O-ring Testing & Characterization:

Project Plan & Product Specifications

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Abstract

The purpose of this report is to define the project's plan and product specifications. Team 1 was asked to develop a method in which to analyze elastomeric gaskets based upon property values. The project plan includes an overview of the steps that will be taken to complete the assignment. The specifications of the project include both design and performance specifications, where design specifications are measurable design and engineering features integral to the design and performance specifications are expectations of design performance in the field. The background information, needs statement, project goal, objectives, and constraints have been identified. A plan has also been devised on how the project will be completed. The next steps for the team will be to secure required testing supplies and equipment, commence sample testing, and analyze the resulting data.

1.0 Introduction

The purpose of this report is to breakdown the plans on how the project will be completed and explain its requirements. This project is being developed by Team #1 and it encompasses elastomeric gasket testing and characterization. Upon completion this project will help eliminate variability in the selection of elastomeric gaskets by creating performance requirements through this project's results. This project is being sponsored by Cummins, Inc. and funded by the Aero-Propulsion, Mechatronics, and Energy Research Building, as well as Cummins, Inc. Our sponsor is a manufacturing company that bases most of its efforts on service diesel and natural gas engines. It was founded in 1919, and currently has branches located in 190 different countries, making the need for standardizing the selection process of O-rings even more crucial. O-rings and/or gaskets are used to create a seal between two or more parts, and their performance can affect the quality of a large range of products and systems.

In this report, the scope of the project is constrained in order to deliver a cost-effective solution in a timely manner. The constraints and the specifications that define the project, along with the methodology in which we will execute the process to complete the project, will be stated following the objectives. A time frame will be devised and displayed in the form of a Gantt chart that will coincide with the methodology in order to complete our project in a timely fashion. Finally, a conclusion detailing what the following steps are in completing this project successfully, will be drafted.

2.0 Project Definition

2.1 Background Research

Each and every Cummins (and non-Cummins) engine currently being produced contains a variety of O-rings also called elastomeric gaskets because they are not always circular in cross section. These O-rings are implemented in order to create leak free joints between engine parts that may contain a range fluids from coolant and lube oil to compressed air. Many of these fluids are subjected to high pressures with internal parts reaching relatively high temperatures when operational. These high temperature and high pressure environments require the joint to be designed with the best quality elastomeric gaskets available. Depending on the working environment, O-rings must also have the capability to function while exposed to the elements and harsh chemicals. In response to these conditions, O-rings are made from various materials; such as silicon rubber, which is resistant to weathering[6], and fluorocarbon, which can be used in the presence of petroleum based chemicals[4]. In order to produce longer lasting, low maintenance engines, the need for better designed joints containing O-rings is increasing.

A typical O-ring is circular in cross section, as seen in Figure 1. Although these will work for most joints, Cummins has found that using an elastomeric gasket with a non-circular cross section, like the ones shown in Figure 2, can increase sealing pressure while using less material. However, the current procedure for determining the best type of O-ring for a specific joint is costly because the process of testing samples requires finite element analysis which can be lengthy. Due to its simplistic shape, the circular O-ring can be quickly and cost effectively designed by using the amount of crush to estimate the sealing pressure created by the mating parts. If a similar process can be applied to O-rings of different cross sections, the time and cost of designing parts can be greatly reduced.

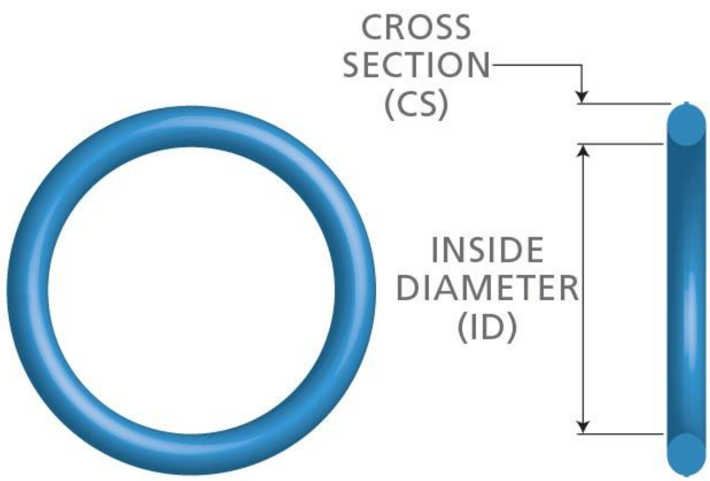

Figure 1: General O-ring Profile[7]

