel drive would make it easier to maneuver the truck in rough terrains. The hydraulic front-wheel drive will be placed in the front axle, under the cab. This means that three out of four axles can be driven at the same time if necessary. It is also possible to just use the front-wheel drive without using the driven back axles.

The maneuverability problem can be solved with a traditional mechanical front-wheel drive, but this solution requires a lot of extra space due to the extra driveshaft from the gearbox. This requires an extra high type of chassis as well as an added weight of 692 kg. By using hydraulic motors to operate the front wheels, a lot of space is saved and there is a lot less reconstruction needed. These motors are located in the front wheel hubs. Figure 1.2 shows a schematic picture of how these work.

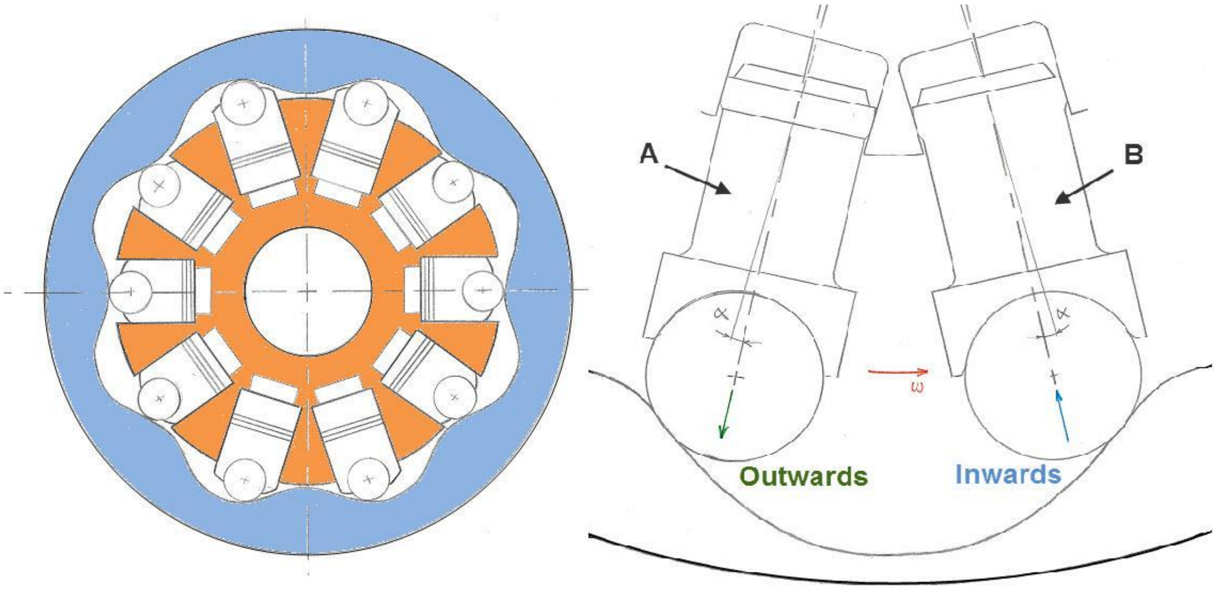

Figure 1.2 - Schematic pictures on how a hydraulic motor work.

The picture to the right shows how piston A is pressurised in the downhill slope making it going outward and creating a driving torque. At the same time piston B is depressurized in the uphill slope which makes it go inward. This will prevent it from interfering with the movement onwards. The motors are designed to always have a little less than half of the pistons pressurized, contributing to the driving torque.

The implementation of the hydraulic front-wheel drive system into Volvo trucks has been developed within the ETT- project, which is a project to make timber hauling more efficient. For more information about this project see the article in appendix A (www.sca.se). The system is in the future meant to suite several different types of trucks while this report is focusing on just the chipper truck.

1.2 Problem description

The hydraulic motors are driven by a hydraulic pump which, in turn, needs to be connected to the rear engine PTO (REPTO) where it gets its power from. There is currently a lack of space around the REPTO, making it hard to have the pump directly mounted on it, it clashes with several of the surrounding components. A provisional solution has been made on an ETT-truck prototype where the hydraulic pump is placed further back on the chassis, within a meter from the REPTO. The pump is then connected with the REPTO with the help of a cardan shaft. This is however just a temporary solution, which is why an overlook regarding the placement of the pump is needed.

There are other PTO’s available for use as well, located on the gearbox. They all differ from the REPTO since they are coupling dependent. A coupling dependent PTO cannot be used while driving, since the PTO will stop when the clutch pedal is pressed, and is thus not suitable for hydraulic FWD. The REPTO will henceforth be called just PTO.

On the chipper truck, it is also needed to have another pump powering the crane and hooklift. The pump is a hydraulic variable pump, henceforth called the body builder pump. This pump needs to be connected, in some way, to the PTO, just like the hydraulic one. The hydraulic pump for the FWD will henceforth be called just FWD pump.

1.3 Purpose

To create concept solutions regarding the placement of the FWD pump and the body builder pump so they fulfill the demands given by the body builder and manufacturer. These concepts are then reviewed, examined and ranked against each other. The best concepts will be presented.

1.4 Delimitations

The concept solutions are meant to suit the truck models FM, FMX, and FH, in combination with the engines D11, D13 and D16. Due to the time limit, this report will focus on a single combination which has been desired by the body builder. The combination is a FH model with a D16 engine.

The components of major concern are the air filter, the crossmember (over the gearbox) and the cab suspension, and this report will focus on these.

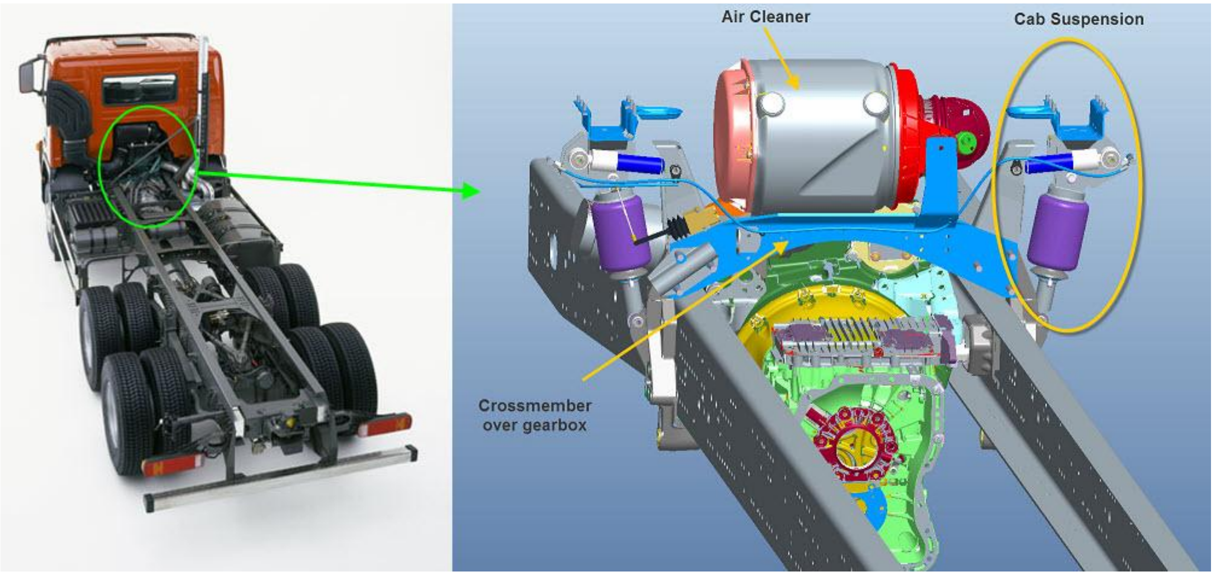

Figure 1.3 – The area of interest, with the air cleaner, cab suspension and the crossmember visible.

It is assumed that every truck will be equipped with the I-shift gearbox, which is a very popular and common variant. Further on it is also assumed that no truck will be equipped with the retarder function, which is a hydraulic service brake, which means there are no retarder pipes to consider.

Depending on the transmission and output ratio of the PTO, pumps of different sizes can be used to power the hydraulic motors. Due to the time limit, this report will only use one size for each pump. The pumps used are a 75 cc FWD pump and a 120 cc body builder pump.

1.5 Problem statement

The questions this report is based on are:

- Is it needed to move the air filter, the cab suspension or the crossmember?
- How much further development will be needed to implement the selected concepts?
- How well do the selected concepts fulfill the given demands?

2 METHODOLOGY

A lot of information regarding product development has been adapted from Ulrich & Eppinger (2012), especially the parts regarding concept development.

2.1 Identifying customer needs

When identifying the customer needs, a five-step method was used. These steps are:

1. Gather raw data from customer
2. Interpret the raw data in terms of customer needs
3. Organize the need into a hierarchy of primary, secondary and (if necessary) tertiary needs
4. Establish the relative importance of the needs
5. Reflect on the results and the process

These steps are meant to give a clear and structured view on what the customer really want. It is meant to ensure that no critical need is forgotten or missed.

2.2 Concept generation

To perform this step in the development process in a structured way, a five-step method for generating concepts was used, these five steps are:

1. Clarify the problem
2. Search externally
3. Search internally
4. Explore systematically
5. Reflect on the solutions and the process

2.2.1 Clarify the problem

To gain a general understanding of a complex problem, it can be broken down into several, easier, subproblems if necessary. However, the problem in this diploma work is not of such a complex structure, creating subproblems is not necessary, and thus will this step be excluded.

2.2.2 Search externally

The purpose with this step is to find existing solutions for both the main problem and the sub problems in a project. There are five different ways to gather this information, these are:

1. Interview lead users
2. Consult experts
3. Search Patents

4. Search published literature
5. Benchmark related products

For this project, step 1, 2 and 4 are the ones of most interest since there is a limit of time for this assignment. The most interesting and useful information was obtained by interviewing lead users and experts. An attempt to find information by searching for published literature was carried out because it is a quite fast way of exploring similar solutions.

2.2.3 Search internally

Internal search is the use of personal and team knowledge and creativity to generate solution concepts. This step is mostly done by a brainstorming session where all the ideas from the group members are brought to the team. There are four guidelines for improving the internal search:

1. Suspend judgment
2. Generate a lot of ideas
3. Welcome ideas that may seem infeasible
4. Use graphical and physical media

Later when the brainstorming for new concept solutions was made, these guidelines were kept in mind.

2.2.4 Explore systematically

When solving bigger problems, a good way is to divide the problem into smaller subproblems (if possible). After the team members have generated (often many) different solutions to the subproblems it might be a good idea to organize and sort these solutions. How to do this in an effective way is by using a “concept classification tree” and the “concept combination table”. Since the problem in this project was not divided into subproblems this chapter was not used.

2.3 Concept evaluation

Like the previous steps of the product development process, the book by Ulrich & Eppinger (2012) has been adapted as well as Pugh (1990). The different concepts was evaluated and eliminated in two steps.

In the first step a concept screening was performed where all the concepts were compared against a reference concept regarding the different criteria. In this step the criteria were not weighted, i.e. they were all equally important. As a tool for this step a matrix was used where all the concepts and criteria were listed. If a concept was better, regarding a criterion, compared to the reference concept it got a “+”, if it was worse it got a “-“ and if equal to the reference, it got a “0”. Like this, every concept obtained a number of “+”, “-“ and “0”. The number of “-” were then subtracted from the number of “+” and a sum was obtained. The concepts that were noticeably inappropriate were weeded out and the remaining ones were refined.

During the second step in the evaluation, all the criteria were weighted and the concepts were compared to a reference concept on more time, called a scoring matrix evaluation. A part of the matrix can be seen in figure 2.1.

		Concept 1		Concept 2	
Metric	**Imp.**	Rating	Score	Rating	Score
Metric 1	2	4	8	3	6
Metric 2	4	5	20	2	8
Metric 3	5	3	15	3	15
Metric 4	3	2	6	2	6
Metric 5	5	4	20	3	15
Metric 6	3	2	6	1	3
Metric 7	3	4	12	4	12
Metric 8	3	5	15	3	9
Metric 9	3	5	15	1	3
Metric 10	3	4	12	5	15
	Total Score		129		92
	Rank	1		2	

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

Figure 2.1 - Example of a scoring matrix. The rating is multiplied with the importance and a score is given. All scores are then added which gives a total score.

The weightings was a number between 1 and 5, were a 5 meant that the criterion was a demand, while the numbers 1-4 was desires of various importance. Each concept was then rated with a number between 1 and 5, where a 3 corresponds to same as reference. A lower number means that the concept is worse than the reference, while a higher numbers means that the concept is better. By multiplying the weighting with the score, followed by summarizing all the scores, each concept gained a total score which made it possible to compare the concepts to each other.

3 GATHERING BACKGROUND INFORMATION

Most information has been gathered by talking to different persons working with the ETT-project at Epsilon AB, as well as persons working at Volvo GTT.

3.1 Examining an ETT-truck

To gain a better understanding on how much space that is available for the FWD pump, a series of visits were conducted at the workshop at Volvo GTT to examine an ETT-truck prototype, also called MaxTrack.

3.2 Study visit

On April 18th 2012, a study visit was conducted at one of the chipper trucks that the body builder has built. The visit took place in Strängnäs, in Södermanland. Both the body builder and the truck driver were available for interviews, along with a reseller from Rolf Eriksson Trucks & Buses AB. The interviews focused on open questions which let the interviewee to respond in their own way. This also made it easier to come up with follow up questions.

4 IDENTIFYING CUSTOMER NEEDS

The customer needs in this diploma work is a combination of needs from the body builder along with the needs from the manufacturer of the truck. Together they form a customer needs chart, as seen in chapter 4.3 Customer needs list.

