Development and System-Level Implementation of Novel Damping Devices

Nikoo Hazaveh, Geoff Rodgers, Stefano Pampanin, Geoff Chase.

Key Aspects of the 2017 Flagship 4 Project:

- **Further develop of the quadrant-specific damping device**
  - Additional configurations to produce different damping behaviour
  - New silicone fluids (previously simple oil) to produce different force-velocity profiles
  - Analytically assess the influence of these different behaviours on structural performance
  - Undertake multi-level structural modelling to better understand/interpret the shake table testing recently completed at the University of Auckland

- **Integration of Damping Devices into a Large-Scale Shake-Table Test.**
  - Ideally, the developed damping device will be incorporated into the QuakeCoRE-ILEE testing at Tongji later this year.

- **Working with practitioners to better understand system-level interactions and detailing for incorporation of devices into field structures**

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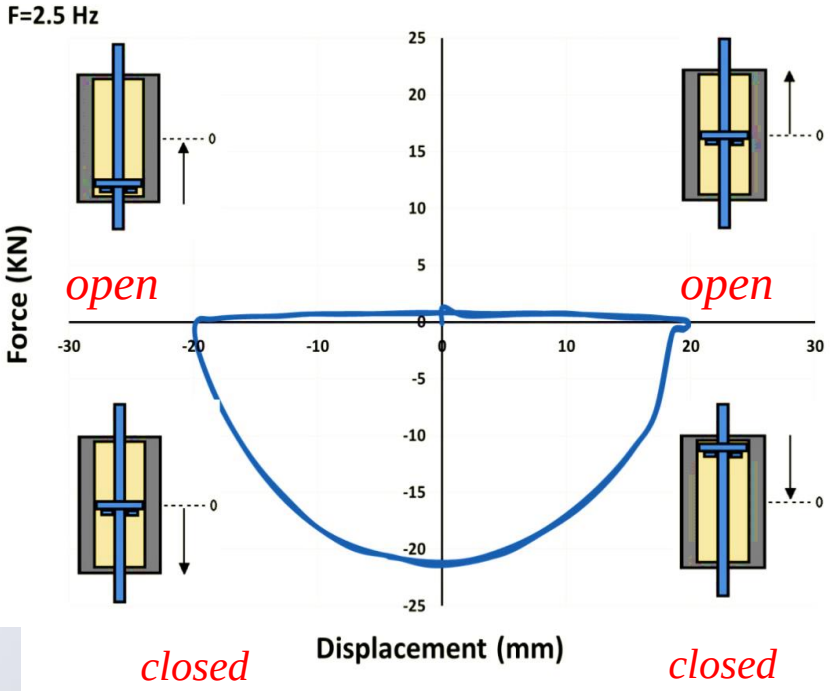
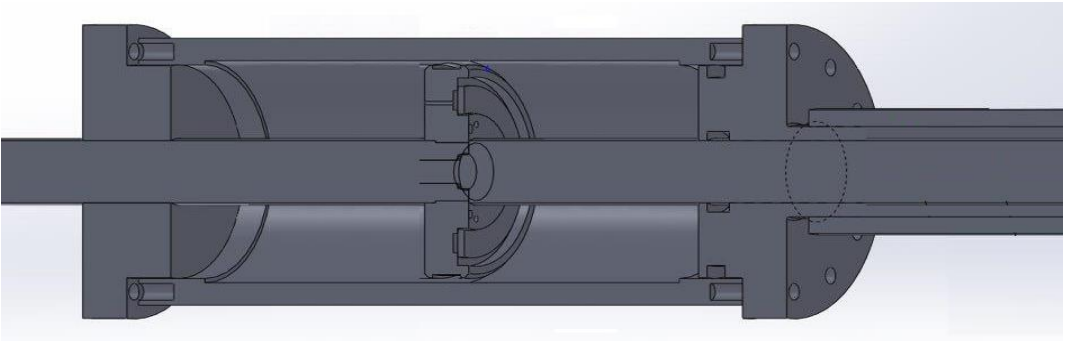
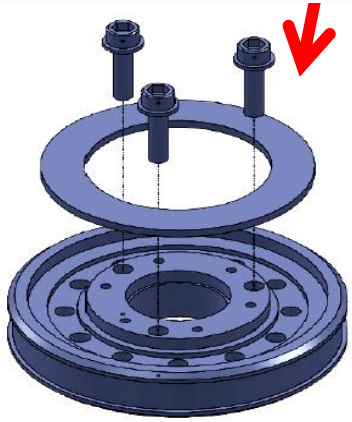
Customisable viscous damping behavior to modify the overall structural response.