During the design process of elastomeric gaskets it is important to consider variables such as percent crush, which is defined as the percentage of differential between the original sealing component height or radial dimension and the compressed height or radial dimension as installed. Another important component to elastomeric gaskets is sealing pressure, which is defined as the pressure generated between the elastomeric sealing component and the mating parts by the crush of the sealing component[2].

Figure 2: Elastomeric gasket of non-circular cross section[3]

Another area of testing that will need to be addressed in the future is the effects of fatigue and creep on these oddly shaped O-rings. Currently there are standards for testing O-rings' performance capabilities, such as the ASTM D1414-19[1], which can be conducted on O-rings with contrasting cyclic loads and working temperatures in order to give insight into how the different properties of an O-ring will be affected by age. Although standards for testing O-rings with a general cross section already exist, standards specific to different O-ring cross sections do not exist. This is important due to the fact that an O-ring with a unique cross section will perform differently than an O-ring with a typical cross section.

2.2 Need Statement

The development of a quick method to test and characterize O-ring/gaskets is needed in order to standardize the selection process of the part in this growing industry. The creation of this scientific method will give engineers the ability to accurately predict the performance of the selected part (O-ring or gasket) within a certain tolerance. This method will involve parameters such as shape factor, crush value, and sealing pressure in order to best apply the data to practical use. This is a crucial step for the project sponsor, Cummins, Inc., in that costs will be reduced in the form of time saved during the design process and less material being used in the finished parts. This new process could also potentially be used for quality assurance when used with the supplier's products.

The current design process for O-rings requires numerous iterations of finite element analysis which is lengthy and therefore costly.

2.3 Goal Statement & Objectives

A new O-ring characterization process needs to be defined that will aid in the design process to more quickly select a suitable O-ring cross section for a specific joint. We will devise a method that will reduce the cost, time, and effort needed to determine the proper cross-sectional profile to use. A single algorithm will be developed that will take into account properties and characteristics to provide a suggestion as to what type of O-ring or gasket would work best for the desired sealing pressure of the condition.

The team is expected to have developed a method to characterize O-rings or gaskets based upon properties such as sealing pressure, crush value, and will also devise a shape factor to be used in the characterization of the O-rings. The procedure will be capable of receiving the shape factor or other specification of any geometrically shaped seal or gasket and accurately predict the sealing pressure. The three previously mentioned properties of sealing pressure, crush value, and shape factor would also be portrayed on a 3-D contour plot for visual representation and analysis. The devised method will involve cost effective and material preserving techniques. This process will reduce the amount of man-hours required and therefore money and resources spent on acquiring a customized solution.

3.0 Constraints

This project could have been applied to just about any elastomeric gasket currently in production but in order to produce results within the time frame given, the scope of the project needed to be defined in a way that produced useful results while being manageable in the time frame given. The first and most restrictive of constraints of a project is the budget. For this project, $2000 was set for the budget which will be used for acquiring samples to be tested and machining a test rig. Beyond the budget, the constraints consisted of parameters set by Cummins that confined the project scope in order to create reachable results. These parameters include limiting the project to testing elastomeric gaskets made from FKM, which is the material most used by Cummins in critical applications. Defining the material limited the range of durometers to be tested to 70 – 80 Shore A[2].

Other factors that will consume time and resources include the availability of test equipment, distance between the team and the sponsor, as well as the confidential nature of certain information that would otherwise aid the team. A MTS machine capable of applying a load of up to 1 kilo-newton has been located and will be available for use by the team. If a sample requires a load greater than the 1 kilo-newton available, that sample may have to be excluded from the experiment. The distance between the team and the sponsor will serve as a constraint on time due to shipping of samples sent from Cummins, which will need to be factored into the timeline. Although the team was able to acquire the Cummins standards on designing elastomeric gaskets, other documents such as engineering prints will not be available to use in designing the test rig. Time will therefore be spent on learning the correct process to design and machine the grooves for the mating flange on the test rig.

