Bi-directional Variable Stiffness Magnetorheological Elastomer (MRE) Design
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What is MRE?
- MRE is a semi-active silicon with embedded iron particles for variable stiffness changes under external magnetic flux

Research Objective
- Feasibility of using MRE as a haptic feedback device.
- Design a MRE device that can increase or decrease the stiffness.
- Design an effective way of providing a “pre-strain” to the base silicon material.

Computational Simulation
- COMSOL 4.3b Finite Element Analysis
- 2D axisymmetric model
- Parametric sweep was run to find the amount of current needed to counteract the permanent magnet.

MRE Composition
<table>
<thead>
<tr>
<th>Components</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>Silicone Resin and curing agent (R-2652)</td>
<td>Base of the MRE</td>
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<tr>
<td>Iron Powder (98%, spherical powder, 1-6 micron size particles)</td>
<td>Active component</td>
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<tr>
<td>Toluene</td>
<td>Solvent</td>
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<tr>
<td>3-glycidyloxypropyltrimethoxysilane (GPTMS)</td>
<td>Silane coupling agent</td>
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MRE Fabrication Procedure
- MRE without silane agent: Silicone resin was dissolved in toluene at 60°C and iron particles were added and stirred vigorously for an hour.
- MRE with silane agent: GPTMS was dissolved in toluene at 60°C for 1 hour and iron particles were added and modified in the prepared solution at 80°C for 3 hours. Silicone resin was added and dissolved at 60°C for an hour.
- The curing agent was then added to both mixtures.
- Vacuum was applied to remove bubbles in the mixture for 30 minutes.
- The mixture was poured into a glass dish and cured in an oven at 90°C overnight.
- For the magnetically cured samples, they were put in between two coils in the oven.

MRE Results
- Samples of MRE will be tested in the Bose Dynamic Mechanical Analysis (DMA) for shear modulus, stiffness, and damping.
- Each test has seven conditions from 1 to 7 Hz with an amplitude of 0.4 mm.
- An initial displacement of 1 mm is applied so that every test starts from the same reference point.
- The field is ranged from 0 to 25 mT.

Future Work
- Finish testing the samples and analyze the data.
- Control system will include a magnetic field sensor and a load cell.