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Dry Sump Design Project
Engineering Design ACMA4008

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1 Abstract

This report documents the design process of taking a pre-existing wet oil sump and, through the voice of the customer, converting it into a dry oil sump design concept. A QDF was used to analyse and categorise the voice of the customer through the 'house of quality' method. This provided the remaining design process direction in the creation of design renders. Later, these renders were narrowed down through a design selection exercise to isolate the desired combination of parts and assembly format.

The report finally looked at how this process might be assessed and how this assessment might be applied to other design processes.

2 Design Assessment & Requirements

2.1 Introduction

In this engineering design project centred on oil sumps, our primary focus is to enhance the existing oil containment system through the analysis of customer needs. The final designs from this project aim to optimize the design of the sumps. Through a meticulous analysis of end-user needs alongside other considerations, such as environmental and industrial standards, this project aims to identify and prioritize features crucial to the provided requirements. Additionally, the design will avoid spending time on items which are shown to be unimportant to the final product.

2.2 Problem Identification

In this section, I aim to define what the user's needs are, and therefore determine the manufacturer's needs. With these, a QFD matrix will be defined with the traits needed to accurately pursue the redesign of the sump. This method helps the design process by ensuring that no requirements are overlooked (J.B. Revelle, 1998).

As this is a design-oriented problem, the competitor within the QFD matrix has been replaced with the previous design this report aims to improve upon. In this house of quality, I have used the ratings provided to assess the various design attributes, how they are currently standing, and their relationship to each other. The key assessment is that the customer doesn't value the ease of manufacture, and therefore cost, in comparison to the other factors. Additionally, the QFD shows that it will be important to optimise the size and weight of the components to guarantee both the final weight of the parts, along with ease of installation and to a lesser extent maintenance. These will affect the cost, which is strongly associated with ease of manufacture, as they have a negative correlation with this

functional requirement. This is due to the size and weight adding to material and production time; both factors within manufacture.

Through this project, it is important to incorporate the competitor's (or in this case the previous design's) "HOWs" with high ratings (K. Paryani, 2010). While improving other aspects of the product, an eye should be kept on maintaining already highly rated aspects of the design, and understanding why/what the customer currently likes about these attributes. Currently, the customer has rated the weight as an 8 & 7 respectively. This indicates the current design for fills these requirements well, and these shouldn't be compromised in favour of other factors.

Table 1 Dry Sump House of Quality using Template (FileStage, 2023)

Relative Weight	Customer Importance	Customer Requirements	Functional Requirements					Competitor (Current Wet-Sump Design)
			Number of Fixings	Mass of material used	Sump Size	Pick-up Line Geometry/Shape	Ease of manufacture	
22%	8	Light Weight	○	●	●	▽	▽	8
14%	5	Ease of Installation	○	○	○	●	▽	4
25%	9	Flood-Resistant in Roll-over	▽	▽	▽	●	▽	1
19%	7	Low Cost	●	○	○	▽	●	6
19%	7	Ease of Access for Maintenance	○	▽	○	▽	○	7
Importance Rating Sum (Importance x Relationship)			342	300	358	350	233	
Relative Weight			22%	19%	23%	22%	15%	
Technical Competitive Assessment								

Correlations	
Positive	+
Negative	-
No Correlation	

Relationships		Weight
Strong	●	9
Medium	○	3
Weak	▽	0

2.3 Literature Review

The main feature of a wet sump is that the oil is stored under the engine in an oil pan (CarsBlog, 2023). This helps make the construction of wet sump engines relatively simple and straightforward (NBE, 2024), and the maintenance/installation is also made easier (Iger, 2021). It can be inferred from this that wet sumps are reasonably cheaper to have in an engine. However, this setup reduces the power of an engine and also means the engine must be mounted higher up (NBE, 2022). Therefore, it is often advantageous to use dry sumps. The main feature of a dry sump is that the oil is stored externally in an additional reservoir (CarsBlog, 2023). Due to this, dry sumps often have a shallow oil pan (NBE, 2022), meaning no (or very little) oil is in the engine.