3.1 Design Specifications

In order to accomplish the goals of the project, data must be gathered from tests performed on samples of elastomeric gaskets during a vertical load test. The tests will be performed on a Mechanical Testing and Sensing machine (MTS). For this project the MTS machine used has the capability to apply a load of up to 1 kilo-Newton but also has interchangeable load cells of 1, 100, and 500 Newtons. This allows for greater accuracy when the full 1 kilo-Newton load need not be applied. The test rig needs to be built in order to be compatible with the MTS machine and it should be capable of testing samples in succession, quickly and without great effort between tests. To achieve this, the test platform should be able to receive elastomeric gaskets of varying cross sections and sizes by having multiple grooves of varying widths or a groove with an adjustable component. The test platform should be adjustable so that the sample being tested can be centered under the load cell and perpendicular to the motion of the load cell. The test rig will have controllable parameters such as the length that the load cell moves, which will be dictated by the percent crush given for that particular test. Given a particular percent crush, the MTS machine should output the load needed to achieve that amount of crush. Along with the load testing procedure, a sealing pressure sensing technique will be utilized. The technique to be used is Fujifilm Prescale, which is a film that is placed between two surfaces to be pressed together. Once contact is made between the surfaces, the film will change color depending on how much pressure is applied. The Fujifilm Prescale system has 7 different sensitivities to accommodate pressures ranging from 7.2 PSI to 43,200 PSI to ensure the best resolution for the application. The sensitivities are shown below in Table 1.

Table 1: Fujifilm Prescale Pressure Ranges

Film Type	Pressure Range
Extreme Low	7.2 - 28 PSI (0.5 - 2 kg/cm^2)
Ultra Low	28-85 PSI (2 - 6 kg/cm^2)
Super Low	70 - 350 PSI (5 - 25 kg/cm^2)
Low	350 - 1,400 PSI (25 - 100 kg/cm^2)
Medium	1,4000 - 7,100 PSI (100 - 500 kg/cm^2)
High	7,100 - 18,500 PSI (500 - 1,300 kg/cm^2)
Super High	18,500 - 43,200 PSI (1,300 - 3,000 kg/cm^2)

Accuracy of the Fujifilm is ±10% if the visual method is used, which is done with literature provided by Fujifilm. There is also a method that utilizes a scanner and software that increases the accuracy to ±2%[5]. If the scanning method is chosen, the film will have to be sent to a Cummins facility to be scanned and analyzed because at the moment there is not a scanner available for use.

From the data produced by the tests, a shape factor pertaining to a particular cross section will be defined and a 3-D contour plot will be made. On the contour plot will be the percent crush, sealing pressure and the shape factor which will be deduced from a correlation in the data across the different cross sections. With the use of the 3-D contour plot, an estimation of sealing pressure will be able to be found for a specific cross section and percent crush.

3.2 Performance Specifications

The testing to be performed on the samples will be done within a range of 10% to 35% crush. The reasoning behind defining this as the range comes from the Cummins Standard where the bottom end of the percent crush range is defined as 10% because anything below this will not deform the O-ring enough to fill the gland and create a seal. The top end is defined as 35% because any application requiring a percent crush above 30% should be done with caution and with the supplier's expertise to ensure the O-ring will not be damaged by overloading it[2].

4.0 Methodology

4.0.1 O-ring Testing

In order to continue with this project, the team must find a suitable MTS machine to compress the test samples to values ranging from 10 to 35 percent crush. Upon finding a suitable machine, the team will design and machine a receiver to accept the assortment of elastomeric gaskets to be tested. In order to design a test rig properly, research must be done on the design standards for O-ring grooves, standard testing procedures and standards for irregular elastomeric gaskets. Before testing can commence, the team will need to acquire a pressure sensing tool such as Fujifilm Prescale that can be used to find the sealing pressure at each crush value interval. Cummins will provide three samples of each cross-section they want to have tested, and each sample will allow for a minimum of two test samples.

