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INGENIEURLEISTUNGEN

DEGREE WORK

Fixation of a power-steering pump

Infästning av styr servopump

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EXAMENSARBETE

Infästning av styrservopump

Sammanfattning

Detta 10 poängs examensarbete är den sista delen av min maskinteknik utbildning på 120 poäng. Vilken utförts vid högskolan i Trollhättan/Uddevalla.

Opel har börjat utveckla en ny modell av Astra som planeras vara i produktion mellan åren 2004 och 2005. Bertrandt AG är kontrakterade för att bistå med utvecklingen av denna bil.

Detta examensarbete handlar om att hitta en position för en EHPS-pump (Electric Hydraulic Power Steering). Det är en ny typ av elektrisk driven hydraulisk styrservopump. Först skall en lämplig plats presenteras, sedan skall masscentrum och vikt kalkyleras för pumpen i denna positionen. Detta medger att spänningen kan kalkyleras på gummi kuddarna som skall förhindra vibrationer att sprida sig i systemet. Det är viktigt att det är tryckspänning i gummi kuddarna. Efter detta skall servopumpen fästas i denna positionen med någon typ av fästelement. Arbetet skall leda till en lösning på fästelement mellan servopumpen och hjulhuset. Ritning skall också göras på det valda konceptet.

En CAD modell med omkring liggande delar ligger till grund för att lokalisera en lämplig position för servopumpen. Därefter kommer en QFD-analys utföras för att upprätta en kravspecifikation. Ideerna till fästanordningen är utvecklade genom brainstorming där kravspecifikationen ligger till grund, koncepten är sedan visualiseade i Unigraphics. Servopumpens vikt och masscentrum är kalkylerad med hjälp av Unigraphics. Koncepten är utvärderade med Kepner-Tregoe matrisen och spänningen är enbart kalkylerad på det valda konceptet.

Konceptet B är det fäste som bäst överrensstämmer med kravspecifikationen och är också det fäste som har valts för vidare utveckling (se appendix 4). Detta fäste är lätt att montera i bilen och är även lätt att fästa i servo pumpen med endast två skruvar. För att förenkla lösningen har servopumpen ändrats. Två element har lagts till, det ena på motorkåpan och det andra på pump/ventil enheten (se bild 4 på appendix 7). Detta fäste är lätt att tillverka och är uppbyggd av få delar. Fästet bestar av fyra stål delar, två svetsade till en tredje och det fjärde kopplas samman genom två gummikuddar.

Spänningen i gummikuddarna med denna positionen blir 0.03 N/mm^2 på den bakre och 0.06 N/mm^2 på var och en av de främmre gummikuddarna, de är alltså tryckspänning i alla gummikuddarna och de är även i liknande storhet.

För att göra fästet styvare har ett antal förstyvningar lagts till, se det slutliga utförandet av fästet i appendix 7 och ritning till den samma se appendix 8.

Det har varit svart att uppfylla alla krav och på samma gång ha goda toleranser till omkringliggande delar. Kraven är uppfyllda men toleranserna är fortfarande för små på två ställen.

De två ställena som anses vara kritiska är mellan bakre gummikudden och hjulhuset, och mellan högra sidan på fästet och hjulhuset, där avstånden är 2 mm(se bild 1 på appendix 9).

Projektet är fortfarande i ett tidigt stadium i utvecklingen och många av de omkringliggande delarna kommer fortfarande att ändras och flyttas. Här är några förslag till ändringar som kan göras för att öka toleranserna. Hjulhuset kann ändras under den bakre gummi kudden längs med fästet. Servopumpens motorkåpa kan ändras vid plast örat. Höjden på gummi kuddarna kan minskas.

Nyckelord: Fäste, styrservopump, konceptutveckling.

DEGREE WORK

Fixation of a power-steering pump

Summary

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This 10 credit diploma work is the last part of my education in mechanical engineering, product development 120 credits, at the University of Trollhättan/Uddevalla.

Opel is about to develop a new model of Astra that is planned to be in production between year 2004 and 2005. Bertrandt AG has been contracted to assist in the development of this car.

This diploma work is about finding a location for a new type of power-steering pump (servo pump), an EHPS-pump (Electric Hydraulic Power Steering), a suitable position should be proposed. Then the mass centre and the weight of the servo pump should be calculated, allowing the stress on the rubber mounts to be calculated. The rubber mounts are preventing vibration in the system and it is considered important that the rubber mounts are under compressive stress. After this the servo pump will be fixed in this position. The project should lead to a conclusion for a concept, for the fixation between the power-steering pump and the wheel housing. Manufacturing drawings must also be done for the chosen concept.