4.1 Body builder visit

To gain a better understanding of how the final customer is using the chipper truck and also the technique of the other components, a visit were conducted in Strängnäs. The body builder has built these kinds of trucks before and one of them was working in the forests outside Strängnäs. A lot of information about the working conditions was gathered from the body builder and the driver of the chipper truck. The truck driver also performed a demonstration of the vehicle in full action, see figure 4.1.

Figure 4.1 - The chipper truck in action.

The result out of this meeting was the clarities of the advantage with front-wheel drive on this type of trucks, because these trucks often drive on forest- and gravel roads with sometimes very bad traction. The accessibility of these trucks is a big problem, especially when unloaded, i.e. no container on the back, see figure 4.2.

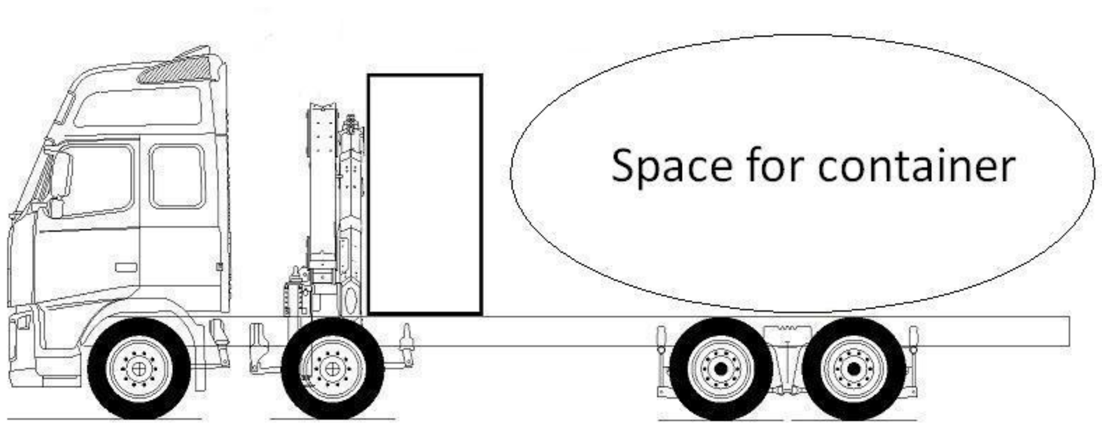

Figure 4.2 - Schematic picture of a chipper truck.

This because a large part of the weight distribution is then taken by the two front axles, which means that a very low weight, compared to the front, are taken by the two axles at the back which are driven. The chipper truck driver must then be careful to not drive into places where the truck might get stuck.

Another advantage with the hydraulic FWD would be the possibility to move the truck, from the crane cab, without having to shut down the chipper equipment. At present, the length of the crane is a limitation which means that the driver has to every so often move the truck sideways to be able to fill an entire container with wood chips. This is a procedure which takes a relatively long time since the driver has to shut down the chipper, move to the truck cab and then move the truck a few meters to the next pile of wood. Just shutting down the chipper takes about two to three minutes, and the whole moving procedure takes about five minutes. As a comparison, the chipper truck can fill a 40 m^3 container in about 15 minutes. This means that just moving the truck a few meters takes a pretty large amount of the work time, time that could be used for producing more wood chips. If the truck had access to hydraulic FWD, it would make it possible to move the truck without shutting down the chipper, which would save time. As a summary to the visit, the following notes were made.

- Both pumps should be a part of the engine module.
- The whole installation should be available for sale as soon as possible.
- It has to be possible to drive the truck up to 10 km/h with the FWD, up to 25 km/h is a desire.
- The installation should be easy to maintain and serve.
- No account needs to be taken about the system weight of the whole FWD installation.

It is possible to increase the hydraulic oil flow that the FWD pump can deliver and thus increase the top speed that the hydraulic motors can reach. This is done by increasing the output ratio from the PTO with the help of a transmission. The standard output ratio is 1:26, and a more suitable ratio would be at least 1:6.

4.2 Needs from the manufacturer

Since the truck the body builder will use will be manufactured by Volvo GTT, it was necessary to listen to their thoughts and ideas on how the FWD pump should be placed. A meeting was arranged with members representing the different areas of interest, which was:

- Chassis
- Production
- Driveline
- Cab
- After market

From Production point of view, the pumps should be an integrated part of the engine module, which means that the pumps will not be connected to the chassis. This will make the assembly easier since no retrofitting is needed. The engine module is suspended with rubber cushions in the frame, allowing it to vibrate relatively to the chassis.

Chassis also wanted both pumps integrated on the engine module. If the pumps would be placed on the chassis, the vibrations can reduce the lifespan of the cardan shaft in the pump installation.

To be able to hoist the engine module, the engine brackets need to be free since that is where the hoisting chains are attached. This also leaves enough space to be able to tighten the brackets when hoisted.

Since most of the final customers who will use this kind of FWD need the PTO for their own equipment, the PTO needs to be free and enough space should be available to be able to mount, for example, other pumps of different sizes. However, with the body builder worked with in this diploma work, it was decided to use a 120 cc hydraulic variable pump as the body builder pump, along with the FWD pump and these are the ones that needed to be fitted. This means that the PTO does not have to be free, but it would be a bonus if it can be arranged.

One of the biggest interferences with the components surrounding the PTO is with the air filter. There are two solutions for solving this, either reconstruct the filter and keep it in the same place, or move it and keep the current construction. Due to the time limit, it was decided that moving the filter is the easiest and best way to solve the problem.

So to summarize the meeting, the following list on notes was made.

- The pumps should be an integrated part of the engine module, which means that the pump should not be connected to the chassis.
- Leave enough space to be able to tighten the engine brackets during assembly.

- Be able to hoist the engine module in the chassis during assembly
- After market builders should still have access to the engine PTO.
- An alternative placement of the air filter is, in this case of the chipper truck, desirable.

4.3 Customer needs list

With the help of the needs gathered from the body builder and the manufacturer, a list was compiled, as seen in table 4.1 below. The needs are weighted with a number between 1-5, where 5 is a demand and the rest are desires of various degrees.

Table 4.1 - List of all the customer needs gathered from both the body builder and the different parts of the manufacturer.

No.		Need	Imp.	Source of need
1	The Pump installation	is reasonable expensive to build	2	Manufacturer
2	The Pump installation	enables tightening of the engine brackets	5	Production
3	The Pump installation	enables hoistening of the engine module into the chassi	1	Production
4	The Pump installation	ensure enough space to reach the engine bracket loops	5	Production
5	The Pump installation	does not interfere with the flywheel housing	5	Driveline
6	The Pump installation	does not interfere with the gearbox unit	5	Driveline
7	The Pump installation	does not interfere with the airfilter	2	Chassi
8	The Pump installation	does not interfere with the crossmember over gearbox	2	Chassi
9	The Pump installation	is a part of the engine module	4	Body builder/Driveline/Chassis
10	The Pump installation	is robust	4	Body builder/Manufacturer
11	The Pump installation	should be implemented to production fast	4	Body builder/Manufacturer
12	The Pump installation	is not contaminated by water	5	Body builder
13	The Pump installation	is not contaminated by dust	5	Body builder
14	The Pump installation	is not contaminated by wood chips	5	Body builder
15	The Pump installation	allows the driver to use the FWD at low speeds	5	Body builder/Marketing
16	The Pump installation	allows the driver to use the FWD at high speeds	3	Body builder/Marketing
17	The Pump installation	enables easy access for service of the pumps	3	Body builder/Service
18	The Pump installation	allows easy replacement of worn parts	3	Body builder/Service

Some needs stand out because of their weighting. For example, the reason why need number 3 only has a 1 as weighting is because although the pump installation is much desired to be a part of the engine module in the final assembly, it is possible to mount the whole installation, without much trouble, after the engine module has been hoisted into the chassis.

Need number 1 has a 2 as weighting since the cost of the whole installation should not be a restriction when generating concepts. A concept with a very high production cost will still perform worse in the evaluation process.

4.4 Final specification list

Based on the demands and desires that emerged during the body builder visit and the meeting with representatives from Volvo GTT, a final specification list was compiled. In the specification list every metric corresponds to one or more demands and needs. The list usually contains a number of metrics that are easy to measure in units, e.g. weight, length, pressure and so on. In this report there are mostly subjective metrics that cannot be measured in units. This because all concepts just will present a geometry of the pump installation and not a very detailed solution, making it impossible to compare them in any other way than by view. The final specification list is shown below in table 4.2.

Table 4.2 – Final specifications. List of all metrics made from the customer needs list.

Metric No.	Need Nos.	Metric	Imp.	Units
1	1	development cost of concept	2	SEK/subj.
2	2	space for tightening the engine brackets	5	subj.
3	3	space for hoistening the engine module	1	subj.
4	4	space for reaching the bracket loops	5	subj.
5	5, 6	grade of interference with the engine module	5	subj.
6	7, 8	grade of interference with the other components	2	subj.
7	9	of what grade attached to the engine module	4	subj.
8	10	number of components	3	No.
9	10	reliability	4	subj.
10	11	time until production	4	days/subj.
11	12	is not affected by rain or splashing water	5	subj.
12	13	is not affected by dusty environments	5	subj.
13	14	is not affected by swirling wood chips	5	subj.
14	15	ability to use up to 10 km/h	5	subj.
15	16	ability to use at ≥25 km/h	3	subj.
16	17, 18	avaliability around the the installation	3	subj.
17	17, 18	time to disassemble/assemble for maintenance	3	s/subj.

Under the column “Need no.”, it is specified which metric belongs to which need. Under the columns “Imp.” and “Units”, the relative importance of each metric is indicated and what units they are measured in. The relative importance was set on a scale of one to five, where five meant an absolute requirement and one meant a very light desire. At first, every importance for each metric was set from the knowledge that so far had been received. Later in the concept evaluation progress these numbers were either confirmed or adjusted when consulting with the supervisor.

5 CONCEPT GENERATION

The concept generation process was divided into two parts, search both externally and internally. The external search was an ongoing process since ideas could be found at any given moment, during meetings, interviews and workshop visits.

5.1 Search externally

Throughout the whole project the contact with both colleagues and supervisors (experts) has been a great help. Before the brainstorming session a small meeting with the supervisors took place in the workshop at Volvo. On that meeting a few main concepts was made up by looking at MaxTrack and then discuss about potential placements for the pumps.

At the beginning, a literature review was examined at Chalmers library where the goal was to find solutions on similar problems regarding packing of different components. Several articles about similar technical solutions with hydraulic front-wheel drive were found, but nothing about how the different components were placed in these solutions. All pictures and explaining texts found were just schematic.

The interview with the body builder (lead user) who builds this kind of trucks was the most rewarding way of gathering ideas for new concepts. The meeting gave a great understanding of the problem and an insight of what environments these trucks work in. The available space behind the cab was big and that made it easier to go the whole hog in the internal concept generation.

5.2 Search internally

This main step in the concept generation was carried out by a brainstorming session which followed the guidelines found in Ulrich and Eppinger (2012). Focus was on getting as many concepts as possible and no concept was to be rejected for looking infeasible. Along with the list of the final specifications as a guideline, a number of concepts were generated.

6 GENERATED CONCEPTS

The brainstorming resulted in 17 different concepts. Figure 6.1 below shows a CAD drawing of the area in which the pump installation is meant to be placed.

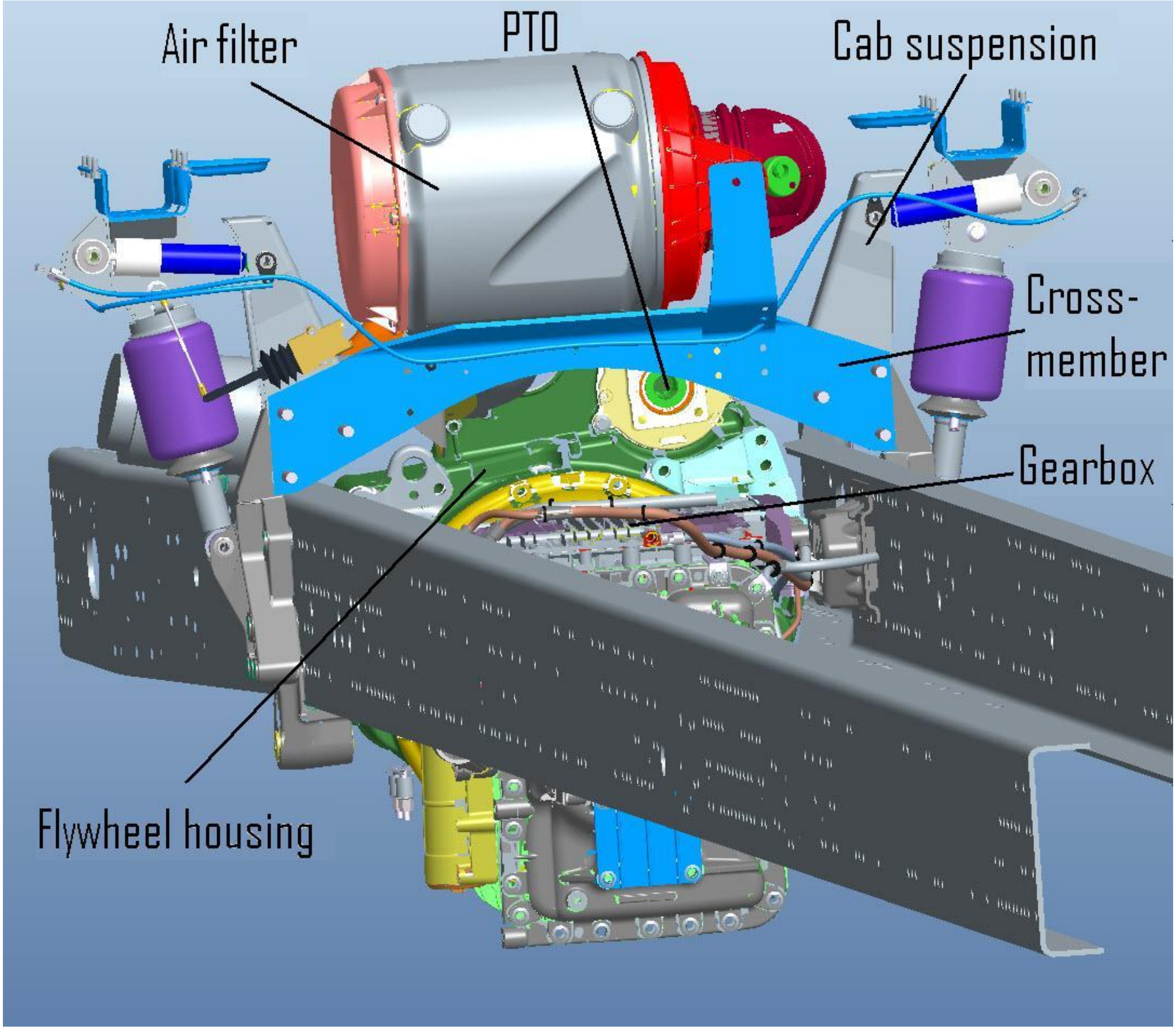

Figure 6.1 - CAD drawing of the area of interest.