4.0.2 Analysis

Once testing has been completed, and data has been compiled for the sealing pressures corresponding to percent crush for each cross section, it will be analyzed. The goal for the analysis is to find a correlation which will help develop a shape factor corresponding to the particular cross sections. This shape factor will then be plotted in a 3-D contour plot against percent crush and sealing pressure. From this contour plot, an estimation of sealing pressure should be able to be found given a particular percent crush and cross section which will help speed up the design process by giving relatively good starting point for a design.

4.1 Schedule

In order to achieve our team's goals in a timely manner, a Gantt chart was made using Microsoft Project, as can be seen in the Appendix A. As a team our first goal was to identify each team member's strengths and weaknesses, and then assign positions with tasks that will hone on these skills. Then, as a team we needed to further understand the project, so we met with Cummins, Inc. representatives and our advisors. This allowed us to define the goal of the project and its goals. We recently met with the project advisors and spoke with our sponsor regarding the testing parameters and added constraints in order to make the project scope manageable in one year.

The next phases in our project are to research possible ways to test the sealing pressure and acquiring the device and materials required for these tests, which we hope to have accomplished by the end of October. Since these pressure tests require another device for processing the outputted data, we must research our options and their related cost and time. Also since we are on a budget, the locating of alternative suppliers for O-rings and Fujifilm Prescale is necessary. This will lead to the acquisition of materials, and then to locating storage for this material. If when acquiring the testing device we don't find a lab that can accommodate our research, one must then be found. We can then research programs that can visually present our data, so that it's useful for our sponsor. If it isn't readily available, we must gain access to the program and learn how to utilize it in preparation for next semester. Our last phase is to do a sample test in order to make sure all of our acquired material is functional and we are prepared for the coming semester.

4.2 Resource Allocation

Shown below in Table 2 are preliminary tasks that will need to be completed before the test rig design work can begin. These tasks are mainly research involved in that they require the team member to document any relevant information that they might find in existing standards.

Table 2: Resource Allocation

Team Member	Task	Time Allotted
Richard Edgerton	Research design specifications for glands grooves and machining processes.	2 weeks
	Preliminary Test rig designs	3 weeks
Tawakalt Akintola	Research standards for irregular O-rings	2 weeks
Emilio Kenny	Research available test equipment to aid in test rig designs.	2 weeks
Kenneth McCloud	Keep webpage updated	continuous
	Fujifilm acquisition	2 weeks
Erin Flagler	Acquire test equipment	1 week
	Find Lab space to conduct test	2 weeks

5.0 Conclusion

Testing individual elastomeric gasket cross-sections for every design need is a tedious, time consuming, and expensive process. The goal of this project is to simplify the process by mapping different cross-sections to a single algorithm to greatly expedite the design process. We will test many different cross-sections and record their individual properties under a 10-35% crush. Upon recording and analyzing each individual cross-section, we will attempt to form a single algorithm or simple method that will take into account shape and percent crush to estimate sealing pressure which will give a reasonable starting point for the design process of the sealing components. Next steps for the project include researching design standards of O-ring grooves and the test equipment to be used so design work on the test rig can begin.

6.0 References

[1]"ASTM Elastomeric Gasket Standard." Technical Standard. n.d. Online. 10 October 2014. <http://www.astm.org/Standards/D1414.htm>.

[2]Cummins, Inc. "Seals, Molded Elastomeric." Technical Standard. n.d. 10 October 2014.

[3]*Elastomeric Static Seal*. n.d. Webpage. 10 October 2014. <http://articles.sae.org/12886/>.

[4]*Flourosilicone*. n.d. Webpage. 10 October 2014. <http://www.aceseal.com/ring-materials-flourosilicone-c-17_24-l-en.html>.

[5]*Fujifilm Prescale*. n.d. Webpage. 10 October 2014. <http://www.fujiprescaleusa.com/>.

[6]*Silicone*. n.d. Webpage. 10 October 2014. <http://www.aceseal.com/ring-materials-silicone-c-17_20-l-en.html>.

