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Mechanical and Manufacturing Engineering

Engineering Design

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Table of Contents

1	Introduction	iv
1.1	Aims	iv
2	Literature Review	iv
2.1	Wet sump systems	iv
2.2	Dry sump system	v
3	Problem identification	v
3.1	Problem statement	v
3.2	Quality function deployment (QFD)	vi
4	Design Specification	vii
4.1	Dry Sump Pan	vii
4.2	Oil Pickup Adaptor	vii
5	Existing Designs.....	viii
6	Concept Designs.....	ix
6.1	Design Concept 1	x
6.2	Design Concept 2	xvi
6.3	Design Concept 3	xviii
7	Design Feature Rating	xxi
8	Final Design.....	xxiii
8.1	Technical drawing	xxiv
9	Evaluation Framework.....	xxiv
10	conclusion.....	xxv
11	References	xxv

1 Introduction

A wet sump system is used in cars that are commonly used for day-to-day commuting. Although wet sump systems are common, they usually tend to struggle in high performance applications such as motor racing due to starving the engine of oil. In this case a dry sump system is used as it tends to perform better in high performances applications. This is because a dry sump system ensures that an engine is never starved of oil. This report will look at the processes that take place when designing a dry sump system in accordance with customer specifications.

1.1 Aims

The aim of this design project is to design a dry sump system that has the specifications that a shown below:

Customer requirement	Importance rating (1-10)
The product should be lightweight	8
The product should be easy to install (initial set-up)	5
In the event of a roll-over, the engine should not be flooded with lubricant	9
The product should be low cost	7
The product should allow easy/fast access for servicing/maintenance	7

Figure 1: Image showing the customer requirements and their importance.

The above image of the specifications that the customer requires influences our design as the customer satisfaction and needs are quite important as this will influence their need and use of the product. We can see from Figure.1 that the most important requirement is for the engine to not be flooded in the event of a roll over meaning that when designing the dry sump system this should be most important factor.

2 Literature Review

2.1 Wet sump systems

The most popular technique for oiling engines is a wet sump system. It employs the oil pan, also known as the lower portion of the engine crankcase, as the oil reservoir. After lubricating the engine and sucking oil from the pan, gravity causes the oil to just drain back down. While this straightforward design works well for daily driving, it is limited in high-performance scenarios.

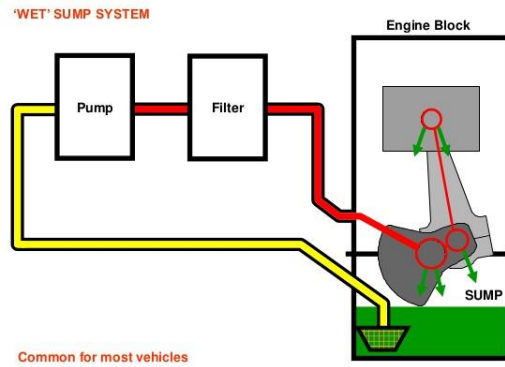


Figure 2 : Image showing how a wet sump system function.

2.2 Dry sump system

With a dry sump arrangement, the conventional oil pan under the engine is removed. Rather, it stores oil in a different reservoir (Deshpande, Agarkar and Mahajan,). This makes it possible to run two pumps: one to pressurize the oil for circulation, and the other to scavenge it from the engine crankcase (F. Corzo, Ramajo and Nigro, 2018). As a result, oil doesn't starve while driving at high speeds and engine reliability is increased.

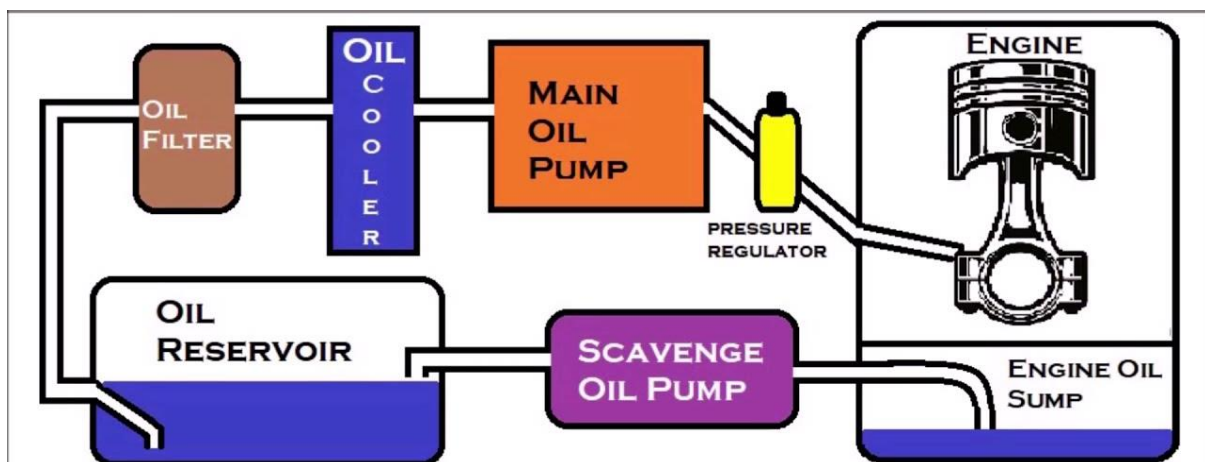


Figure 3: Image showing how a dry sump system function.

3 Problem identification

3.1 Problem statement

G-forces can result in oil starvation in high-performance applications, making a traditional wet sump lubrication problematic. To address this a design of a dry sump system that has an oil pickup adaptor and pan, is the main goal of this research. This will be done alongside with the customer requirements which are:

- Should be light weight.
- Should be easy to install.
- Engine should not be flooded with oil in the case of the car rolling over.
- Should be low cost.
- Assessable for maintenance.

This will ensure that the customer will be able to achieve their targets for their high-performance vehicle.

3.2 Quality function deployment (QFD)

A QFD is a systematic process by which manufacturers generate engineering specifications and suitable production methods from customer requirements. This is done by Making a strategy to fulfil those demands. This means that by using QFD manufactures can make sure that their products can be manufactured efficiently, and they can design products that satisfy the needs of their customers.

Below is and image showing a QFD drafted to help in building engineering specifications and suitable production methods:

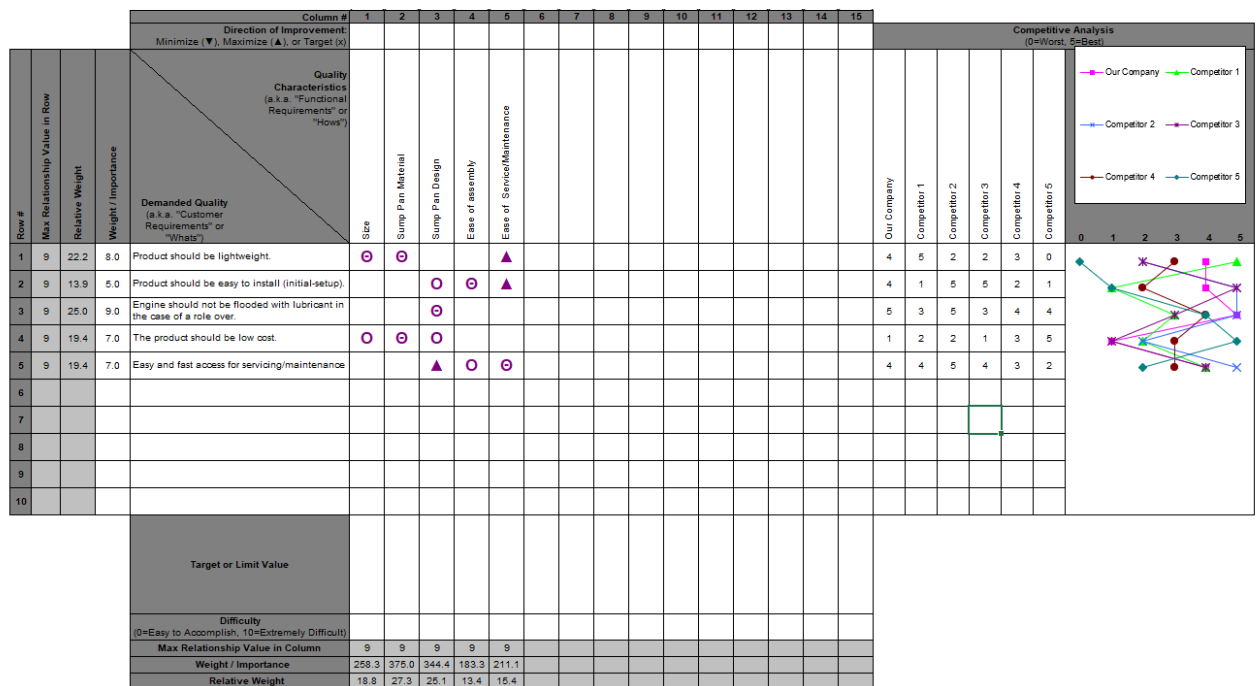


Figure 4: QFD for dry sump system.

The above QFD shows that to achieve customer satisfaction the design of the sump pan must meet the following requirements:

1. Minimizing the number of steps needed to install the sump pan – This can be done by developing a good, detailed step by step guide which requires minimal tools to install the sump pan.
2. Reduction of sump pan design complexity – This can be achieved by designing a simple and modular sump pan that is easy to install and disassemble. The design should also be matching the mountings for the old sump pan.
3. Anti – slosh baffle – The anti – slosh baffle should maximise efficiency by having baffles that are proven to minimise oil movement during rollovers to reduce the chances of starving the engine of oil.
4. Optimized material selection – this can be achieved by using a material that is lightweight and high – quality yet also cost effective for the sump pan and the oil pick up pipe.
5. Service/maintenance accessibility – maximising the accessibility to the sump pan bolts and drain plug for maintenance is key as it will insure easy and fast servicing and repairs when needed.

4 Design Specification

4.1 Dry Sump Pan

- Material: to reduce cost and weight the use of a lightweight aluminium alloy will help us achieve the requirements set by the customer.
- Baffling: to help optimise the control of the oil during manoeuvres and in the case of a roll over, the configuration of the oil baffle will be two baffles across the width and a baffle plate.
- Drain plug: the drain plug hole will be a 15.5mm hole for a m14 thread. The drain plug hole will be located at the back bottom of the oil sump.
- Mounting points: the oil sup should fit on the crank case that the old oil sum has come off which will mean that installation and disassembly will be easy.

4.2 Oil Pickup Adaptor

- Material: a durable aluminium alloy to balance between strength and cost.
- Compatibility: to have a design that will integrate well with the existing engine block.
- Pick up point: will have a pickup point that is located in a position where it can pick up oil constantly and will not run dry and suck up air into the system.

- Filter mounting: flanged mounting.

5 Existing Designs

A dry sump oil pan has already been designed before and this section of this report will look at the existing sump pans on the market and their features to help with ideas and seeing how to best design the customers dry sump pan and oil pick up pipe.

1.



Figure 5: Existing dry sump pan 1.

From this design we get to see mainly the baffling system on the dry sump pan. This baffling system has slashed holes in it to allow the oil dripping back from the engine to go to the bottom of the sump pan, but this also allows restriction in the case of the vehicle overturning restricting the oil from flooding the engine. This baffle is secured to the oil pan by bolting it down. This design doesn't have an oil pick up pipe but has return lines at the bottom of the pan.

2.



Figure 6: Existing dry sump pan 2.

From this oil pan we see that this design does not have a baffle system meaning that if the car were to overturn the engine would be flooded. This design also uses the return lines to the pump which are located at the bottom of the sump-pan.

3.



Figure 7: Existing dry sump pan 3.

This dry sump pan design is like Figure 4 in terms of the baffling system. The main difference is that this baffling system has no holes to allow the oil to go to the bottom of the pan. It is more designed to let the oil sit on top of the baffle, but allowing it to overflow to the bottom of the pan when there is too much oil on the baffle. It also has a pickup pipe to pick up the oil from the pan to the oil pump. This oil pickup pipe will pick up oil from the top of the baffle.

6 Concept Designs

This section of the report will show the design concepts that have been developed to solve the problem that has been identified above. It will show the isometric, top, front, right, and bottom views of the dry sump pan, its baffle design and pick-up pipe. These designs have been modelled and produced using CAD software.

6.1 Design Concept 1

Dry sumps pan.

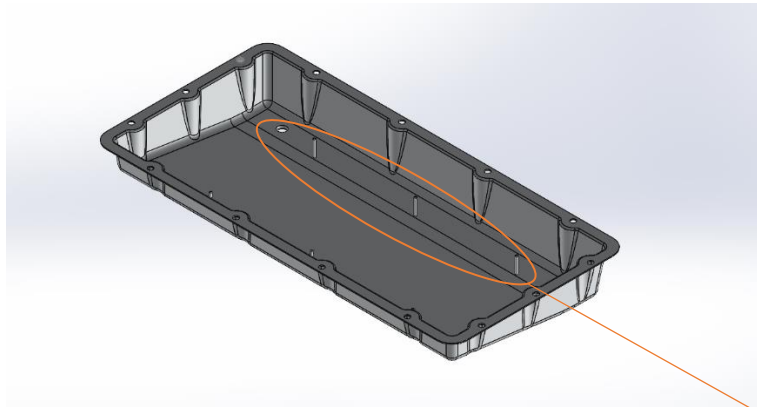
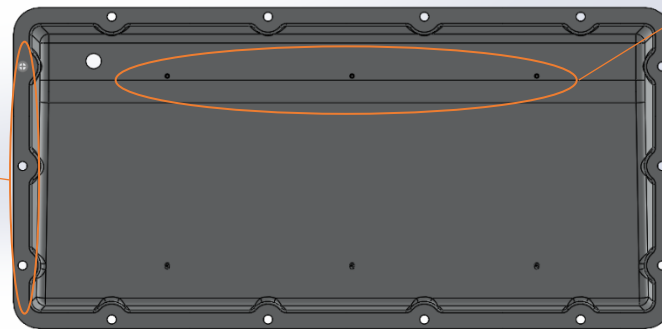


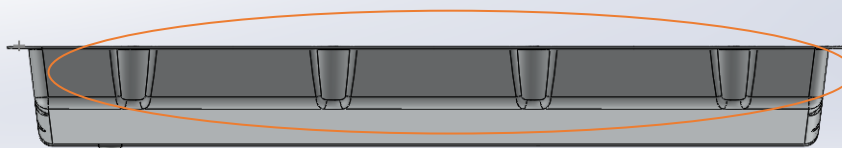
Figure 8: Isometric view of dry sump pan.



Holes to allow dry sump to be bolted to crankcase.