When generating the concepts, a simplified and schematic version of figure 6.1 was used, see figure 6.2. This made it easier to present the concepts in an easy and quick way. All concept views are drawn from behind, i.e. they present a view standing on the back left side of the truck. The flywheel housing (A), see figure 6.2, is the rearmost part of the engine and it connects the engine with the gearbox unit. The engine module is then mounted on the frame sides (B) with the help of brackets mounted to the flywheel housing.

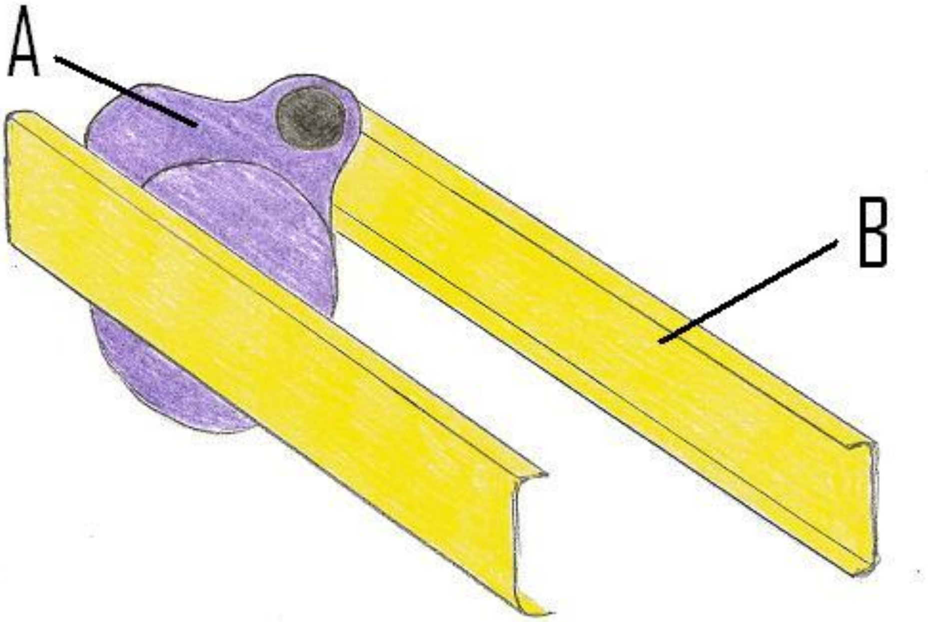

Figure 6.2 - Schematic drawing of the flywheel housing and the frame sides.

Two types of pumps will be referred to in the different concepts, a FWD one and a body builder one. The FWD pump is used for powering the hydraulic FWD, while the body builder one is used for, in this case, a hooklift and timber crane. The FWD pump will from now on be called pump C while the body builder one is called pump D.

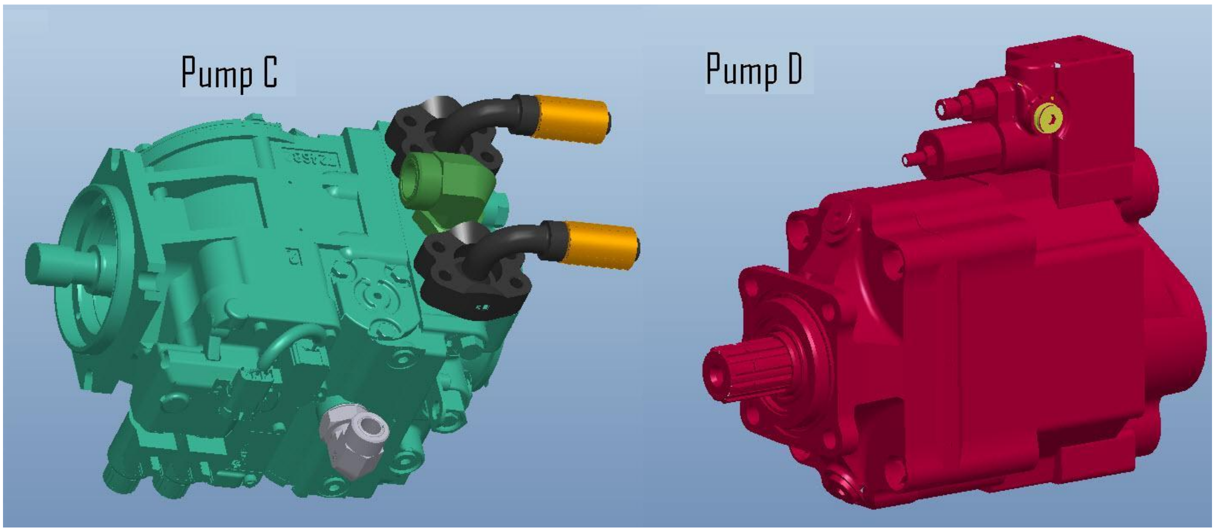

Figure 6.3 - CAD drawings of pump C and D.

6.1 Concept 1

Pump C is mounted directly on the PTO, which can be found on the upper right of the flywheel housing (A). Pump D is placed right after the FWD pump, using the interface at the rear end of the first pump.

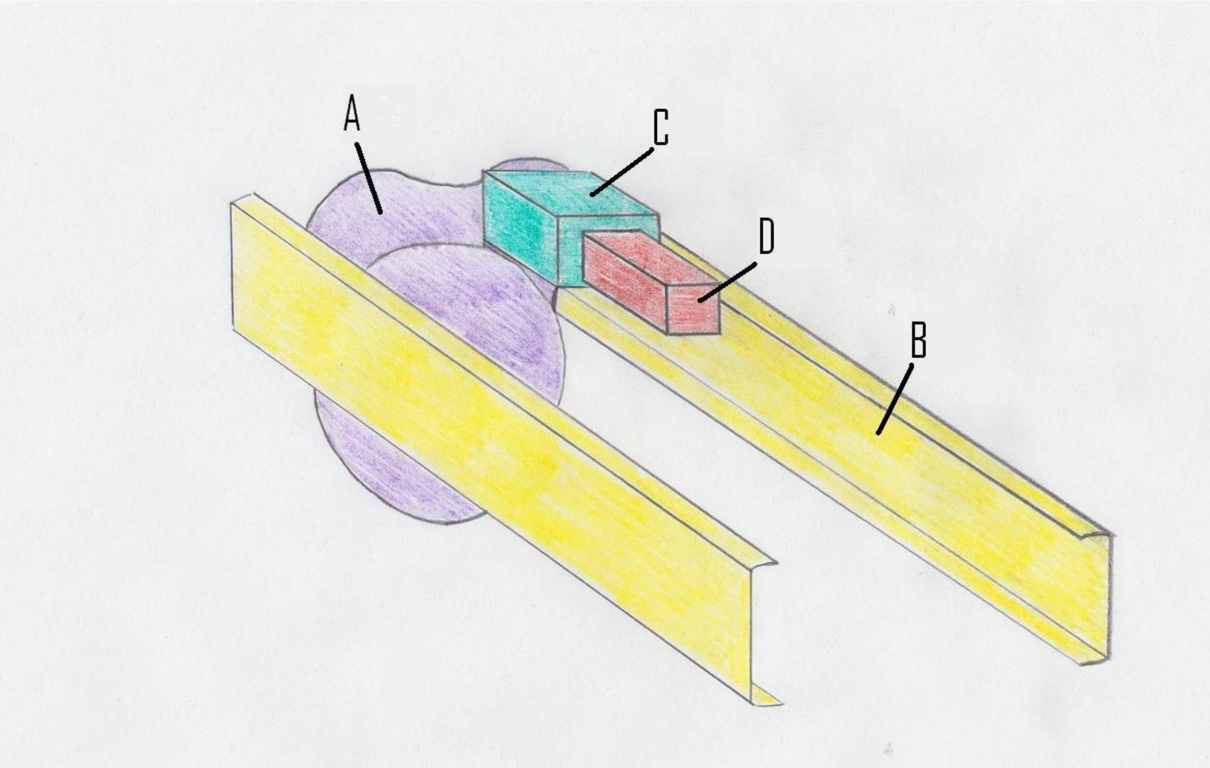

Figure 6.4 - Concept 1. Both pumps are mounted directly on the PTO.

6.2 Concept 2

Pump C is placed parallel to the PTO with a transmission (E) connecting them. The transmission consists of three gears, one mounted on the PTO, one on the FWD pump and the third one placed between them, connecting them together. This makes the PTO free to use for other applications, in this case pump D, as well as allowing the use of a higher ratio output for pump C. This is done by changing the size of the gears mounted on pump C and the PTO. It is also possible, if there is enough space, to switch place on the pumps so that pump C is placed on the PTO.

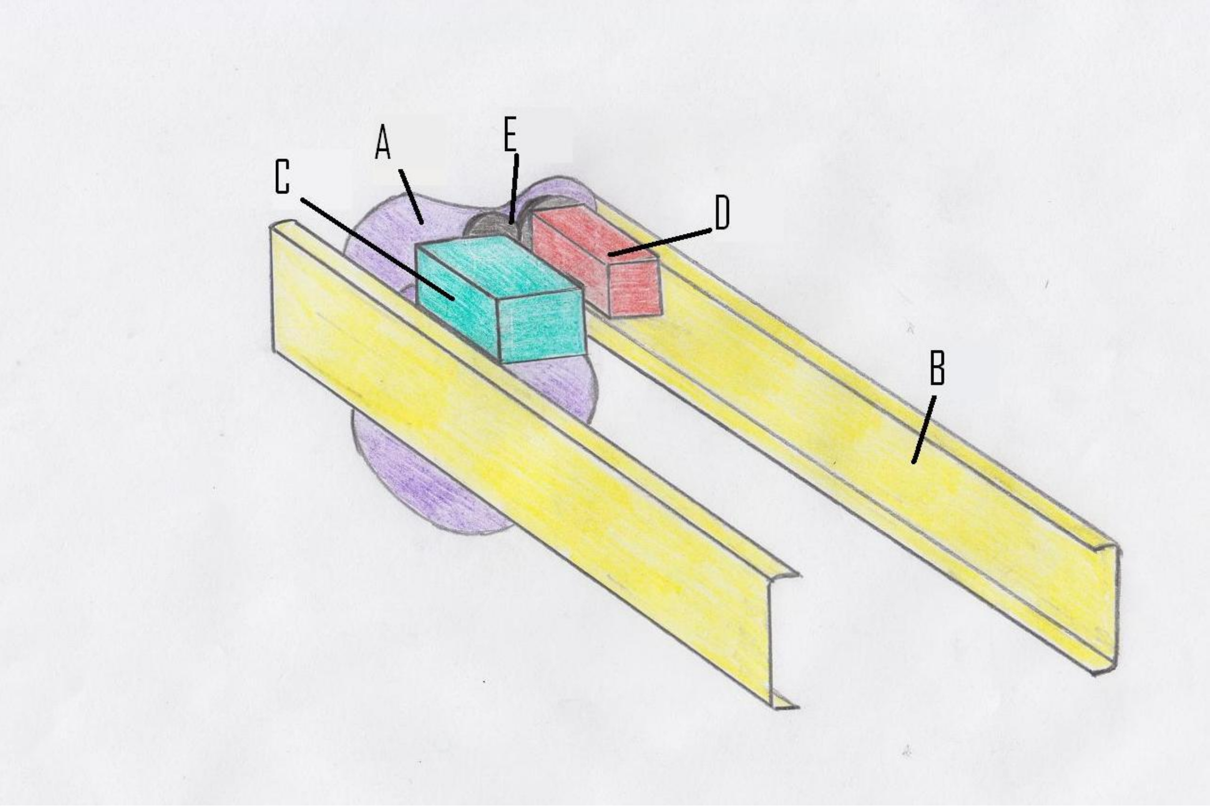

Figure 6.5 - Concept 2. Both pumps are mounted, parallel to each other, on a transmission which in itself is mounted on the PTO.