Choose the optimal damping response behaviour for any given application







One way valves enables selection of when damping forces are provided to the structure, enabling the customisation of the overall structural hysteretic response.

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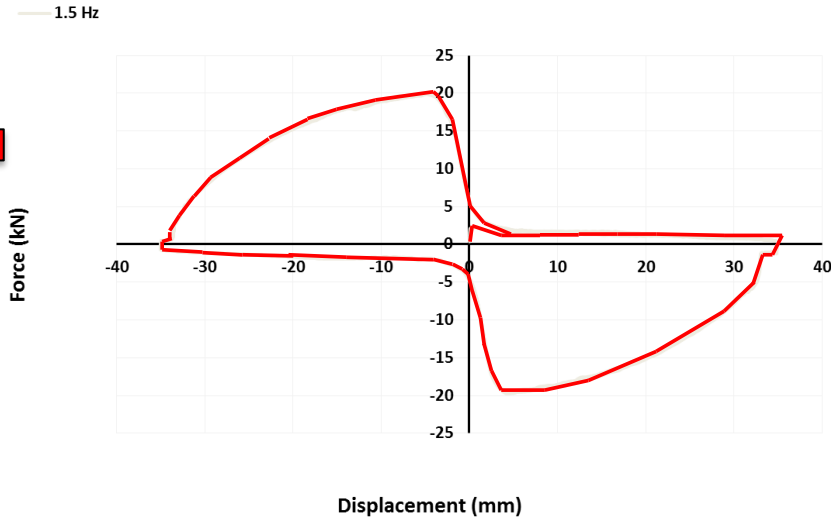
Large-Scale Testing (15 tonne structure) on the University of Auckland Shake-Table



Any individual quadrant or any combination of two or more quadrants can be included in the response

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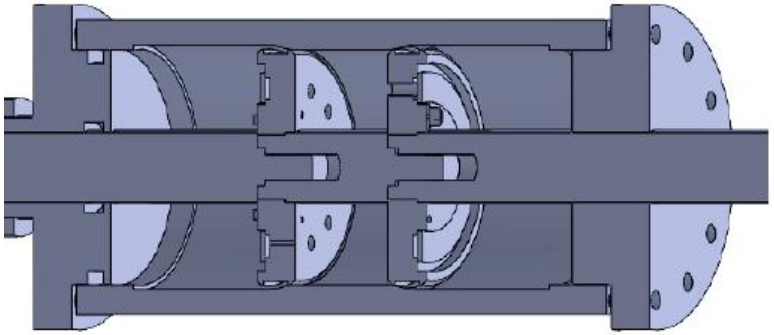
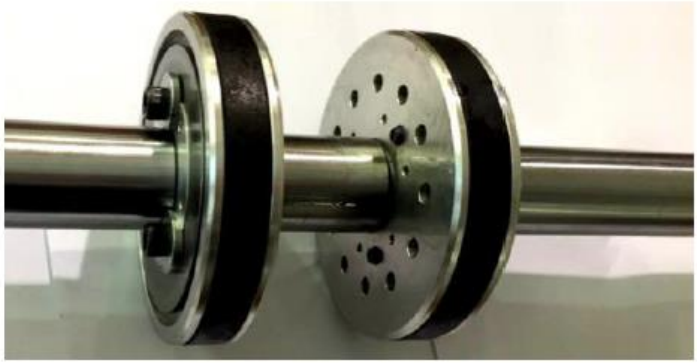
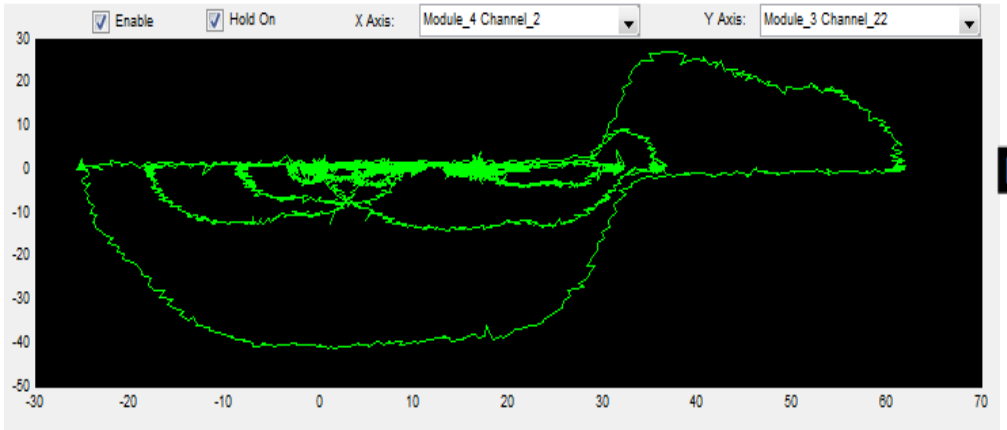
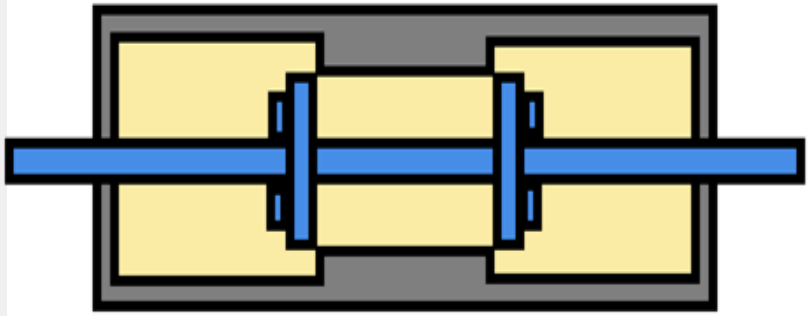
Additional configurations to produce different damping behaviour