[7]*Typical O-Ring Model*. n.d. Webpage. 10 October 2014. <http://fs23.formsite.com/parcoinc/images/O-ring_Cross_Section_V2.jpg>.

7.0 Appendix

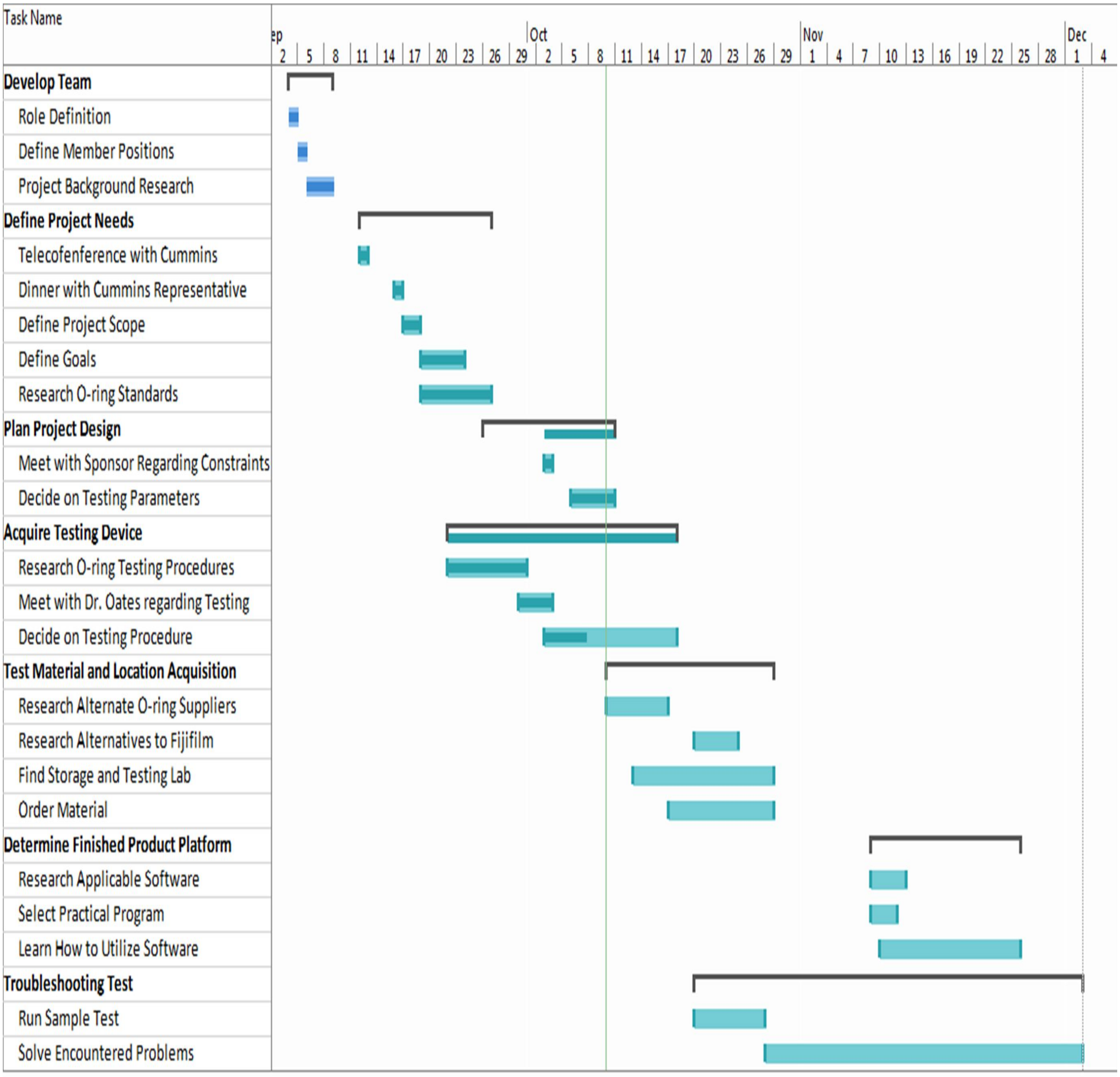

Figure 3: Gantt chart