A CAD model containing the surrounding parts is used to find a suitable position for the servo pump then a QFD-analysis is used to establish a requirement specification. The ideas for the fixation of the servo pump are developed through brainstorming based upon the requirement specification and visualised in Unigraphics. The weight and the mass centre are found through estimations and calculations, using Unigraphics. The concepts are evaluated using a Kepner-Tregoe matrix and the stress is calculation on the chosen concept only.

Concept B is the solution that best meet the requirement specification and also the one that is chosen for further developing (see appendix 4). It is easy to mount this bracket into the car and also easy to attach the servo pump to the bracket with two screws only. To make the fixing easier, two elements has been added to the servo pump, one on the motor cover and the other one on the pump/valve unit (see picture 4 in appendix 7). This concept is easy to manufacture and contains few components. The bracket is made of four steel parts, two welded to a third and the fourth is connected with the other parts by two rubber mounts.

The stresses that appear in the rubber mounts are 0.03 N/mm^2 on the rear mount and 0.06 N/mm^2 on each of the front rubber mounts which means that all the stresses are compressive and also in similar quantity as each other.

To make the bracket stiffer depressions have been added. The final design of the bracket is shown in appendix 7 and for the manufacturing drawing see appendix 8.

During the assignment several problems occurred whilst trying to achieve the set demands and still maintaining adequate clearance to surrounding parts. Although all the demands have been reached, the clearances between parts are not sufficient in two places.

The two critical places are between the rear rubber mount and the wheel housing and between the right flange on the middle of the bracket and the wheel housing. In these places there are only a clearance of 2 mm(see picture 1 in appendix 9).

This project still is in an early stage of development and many of the surrounding parts will therefore still be changed and moved. Here are some changes that could be made to improve the clearances. The wheel housing could be change under the rear rubber mount and along the underside of the bracket. The motor cover of the servo pump could be changed where the plastic ear has been added. The height of the rubber mounts could also be reduced.

Keywords: Bracket, power-steering pump, servo pump, concept developing.

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Table of contents

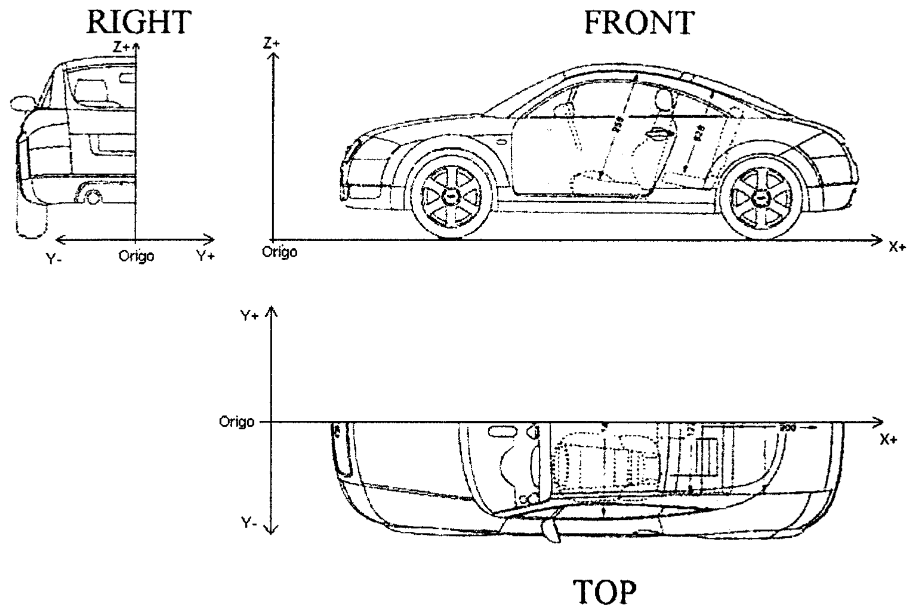
1 Introduction

This 10 credit diploma work is the last part of my education in mechanical engineering, product development 120 credits, at the University of Trollhättan/Uddevalla.

The reader of this report is assumed to be familiar with the product development tools Quality Function Deployment (QFD) and Kepner-Tregoe evaluation matrix.

1.1 Coordinate system

In this chapter the coordinate system briefly will be explained so the reader understand, when this project contains directions and measures referred to the absolute zero point. When developing a new car model within a CAD-system most car companies are working with the left side parts of the car only. The right side parts are mirrored and all measures are referred to a absolute zero point. The location of the coordinate system can been seen in picture 1.1 below.



