Determining the Effectiveness of Oleophobic Gaskets

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Table of Contents

Table of Figures

Table of Tables

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. The team has performed preliminary 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. This will be an increasing item of importance in the coming weeks.

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 degrees 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 are the first people 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.

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 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 & 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

2.4 Constraints

Multiple constraints must be adhered to in order to determine the effectiveness of oleophobic gaskets. These vary from monetary constraints to bounds on the technical specifications.

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.

Test Rig Properties:

- The test rig must be able to vary the oil pressure between 0 – 15 psi.
- The test rig must be able to operate within a temperature range of 22 – 150 degrees Celsius.
- The test rig must be capable of measuring the leak rate in small scales. Since it is expected that the amount of leaked oil will be small, the test rig must be sensitive to the amount of oil that is leaked.

Time Constraints:

- 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.

2.5 Methodology

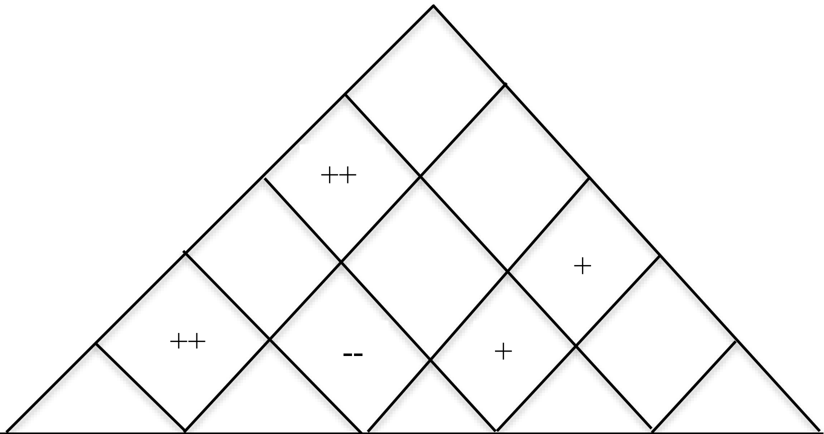
The first major objective of the project that must be completed is to determine what options are currently on market to make gaskets oleophobic. In order to determine which options are available, the team will research the market using the internet, and by contacting suppliers to get professional feedback. 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 difference 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 will be created at a later date and followed by the team. 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.

After first speaking with the sponsor and defining their requirements, a diagram known as a House of Quality (HOQ) was constructed (Figure 1). 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

3 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, cost efficiency, and applicability.

The team's next step in this experiment will be to narrow down the types of oleophobic solutions to test including method of applicability and relevant choice of material. The leak rate test rig should then be designed using a 3D rendering program to provide a better understanding of how to test the gaskets. The team will continue to hold informal and formal Bi-Weekly meetings to have regular updates on the progress of the project. A schedule will be made in the near future to adhere the team to deadlines that must be met for the success of the project.

4 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.