6.3 Concept 3

In this concept a transmission (E) is mounted directly on the PTO, maybe a worm gear. The purpose of the transmission is to make it possible to have pump D angled out from the PTO. As showed in the picture below, the pump is set at a ninety degree angle against the PTO, towards the middle of the flywheel housing (A). However, the angle does not have to be ninety degrees and the pump does not have to be angled towards the middle of the flywheel housing, it can be angled at any direction. Pump C is mounted directly after the transmission, in a straight line out from the PTO.

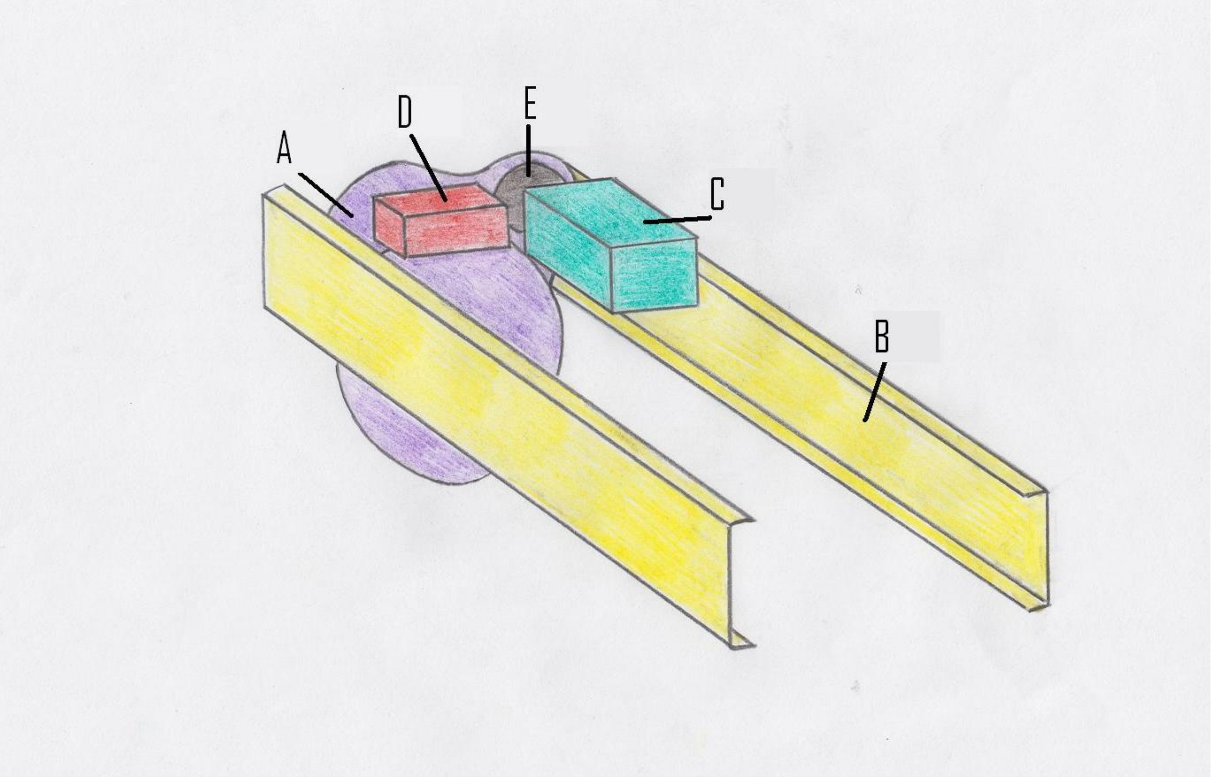

Figure 6.6 - Concept 3. Both pumps are mounted on a transmission which is mounted on the PTO.

6.4 Concept 4

Like concept 2, this concept makes use of gears to move pump C away from the PTO, as well allowing the higher ratio output. However, the FWD pump is now placed further back on the chassis in order to avoid it from interfering with the components surrounding the PTO. To be able to power the FWD pump, a cardan shaft (F) connects the pump with the gear (E) in the transmission. The PTO is then free to use for pump D.

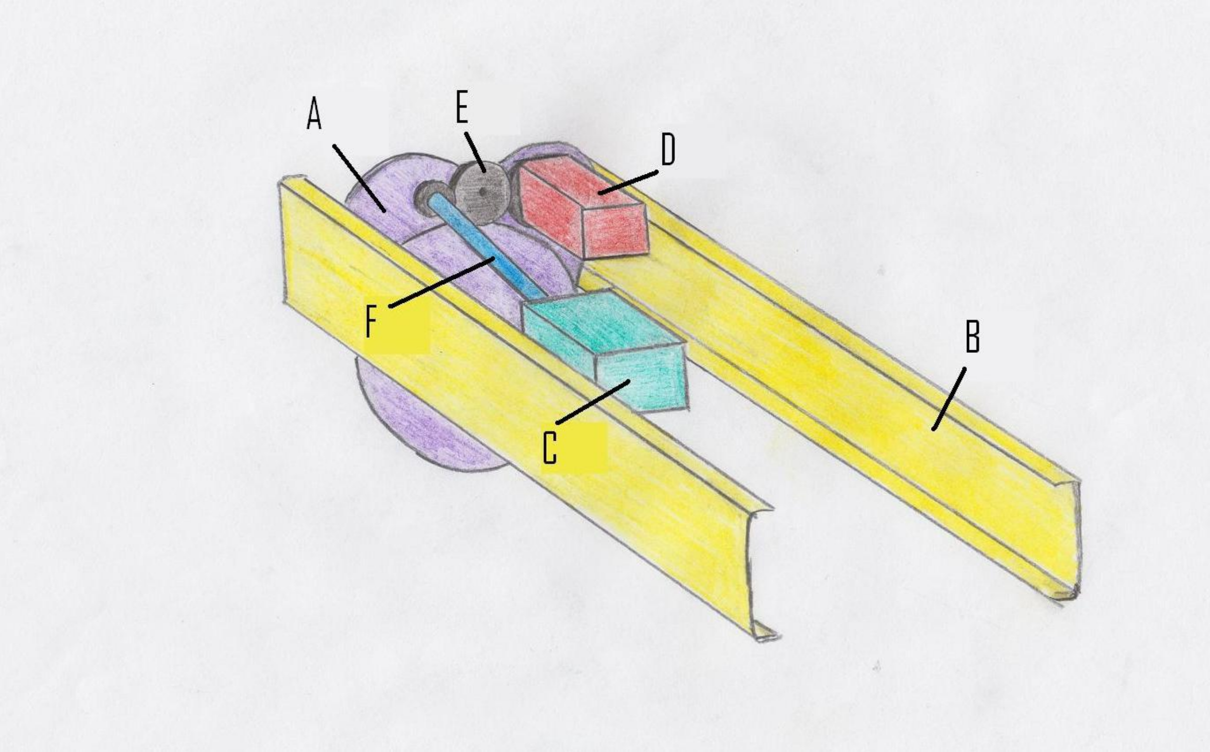

Figure 6.7 - Concept 4. Pump C is mounted on the chassis with a cardan shaft connecting it to a transmission which is connected to the PTO.

6.5 Concept 5 & 6

It is possible to add another PTO housing (G), also called a Koblam, to the flywheel housing (A). Pump C is mounted directly on this new PTO and gets its power from here. The old PTO can still be used for other applications, in this case pump D. Another variant is to mount pump D on the new PTO and then use the old PTO to power pump C, i.e. just switch location of the pumps.

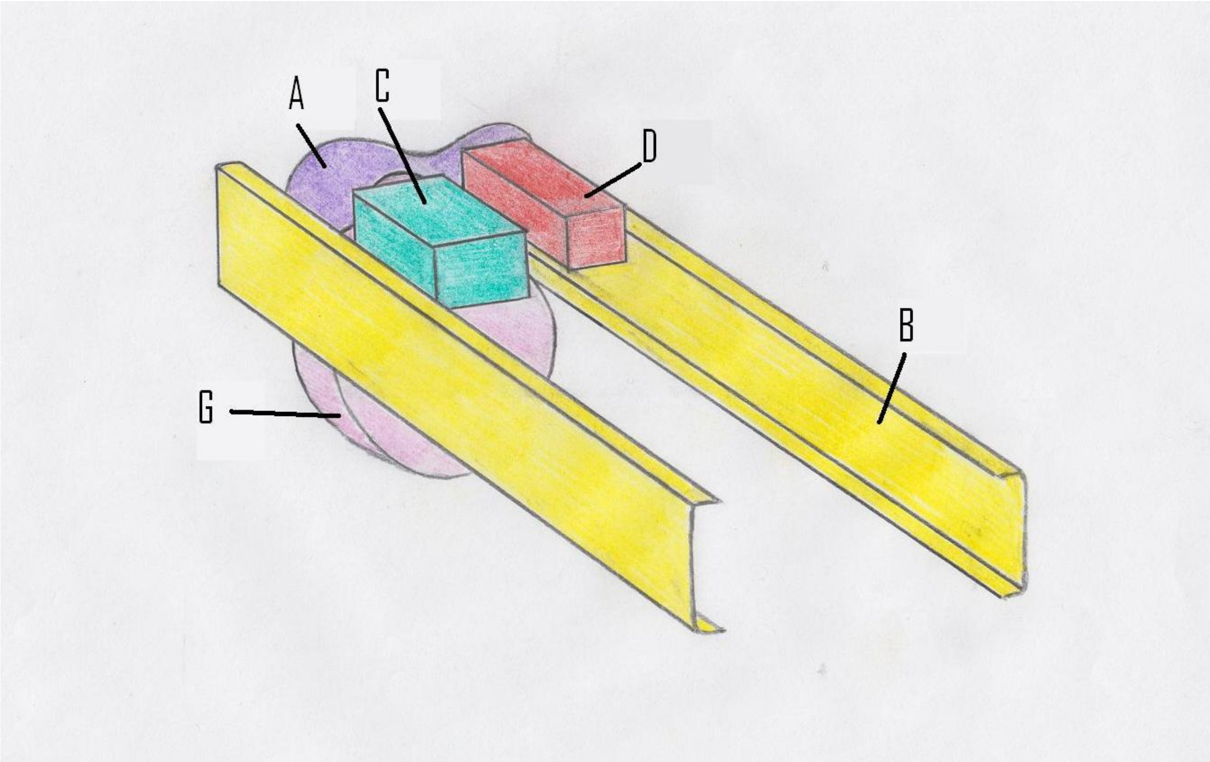

Figure 6.8 - Concept 5 and 6. Another type of PTO housing is added which has a PTO to use for either pumps.

6.6 Concept 7

The current flywheel housing is replaced with a different type (H) which is not a standard part for trucks. This part is constructed by Volvo Construction Equipment, an affiliated company of Volvo AB, and does not have the common PTO at the top right corner. The different type has two PTO´s placed at the lower part of the housing which can be used in both directions. However, this part would need some redesigning to fit in a truck, and therefore it is assumed that the modified flywheel housing would be equipped with the standard PTO interface. In this case pump C is placed on one of the lower PTO's while pump D is placed on the standard PTO. However, pump C does not have to be placed on this side; any of the four lower PTO's can be used.

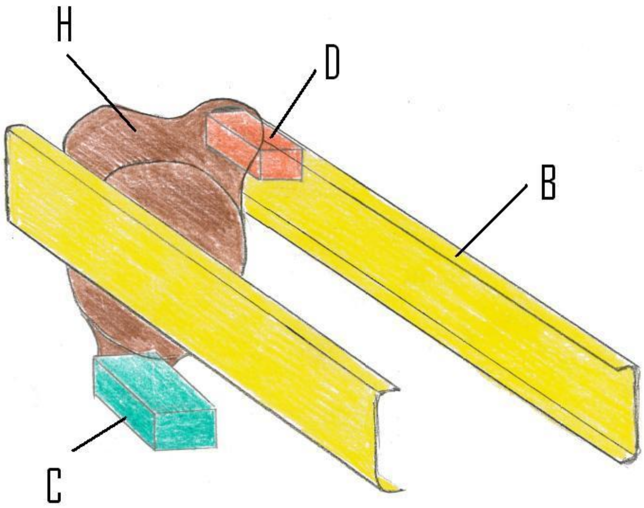

Figure 6.9 - Concept 7. A new type of flywheel housing is used.

6.7 Concept 8

Same as concept 7, but in this case pump D is placed on the second of the lower PTO's, leaving the upper PTO free to use for other applications. And just as in concept 7, both pumps can be placed on any of the lower PTO's.

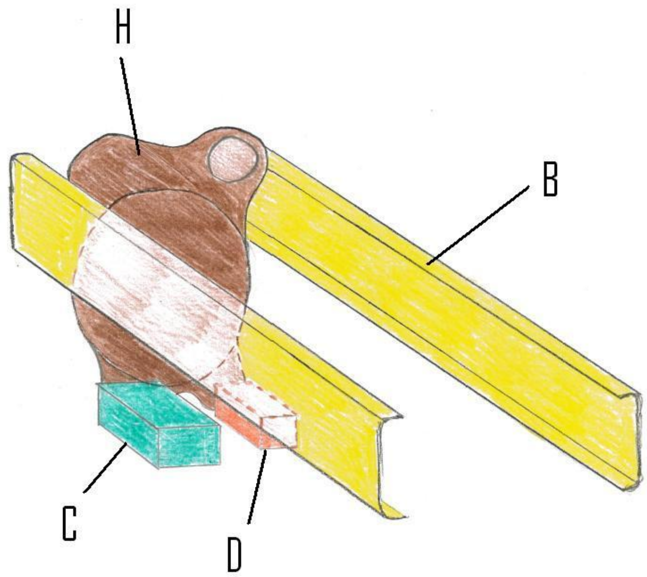

Figure 6.10 - Concept 8. A new type of flywheel housing is used.