2.4 Design Specification

The objective of this product is to create a dry sump pan based on previous models for a wet sump. This should meet the customer requirements as shown and assessed above, and be manufacture-ready. Additionally, a pickup adaptor is required, also looking to meet the customer requirements.

The pickup adaptor and sump pan should have easily manufacturable geometry in order to simplify the manufacturing process. Any shapes added to the sump design should be simple, and similar to existing geometry. Additionally, any parts or additions to the filter line will make use of stock material shapes. Ease of manufacture will have a significant impact on price; complex geometry will require more manufacturing processes in order to achieve drawing dimensions.

This geometry must also prevent fluid from collecting in the sump pan when the engine isn't level. The pick-up adaptor should be able to continue re-cycling oil through the engine, even if the engine is on its side. This will be categorised as a basic requirement, due to the specific requirement from the consumer.

The number of fixings used in the new pickup adaptor should be no more than 6 and should be easily accessible. These fixings should additionally be universal sizes. This is to assist in the maintenance and installation requirements of the end user. The fixings should face the open, in the direction of access to the parts. The placement of the pickup adaptor shouldn't be blocked or intersected by the shape of the sump pan. The pickup adaptor should be able to be placed in/removed from its location without difficulty.

The sump pan should support the pickup adaptor if possible. The current pickup adaptor in its current position is supported at a point far from the end of the oil line. As an 'excitement' requirement, this design should aim to fix the adaptor end to the sump without impacting maintenance access. This will secure the line and significantly improve lifetime durability.

The final design should follow the original wet sump as much as possible. Maintaining parts of the original design will ensure manufacturing processes won't need to change significantly, and the new design will impact the minimum amount of new conformance requirements as possible.

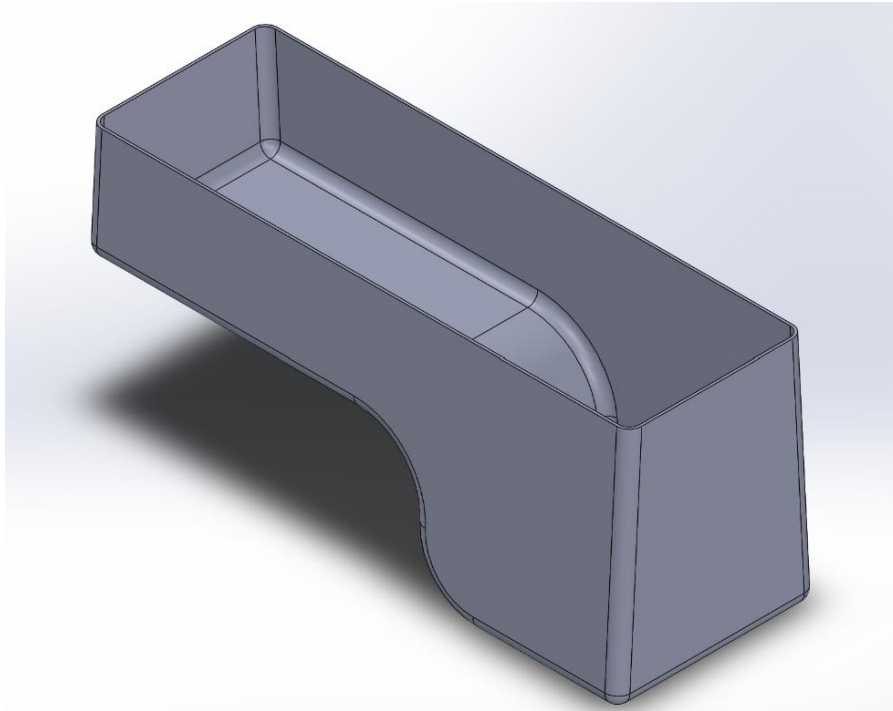
The design should also have as little material used in the design as possible, to maximally reduce the weight of the product. Reducing the weight/amount of material will help meet the cost and weight reduction requirements of the product.