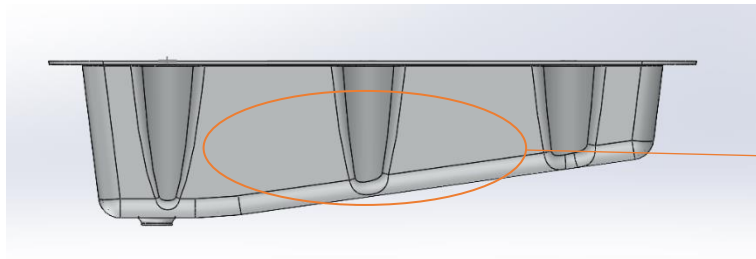
Raised up screw holes for baffle plate to be secured to.

Figure 9: Top view of dry sump pan.



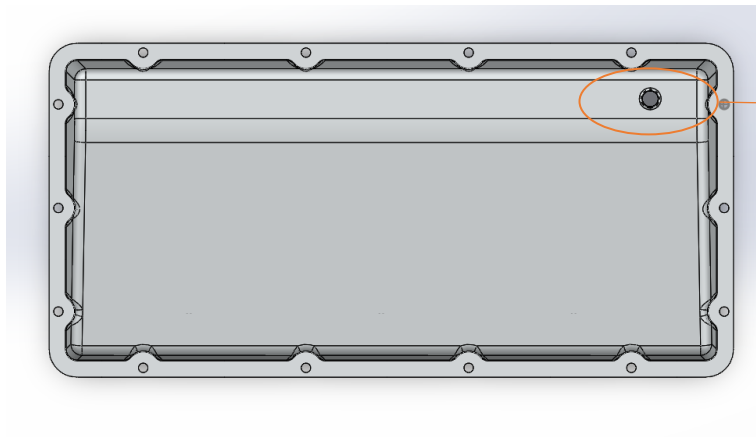
Ingresses to allow socket wrench to fit for easy removal of sump bolts.

Figure 10: Front view of dry sump pan.



The dry sump is made out of aluminium as it is strong and lightweight.

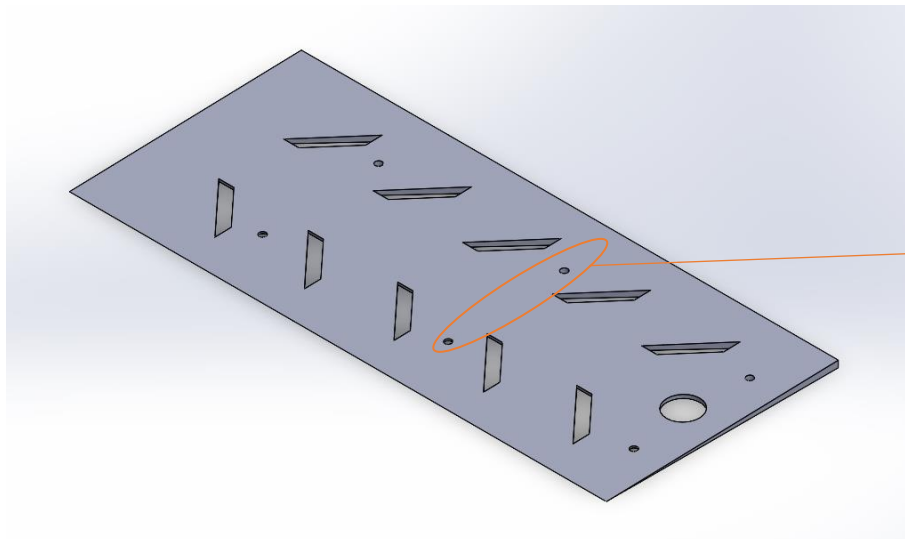
Figure 11: Right view of dry sump pan.



Sump drains plug for easy maintenance of the dry-sump system.

Figure 12: Bottom view of dry sump pan.

Baffle



Holes to allow baffle to be fastened to the dry sump pan.

Figure 13: Isometric view of baffle.

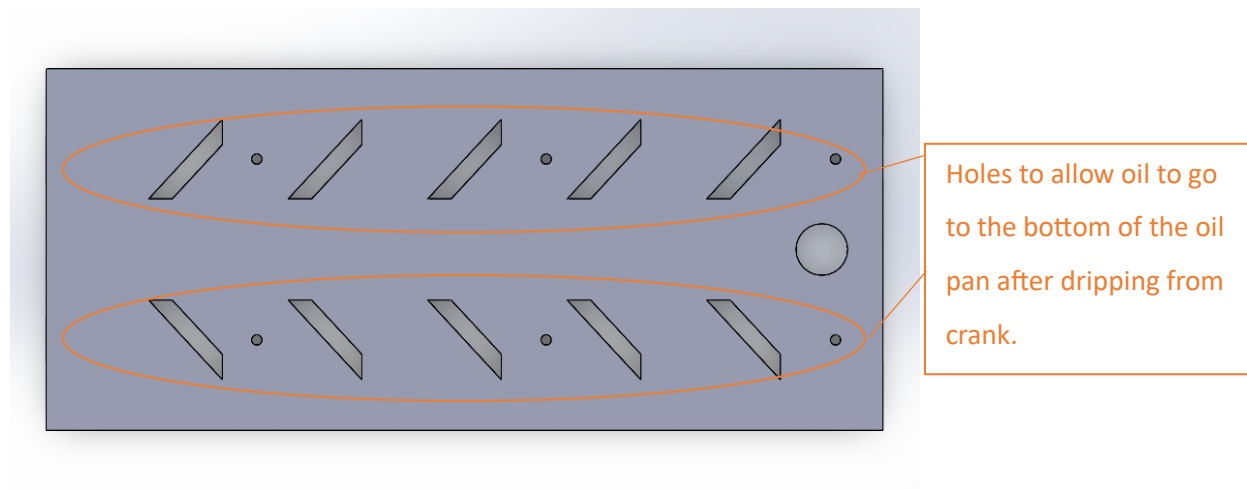


Figure 14: Top view of baffle.

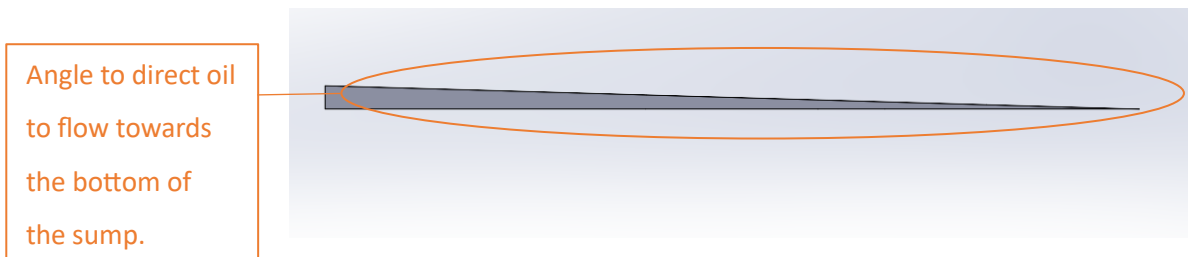


Figure 15: Right view of baffle.

Hole for pick-up
pipe to go through
the pick-up point
at the bottom of
sump-pan.

