Project: Determining the Effectiveness of Oleophobic Gaskets

Project Plans and Product Specifications

Team Number: 1

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ABSTRACT

The goal of this Cummins Inc. sponsored project is to determine the effectiveness of oleophobic gaskets compared to standard nonoleophobic gaskets. This objective will be completed by utilizing on market oleophobic sealing solutions on current gasket materials and then testing these gaskets in an experimental test rig, which will be designed and constructed by the team. The effectiveness of the oleophobic gaskets will be assessed by comparing the respective leak rates of each gasket type under various temperatures and pressures to that of baseline gasket leak rates. The team has performed research on types of oleophobic solutions and have begun investigating which of these solutions are potential candidates to create an oleophobic gasket. The test rig must be designed and built by the team so that it can test gaskets at several different oil temperatures, pressures, and flange surface conditions. A House of Quality showed the team that the primary engineering characteristic tested is gasket leak rate. The team used a Gantt chart to create a time dependent project plan, and identified critical tasks that the team must complete in order to finish this experiment on time and successfully. The team also assigned whom is responsible for specific tasks, thus adding more detail to the project plan.

1. Introduction

Cummins Inc. has proposed a project to determine the effectiveness of oleophobic gaskets to reduce the measured leak rate at low pressure, large joints on engines compared to the current gaskets used on engines. Oleophobic items are items which repel oil by having a lower surface energy than the oil. A gasket is an item which is placed between two flanges to form a seal, which is meant to prevent oils from leaking to the opposite side of the flange. The theory behind the project is that if the gasket can repel the oil, it is less likely that oil will be capable of leaking past the gasket.

In order to determine the effectiveness of oleophobic gaskets, the design team needs to determine what products on the market can be used to give a gasket oleophobic properties, create oleophobic gaskets using these products, and design and build a test rig which measures the leak rate of a gasket at various temperatures and pressures. Once the design and construction of the project is complete, tests will be performed on oleophobic and standard gaskets using the test rig and results will be compared to determine the effectiveness. The test rig must be capable of testing oils that range from 22 to 150° Celsius and inducing a pressure on the oil ranging from 0 to 15 psi.

2. Project Definition

2.1 Background Research

Gaskets materials are used for different applications to prevent leakage of fluids at a joint, typically flanged bolted joints. These gaskets are usually metallic, polymeric, or paper materials, and they are expected to function effectively when subjected to various pressures and temperatures.[1] Gaskets are more likely to fail under adverse conditions, such as at higher pressures, higher temperatures, and poor flange surface conditions. The failure of gaskets can also be dependent on the size of the gasket, as larger gaskets have more potential leak paths. This project team is saddled with the task of determining if the use of an oleophobic gasket would prevent/reduce the effect of a gasket failure, while still having the reliability and durability of standard gaskets. The gasket performance will be tested with the use of a test rig, which is the second responsibility of the team.

Figure 1. Nonoleophobic (left) vs. oleophobic (right)

To have oleophobic properties means a material will have a tendency to repel oil from its surface which can be seen in Figure 1.[2] Oleophobicity is reliant upon the concept of surface energy, which is the excess energy on the surface of a bulk material.[3] Therefore, oleophobic material must have a lower surface energy than oil.

This project is a first for FAMU/FSU senior design, meaning it is not a continuation of a previous project. Also, Cummins Inc. has not performed research or tests of their own, meaning that this senior design team is the first group to work on this project. Previous works related to this project involving oleophobic coatings are found on various items such as phones and clothing. Additionally, oleophobic impregnators are used as a tile and grout sealer. These sealants are not intended to prevent oil leakage. All of the aforementioned oleophobic solutions aim to simply repel oil from a surface, allowing the surface to maintain a clean finish. Currently, the design team has found no existing work involving the use of oleophobic sealing solutions on gaskets.

A related piece of literature to this project is the article *Fabrication of Super-hydrophobicity and Oleophobic Sol-gel Nanocomposite Coating*.[4] This article discusses how to lower the surface energy of a material through the application of a fluoropolymer. This article is relevant to the project as fluoropolymers are typically found in oleophobic sealing solutions confirming the feasibility of on market sealing solutions.