3 Design Methodology

3.1 Design Concepts

Firstly, I would make a change to the shape of the oil sump. As shown below in Figure 1, the sides of the have a slight gradient, in this image 19:1. This will prevent the oil pooling as the engine rolls over and experiences g-forces due to high turn rates.

Figure 1 First Dry Sump SolidWorks Render ISO View

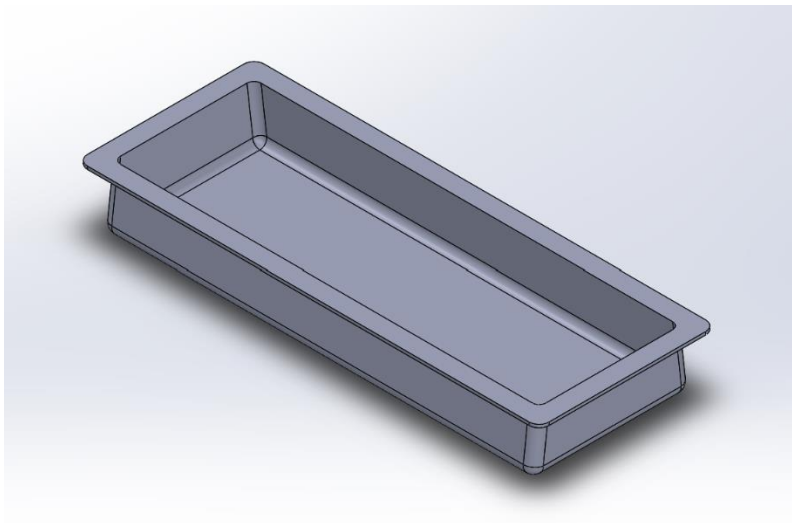


This would also be a simple change to introduce. It wouldn't pose significant problems to the production of the product and would help to prevent the engine from flooding. This aims to help fulfil three of the objectives of the design specification. It follows the original design specifications of the original design sump and doesn't affect how the part fits in the engine. While doing this, it keeps the geometry simple and helps solve an aim from the customer highlighted in the QFD.

Below, the sump has had the tray removed. This serves to meet multiple objectives. The removal of the pan will decrease the material drastically, which will reduce the weight of the component. The reduced weight is a significant factor for the consumer.

Raising the base of the sump will also reduce the total volume available. Reducing the volume will limit how much oil can sit in the sump at any given time, and therefore increase the volume of oil in the remote oil reservoir. Improving the oil volume of the reservoir will help prevent flooding the engine and not being efficiently circulated.

Figure 2 Second Dry Sump SolidWorks Render ISO View

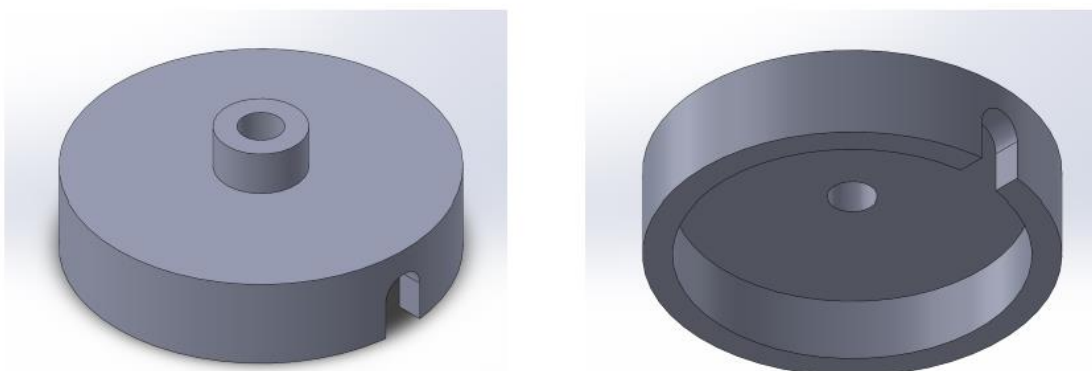


Additionally, this will reduce the price requirements slightly for the product. This shape is simpler than that in Figure 2, which will help reduce the production cost. The length of the pump system will as be reduced, which will help bring the cost down further.