Picture 1.1 The location of the coordinate system.

1.2 Background

Opel is about to develop a new model of Astra, planned to be in production between year 2004 and 2005. Bertrandt has been contracted to assist in the development of this car.

This new Astra is currently in the alpha stage of development. Alpha is the stage in development when the entire assembly is put together for the first time in the CAD-system. At this stage all parts will be altered to match and fit with each other.

This project is about finding a location for a new type of power-steering pump (servo pump). The mass centre of the servo pump should be calculated so the fixation stresses in the rubber mounts can be estimated (further explanation is given in 4.3).

Most cars have a hydraulic servo pump (HPS, Hydraulic Power Steering) driven from the crankshaft by a rubber belt. The pump is continuously operated and loads the engine the whole time it is running. There is another type of servo pump that operates fully by electricity (EPS, Electric Power Steering). This pump type has to be placed directly on the steering column. Finally, the type of servo pumps that the Astra currently use. An electric-hydraulic servo pump (EHPS, Electric Hydraulic Power Steering). These electric driven servo pumps are only in use when needed, for example at slow speed and large wheel movements. The reason for this is to avoid continuous load on the engine, and therefore reduce loss in engine power but also to achieve a better fuel efficiency. An advantage the EHPS unit has compared to the EPS is that it can be placed anywhere in the car.

1.3 Purpose/goal

The first goal of this project has been to locate a suitable position for the servo pump. The weight and the mass centre of the servo pump have then been calculated, allowing the stress on the rubber mounts that prevent vibration in the system (see chapter 4.3), to be calculated. It is considered important that the rubber mounts are under compressive stress.

The project should lead to a conclusion for a concept for the fixation of the servo pump on the wheel housing. Manufacturing drawings must be made for the chosen concept.

1.4 Delimitation

A study to get ideas will only be made on the present Opel Astra in production.

The requirement specification is to be prepared for development and should contain requirements for this only.

The hydraulic hoses connected to the servo pump are not considered in this project.

Only rough calculation of the servo pump’s weight and mass centre is required. The value of the stress is not that important, only that the stress is compressive in all rubber mounts.

Only static loads will be considered when calculating the stress.

Final design and manufacturing drawings should be prepared for the chosen concept only.

2 Company presentation

Bertrandt AG is a consulting agency in the car industry. With great knowledge and flexible teamwork Bertrandt covers the whole development, from the initial design concept to start of production. Bertrandt develop and produce prototypes in the areas interior, body-in-white, aggregates, engine and chassis as well as transmission systems.

Bertrandt is a well-established company and still expanding. They have offices in five countries, Germany, France, Great Britain, Sweden and Spain. Their locations have been specifically chosen to support the relationships with customers such as Audi, BMW, Ford, Mercedes, Opel and Saab among others. Bertrandt is also able to offer rapid prototyping services from their new test centres, which can visualise the design for the customer.

The office in Rüsselsheim works mostly for Opel but also for Saab, in a supporting role to the office in Trollhättan/Sweden, and they also work with suppliers to these car manufacturers.

2.1 Company history

1974	Founding by Harry Bertrandt.
1978	Entrance into product development in automotive engineering.
1980	Sindelfingen starting expands.

1982-86	New branch offices in Heilbronn, Ingolstadt, Paris and Stuttgart.
1989	New business area of rapid prototyping.
1992-95	New offices in Rüsselsheim, Cologne, Wolfsburg, Munich.
1993	Management buyout.
1995	New business areas: trials, testing, prototype manufacture. New branch office in Leamington Spa.
1996	Appearance on the stock exchange.
1997	Changeover to the new market.
1998	Controlling interest in S.A. EDEFI CAO. New branch office in Dunton, Strasbourg, Stadthagen, Böblingen and Ingolstadt. Controlling interest in Zapadtka + Ritter.
1999	25-year anniversary. New branch office in Guyancourt, Garching, Trollhättan, Ginsheim-Gustavsburg, Nânterre, Holding in Guyancourt, Commencement of building work and laying of the foundation stone for the technology centre in Ehningen.
2000	Bertrandt AG acquires a majority interest in Novel Lahnwerk Engineering S.A. of Spain.
2001	Moving the office in Rüsselsheim to Ginsheim-Gustavsburg.

3 Method

A CAD model containing the surrounding parts is used to find a suitable position for the servo pump.