There are four main types of gaskets used on engines to create seals: paper gaskets, FIPG gaskets, molded elastomer gaskets, and rubber coated metal gaskets. Paper gaskets are composed of 90% fibers and 10% elastomeric binder.[1] These gaskets are widely used because of how cost effective the production process is for them; however, they are subject to many failure modes such as weeping oil through the paper and bolt load relaxation. FIPG gaskets are gaskets that are applied to flanges in a liquid state and cure to create a seal. FIPG gaskets rely on adhesion to the flange surface to prevent leakage rather than pressure, as the other gaskets do. Rubber coated metal gaskets are composed of a metal core, which is coated with a thin layer of rubber, typically 25-75 μm thick.[1] Rubber coated gaskets are typically used in high temperature applications. The final type of gasket, molded elastomer gaskets, are gaskets which are composed of elastomers which were molded into a particular shape for usage. An example of a molded elastomer gasket is an o-ring. These gaskets typically display the best sealing characteristics of the four types of gaskets.

2.2 Need Statement

Cummins Inc., the largest diesel engine manufacturer in the world, would like to investigate if introducing an oleophobic substance to gaskets will decrease the amount of oil leakage experienced at various joints on their engines. Within the scope of the investigation is to research different types of oleophobic products, the different application procedures for these products, and which materials are compatible with these products. The contact joints that Cummins Inc. is most interested in are larger, low pressure flange joints. Examples of such a joint is the joint between the engine block and the oil pan. In such a joint, the oil is at a low pressure, but there is a large exposed gasket length for potential leaks to occur at. Currently gaskets prevent oil leakage solely though contact pressures between the gasket and the flange surfaces, which create a seal. The purpose of this project is to determine if using an oleophobic gasket would reduce the amount of oil leakage compared to current gaskets used by Cummins Inc.

Need Statement:

"Gaskets used at large joints where the oil is at low pressure leak more oil than desired."

2.3 Goal Statement and Objectives

Goal Statement: "Determine the effectiveness of oleophobic gaskets through the use of a test rig designed by the team."

Table 1. Project Objectives

Objective Number	Objective
1	Create oleophobic gaskets using on market products
2	Construct a test rig that will measure the leak rate of a gasket
3	Design the test rig to be capable of varying pressure and temperature
4	Test oleophobic gaskets and currently used gaskets for leak rate and compare results

3. Constraints and Specifications

3.1 Project Constraints

Multiple constraints must be adhered to in order to determine the effectiveness of oleophobic gaskets.

Monetary:

- The total budget of the project may not exceed $2,000. This includes all costs, such as purchasing oleophobic solutions, raw material, and any required data acquisition devices.

Time:

- The test rig construction must be completed in time to perform testing, which should be at least 2 weeks prior to the project completion date.
- The leak rate test results will be finished by the end of the Spring 2016 semester.

3.2 Design Specifications

Measurable design specifications important to this design include dimensions and internal stress bearing capacity of the test rig, flange dimensions, as well as the clamping pressure needed for the bolts on the flanges. Through preliminary calculations and assumptions, some materials have been considered for the design. For example, the test rig can be made from an aluminum alloy, and the bolts can be made from steel.

Table 2. Design Specifications

Design Specifications	**Expected Value**
Test Rig Dimensions	Inner Diameter (ID): 55 mm Outer Diameter (OD): dependent upon analysis results
Test Rig Stress Capacity	Dependent upon analysis. Must withhold maximum pressure of 50 psi as set by sponsor (safety factor).
Flange Dimensions	Inner Diameter (ID): 55 mm Minimum Outer Diameter (OD): 120 mm
Clamping Pressure	Minimum of 2 MPa according to Cummins standards. Maximum of 20 MPa according to Cummins standards.

3.3 Performance Specifications

The coated gasket would sit between the flanges of the test rig providing adequate sealing and minimal leak rate during testing, simulating an actual bolted joint on an engine. The operational temperature of the test rig will be between 22-150° C with ± 2° C accuracy, and the oil pressure will range between 0-15 psi with an accuracy of ± 0.1 psi. The pressure sensor must be very precise as it will be used to measure the leak rate, which is expected to be very small. A very precise pressure sensor will provide the necessary resolution. The test rig will be heated through an external source such as an electric hot plate, which will display the external temperature on its digital display. This heating arrangement will induce elevated temperature within the oil, which can be measured via a temperature sensor within the test rig.

4. Methodology

The first major objective of the project that must be completed is to determine what options are currently on market to make gaskets oleophobic. In order to determine which options are available, the team will research the market using the internet, and by contacting suppliers to get professional feedback. Once current market items are determined, they will be evaluated by the team for practicality, performance, and environmental applications. A pugh decision matrix will be utilized to compare the different concepts for oleophobic gaskets. The team will then select the suitable method(s) to make an oleophobic gasket and procure these “on market” products. Using these products, the team will create the oleophobic gaskets, which will be leak rate tested.

