Validation study of Silastic J viscoelastic model

ABSTRACT

This research project will explore a simple validation study of a new Silastic J viscoelastic material model from design of experiments through testing, modeling, feature extraction and application of a validation metric. Time domain strain data will be collected from an aluminum ring structure with a constrained damping layer of Silastic J. Results from these experiments will compared with an ABAQUS explicit model using time domain features and statistical metrics.

The current Silastic J material model is developed from material tests in the 0 to 10 Hz range over varying temperature ranges. Typically material models are then developed for higher frequency ranges by using Time Temperature Superposition (TTS) to extrapolate how a material would behave at a given temperature for a specified frequency. This study will determine if the viscoelastic model based on TTS holds true for higher frequency ranges.

INTRODUCTION

Silicone rubber is a unique synthetic elastomer made from a cross-linked polymer, which is reinforced with silica. Its characteristics are such that it provides the perfect balance of mechanical and chemical properties required by many of today's most demanding applications.

Silastic rubber excels in the following areas:

- High and low temperature stability
- Inertness (no taste or smell)
- Translucent and easy to color
- Wide hardness range, 10 - 80 Shore A
- Chemical resistance
- Weatherability
- Sealing performance
- Electrical properties
- Compression set resistance

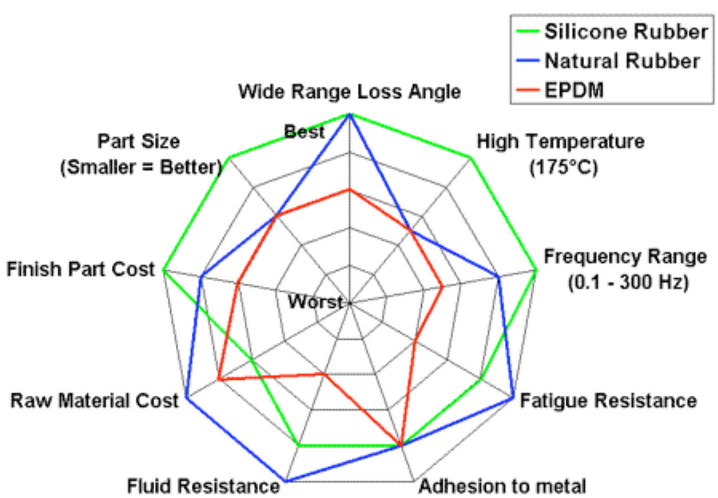

Figure 1 - Comparison of performance properties between Silastic, Natrual, and EPDM rubbers.

Silicone rubber can be used in a variety of applications. Listed below are examples of finished goods.

- Automotive
- Aviation and Aerospace
- Babycare
- Energy - Power and Utilities
- Extruded Profiles
- Gaskets and Seals (Air and Water)
- Gaskets and Seals (Fuel and Oil)
- Hose
- Keypad / Data Entry
- Medical
- Office Equipment
- Protective Equipment and Masks
- Rollers (Industrial)
- Sponge
- Sports Gear
- Toys
- Wire and Cable

Silastic rubbers fall into the realm of viscoelastic materials, that is stress and strain in the material are rate and temperature dependant. Early scientists defined matter as a solid, liquid, or gas. They found that some materials fit in more than one of these phases. For instance, honey is a good example of a material with the physical properties of both a solid and a liquid. If one allows honey to flow from a container and then quickly tips the container up, a portion of the honey will be pulled back into the container. Liquids don't typically respond to tensile force or pulling force. Scientists defined this material as viscoelastic because it exhibited the characteristics of a viscous liquid and an elastomeric solid. Silly putty, chewing gum, and polyurethane memory foam are also examples of viscoelastic materials.

Almost all polymers exhibit viscoelastic behavior. Polymers (and other viscoelastic materials) behave more like solids at low temperatures and fast deformation speeds. They are more like liquids at high temperatures and slow deformation speeds.

Commonly used viscoelastic models are the Kelvin material and Maxwell material. Each model can be represented by springs and dashpots set in combinations of series and parallel elements. This study will focus on the Maxwell material model.

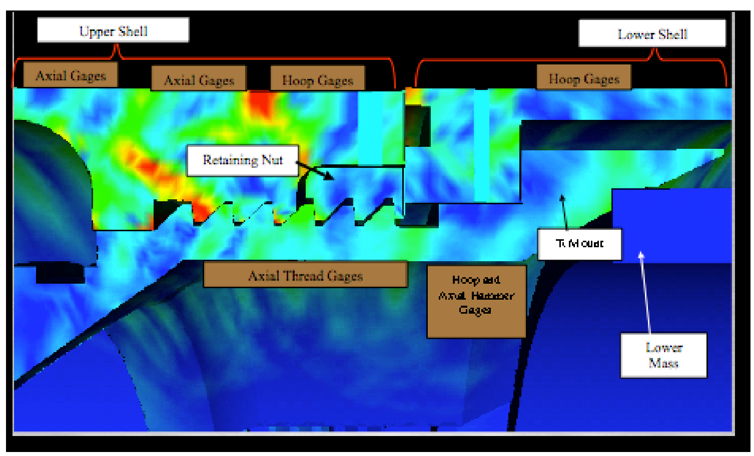

Figure 2 - High fidelity simulation of a threaded interface. Friction and non-linear interactions

This viscoelastic behavior makes modeling the materials challenging. In high fidelity structural dynamics models, the unknown behavior of these materials contributes a large portion of uncertainty in the final prediction. By performing a validation study of the Silastic J material, this behavior and uncertainty can be quantified leading to greater reliability of the predictive modeling efforts at Los Alamos National Laboratory.

Because the material in question is rate dependant, one parameter of variation for the validation experiment and the model input would be frequency of input. Another parameter may be the amplitude of excitation. The materials are also temperature dependant, however controlling the temperature of the experiment precisely would prove to be difficult, so it will be considered a random variable. For the model, there are several input parameters that may be varied to provide a statistical understanding of the behavior. With this information a small Design of Experiments (DOE) can be carried out to provide information on how test and run parameters should be varied.

The typical response that is of interest for the structural dynamics models is shock loading, therefore time domain, and not frequency domain analysis is used. Time domain features and metrics will therefore be developed for the validation of the Silastic J model. A sample feature could be the logarithmic decrement of the strain signal. Once extracted from experimental and simulated data the feature will be put through a series of statistical tests to determine if both sets of data are equivalent.

Optional information that would be of interest is as follows:

- A sensitivity study of the response feature to input parameters.
- Identifying sources and form of uncertainty in the process.
- Quantification of the uncertainty.
- Propagation of uncertainty.

Depending on the number of replicates the group is able to obtain during the time, non-probabilistic methods maybe employed to help validate the model.

SCHEDULE

Weeks	Tasks
1	Orientation
2	Background research on the topics of viscoelastic materials, design of experiments, and validation.
3	Modal testing, design of experiments, modeling.
4	Design of experiments, frequency dependant testing, and modeling.
5	Modeling, testing, and sensitivity study (?).
6	Finish testing, modeling runs, and feature extraction.
7	Validation Metrics, feature extraction, writing.
8	Wrap-up, presentation, and begin writing.
9	Final wrap up, and presentation.