6.8 Concept 9

In an attempt to move the pump installation more to the middle between the two frame sides (B), pump C is placed on the PTO, but with a transmission (E) connecting them. The transmission consists of two gearwheels set with a 45 degree angle. This aims the pump towards the center of the chassis to avoid clashing with the crossmember and, preferably, the air filter. Another 45 degree angle transmission (E) is then placed on the FWD pump, followed by pump D which is now set parallel to the frame sides.

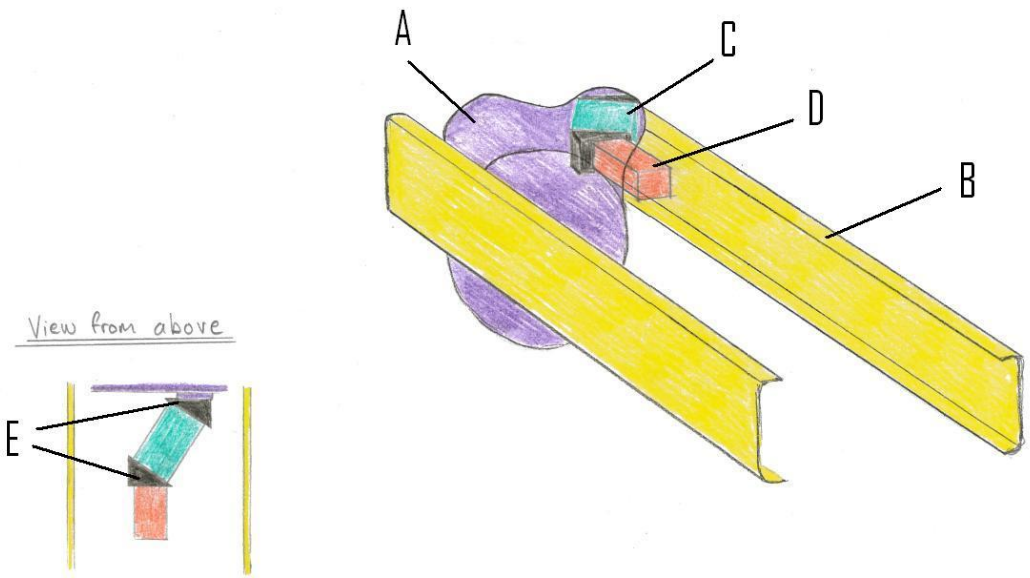

Figure 6.11 - Concept 9. Pump C is placed on an angled transmission out from the PTO. Pump D is then placed on another angled transmission which angles the pump straight back on the chassis.

6.9 Concept 10

A cardan shaft (F) is placed on a transmission (E), which is placed on the PTO, connecting it to pump C. This leaves the PTO free for other applications. The pump is placed on the chassis and pump D is placed right after, attached only to pump C.

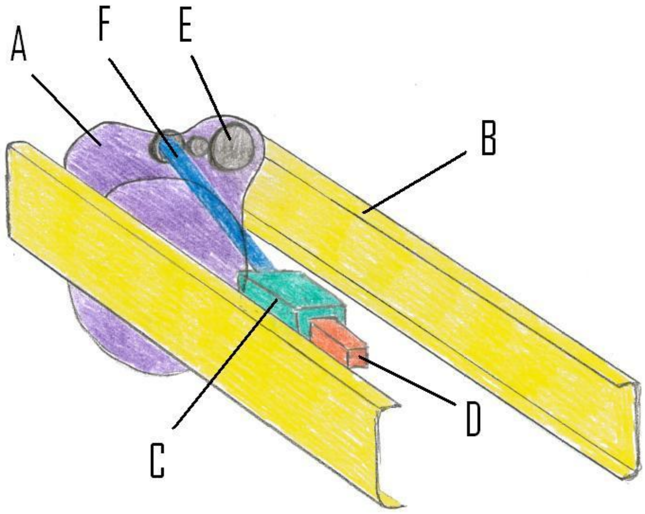

Figure 6.12 - Concept 10. Both pumps are mounted on the chassis with a cardan shaft connecting pump C to a transmission, which is connected to the PTO.

6.10 Concept 11

Same as concept 10, but now the cardan shaft (F) is connected straight from the PTO to pump C.

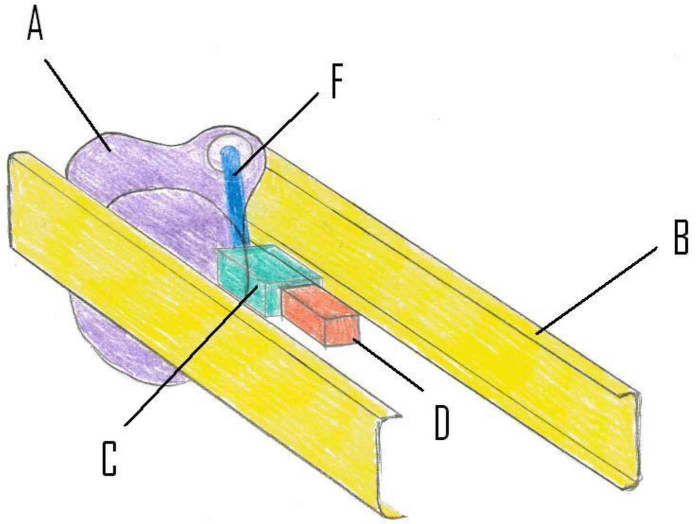

Figure 6.13 - Concept 11. Both pumps are mounted on the chassis and a cardan shaft is connecting pump C to the PTO.

6.11 Concept 12

Pump C is placed on a transmission (E) which allows the pump installation to be moved away from the PTO and more to the middle of the chassis. Pump D is placed right after pump C and the PTO is free to use for other applications.

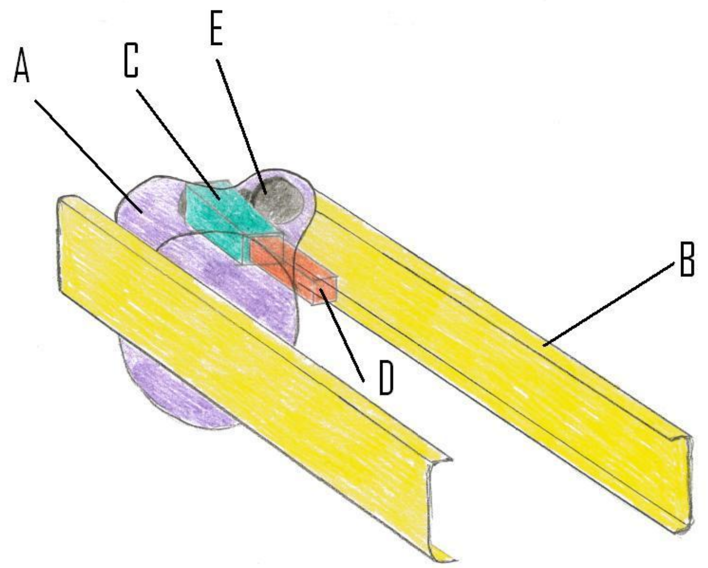

Figure 6.14 - Concept 12. Both pumps are placed on a transmission which is mounted on the PTO.

6.12 Concept 13

Like concept 5&6, a whole new PTO housing, a Koblam, is placed after the flywheel housing (A). However, this time there are two of these housings (G) which placed after each other giving two new PTO's. Pump C and pump D are then mounted on each of these new PTO's. The original PTO is free to use for other applications.

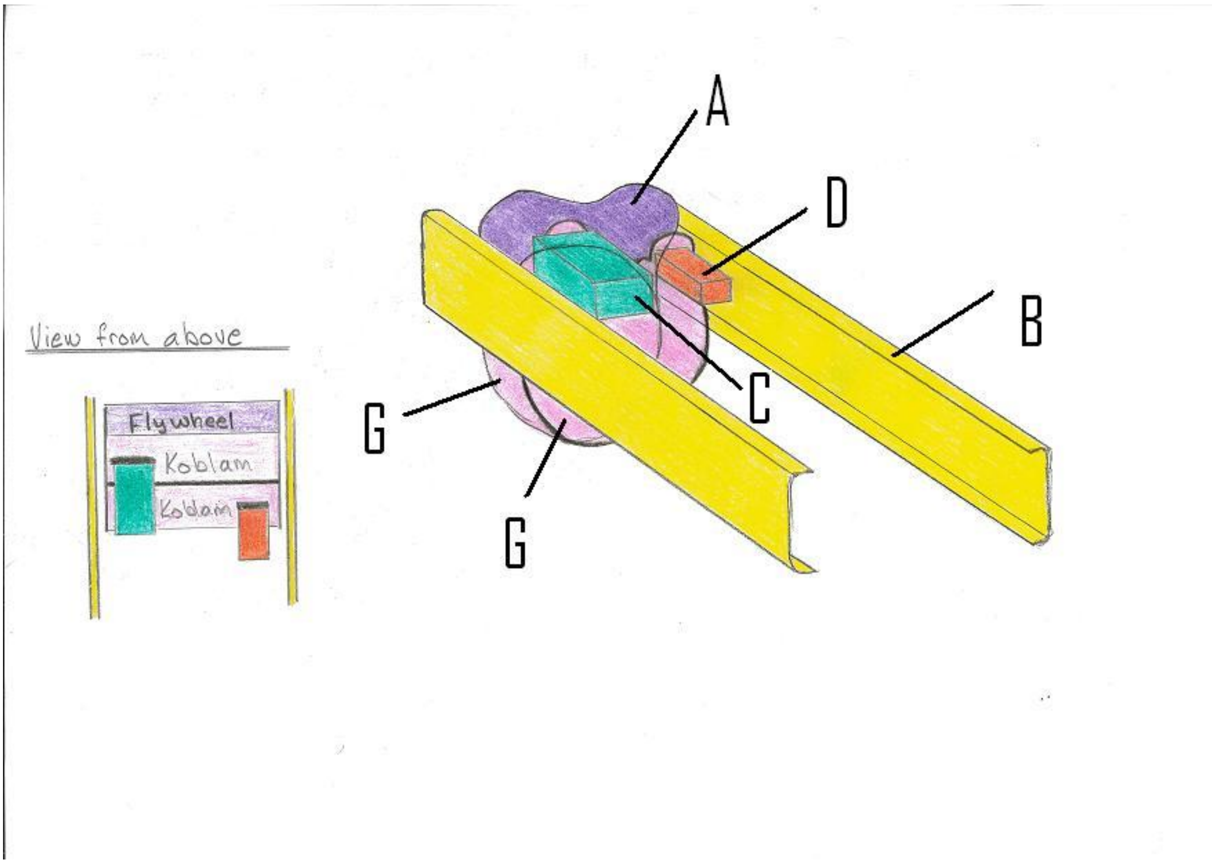

Figure 6.15 - Concept 13. Two extra PTO housings are added after the flywheel housing, each with a new PTO on which the pumps are placed.

6.13 Concept 14

Same as concept 10, but the pump installation (C and D) is mounted on the gearbox unit instead of the chassis. This makes the pump installation a part of the engine module. The cardan shaft (F) is connected to a transmission (E), connected to the PTO.

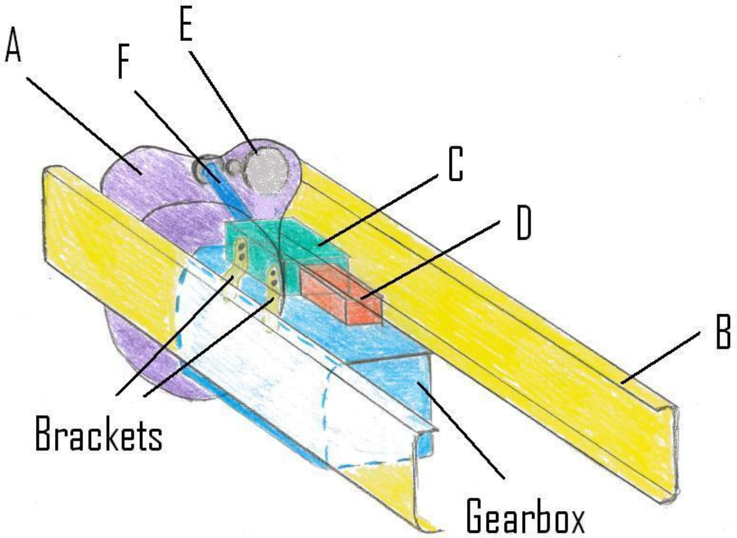

Figure 6.16 - Concept 14. Both pumps are mounted on the gearbox with a cardan shaft connecting pump C to a transmission which in itself is mounted on the PTO.

6.14 Concept 15

A cardan shaft (F) is connected from the PTO to a transmission (E) placed above the gearbox unit. The transmission consists of, in this case, three gears with the middle one connected to the cardan shaft. The middle gear then powers the other two gears. The gear to the right is then connected to pump C while the left on is connected to pump D. By changing the size of the gears, different ratios of output can be used for both pumps.