The other major objective of the project is to design and build a test rig which will be capable of measuring the leak rate of gaskets. The team will discuss with the sponsor to determine if there are any company standards for test purposes, such as leak path length, standard diameters, pressure ranges, and availability of current gaskets used by the sponsor. Using this information, the required size of the system can be determined and designing can begin on the test rig. The physical designing of the testing rig will utilize CAD software for visual purposes as well as part drawings, and any mathematical calculations will be done using Mathcad in order to ensure accuracy.

Testing will be performed on the oleophobic gaskets using the test rig built by the team. The leak rate test results for the oleophobic gaskets will be compared to standard gaskets, which will allow the team to draw conclusions on the effectiveness of an oleophobic gasket. The tests will be performed using different oil pressures and temperatures within the test rig, which will provide more data to compare with standard gaskets.

In order to prevent exceeding the $2,000 budget, price will be weighed in every decision to make sure the team makes the best decision between performance and costs. Items which will be used in the building of the test rig will be quoted to ensure the lowest possible price was obtained, thus using the team’s budget efficiently. In order to keep the project on schedule, a Gantt chart was created (Appendix A). The Gantt chart will continuously be updated by the team as the project advances, allowing for proper planning if the project deviates from the original schedule.

4.1 Resource Allocation

Background research has already begun and is nearly complete for this project. The background research phase was completed as an entire team, where individual team members were assigned small topics to research and share with the team. Heather Davidson and Norris McMahon researched the science behind oleophobicity, while Daniel Elliott researched common causes for gasket failures. Erik Spilling researched into what types of oleophobic spray coatings are currently available on market, and David Dawson researched if a product could be used to impregnate a material to create oleophobic characteristics for the material. Further research is being performed by the team, including researching temperature and pressure measurement devices, machining practices, pressure vessel minimum thickness criteria, bolt load and its effect on clamping force, and continued research into oleophobic solutions. The entire team contributed to the background research phase of the project.

The senior design team decided to divide into sub-teams so that the necessary effort could be applied to both the oleophobic gasket aspect of the project, as well as the design and fabrication of the test rig, simultaneously.

- Gasket Team:
  - The gasket team is responsible for continued research into what process and products can be used to create an oleophobic gasket. This sub team consists of Norris McMahon, David Dawson, and Aruoture Egoh. Once the gasket team identifies the available oleophobic solutions on market, they are responsible for selecting the solutions for the team to purchase and test. The gasket team will also be responsible for creating the oleophobic gaskets, whether that involves spraying an oleophobic solution onto existing gaskets or some other means that the team identifies. The gasket team is also responsible for providing the gasket needs to Cummins Inc., so that Cummins Inc. can provide the necessary gaskets for testing.
- Test Rig Design Team:
  - The test rig team is responsible for generating concepts for the test rig, performing the calculations to determine the design details for the test rig (such as wall thickness, bolt loads, etc.), creating the CAD models and drawings, material

selection, and creating a list of raw material quantities which will need to be purchased. The test rig design team will work as a group to complete all of the aforementioned tasks, since the team believes a group effort will yield the best design. The test rig design team consists of Erik Spilling, Heather Davidson, and Daniel Elliott.

Parts ordering will need to be done as the sub teams reach final concepts. David Dawson will be responsible for maintaining the team budget, and thus will also be responsible for the parts ordering. The sub teams will provide David with a list of the desired raw materials, and David will check to make sure that the parts/materials can be purchased within the team's budget, and make the purchases.

Fabrication will be performed by the entire team. The raw materials for the test rig will be machined by the COE machine shop, but the assembly of the test rig will be done by the entire team.

The testing process will be performed by the entire team as well. Since a large number of tests are expected to be performed, the team plans to do one set of tests as a group. These initial tests will be done together to create a step by step testing process that the entire group understands. Then, testing will be broken into smaller groups so that the entire team does not need to be present for every single test run. The smaller groups will be groups of two or three.

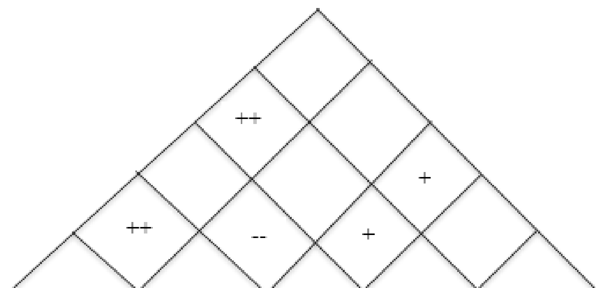
The team web page will be designed by Heather Davidson and Norris McMahon. The team will utilize the advice and resources provided by Ryan Kopinsky in order to best design the team web page.