A QFD-analysis is used to establish a requirement specification.

The ideas for the fixation of the servo pump are developed through brainstorming and visualised in Unigraphics.

The weight and the mass centre are found through estimations and calculations, using Unigraphics.

To see if the rubber mounts are under compressive stress an estimation is made. This estimation is made only with consideration on where the rubber mounts and the mass centre of the servo pump is positioned.

The concepts are evaluated using a Kepner-Tregoe matrix. The result from this matrix is then analysed by the advisor who will help determine which concept to be developed further.

A more careful calculation of the stress is made on the selected concept.

Manufacturing drawings are prepared in Unigraphics.

4 Procedure

4.1 Packaging

The servo pump on the present Astra is located near the steering column, (see pictures 1-3 in appendix 1). However, on the new Astra there is no space available in this location. According to information received from Opel, the new location of the servo pump should be somewhere on the right wheel housing, behind the headlight. It must also be in front of the suspension housing and to the right of the liquid retainer used for the engine cooling (see picture 4 in appendix 1).

On the present Astra design, an air inlet is situated in the position described above (see picture 5 in appendix 1). On the Astra being developed, the air inlet will be moved to the opposite side of the car where the battery presently is. The battery will be moved to the trunk. The reasoning behind these modifications is to get more weight at the rear of the car, in order to get a better weight distribution.

In the front of the car there is a system called ‘pedestrian protection area’. This is an area where no parts should be mounted that might increase the damages on a pedestrian in case of a collision. Therefore the servo pump has to be outside this area (see picture 6 in appendix 1). The pedestrian protection area extends 60 mm below the bonnet.

The servo pump package is pre-assembled outside the car. Then the complete package is mounted as one unit (the servo pump package is described in chapter 4.3). The mounting of the servo pump package is made with a screw-mounting tool, operated by an industrial robot. The position of the mounting tool is visualised in the CAD-model by three grey cylindrical bars. The mounting tool must have enough free space to mount the package. This must be taken into consideration when choosing the location of the package. The position for the tool is shown in picture 7 appendix 1. The front of the tool is intersecting a yellow volume that shows the access area for changing the headlight bulb. This zone can be used when mounting the servo pump package but not used by permanently mounted parts. When choosing this position for the mounting tool a new bracket had to be made for the rear left bar (see picture 8-9 in appendix 1). This because of the bar intersecting the suspension housing so the bar had to be moved in the z-direction (coordinate system is explained in chapter 1.1).

The packaging of the servo pump should not intersect with other parts. Clearances to surrounding parts have not yet been determined, because the project is still in an early stage of development. Many of the surrounding parts have been changed and moved during this project, as have the position of the servo pump and the shape of the liquid retainer. The position and shape of the pump, which has been used in this project, can be seen in pictures 10-12 in appendix 1.

4.2 QFD and Requirement specification

When the packaging of the servo pump was completed a requirement specification for the fixation was prepared, using a limited QFD- analysis (see appendix 2). The first step in the analysis was to identify the customers demands on the fixation. The demands were partly specified from the customers and partly taken from a brainstorming. The importance weighting, raging from 1 to five where 1 is less important and 5 is most important, was based on the limited information provided by the customer. The design requirement specification was developed in collaboration with the advisor. The connections (strong =9, medium =3 and weak =1) between the customers demands and the design requirement were established after careful consideration.

The design requirements from the QFD-analysis were now transferred to a requirement specification where the targets were set (see appendix 3). These targets were also developed in collaboration with the advisor and based on the information given by the customer. Some of the design requirements have no targets in this early stage in the development but this does not mean that they are unimportant and that is why they are mentioned in the requirement specification.

4.3 Development

According to information received from Opel the fixation of the servo pump should be designed as follows. A bracket is screwed on to the wheel housing at three places. The screws are welded from the underside of the wheel housing. On top of the bracket a second bracket is used for fixing the servo pump. Between these two brackets a number of rubber elements are used to reduce vibration. The servo pump with brackets and rubber elements will be mounted into the car as one complete unit.

If considered necessary the servo pump can be modified a little bit so it is easier to mount the pump to the bracket. For example, by introducing plastic ears on the motor cover.

The QFD-analysis and the requirement specification would be considered when developing the concepts.

A number of different concepts were considered. After discussion with the advisor, a few of them were selected for closer study and evaluation. These concepts are shown in appendix 4 and described in section 4.3.1.