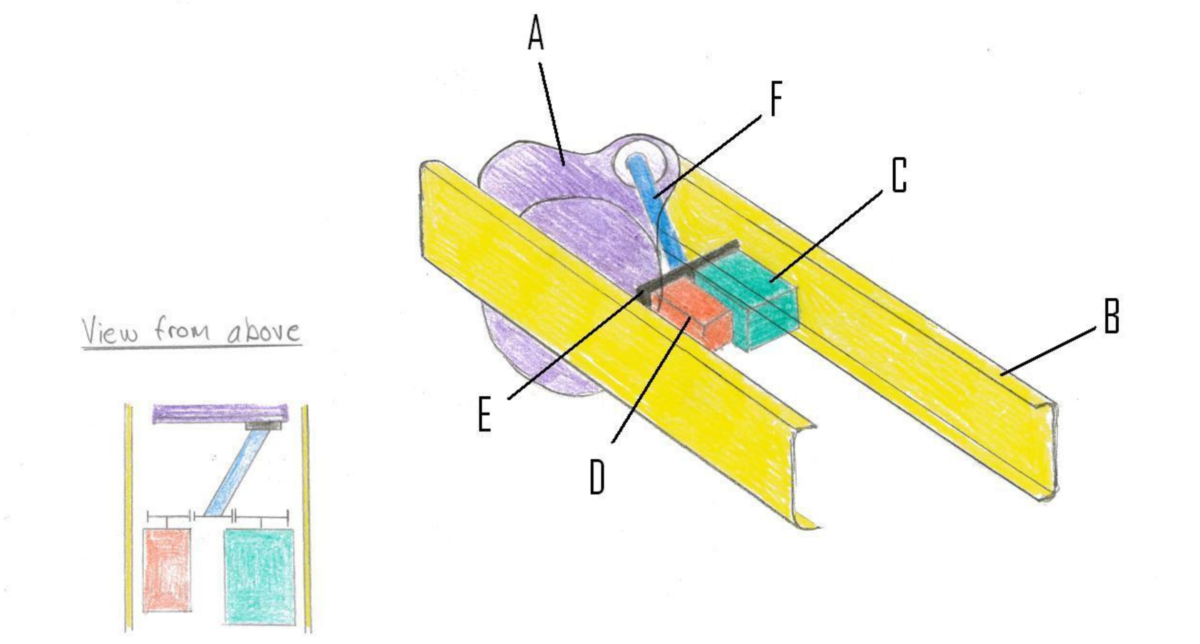

Figure 6.17 - Concept 15. The pumps are mounted beside each other on the chassis with a transmission connecting them. A cardan shaft is connected between the transmission and the PTO.

6.15 Concept 16

To avoid clashing with the crossmember above the gearbox, pump C is placed with a 90 degree angle relative the PTO interface. Pump D is placed on top of pump C and both are connected to a transmission (E) which is mounted on the PTO.

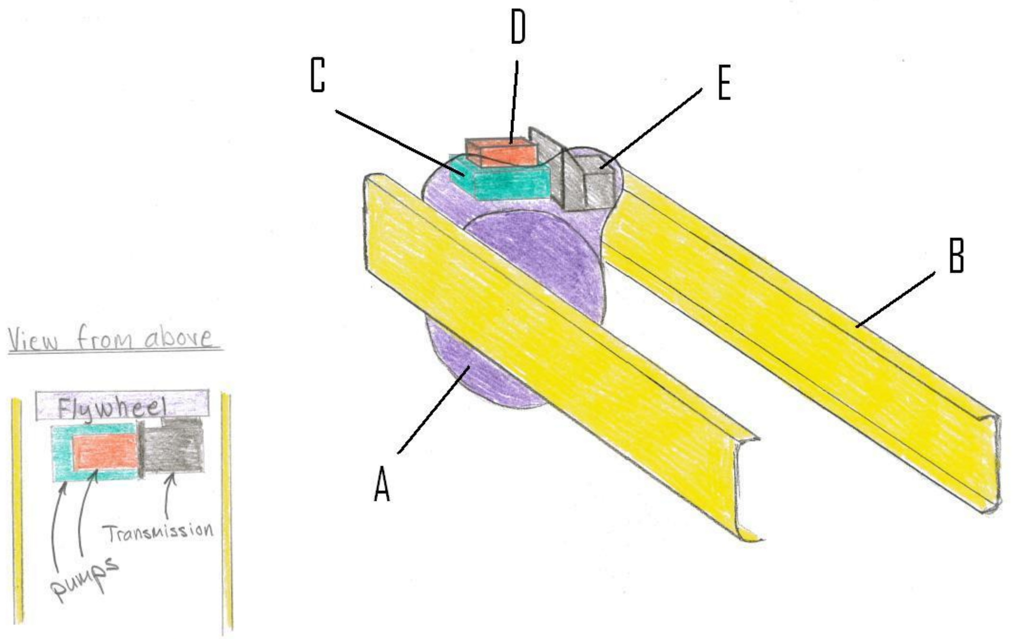

Figure 6.18 - Concept 16. Both pumps are placed 90 degrees relative to the PTO with a transmission. Pump D is placed on top of Pump C.

6.16 Concept 17

Same as concept 14, but now the cardan shaft (F) is connected directly to the PTO instead of using a transmission (E), making the concept look more like concept 11.

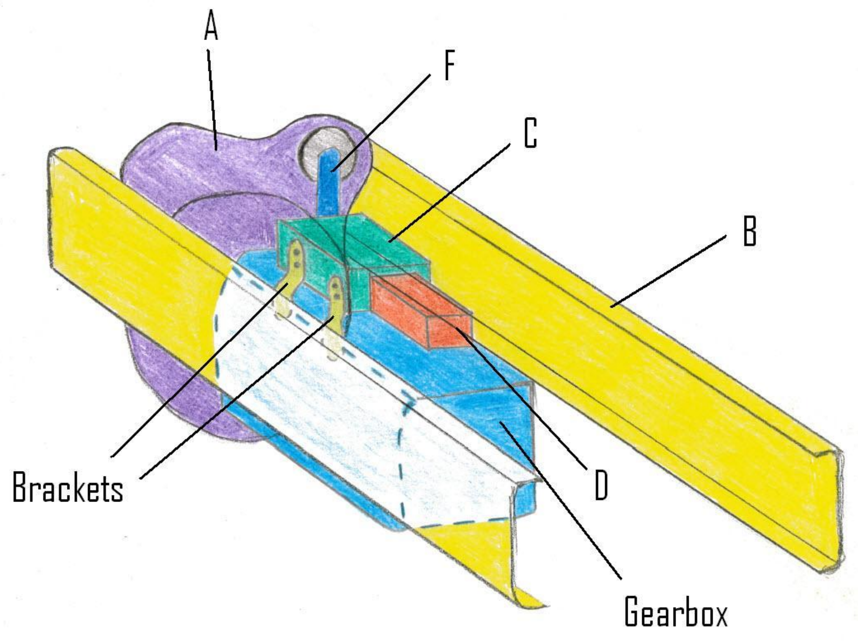

Figure 6.19 - Concept 17. Both pumps are mounted on the gearbox with a cardan shaft connecting pump C to the PTO.

7 CONCEPT EVALUATION

The evaluation was divided into three parts, concept screening, concept scoring and final concept selection. The screening and scoring was made to weed out the bad concepts, while the final selection was made to select the final concepts to be presented as solutions.

7.1 Concept screening

In a first step to evaluate the generated concepts, a concept screening matrix was used, see chapter 2.3 on pages 6-7. The purpose of this simpler form of evaluation matrix was to exclude obvious bad concepts. Concept 11 was used as a reference concept because its similarity of the solution today and thus easiest to relate to and compare the other concepts against. With the help of screenshots from the CAD-drawings every concept was compared against the reference concept for each point in the final specification. Every concept therefore obtained a number of “+”, “-“ and “0”, and further on a result. As a tool for evaluating the concepts, screenshots were taken from CAD drawings where all concepts were sketched in a 3D environment. An example of a screenshot used can be seen in figure 7.1.

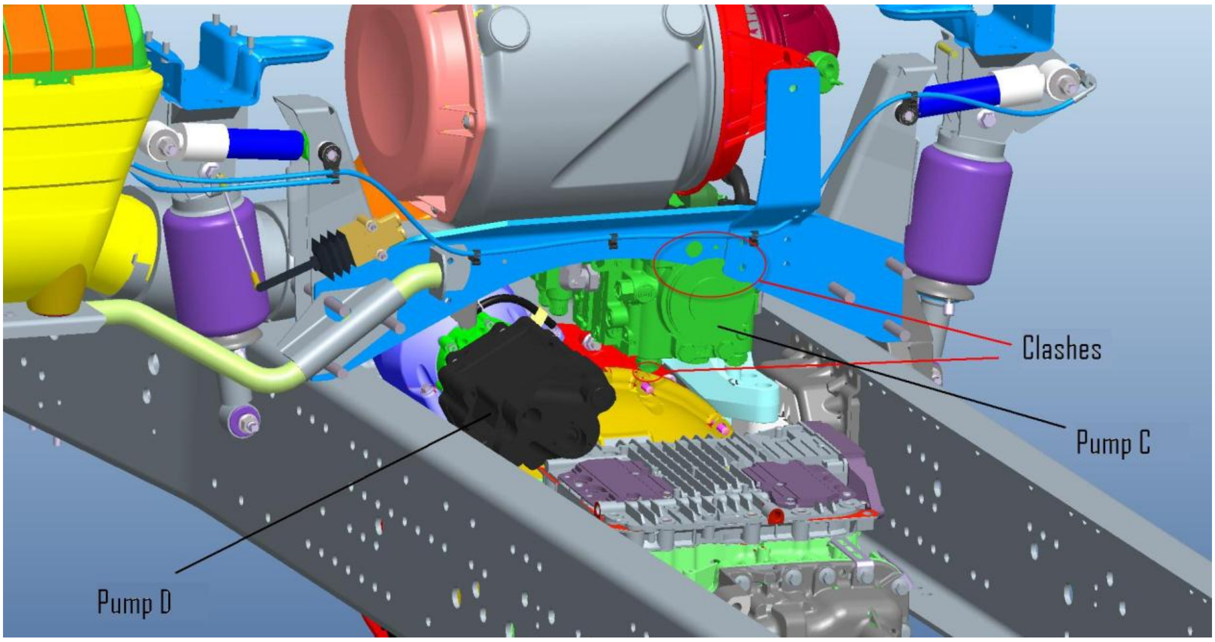

Figure 7.1 - Screenshot of concept 5. An extra PTO housing has been added with pump D mounted on it. Pump D is mounted on the regular PTO.

The completed matrix can be seen below in figures 7.2 and 7.3 on the next page.

Need Nos.	Metric	1	2	3	4	5	6	7	8
1	development cost of concept	-	-	-	-	-	-	-	-
2	space for tightening the engine brackets	0	0	0	0	-	-	0	0
3	space for hoisting the engine module	0	0	0	0	-	-	0	0
4	space for reaching the bracket loops	0	0	-	0	0	0	0	0
5, 6	grade of interference with the engine module	0	0	0	0	0	-	-	-
7, 8	grade of interference with the other components	-	-	-	-	-	0	0	0
9	of what grade attached to the engine module	+	+	+	0	+	+	+	+
10	complexity of installation	+	-	-	-	+	+	+	+
10	reliability	+	+	+	0	+	+	+	+
11	time until production	-	-	-	-	-	-	-	-
12	is not affected by rain or splashing water	0	0	0	0	0	0	0	0
13	is not affected by dusty environments	0	0	0	0	0	0	0	0
14	is not affected by swirling wood chips	0	0	0	0	0	0	0	0
15	ability to use up to 10 km/h	0	0	0	0	0	0	0	0
16	ability to use at ≥25 km/h	0	+	+	+	-	0	0	0
17, 18	avaliability around the the installation	-	-	-	0	-	-	-	0
17, 18	time to disassemble/assemble for maintenance	0	+	0	+	0	0	+	+
	∑+	3	4	3	2	3	3	4	4
	∑0	10	8	8	11	7	8	9	10
	∑-	4	5	6	4	7	6	4	3
	Net score	-1	-1	-3	-2	-4	-3	0	1
	Rank	3	3	5	4	6	5	2	1
	Continue?	Yes	Yes	Yes	Yes	Consider	Yes	Yes	Yes

Figure 7.2 – Part one of the filled concept screening matrix.

Need Nos.	Metric	9	10	11	12	13	14	15	16	17
1	development cost of concept	-	0	0	-	-	0	0	-	-
2	space for tightening the engine brackets	0	0	0	0	-	0	0	-	0
3	space for hoisting the engine module	0	0	0	0	-	0	0	0	0
4	space for reaching the bracket loops	-	0	0	0	0	0	0	-	0
5, 6	grade of interference with the engine module	0	0	0	0	-	0	0	0	0
7, 8	grade of interference with the other components	0	-	0	-	-	0	0	-	0
9	of what grade attached to the engine module	+	0	0	+	+	+	0	+	+
10	complexity of installation	-	-	0	-	-	0	-	-	-
10	reliability	+	0	0	+	0	+	0	+	+
11	time until production	-	-	0	-	-	-	-	-	-
12	is not affected by rain or splashing water	0	0	0	0	0	0	0	0	0
13	is not affected by dusty environments	0	0	0	0	0	0	0	0	0
14	is not affected by swirling wood chips	0	0	0	0	0	0	0	0	0
15	ability to use up to 10 km/h	0	0	0	0	0	0	0	0	0
16	ability to use at ≥25 km/h	+	+	0	+	-	0	+	+	+
17, 18	avaliability around the the installation	-	0	0	-	0	0	0	-	0
17, 18	time to disassemble/assemble for maintenance	-	0	0	0	+	0	+	0	0
	∑+	3	1	0	3	2	2	2	3	3
	∑0	8	13	17	9	7	14	13	7	11
	∑-	6	3	0	5	8	1	2	7	3
	Net score	-3	-2	0	-2	-6	1	0	-4	0
	Rank	5	4	2	4	7	1	2	6	2
	Continue?	Yes	Yes	Yes	Yes	No	Yes	Yes	Consider	Yes

Figure 7.3 - Part two of the filled concept screening matrix

As shown in figures 7.2 and 7.3 only concept 13 was eliminated directly after the screening, this because it obtained a very low net score together with a lot of minuses. The outlook for this concept was estimated to be poor since there were too many minuses to overcome. Two other weaknesses with the concept were its weight and size. In this report we just focus on a chipper truck where the weight is not an issue, but if the final solution should be able to be implemented on other types of trucks it cannot weigh too much. The whole system for the hydraulic front-wheel drive has been given a weight of 500 kg to stay within, and one Koblam (extra PTO housing) adds about 200 kg. It would therefore be impossible to add two Koblams to the installation and at the same time reach the weight restriction. One Koblam also adds the length of the engine module with 20 extra centimeters; two extra Koblams would add 40 centimeters between the flywheel housing and the gearbox. This might result in construction of extra brackets to carry the engine module and other unseen problems. Concept 5 and 16 also received a quite low net score and it was not clear to bring them into next evaluation round. But together with the supervisor it was decided to have them in the next evaluation process just to be sure that it was two bad concepts. The remaining concepts all scored too similar to exclude from the next evaluation round, which is why they were kept.