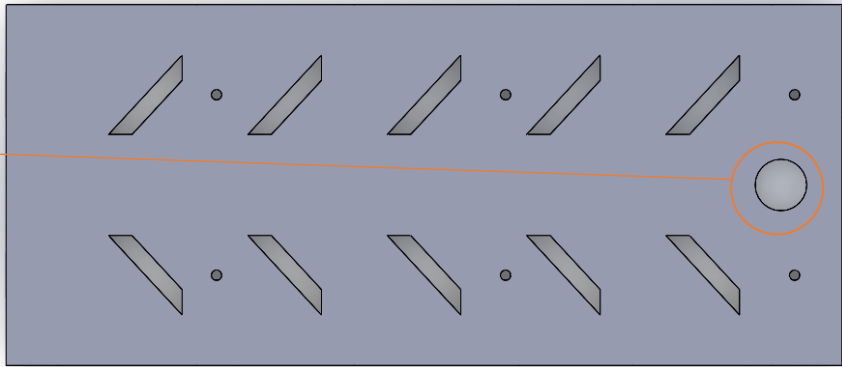
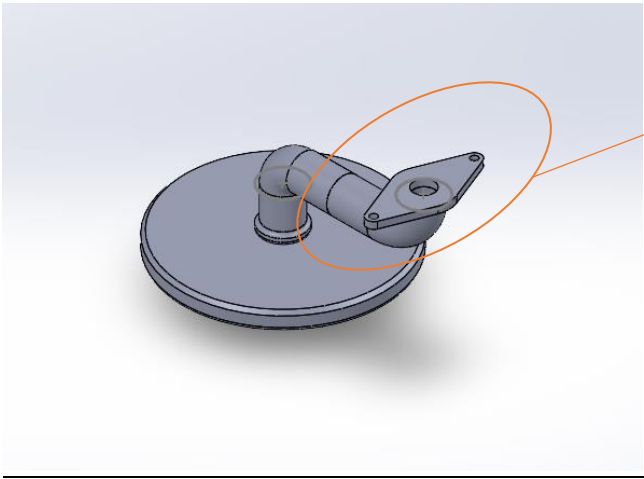


Figure 16: Bottom view of baffle.

Pick-up pipe



Flange to match the
connection on top half
of engine.

Figure 17: Isometric view of oil pick-up pipe.

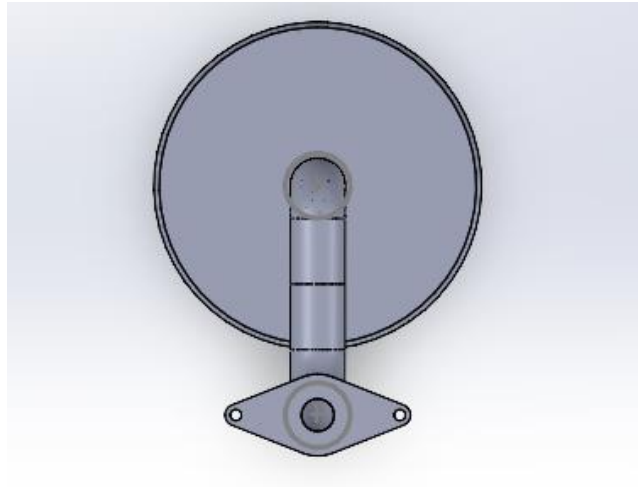


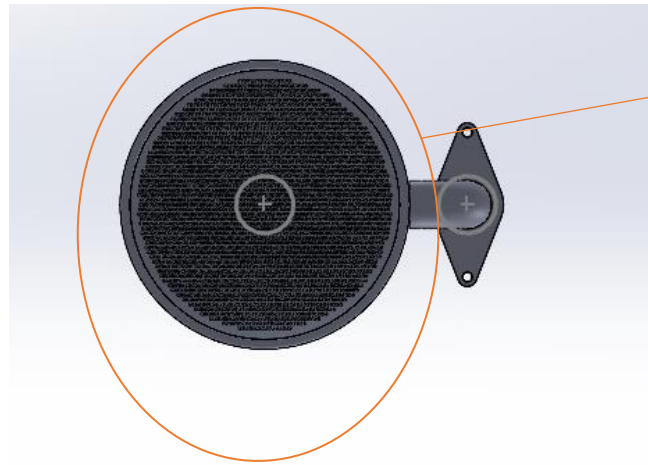
Figure 18: Top view of oil pick-up pipe.



Figure 19: Front view of oil pick-up pipe.



Figure 20: Right view of oil pick-up pipe.



The little holes are a mesh that will filter bigger particles that may be in the oil out from not going to the rest of the engine.

Figure 21: Bottom view of oil pick-up pipe.

6.2 Design Concept 2

Dry sump pan.

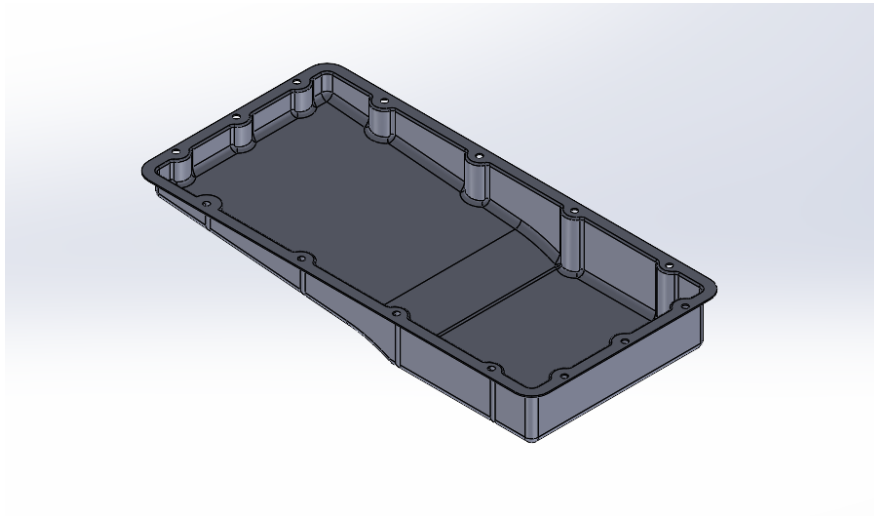


Figure 22: Isometric view of dry sump pan.

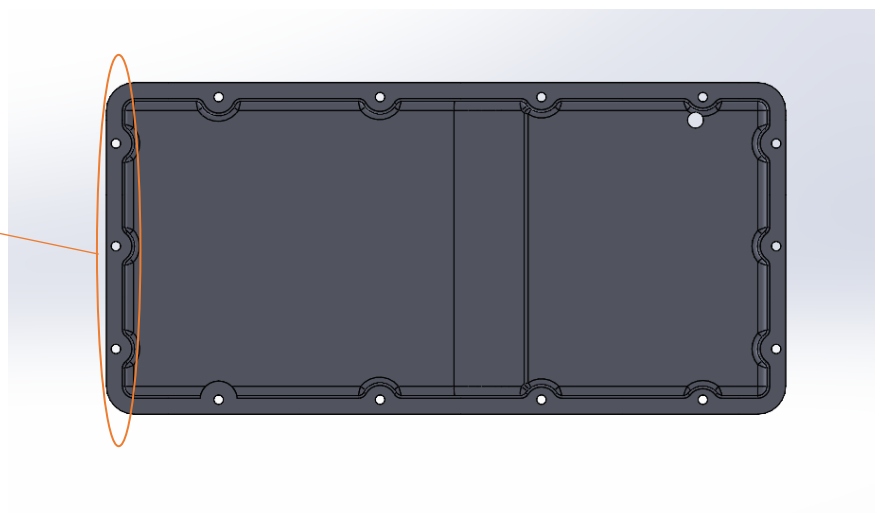


Figure 23: Top view of dry sump pan.