4.3.1 Concept description

Concept A: This bracket consists of three parts. The bigger part are made of a lot of different parts, bended and welded together to reach the final shape. Between these three parts four rubber mounts are located. The servo pump is attached to the bracket with three screws and to facilitate the fixing between the servo pump and the bracket two parts are added, one on the motor cover and one on the liquid retainer (see concept A in appendix 4).

Concept B: This concept consists of few components. The bracket is made of four steel parts. Two smaller parts welded to a bigger third part and the fourth part is connected with the other parts by two rubber mounts. The servo pump is attached to the bracket with only two screws. To manage this, two parts has been added. One part on the pump/valve unit and one part on the motor cover. Between the added part on the motor cover and the bracket another rubber mount is located (see concept B appendix 4).

Concept C: The servo pump is attached to the bracket with two screws and one weld spot. Two parts are welded together. The third part is welded to the servo pump and between those parts a rubber mount is placed. Two plastic parts are added on the motor cover to ease the fixation between the servo pump and bracket. Between these two plastic parts on the motor cover and the bracket two more rubber mounts are located (see concept C in appendix 4).

Concept D: This concept consists of four steel components and one plastic component. The servo pump is attached to the bracket with one weld spot and with a plastic ear on the motor cover. Two smaller parts are welded to a bigger third, the fourth and fifth are connected to the servo pump, both are welded to the pump. Three rubber mounts are located between the parts connected to the servo pump and the rest of the bracket (see concept D in appendix 4).

Concept E: This concept consists of five steel components. The servo pump is attached to the bracket with three screws. Two smaller parts are welded to a third, the fourth and fifth are connected to the servo pump. Three plastic parts are added, one on the liquid retainer and two on the motor cover. Three rubber mounts are located between the parts connected to the servo pump and the rest of the bracket (see concept E in appendix 4).

4.4 *Calculation of mass centre*

When calculating the mass centre of the servo pump the first step is to calculate the weight and the mass centre of the different components of the servo pump. The servo pump components are an electric motor, motor cover, pump/valve unit, liquid retainer, liquid and two contacts (see pictures 1-2 in appendix 5). The liquid retainer has a volume of 0.8 litre, and it has been estimated that it contains 0.6-litre oil. The components, pump/valve unit and contact are approximated as solid bodies to simplify the calculation.

The motor and the pump/valve unit are mainly made of steel with a density of 7.8 kg/dm^3. The cover, contacts and liquid retainer are made of polyamide plastic 6.6 with 30%

fibreglass. The polyamide has a density of 1.1 kg/dm^3 and the fibreglass has a density of 2.5 kg/dm^3. This gives the fibreglass-reinforced polyamide a density of 1.52 kg/dm^3. The liquid in the retainer is hydraulic oil with a density of 0.8 kg/dm^3.

The calculation of weight and mass centre of the servo pump is made in Unigraphics. The result is present in chapter 5.3.

4.5 Evaluation of concepts

The concepts are evaluated so the most appropriate concept is chosen for further development. The choice is based on the result of the Kepner-Tregoe matrix and the advisor's opinion.

4.5.1 Kepner-Tregoe evaluation matrix

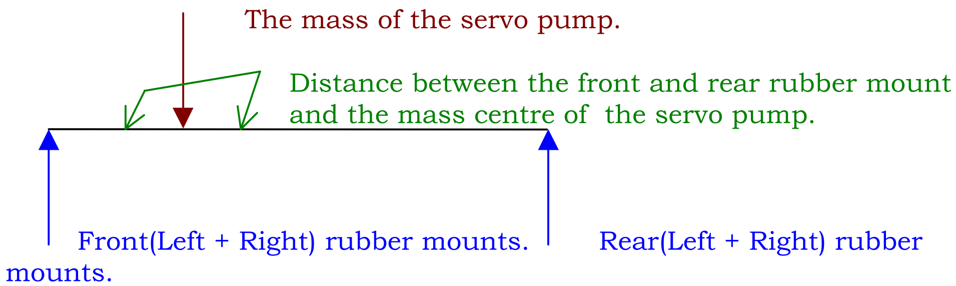
In the Kepner-Tregoe matrix (see appendix 6) the concepts are evaluated regarding how good they meet the targets from the requirement specification (see appendix 3). The weighting in the Kepner-Tregoe matrix was made using the technical importance values from the QFD-analysis. The values were divided with the total sum of the technical importance value. This value is used in the Kepner-Tregoe matrix multiplied with a 5 graded scale that shows how good the concepts meets the criteria taken from the requirement specification. Here means 1 that it does not comply with the criteria and 5 means that it complies very good to the criteria.