1-3 damping device as tested on the Auckland shake-table (the opposite diagonal to the 2-4 device)



1-3 device has demonstrated potential to re-centre a structure with a residual drift (due to resistance away from centre)

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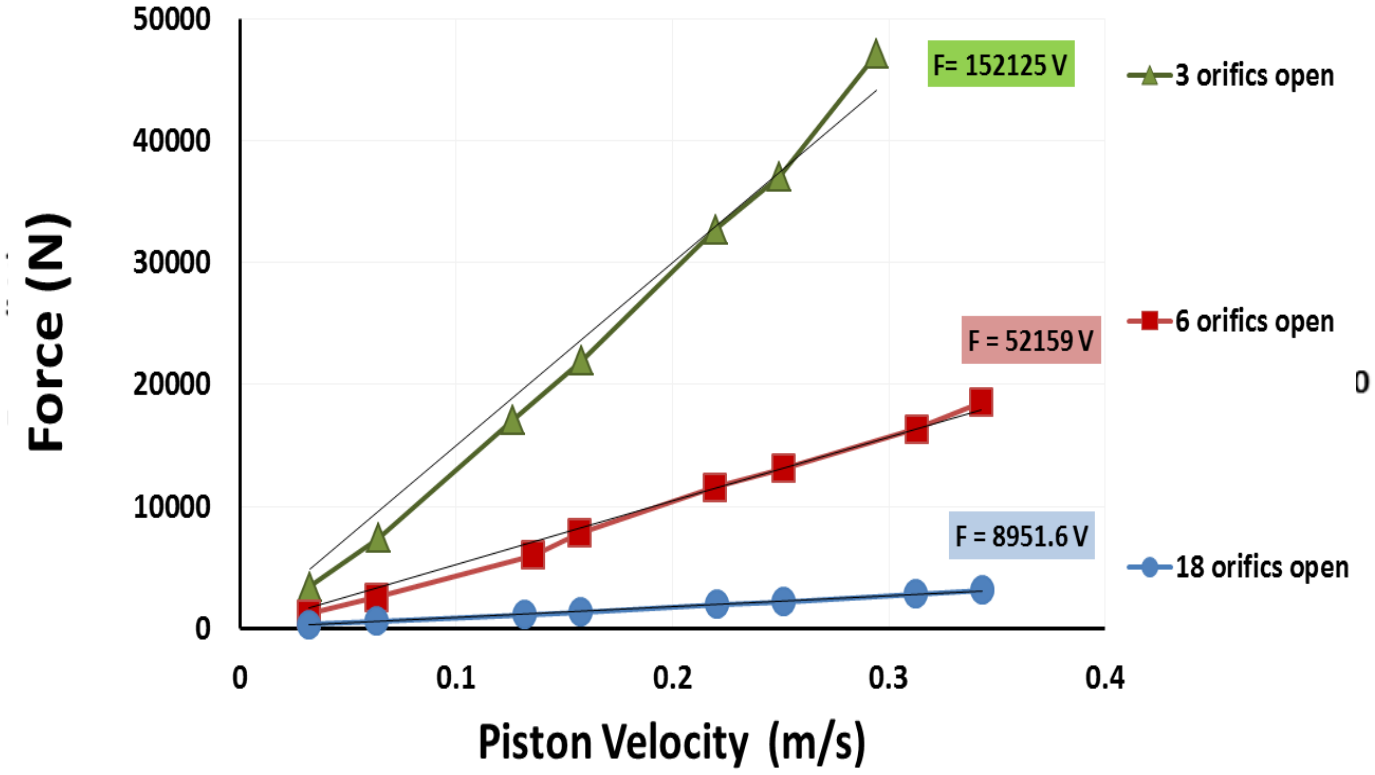
New silicone fluids to decrease temperature dependence and (hopefully) create a non-linear velocity response