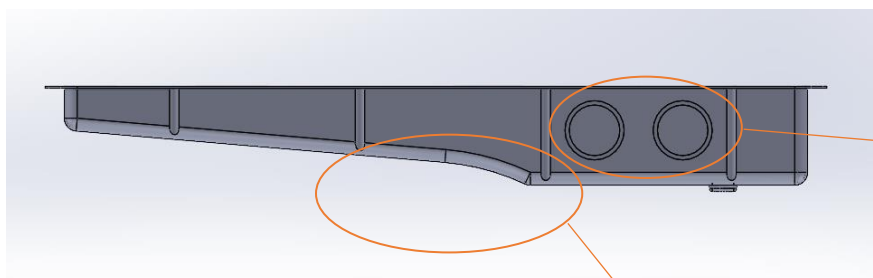
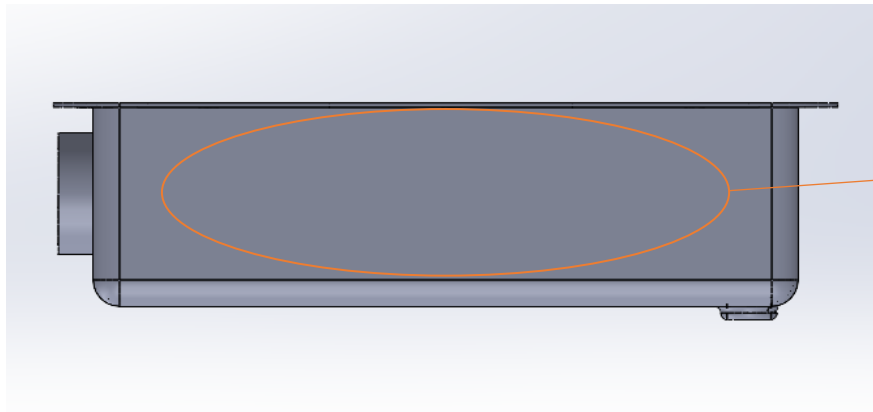


Figure 24: Front view of dry sump pan.

Oil return holes for the oil to go to the oil pump and cycle back.

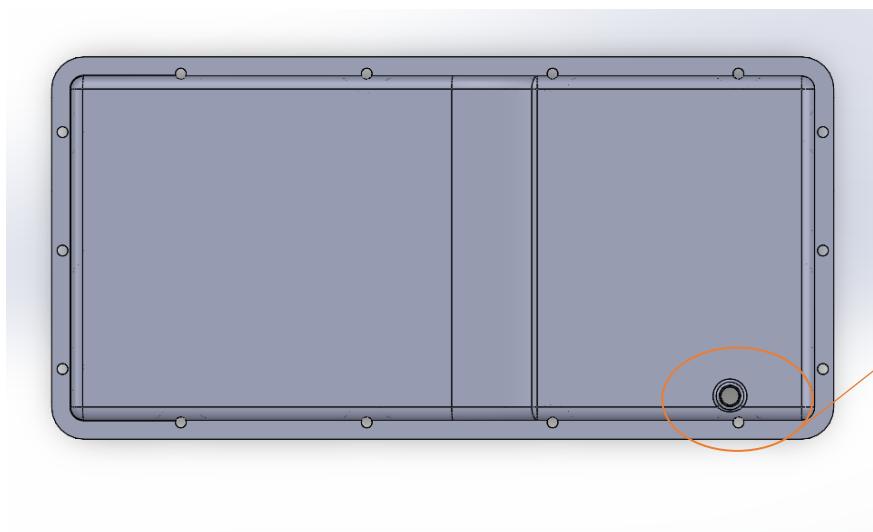


The dry sump is made out of aluminium as it is strong and lightweight.

Figure 25: Right view of dry sump pan.



Figure 26: Left View of dry sump pan.



Sump pans drain plug hole.

Figure 27: Bottom view of dry sump pan.

6.3 Design Concept 3

Dry sump pan.

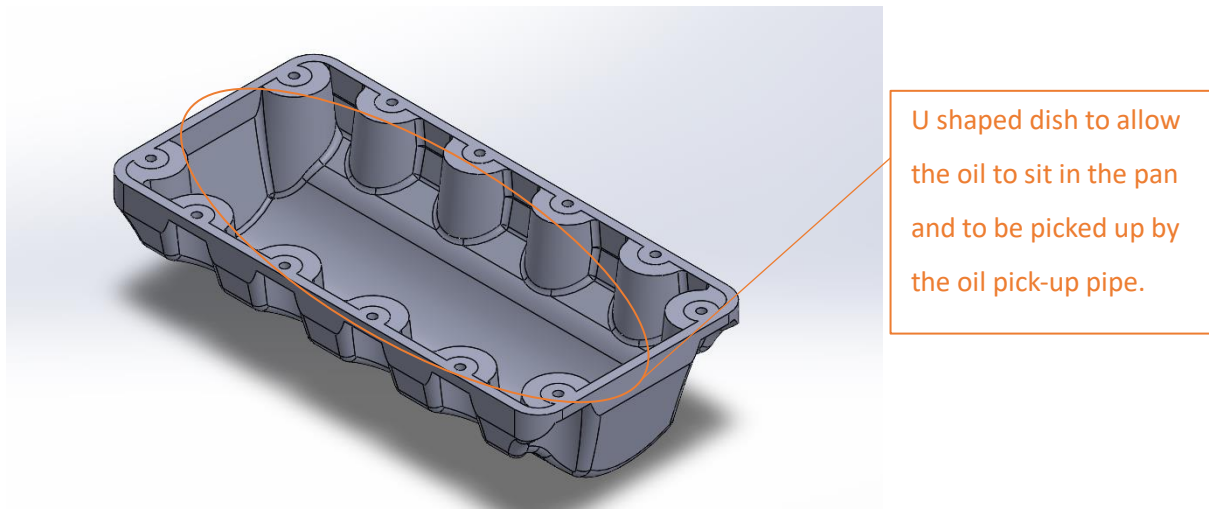


Figure 28: Isometric view of dry sump pan.

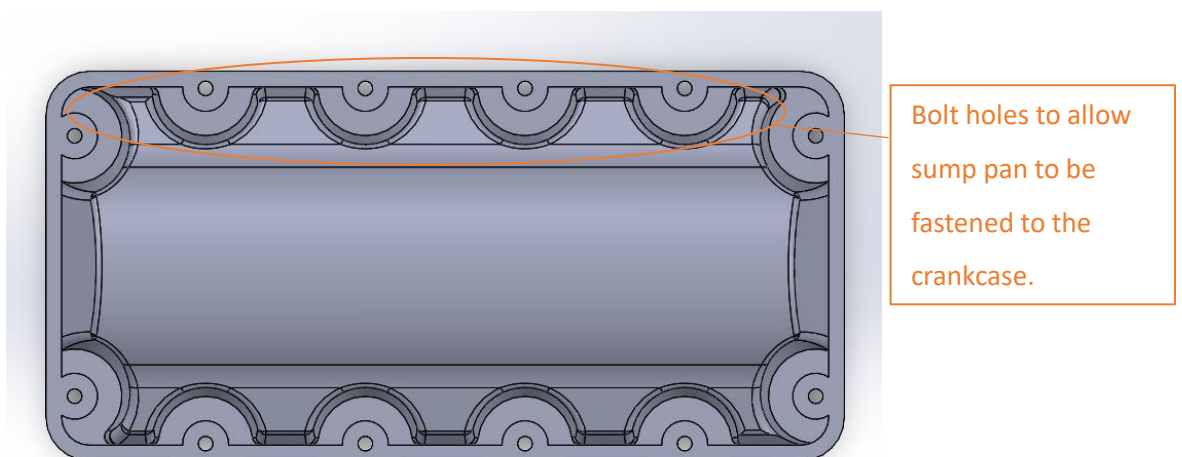


Figure 29: Top view of dry sump pan.