4.6 Calculation of stresses in rubber mounts

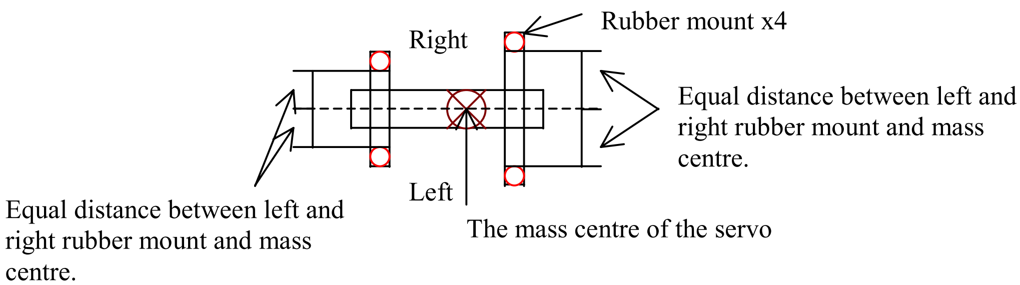
The rubber mounts are used to prevent the stress being transferred from the servo pump to the wheel housing and also to prevent vibrations from the wheel housing to be transferred to the servo pump. They also reduce stresses caused by misalignments. The dimension of the rubber elements is 20 mm in height and also in diameter.

Before calculating the stress the load on each rubber mount has to be calculated. When calculating the load two equations are needed, the force equilibrium equation and the moment equilibrium equation. To make the calculation easier this problem is calculated as a 2D beam on two supports, see picture 4.1.

When using these two equations, the result received is the force on the front and rear rubber mounts. Because of symmetry in relation to mass centre the left and right rubber mount will be equally loaded, see picture 4.2.



Picture 4.1 2D-load problem seen from the side.



Picture 4.2 Simplified picture showing the symmetry between left and right rubber mount and mass centre of the servo pump seen from above.

After the forces has been calculated on each of the rubber mounts the stresses are calculated with the equation "definition of stress" or in letters $\sigma = F/A$ where F is the force, A is the area and σ is the stress.

5 Result and Analysis

5.1 QFD

The design requirement that got the highest value in the QFD-analysis was "costs" with a value of 98. This is not a surprise, because most things are related to costs, for example the cost will be lower if it is easy to manufacture. Since it is very early in the development of the car and the concept certainly will change shape many times more, the cost is not considered to be of that great importance at this stage.

The second highest value 97 was “ease of mounting the power-steering package into the car, fully automatic”. Fully automatic means that a robot can mount it completely. The robot will pick up the package from a rack and then mount it in the car straight from above. This means that the servo pump package need to have free space during the mounting and also that it is easy to mount.

After these, two other design requirement follow with almost the same value. These are “ease of mounting the power-steering pump to the bracket” and “ease of mounting the power-steering package into the car, partly automatic” with values of 59 and 57 respectively. Ease of mounting the power-steering pump to the bracket got the value 59 since it is important that it is easy to manufacture and mount. Ease of mounting the power-steering package into the car, partly automatic has got a value lower than fully automatic. The reason for this is that during partly automatic mounting the pump package is put in place in the car manually and then a robot automatically screws it to the wheel housing. Compared to fully automatic where it is both placed in the car and screwed automatically by a robot, otherwise the same customer demands has to be considered.

After these there is a gap to “vibration behaviour”, “few components” and “weight” with values of 46, 45 and 42 respectively. Vibration behaviour has got a pretty high value since it is important that the rubber mounts for the servo pump to have compressive stresses. To achieve this the rubber mounts has to be placed as far away from the mass centre as possible. When placing the rubber mounts the customer demands “easy to manufacture”, “hold the power-steering pump” and “low influence on surrounding parts” has to be considered carefully. “Few components” has got a value of 45. A solution with few parts is often more reliable and cheaper than one with many parts. However the shape can become so complex that it will be a drawback. “Weight” has got a value of 42. The weight influences on how reliable it is and how easy it is to manufacture and mount.

The design requirement with the lowest value is “corrosion resistance” with a value of 27. The corrosion resistance has no influence on the ease of mounting, manufacturing or the other customer demands and it is also easy and rather cheap to protect against corrosion with some kind of coating or paint. (See QFD-analysis appendix 2).