Below, is a concept design for the new oil pickup adaptor. The adaptor is intended to be fitted at the base of the sump, collecting oil from as low a point as possible. This design aims to address several problems with the original design.

First, this pickup adaptor will be fixed to the base of the sump. The original design was free at the end, and this could lead to stress along the long length of the unsupported pipe the component was attached to; which would end with slow component wearing. Supporting the adaptor at the end will help support the weight of the pipe, and against any jostling the part might experience.

Figure 3 Oil Pickup Adaptor Render SolidWorks ISO View from Top and Bottom



This pickup adaptor also does not use any fixings which, as outlined in the specification, is important to reduce. Reducing fixings will help to keep costs down and will improve manufacturability. This component would be secured by a threaded top, fixed into the end of the pipe. Variations of this design come in the number used. More pickup adaptors placed

around the oil sump would further guarantee that the oil would always be pumped back around the system, no matter what orientation the vehicle was in.

3.2 Design Isolation

The design isolation exercise will be conducted against the customer requirements established in the QFD. Using the variation of design ideas in the previous segment, the individual parts will be assessed against the customer's needs and then the best two shall be used in a final design.

Table 2 Design Isolation Table using Customer Weightings

Feature	Weighting	Design 1A	Design 1B	Design 2A	Design 2B
Light Weight	8	5	8	7	9
Ease of Installation	5	7	7	5	8
Flood-Resistant in Roll-over	9	6	8	9	4
Low Cost	7	6	7	5	8
Ease of Access for Maintenance	7	4	7	3	6
		199	269	218	246

As shown in the figure above, the selected combination is of design B1 and design B2, being the shallow oil sump and double pickup adaptor. These values have been generated by a variety of means. Weight and flood resistance can be quantified easily by comparing the amount of material used in the part and the volume of the sump and the predicted flow of oil respectively.

For the other values, however, quantifying these is more complex. A mixture of user feedback, engineering input and foreseeable difficulties have influenced a generic score. For the ease of installation, different factors came into play. For the second design variant, the fact that twice the parts would be required significantly reduced the double pickup adaptor setup. For Ease of maintenance, similar factors came into play for the double adaptor setup. Additionally, the awkward shape of the deep tray would make maintaining this part significantly harder.

3.3 Final Design & Technical Drawings

Using this selection, below is an image of an assembly model of the final design as selected here. This uses two pickup adaptors and a shallow oil sump for the reasons previously listed. These have been placed apart from each other so to maximise the coverage they provide.