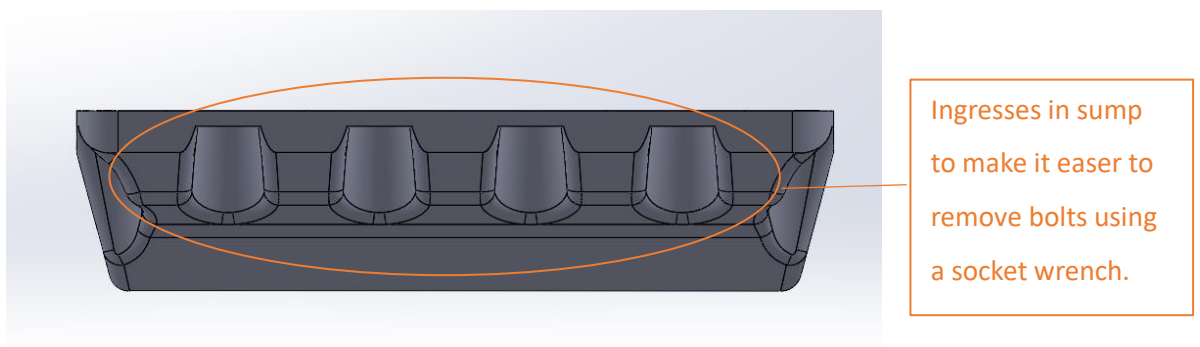
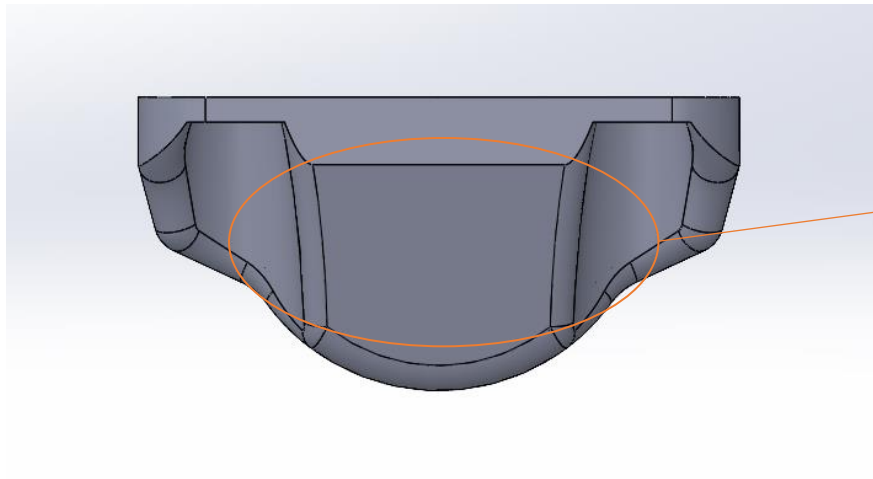


Figure 30: Front view of dry sump pan.



This sump pan is made from steel as steel is quite strong.

Figure 31: Right view of dry sump pan.

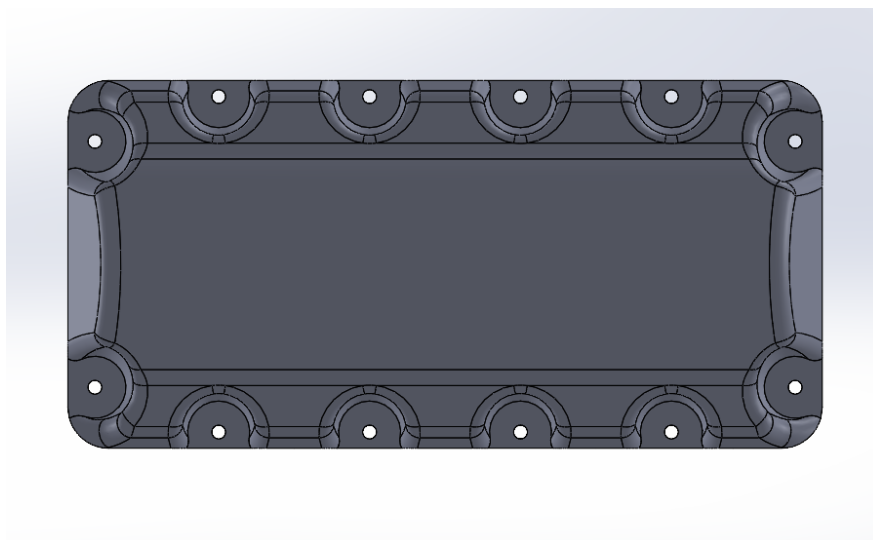


Figure 32: Bottom view of dry sump pan.

Baffle

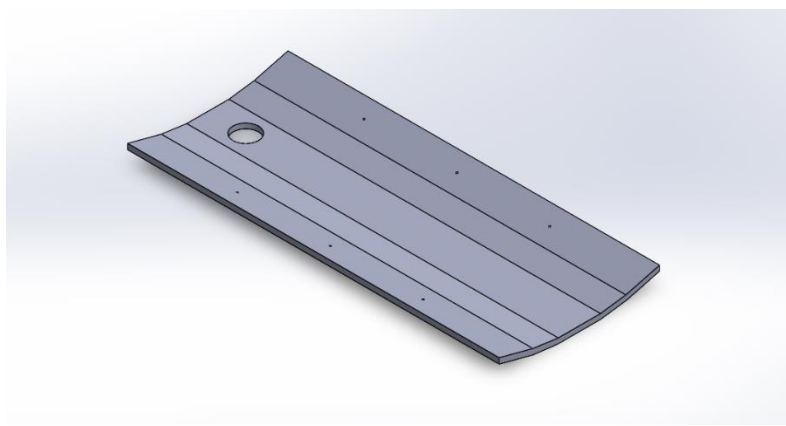


Figure 33: Isometric view of baffle plate.

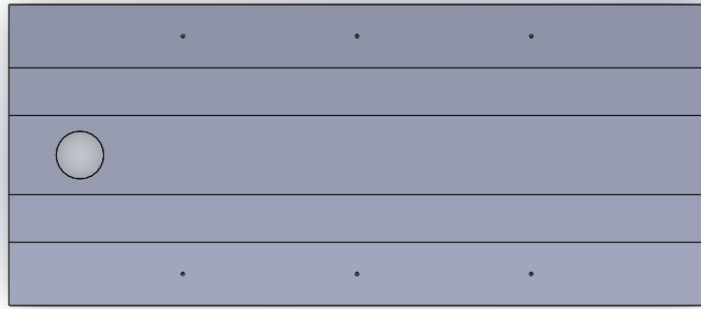


Figure 34: Top view of baffle plate.

