O-ring Testing & Characterization:

Needs Assessment

Group 1

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Abstract

There are many different applications where O-rings are necessary. These numerous applications call for many different sizes, cross-sections, and materials in O-ring design, as not all “O-rings” are circular. There is no current system in place to classify and purpose various O-ring shapes for specific design specifications, so each custom sample requires time and effort to test. This creates a need for a fast and easily reproducible method to test various O-ring applications. The purpose of this project is to simplify the O-ring selection process. This will be accomplished by testing O-rings with many different cross-sections and sizes. The data from these tests will be mapped to a contour plot using single algorithm. The plot will provide an estimation of sealing pressure based upon physical characteristics of the O-ring in consideration.

1.0 Introduction

The purpose of this report is to breakdown various introductory aspects of the project in order to give direction to the design process. The project in which this report is based on is the O-ring testing and characterization project, which is being designed by Group #1. Upon completion this project will help eliminate variability in the selection of O-rings, given certain performance requirements. This project is being sponsored by Cummins Inc. and funded by Aero-Propulsion, Mechatronics, and Energy Research Building as well as Cummins Inc. Cummins Inc. is a manufacturing company that basis 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 are used to create a seal between two or more parts, and so their performance is crucial because it can affect the quality of a large range of products.

In this report, the project definition will be clearly stated. This is done by first stating what the current problem at Cummins is, and the reason for this project. Then after knowing the situation a goal, and its accompanying objectives, will be defined in order to alleviate this problem. Along with these objectives, the constraints on the project and the methodology in which we will implement our designing process will be stated. Along with the methodology, a time frame will be devised and displayed in the form of a Gantt chart, 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 Information

Each and every Cummins (and non-Cummins) engine currently being produced contains a variety of O-rings. 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 under high pressures and the inner parts can reach relatively high temperatures when the engine is in use, which puts a high amount of stress on the joints. O-rings are also exposed to the elements and also need to resist harsh chemicals in the working environment which can vary greatly. In order to combat specific conditions an O-ring might face, they can be made from different materials such as silicon rubber which is resistant to weathering[1] and fluorocarbon which can be used in the presence of petroleum based chemicals[2]. 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. Although these will work for most joints, Cummins has found that cross sections of different shapes will work better for certain joints and can be more cost effective due to a decrease in material used. 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.

Another area of testing that will need to be addressed in the future is the effect that service and age in general has on these oddly shaped O-rings. Currently there are standards such as the ASTM D1414-19[3] which describes how a test should be conducted that will give insight into how the different properties of an O-ring will be affected by age. Although there already exists standards like this for testing O-rings with a general cross section, there does not exist standards specific to an O-rings cross sections which of course will perform differently than a typical O-ring.

Figure 1

2.2 Need Statement

The development of O-ring testing and characterization is needed in order to standardize the selection process by creating an accurate scientific method that can allow engineers the ability of performance predictability. This method in which to test and characterize O-rings must result in parameters such as shape factor, crush value, and sealing pressure in order to best apply the data to practical use. This is a critical step that will help optimize the design process for the project sponsor, Cummins, 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 supplier's products.

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

2.3 Goal Statement

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 would work best for the desired sealing pressure.

2.4 Constraints

- Design Budget is $2000 total
- Regular testing equipment is expensive and not accessible
- Access to some relevant information is limited or classified
- Method must reduce time and cost compared to past or current procedures
- Method must be applicable to a variety of general or more common shapes
- Trial consistency of measured date should not exceed +/- 7% to ensure reliability

2.5 Expected Results

The group 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 a non-circular O-ring 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.

2.6 Methodology

O-ring Testing:

- Find suitable actuator to crush O-rings to desired values with acceptable tolerances.
- Form a mating flange with the appropriate grooves for multiple O-ring cross-sections.
- Acquire Fuji pre-scale paper or other pressure measuring device to determine sealing pressure.

Analysis:

- Analyze data from individual O-ring cross-sections and map sizes to sealing pressures over a range of crush values
- Consider multiple sizes and shapes to develop an algorithm that simplifies the O-ring design process

3.0 Conclusion

Testing individual O-ring 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 many of the most common 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 (the deformation in the direction of the compression). Upon recording and analyzing each individual cross-section, we will attempt to form a single algorithm or simple method that will take into account size and shape in order to prescribe an O-ring type for the desired sealing pressure and application

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