4.2 Schedule/Deliverables

A schedule of the team's project plan for the rest of the Fall semester can be found in a Gantt chart (Appendix A). This Gantt chart encompasses a work breakdown structure (WBS) which details who is responsible for each task. The arrows in the Gantt chart show the prerequisite relationship between two tasks. Additionally, critical tasks can be identified by their duration in the time schedule. For example, part acquisition is a very critical task as it is expected to take the longest, and the project cannot precede without the completion of it.

4.3 House of Quality

After first speaking with the sponsor and defining their requirements, a diagram known as a House of Quality (HOQ) was constructed (Figure 2). This diagram relates the sponsor's requirements with various engineering characteristics. For instance, there is a strong correlation between the requirement of comparable performance and the characteristic gasket leak rate. Additionally, the diagram also depicts the relationship between any two engineering characteristics. This is illustrated in the top triangle of the "house." There is a strong positive correlation between the project budget and the test rig pressure. To simulate higher pressures in the test rig a more complex design is required, and this will require money thus increasing our budget. Through this diagram, the number one engineering characteristic identified was the gasket leak rate.



Direction of Improvement		Down	N/A	Down	N/A	Up
		Engineering Characteristics				
Customer Requirements	**Customer Importance**	Gasket Leak Rate (sccm)	Flange Surface Roughness (µm)	Project Budget ($)	Test Rig Pressure (psi)	Oil Temperature (°C)
$2,000 budget	8	Δ	Δ	•	○	○
Test various pressures	7	○		○	•	
Test various roughnesses	6	○	•	○		
Comparable performance	9	•	Δ		○	○
Test various oil temp.	7	○		○		•
Absolute Importance		225	145	192	165	165
Relative Importance		0.26	0.16	0.22	0.18	0.18
Rank Order of ECs		1	4	2	3	3

++	Strong positive
+	Positive
-	Weak
--	Strong weak

•	Strong (9)
○	Medium (6)
Δ	Weak (3)

Figure 2. Constructed HOQ using sponsor information

5. Conclusion

The purpose of this project is to determine if the development and implementation of oleophobic gaskets would be useful in practical applications. This will be achieved by researching modern oleophobic gasket solutions and selecting the best solutions to test in an oil leak rate test rig, which will be constructed by the team. These oleophobic gaskets will be compared to baseline model tests using engine oil at pressures between 0 - 15 psi. The goal of the test rig is to be capable of operating with oil temperatures of 22 to 150 °C. The results from this experiment will provide a better understanding if oleophobic gasket solutions are effective in terms of practicality, performance, and applicability.

The team continues to narrow down the types of oleophobic solutions to test, including method of applicability and relevant choice of material. Our House of Quality Matrix determined that our number one engineering characteristic to design for is the ability to measure the leak rate. The team will continue to hold informal and formal Bi-Weekly meetings to have regular updates on the progress of the project. A schedule in the form of a Gantt chart has been put in place to allow the team to have a visualized timeline of major and minor tasks throughout the completion of this project.

In the time before the next deliverable, the team will continue to generate concept designs for the test rig which will best simulate a gasket joint on an engine, and have the ability to accurately measure the oil leak rate. The team will also work with suppliers to negotiate correct quantity and price packaging for oleophobic sealing solutions which will be capable of coating the necessary number of test gaskets. The goal for the next deliverable is to have a final design selected and modeled on CAD, and for the final selections for the oleophobic solutions to have been determined.

References

[1] "Gasket Materials and Selection." Gasket Materials and Selection. N.p., n.d. Web. 25 Sept. 2015.

[2] "Spigen." Galaxy S4 Screen Protector GLAS.t NANO SLIM Premium Tempered Glass-Oleophobic Coating. N.p., n.d. Web. 25 Sept. 2015.

[3] "Surface Energy and Wetting." Surface Energy and Wetting. N.p., n.d. Web. 25 Sept. 2015.

[4] "Fabrication of Superhydrophobic and Oleophobic Sol–gel Nanocomposite Coating." Fabrication of Superhydrophobic and Oleophobic Sol–gel Nanocomposite Coating. N.p., n.d. Web. 25 Sept. 2015.

Appendix A

Gantt chart displaying the projected schedule for this semester.