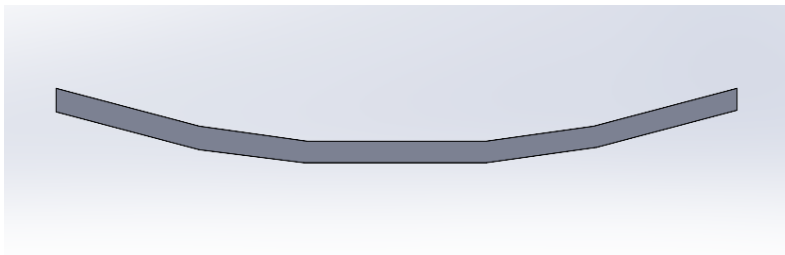
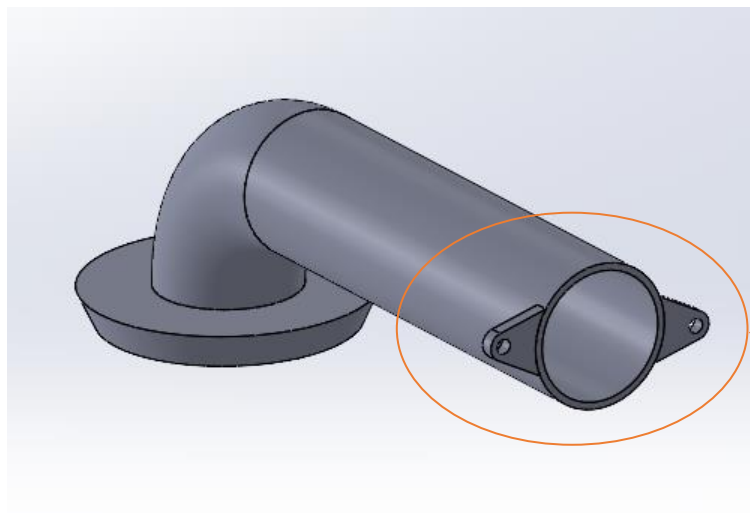


Figure 35: Right view of baffle plate.

Pick-up pipe



Flanges to connect
the oil pick up pipe
to the rest of the oil
pick up system.

Figure 36: Isometric view of oil pick up pipe.

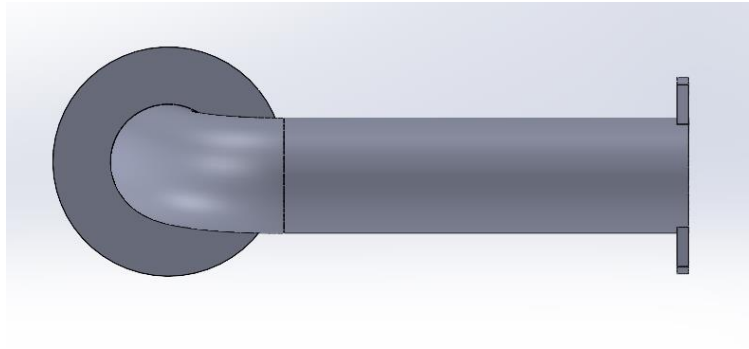


Figure 37: Top view of oil pick up pipe.

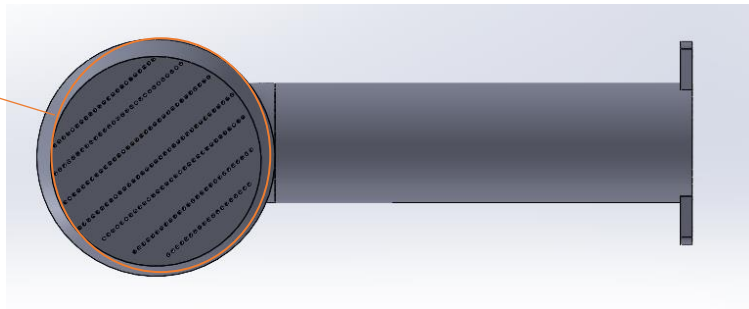


Figure 38: Bottom view of oil pick up pipe.

Small holes to pick up oil the small holes are to not pick up sediment that may be in the oil.

7 Design Feature Rating

Table 1: Design Feature Rating.

Feature	Weighting	Concept 1	Concept 2	Concept 3
Weight	8	9	9	5
Ease of installation	5	8	8	5
Baffling system	9	9	0	4
Cost	7	5	10	2
Ease of maintenance	7	10	10	1
Serviceability	7	10	10	1
Total weighting		54	42	19

This table above shows the features that are required by the customer and their importance which is the weighting, this is shown against the 3 concept designs that have been produced. This is to help

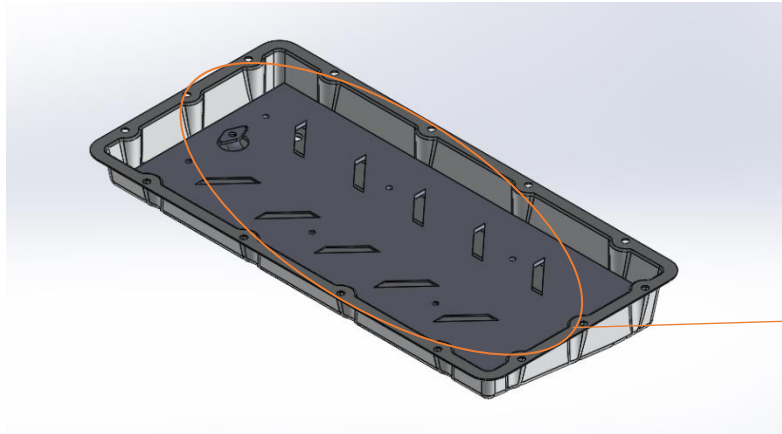
show which design best suits our customers needs and will give them customer satisfaction. From Table 1 we see that:

- In terms of weight which is the second most important feature that the customer requires, concepts 1 and 2 come out on top with a weighting of 9 as they are both made of aluminium whereas concept 3 has a weighting of 5 as it is made from steel. Although steel is stronger it weighs more meaning it will not fulfil the weight feature (Zhang and Xu, 2022).
- In terms of ease of installation, we see that concepts 1 and 2 also share a weighting of 8 as this is judged based on weight. It is based on weight because due to how the vehicle will be used by the customer the sump pan may need to be changed at the most inconvenient situations such as on the side of track with no workshop lift available and a sump/gearbox jack. Due to concept 3 being the heaviest it gets a weighting of 5.
- The baffling system is the most important customer requirement as it saves the engine from being flooded by oil in the case that the vehicle rolls over. In terms of our concept designs we see that concept 1 has the highest weighting of 9 as it has a baffling system that mainly focuses on restricting or slowing down oil from flooding the engine in the case the vehicle rolls over. Concept 2 has a weighting as it does not have a baffle system and concept 3 has a 4 as its baffle doesn't allow oil to get to the bottom of the fan which may cause the pickup pipe to suck in air.
- The cost feature is based on cost of materials and cost of production. From this we see that concept 1 has a weighting of 5 as it has 3 different parts that will have to be produced in order of the concept to work whereas concept 2 has no baffle and pick up pipe cutting the production cost as it will not be difficult to produce. Concept 3 has a weighting of 2 because it will cost more to make as it will be more difficult to manipulate the steel.
- Ease of maintenance and serviceability give concept 1 and 2 a weighting of 10 as they have drain plugs which allows the vehicle to be serviced easily and if need be if the sump is removed it is not as heavy as compared to concept 3. Concept 3 got weightings of 1 as in order to service and maintain the sump has to be removed every time and the sump is quite heavy due to the material.

From the excise above it is noted that when all the weights are added together concept 1 comes out on top of the other concepts, meaning that in this case concept 1 will be the best solution to the customers problem as it tackles all the customer requirements especially the most important requirements that are needed by the customer to achieve a level of customer satisfaction.