7.2 Concept scoring

The concept scoring was done with the help of representatives from Volvo GTT, as well as the supervisor. As in the case of the concept screening evaluation, CAD drawings were used to get a better view on how the concepts work. However, some changes were first done to the final specification. The changes were done by consulting the representatives and discussing each metric.

- Another type of cost for the installation was added, the manufacturing cost.
- Space for reaching the bracket loops was ignored, due to the similarity to the metric "Space for hoisting the engine module". To be able to hoist the engine module, the bracket loops need to be reached anyway.
- The metric "Of what grade attached to the engine module" was ignored since a concept can either be a part of the engine module, or not, there is no alternative in between.
- Metrics 12-14 were ignored, due to the fact that all installations are to be considered enough protected from surrounding environments.
- The ability to use the installation up to 10 km/h is also ignored since a 75 cc pump is enough to power the truck up to 10 km/h in all the concepts
- Reliability was ignored since it was considered to be a lot like metric 8, the complexity of the installation

Although several metrics were ignored, the scoring matrix still had eleven metrics which gave a clear view on which concepts to follow up and which to ignore, as seen in figure 7.4 on the next page.

Need Nos.	Metric	Imp.	1		2		3		4		5		6	
			Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
1	manufacturing cost of concept	2	5	10	5	10	5	10	3	6	4	8	4	8
1	development cost of concept	4	2	8	2	8	1	4	2	8	1	4	1	4
2	space for tightening the engine brackets	5	2	10	3	15	2	10	3	15	1	5	1	5
3	space for hoistening the engine module	3	3	9	3	9	2	6	3	9	1	3	1	3
5, 6	grade of interference with the engine module	5	3	15	3	15	3	15	3	15	1	5	2	10
7, 8	grade of interference with the other components	3	2	6	1	3	1	3	2	6	2	6	2	6
10	complexity of installation	3	4	12	4	12	3	9	3	9	4	12	4	12
11	time until production	3	2	6	2	6	1	3	2	6	1	3	1	3
16	ability to use at ≥ 25 km/h	3	3	9	5	15	4	12	5	15	2	6	3	9
17, 18	avaliability around the the installation	3	4	12	4	12	3	9	3	9	1	3	1	3
17, 18	time to disassemble/assemble for maintenance	3	3	9	4	12	4	12	4	12	4	12	4	12
				106		117		93		110		67		75
		Rank	6		1		8		4		12		10	

Need Nos.	Metric	Imp.	7		8		9		10		11		12	
			Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
1	manufacturing cost of concept	2	5	10	5	10	5	10	3	6	3	6	5	10
1	development cost of concept	4	1	4	1	4	2	8	2	8	3	12	2	8
2	space for tightening the engine brackets	5	3	15	3	15	3	15	3	15	3	15	3	15
3	space for hoistening the engine module	3	3	9	3	9	2	6	3	9	3	9	3	9
5, 6	grade of interference with the engine module	5	1	5	1	5	1	5	3	15	3	15	3	15
7, 8	grade of interference with the other components	3	3	9	3	9	1	3	3	9	3	9	1	3
10	complexity of installation	3	5	15	5	15	2	6	3	9	3	9	4	12
11	time until production	3	1	3	1	3	1	3	2	6	3	9	2	6
16	ability to use at ≥ 25 km/h	3	4	12	4	12	4	12	5	15	3	9	5	15
17, 18	avaliability around the the installation	3	4	12	4	12	3	9	3	9	3	9	3	9
17, 18	time to disassemble/assemble for maintenance	3	5	15	5	15	1	3	3	9	3	9	3	9
				109		109		80		110	REF	111		111
		Rank	5		5		9		4		3		3	

Reference

Need Nos.	Metric	Imp.	13		14		15		16		17	
			Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
1	manufacturing cost of concept	2		0	5	10	3	6	5	10	5	10
1	development cost of concept	4		0	2	8	2	8	1	4	2	8
2	space for tightening the engine brackets	5		0	3	15	3	15	2	10	3	15
3	space for hoistening the engine module	3		0	3	9	3	9	2	6	3	9
5, 6	grade of interference with the engine module	5		0	3	15	3	15	2	10	3	15
7, 8	grade of interference with the other components	3		0	3	9	3	9	1	3	3	9
10	complexity of installation	3		0	3	9	2	6	1	3	3	9
11	time until production	3		0	2	6	2	6	1	3	2	6
16	ability to use at ≥ 25 km/h	3		0	5	15	5	15	4	12	3	9
17, 18	avaliability around the the installation	3		0	2	6	3	9	3	9	2	6
17, 18	time to disassemble/assemble for maintenance	3		0	3	9	5	15	1	3	3	9
				0		111		113		73		105
		Rank			3		2		11		7	

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

Figure 7.4 - The scoring matrix fully filled in.

Concept 7 and 8 got the same score in all the metrics. This can be explained by the fact that it does not matter on which PTO to put pump D since it will not interfere with any of the surrounding components. The placement of the pump is also the only thing that differs between them.

7.2.1 Reflections of the results

Several conclusions could be made after the evaluation by studying the matrix.

- The scoring matrix confirmed what the concept screening matrix had shown; concept 5 and 16 could have been excluded before the evaluation.

- All concepts with a score under 80 were to be ignored for further development.
- Concept 3 needed more focus to decide whether to use it in the next step of the evaluation process. After a discussion within the group, it was decided that the concept would have a too complex transmission and should not be further used in the process.

This left eleven concepts, all with a score over 100 points, for further evaluation.

7.3 Final concept selection

The reason for not using yet another matrix during this step was because all the remaining concepts were very close to each other in terms of their score, as well as several similarities in their construction. Both the screening and the scoring matrices are tools for getting an overview on what concepts to reject and which to keep. Therefore the outcome should not be seen as the absolute truth, there should always be a reflection and discussion over the results.

As the final step in the evaluation process, a meeting was held within the group to discuss which concepts to keep and which to reject. The eleven concepts were divided into two groups; one group containing the concepts which did not have a cardan shaft, and the other group with concepts with a cardan shaft.

From the group without cardan shafts, concept 1 and 2 were chosen and concepts 7, 8 and 12 were rejected. Concept 7 and 8 were rejected simply because they both give a lack of ground clearance which could cause big problems for trucks operating in rough terrains, such as the case with the body builder in this project. The ground clearance would be reduced from around 35 centimeter, measuring from the ground to the lowest part of the engine on a normal truck, to just about 20 centimeter with these concepts. Also, since these are not made for this type of truck, it would take a long time to develop these and it would cost a lot more money than the rest of the concepts.

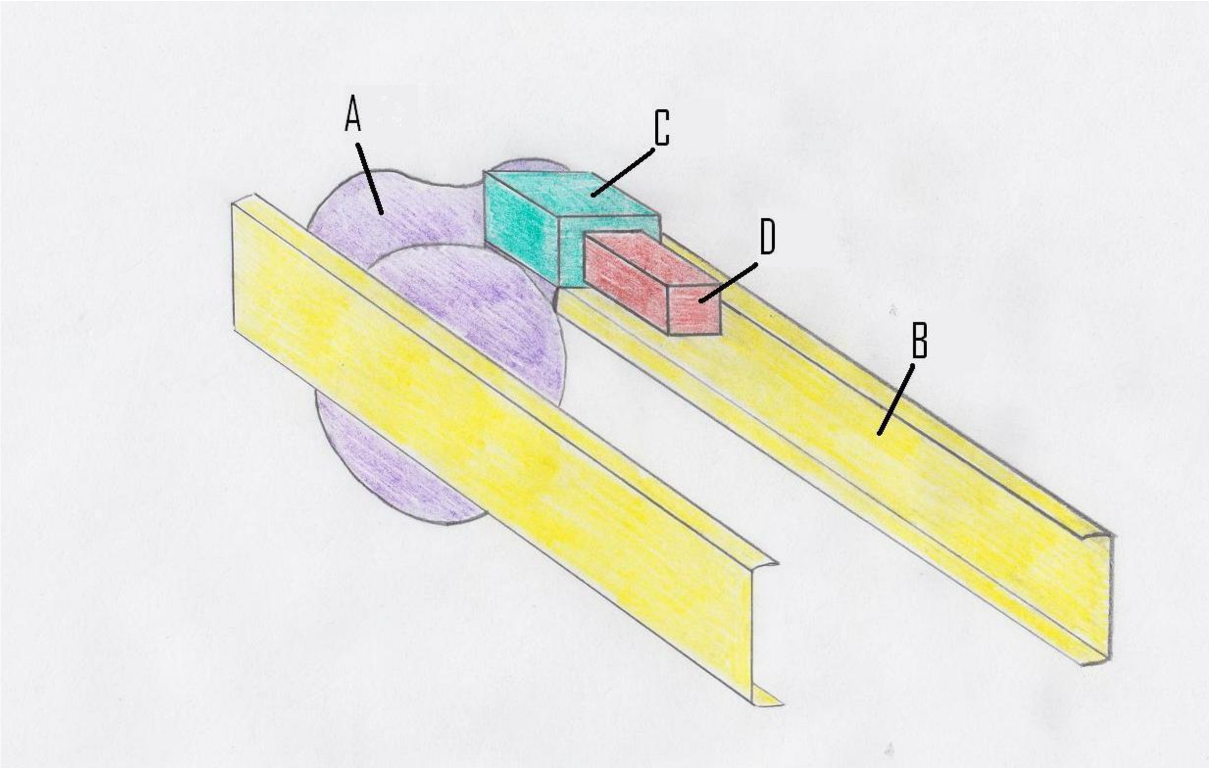

Figure 7.5 - Concept 1. Both pumps are mounted directly on the PTO.

Concept 12 was considered more complex than concept 1 and 2 and was thus rejected. Concept 2 is more compact and concept 1 is easier to both assemble and develop.

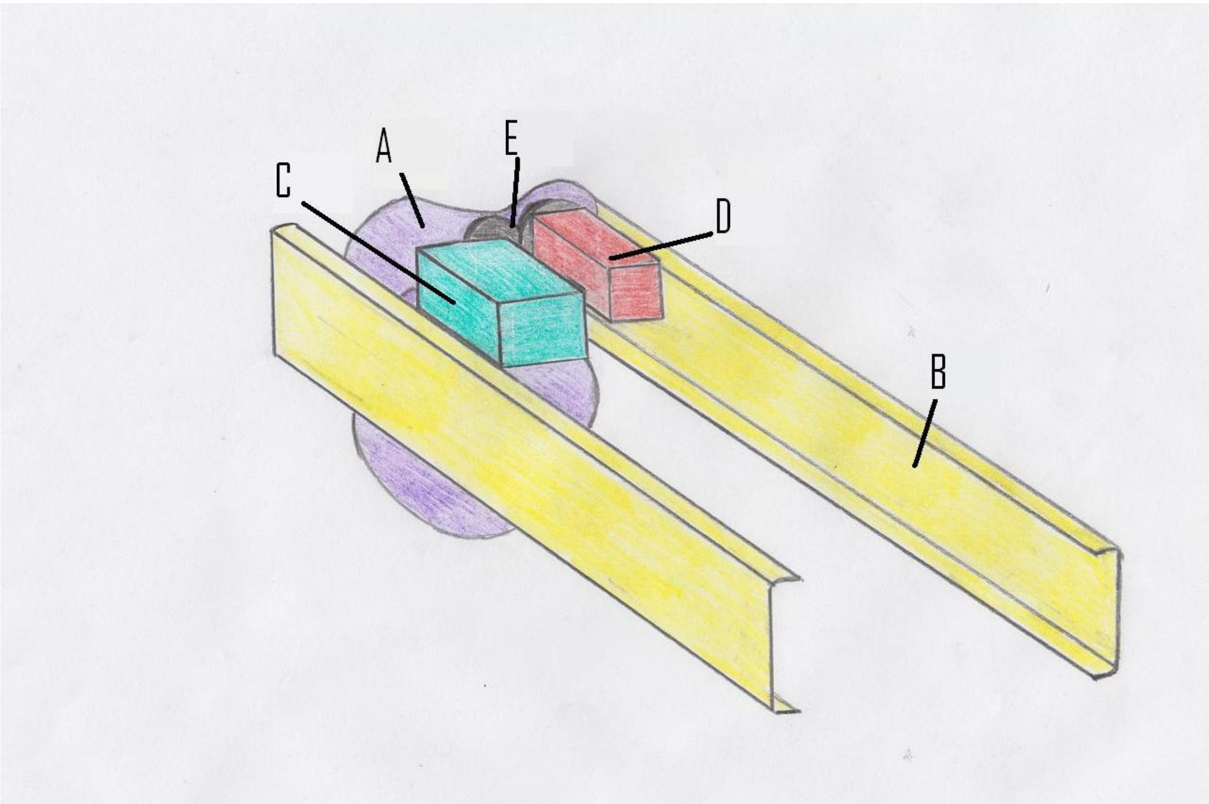

Figure 7.6 - Concept 2. Both pumps are mounted, parallel to each other, on a transmission which in itself is mounted on the PTO.