5.2 Kepner-Tregoe matrix

The Kepner-Tregoe matrix gives a numerical value on how well the concepts comply with the requirements. In this matrix, 5 mean very good compliance and 1 means that it does not comply with the criteria. The stresses have not yet been calculated. However, in the matrix they have been estimated to be either acting in compression or tension. The stress will be calculated for the chosen concept only. The Kepner-Tregoe matrix can be found in appendix 6 and the concepts in appendix 4.

Concept A has got a value of 2.96 of maximum 5.00. This is acceptable compliance, according the scale in appendix 6. This concept can not be mounted fully automatic because it is so wide it will interfere with the fender of the car. However, partly automatic is working because, then it will be placed in the car manually which means that you can put the package in place by tilting. The servo pump is easy to attach to the bracket with three screws. The vibration behaviour is very good because of the four rubber mounts and its rather long distances from the mass centre. The cost has poor compliance because of the complexity of the shape. The bracket is hard to manufacture and contains a lot of different parts. When manufacture this bracket, there will be a lot of material waste because of its complexity in shape. There will also be a lot of operations that will increase the manufacturing cost and time.

Concept B has got a value of 4.61 which is almost very good compliance, according the scale in appendix 6. It is easy to mount this bracket fully automatic and also partly automatic because of its narrow shape. The servo pump is easy to attach to the bracket with two screws and the vibration behaviour is good since two of the three rubber mounts are located where the highest force will appear, (the highest force will appear where the mass centre is). The force from the weight of the servo pump is almost identical on each rubber mount. This concept is easy to manufacture and contains few components. The bracket is made of four steel parts. Two parts welded to a third part and the fourth part is connected with the other parts by two rubber mounts.

Concept C has got a value of 4.28 which is good compliance, according the scale in appendix 6. It is easy to mount this bracket fully automatic and also partly automatic because of its narrow shape. The servo pump is easy to attach to the bracket with two screws and one weld spot.

The vibration behaviour is poor since only one of the rubber mounts is located where the mass centre is and all rubber mounts are positioned to the right of the mass centre which causes tension loads in some of the rubber mounts. This concept is easy to manufacture and contains only three steel components. Two parts are welded together and the third part is welded to the servo pump and between those parts a rubber mount is placed.

Concept D has got a value of 4.19 which is good compliance, according the scale in appendix 6. It is easy to mount this bracket fully automatic and also partly automatic because of its narrow shape. The servo pump is easy to attach to the bracket with one weld spot and with a plastic ear on the motor cover. The vibration behaviour is poor since all rubber mounts are positioned to the right of the mass centre, which causes tension loads in some of the rubber mounts. The concept is easy to manufacture and contains four steel components and one plastic component. Two parts are welded to a third, the fourth and fifth are connected to the servo pump, both are welded to the pump. Three rubber mounts are located between the parts connected to the servo pump and the rest of the bracket.

Concept E has got a value of 4.30 which is good compliance, according the scale in appendix 6. It is easy to mount this bracket fully automatic and also partly automatic because of its narrow shape. The servo pump is easy to attach to the bracket with three screws. The vibration behaviour is good because of the placement of the rubber mounts, but it is only one rubber mount where the biggest force will appear from the weight of the servo pump. This concept is easy to manufacture and contains five steel components. Two parts are welded to a third, the fourth and fifth are connected to the servo pump. Three rubber mounts are located between the parts connected to the servo pump and the rest of the bracket.

Concept B has got the highest value, 4.60 of maximum 5.00 and is chosen for further development. The choice is based on the result of the Kepner-Tregoe matrix and also supported by the advisor.

5.3 Mass centre

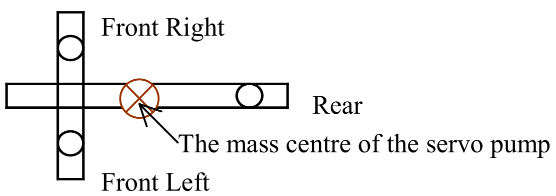
The calculation of the weight and the mass centre of the servo pump is made in Unigraphics (also explained in section 4.4). The distances are measured from the mass centre to the absolute zero point. The mass centre can be seen in picture 3 in appendix 5 and the absolute zero point is explained in section 1.1. The weight of the entire servo pump, filled with 0.6-litre hydraulic oil, is 4.7 kilogram.

The coordinates of the mass centre are:

- X=1519
- Y= 582
- Z= 692

5.4 Stress calculation

Calculation of force and stress in the rubber mounts on the final bracket design using the data received from Unigraphics. In picture 5.1 a simplified drawing of the final design can been seen. This picture also shows that the left and the right front rubber mounts are symmetrically placed in relation to the mass centre of the servo pump.