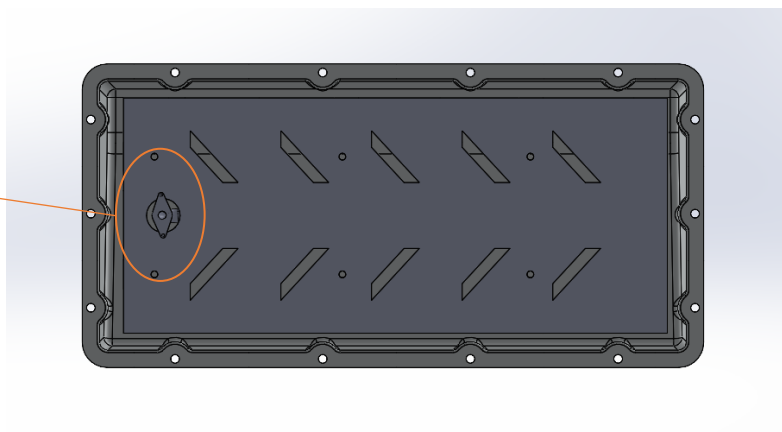
8 Final Design

Bellow are images of the final design of the dry sump system with the customer requirements needed. The system contains the sump pan, baffle plate, and oil pick-up pipe.



Baffle plate sitting secured to the mounting holes that are on the bottom of the sump pan.

Figure 39: Isometric view of assembled dry sump system.



Oil pick-up pipe coming out of the hole in the baffle plate to where it will connect to the rest of the system where it goes to the oil pump and to the rest of the engine.

Figure 40: Isometric view of assembled dry sump system.

The final design of the dry-sump system is made of aluminium as aluminium is strong and lightweight. This will allow the system to be strong but as well makes it not add extra weight to the vehicle that the customer will be using to race as the car needs to be as lightweight as possible. This design best suits the customers' requirements as seen in the design feature ratings and prioritises the customers most important features.

8.1 Technical drawing

Bellow is a technical drawing in the BS 8888 format of the dry sump pan:

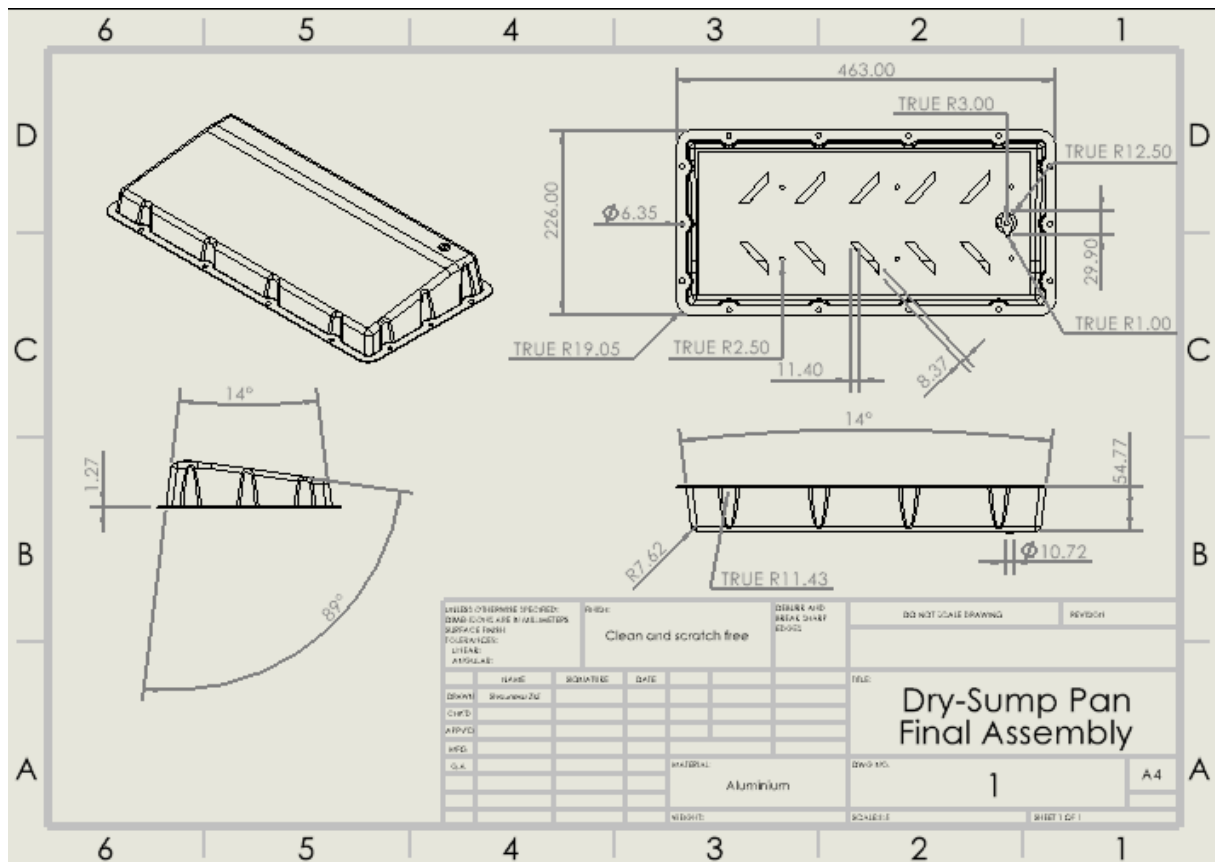


Figure 41: Technical Drawing.

9 Evaluation Framework

To ensure that our dry sump system functions well and will not have any quality issues and will not fail when being used some testing will have to take place in order to make sure it functions as intended. Bellow are ways that the designed dry sump system can be tested:

1. Visual and feel inspections: start by looking for any visible damage, such as cracks, dents, or leaks, on the dry sump pan. Also feel the sump pan for any bumps and inconsistencies the material as these could be points of failure in the future.
2. Pressure testing: this is to find any leaks in the system. To find any escaping air bubbles, which would indicate leaks, you can pressurize the system with air and then apply soapy water. Look at all connections and mating surfaces to see if the soapy water bubbles, if it does it indicates a leak at that point (Bloch, 2017).

3. Vacuum test: similar to a pressure test, make sure the system can sustain negative pressure by running a vacuum test. Create a vacuum in the system and keep an eye out for any gradual vacuum loss, as this could point to leaks (*Oil-Pump-Systems-Drives-and-Pans-Part-2*).
4. Flow test: After installing the system, start the car and keep an eye on the oil flowing via the dry sump system. Make sure that the engine is receiving oil, as well as that the system is pumping oil from the pan to the reservoir. Keep an eye on the oil pressure to make sure it remains within the needed range (Deshpande, Agarkar and Mahajan,).
5. Dynamic testing: Test drive the car in a variety of situations, such as with varying loads and speeds. Make sure that the dry sump system can sufficiently deliver oil to the engine in all operating circumstances by keeping an eye on how it performs during cornering, acceleration, and deceleration (Fatourehchi *et al.*, 2018).
6. Secondary inspection: to ensure top quality it is important to get a secondary inspection from a professional mechanic to ensure that this design will hold up under any conditions.

These steps will help ensure that the dry sump system is up to par and will work efficiently and perfectly for the customer.

10 conclusion

from this report we see the steps that are taken in designing a specific part for a customer from the customer requirements. This process requires background research first such as QFD modelling to help see which features are the most important. This will lead to the designing of the design solutions. Which will undergo feature ratings to see which is best suit for the customer. This will then allow for the design of the final model and its technical drawing to show all the dimensions for the model. The last step is testing to see if the model will be able to fulfil its required duty.

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