From the group of concepts using a cardan shaft, concepts 10, 14 and 15 were chosen. Since it was desirable to have a transmission and thus getting a higher ratio output from the PTO, concept 10 was chosen over concept 11 since they are basically the same; with the only difference that concept 10 has a transmission. Concept 10 and 4 are very similar, the difference is the placement of the body builder pump. Concept 4 was rejected since the body builder pump would interfere with the crossmember over the gearbox, while concept 10 has no such interference and thus will be both easier and cheaper to implement.

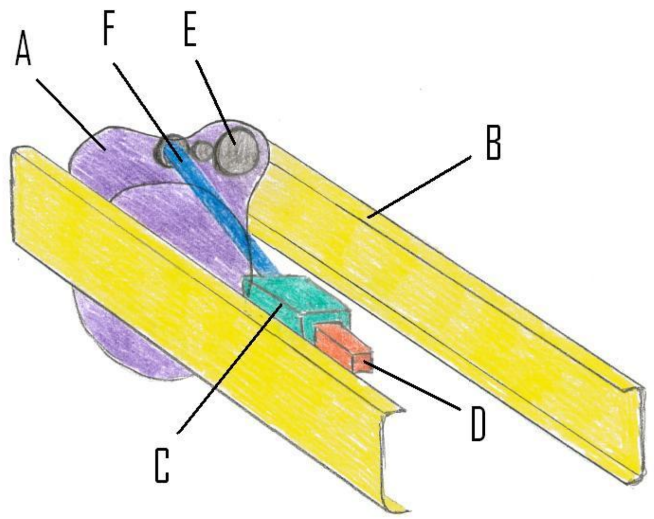

Figure 7.7 - Concept 10, both pumps are placed on the chassis with a transmission connecting pump C to the PTO.

Concept 14 is also similar to concept 10, both have a transmission but the FWD pump is attached to the engine module in concept 14, while it is attached to the chassis in concept 10. Having the pump mounted on the engine module was a highly wanted need, which is why the concept 14 was chosen.

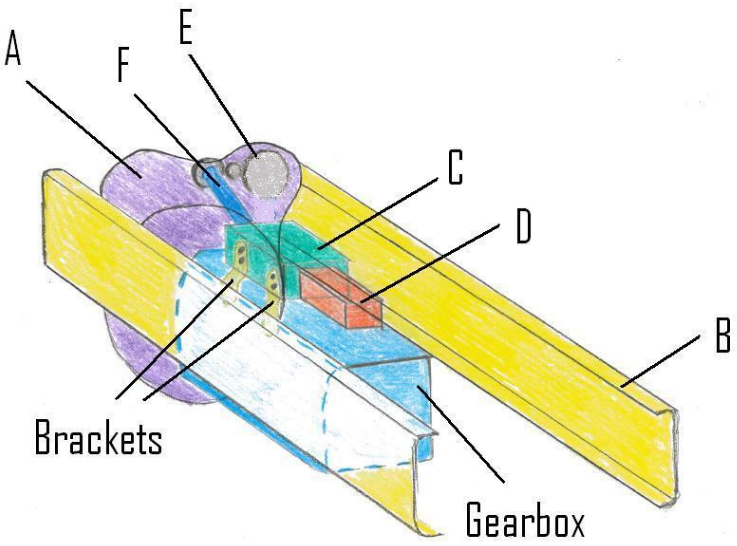

Figure 7.8 - Concept 14, both pumps are mounted on the gearbox with a cardan shaft connecting pump C to a transmission which in itself is mounted on the PTO.

The fifth and final concept to be chosen was concept 15. Here the two different pumps are mounted side by side on the chassis, powered by a transmission which is powered by the help of a cardan shaft connected to the PTO. There is no interference with surrounding components and the installation is easy to service and maintain.

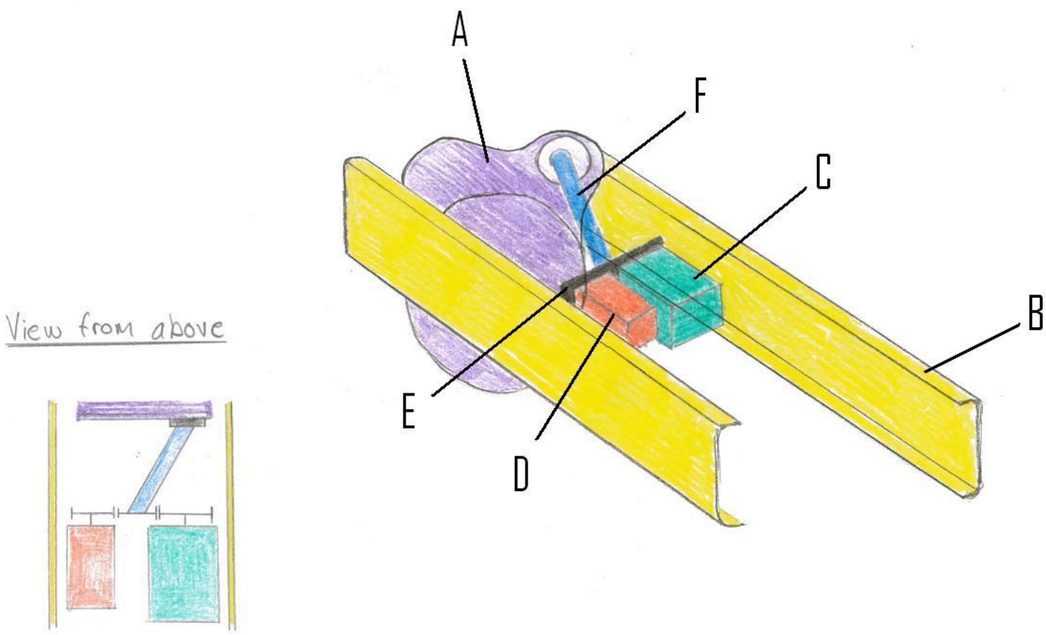

Figure 7.9 - Concept 15. The pumps are mounted beside each other on the chassis with a transmission connecting them. A cardan shaft is connected between the transmission and the PTO.

The chosen concepts therefore are:

- Concept 1 – Pumps directly mounted on the PTO
- Concept 2 – Pumps mounted on a transmission, which is then mounted on the PTO
- Concept 10 – Pumps placed on chassis with a cardan shaft connected to a transmission from the PTO
- Concept 14 - Pumps placed on the gearbox with a cardan shaft connected to a transmission from the PTO
- Concept 15 - Pumps placed on chassis, beside each other and connected to a transmission, with a cardan shaft connected to the PTO

7.4 Reflections over concept 7 and 8

Concept 7 and 8 was omitted due to their lack of ground clearance that would cause problems and the fact that it would take a long time to implement them compared to the others. But the concepts as such are interesting since more coupling independent PTO´s would enable use of more applications, which would be a big advantage.

8 CONCLUSION

This diploma work has resulted in five concepts which we believe would all be possible to implement on a chipper truck. They are still schematic sketches and more development work is needed, especially when it comes to how the transmissions will work and how to construct the mountings for the installation.

- *Concept 1*
  A good solution in terms of minimizing the reconstruction work whiles still a part of the engine module. It is needed to reconstruct the crossmember over the gearbox. A shortcoming is that there is no increase in the output ratio due to the lack of transmission.
- *Concept 2*
  While still mounted on the engine module, it would require reconstruction of the air filter as well as the crossmember. On the other hand, a transmission is used which allows usage at higher speeds and the installation is compact.
- *Concept 10*
  There is no interfering with the surrounding components, making it fast to implement since no reconstruction is needed. As a downside, the pumps are placed on the chassis.
- *Concept 14*
  A very good concept since it is a part of the engine module and does not interfere with any components. A transmission is also used. However, a problem might be to construct the mounting brackets.
- *Concept 15*
  No reconstruction is needed, but the pumps are placed on the chassis, which is a shortcoming. However, the installation makes use of a transmission and the solution is fairly simple.

Some observations have been made throughout the project. First, using a cardan shaft seems inevitable if you do not want to move or reconstruct the crossmember over the gearbox or the air filter. There is simply not enough space for both the FWD pump and the body builder pump to be fitted on the PTO, with or without a transmission. Any of them will interfere with either the crossmember or the air filter. Therefore, there are two types of solutions, either go for a quick solution with a cardan shaft and save time and cost, by not having to reconstruct any components, or reconstruct the affected components and obtain a compact and reliable solution.

Secondly, and this is related to the previous point, it would be highly desirable to have more than one PTO on the flywheel housing. If the hydraulic FWD is implemented, the single PTO will be taken and many trucks have applications which demand a PTO as well. This can be fixed by using a transmission, as done in several of the concepts presented, but this is not the optimal solution.

Lastly, it can be determined that none of the above concepts, or any of the generated ones for that matter, fulfills all the demands given. The chosen concepts all have some weaknesses compared to each other, making it hard to just choose one. As in the case of fulfilling the purpose of the diploma work, we consider it achieved since some of the concepts come very close on fulfilling the demands. The shortcomings are small enough to be dealt with within a reasonable amount of time and cost.

8.1 Recommendations for further work

In order to determine which concept to use, a more detailed view is needed on each concept. Each pump installation should be fully modeled in a CAD environment with all the including parts, like the cardan shaft, transmission and mountings. Since this diploma work present only schematic concepts, more work and research is needed in terms of how to attach the pump installation to the chassis or the engine module. These mountings may not take a lot of time to construct, but they are an important part of the installation.

Developing a transmission should also be a priority since it is an important part of several of the concepts. The transmissions used in this diploma work use gearwheels to transmit the power, but other types may be used as well, such as belt- or chain drive. The main reason for using a transmission is to increase the output ratio from the PTO. At present, the ratio is 1:26 and a desired ratio would be at least 1:6 in order to make full use of the pumps capacity.

In the long term, developing a new type of flywheel housing would be a good way to deal with the lack of space around the existing PTO as well as the lack of the amount of PTO's today. Concept 7 and 8 solved this by adding extra PTO's on the lower part of the housing, but these are not constructed for trucks and need quite a lot of reconstruction. The reduced ground clearance does not suit all trucks though, and therefore this solution may not be the optimal for trucks operating in rough terrain.

REFERENCES

Books

Pugh, S. (1990) *Total Design: integrated methods for successful product engineering*. Wokingham: Addison-Wesley Publishing Company

Ulrich, K.T, Eppinger, S.D. (2012) *Product design and development.* (Fifth edition) New York: McGraw-Hill

Webpages

Lindqvist, M. (2010) Lower fuel consumption and emissions with new timber truck. *Svenska Cellulosa Aktiebolaget.* http://www.sca.com/en/media/news-features/archive/2010/one-more-stack--excellent-for-the-environment. (2012-05-30)

APPENDIX A – Article about the ETT-project

Lower fuel consumption and emissions with new timber truck

After 18 months, the "ETT vehicle" operating on a trial basis in Norrbotten, Sweden, has saved the equivalent of 210,000 kilometres. The truck has the capacity for one stack more than standard timber vehicles and contributes to reducing heavy traffic when transporting SCA's timber.

“To date, the ETT vehicle has demonstrated only positive impacts on the environment,” says Thomas Hedlund, Logistics manager north for timber at SCA Skog, Sweden.

The trial with the ETT vehicle commenced in 2009 and will continue for three years. The project is headed by Skogforsk, which is cooperating with several different partners, of which SCA is included as a land owner.

“The environmental saving is slightly more than 20%. For example, it saved 56,000 litres of diesel and 140 tons of carbon dioxide,” says Thomas Hedlund.

Fewer truck loads

An ETT vehicle weighs 90 tonnes, is 30 metres long and operates between the timber terminal in Överkalix and SCA’s industries in Munksund, a one-way distance of 160 kilometres.

“Using an ETT vehicle, the number of heavy transport in traffic is reduced. In 18 months, an ETT vehicle had the capacity to transport 80,000 cubic metres of timber, with 650 fewer truck loads, compared with a standard timber truck. This means a reduction of 210,000 kilometres, corresponding to about 5.3 times around the globe. In addition, it appears that wear and tear on the roads was reduced since the load is evenly distributed, signifying considerably less pressure on the axle,” says Thomas, and continued:

“There are also several other sub-projects involving the ETT vehicle. One pertains to overtaking – the time it takes to overtake. This project is headed by the Swedish National Road and Transport Research Institute (VTI), which uses cameras to compare all overtaking involving the ETT vehicle with standard timber vehicle as a reference. The objective is to see whether there is any difference in behaviour during overtaking.”

Expanding to more districts

The project group is now hoping that the ETT vehicle will be tested in more districts.

“We recognise a clear environmental impact, so why wait longer to expand the project? It could, for example, be very interesting to test an ETT vehicle between the Töva terminal and SCA’s industries in Sundsvall,” says Thomas. “We are hoping for positive news from the Swedish Road Administration and the Swedish Transport Agency in the future.”

"ett" is the Swedish word for "one".

Source SCA Inside Forest Products 2/2010

Text Misan Lindqvist

Image Per-Anders Sjöquist