Picture 5.1 Simplified picture of the final design seen from above.

The following data are collected from an investigation, explained in section 5.3, made in Unigraphics.

The complete servo pump filled with 0.6 litre hydraulic oil.

weight	4718 Gram

mass	46 Newton

- Distance from the absolute zero point to the centre of mass.

XC	1520 mm
YC	583 mm
ZC	693 mm

Final design

- Distance from the absolute zero point to the support points of the rubber mounts.

	Front left	Front right
XC	1474 mm	1474 mm
YC	547 mm	623 mm
ZC	603 mm	603 mm

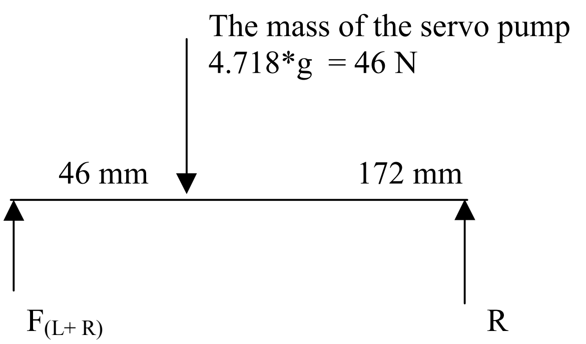
	Rear
XC	1692 mm
YC	585 mm
ZC	694 mm

- Distance from the mass centre of the servo pump to the support point of the rubber mount.

	Front left	Front right
XC	46 mm	46 mm
YC	35 mm	-41 mm
ZC	90 mm	90 mm

	Rear
XC	-172 mm
YC	-2,7 mm
ZC	-1,6 mm

A calculation using the data above gives the stresses:



$F_{(L+R)} + R = 46$ Force equilibrium equation

$46 * 46 = R * (46+172)$ Moment equilibrium equation, calculated around F

$\Rightarrow$

$R = 9.71$ N
$F_{(L+R)} = 36.29 \text{ N} \Rightarrow F_L = F_R = 36.29/2 = 18.15$ N

The force on the rear rubber mount is 9.71 Newton and the force on the front left and the front right is 18.15 Newton respectively.

Stress calculation using the definition of stress, $\sigma = F/A$
The diameter of the rubber mount is 20 mm.

$\sigma_R = 9.71/(\pi*20^2/4) = 0.0309 \text{ N/mm}^2$
$\sigma_{FL} = \sigma_{FR} = 18.15/(\pi*20^2/4) = 0.0578 \text{ N/mm}^2$

The stress on the rear rubber mount is 0.03 N/mm^2 and the stress on the front left and the front right is 0.06 N/mm^2 respectively. The stress is compressive and in similar quantity to each other. To reduce the stress even more a rubber mount with a bigger diameter can be used.

6 Conclusion

Concept B is the concept that best meets the requirement specification (see appendix 4).

It is easy to mount this bracket fully automatic and also partly automatic because of its narrow shape. The servo pump is easy to attach to the bracket with two screws. To make the fixing easier, two elements has been added to the servo pump, one on the motor cover and one on the pump/valve unit (see picture 4 in appendix 7).

The stress that appear in the rubber mounts are 0.03 N/mm^2 on the rear rubber mount and 0.06 N/mm^2 on each of the front rubber mounts which means that all the stresses are compressive and also in similar quantity as each other.

The concept contains few components and is easy to manufacture.

Depressions have been added to make the bracket stiffer. The final design of the bracket is shown in appendix 7 and for the manufacturing drawing see appendix 8. The drawing is a simplified drawing, only containing the important dimensions, such as distances between fixing points.

To reduce weight, material can be removed as holes or slots in the areas shown in picture 1 appendix 9.

There have been some problems fulfilling all demands and also to get adequate clearance to the surrounding parts. The demands have been reached but the clearances are still too small in two places, 2 mm only.

The two critical places are between the rear rubber mount and the wheel housing and between the flange on the middle of the bracket and the wheel housing (see picture 1 in appendix 10).

As previously mentioned this project is still in an early stage of development. Many of the surrounding parts will therefore still be changed and moved.

Some changes that can be made to achieve better clearances are:

- The wheel housing could be changed under the rear rubber mount and along the underside of the bracket.
- The motor cover of the servo pump could also be changed where the plastic ear has been added.
- The height of the rubber mounts could be reduced.

7 References

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