Figure 4 Final Assembly Render of Dry Sump SolidWorks

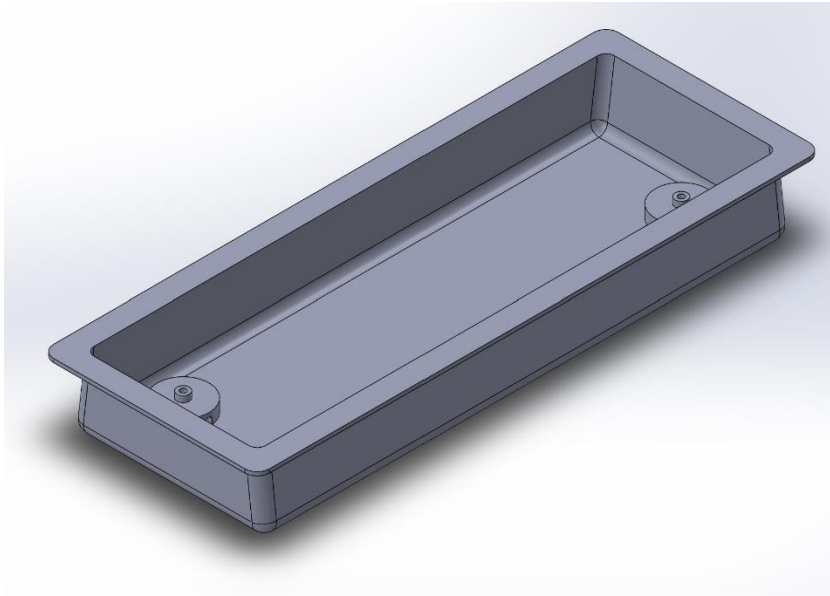


Figure 5 Engineering Drawing of Dry Sump Component

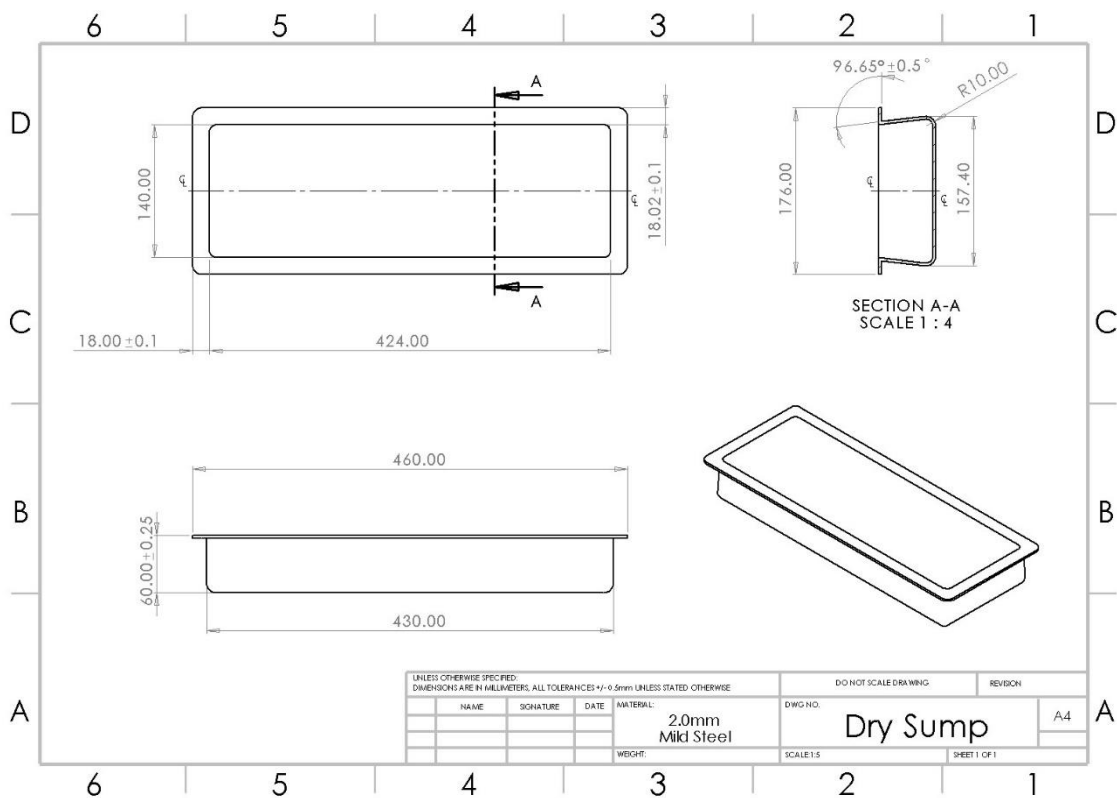
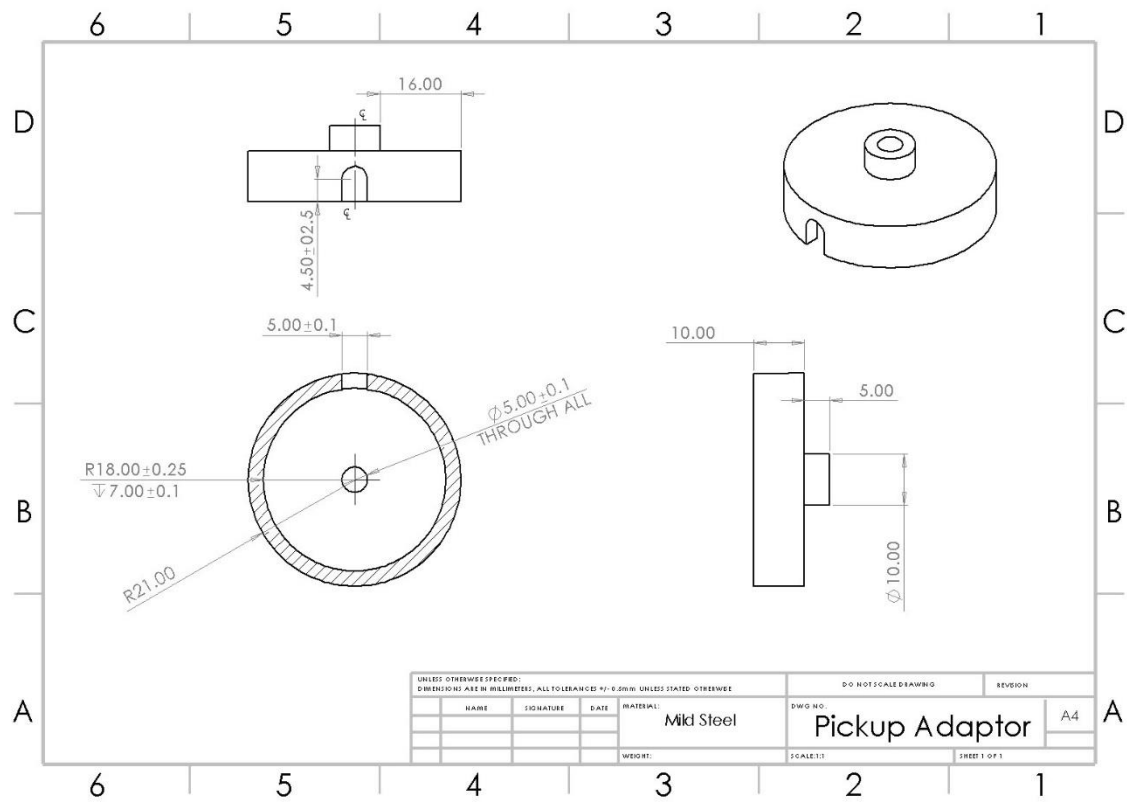


Figure 6 Engineering Drawing of Oil Pickup Adaptor Component



4 Evaluation Framework

A Design Evaluation Framework is a systematic and comprehensive approach used to assess the effectiveness, efficiency, and overall quality of a design solution. It plays a crucial role in guiding designers in evaluating the success of a design in meeting its objectives. The initial specification is used to provide a list of clearly defined objectives and measurable criteria so that the design can be accurately assessed.

These criteria should also reflect the voice of the customer at every stage. Customer-centred evaluation is prioritized throughout the design process, involving gathering feedback from end-users through methods such as usability testing, interviews, and surveys, ensuring that the design meets their needs and expectations.

The next aspect to evaluate is the functionality and performance of the design. This includes assessing whether the design meets the specification requirements. Testing should be carried out in order to assess each point in detail and examine the degree to which they were successful. These results should then be entered into a final version of the House of Quality (QFD). This will inform start-to-end where the future projects can focus on with more detail. In conjunction to the specification, the assessment should evaluate compliance with relevant engineering and IMechE standards to promote best practices.

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