Currently, using basic oil with Newtonian behaviour:



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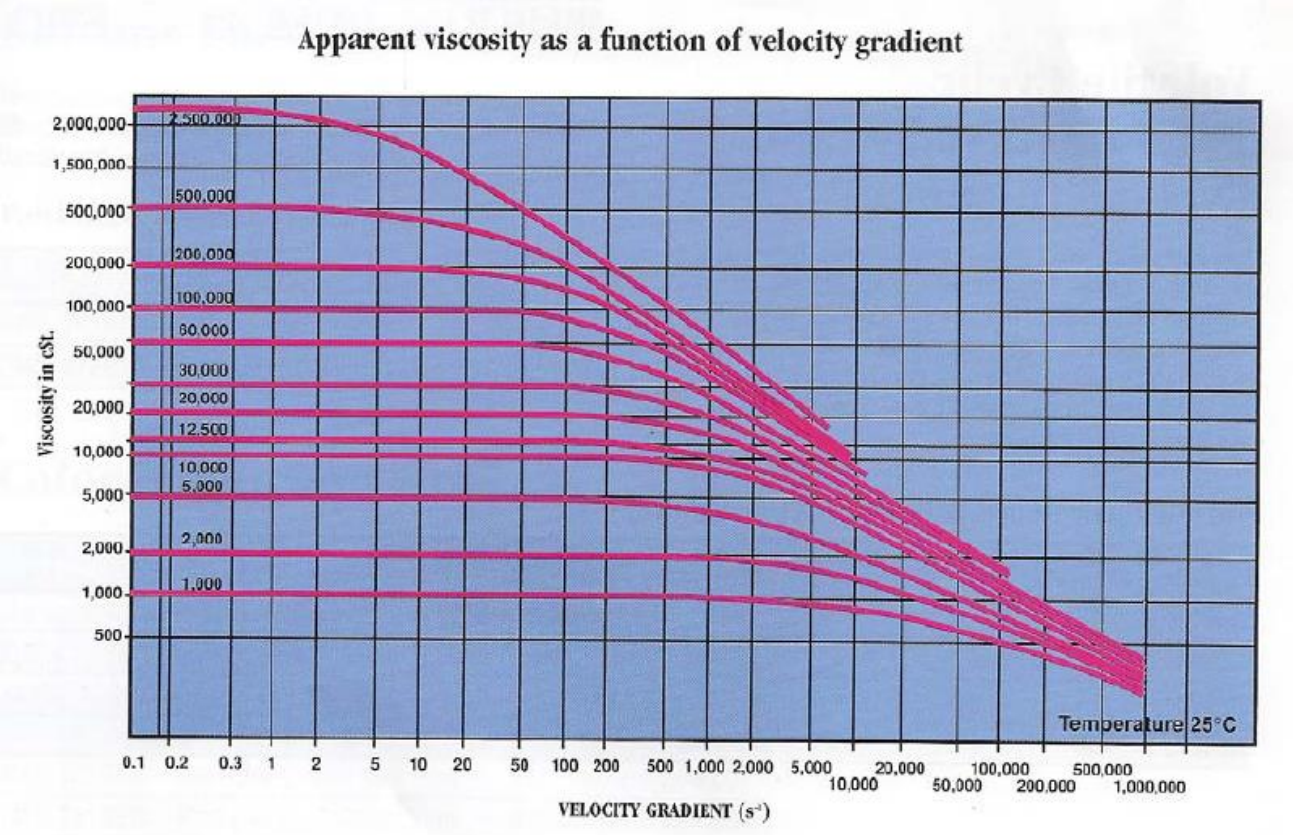
New silicone fluids to decrease temperature dependence and (hopefully) create a non-linear velocity response

New Silicone fluids have already arrived from the US, with viscosities of 100, 500, 1 000, 10 000, and 100 000 cSt (current oil has viscosity of 140cSt)



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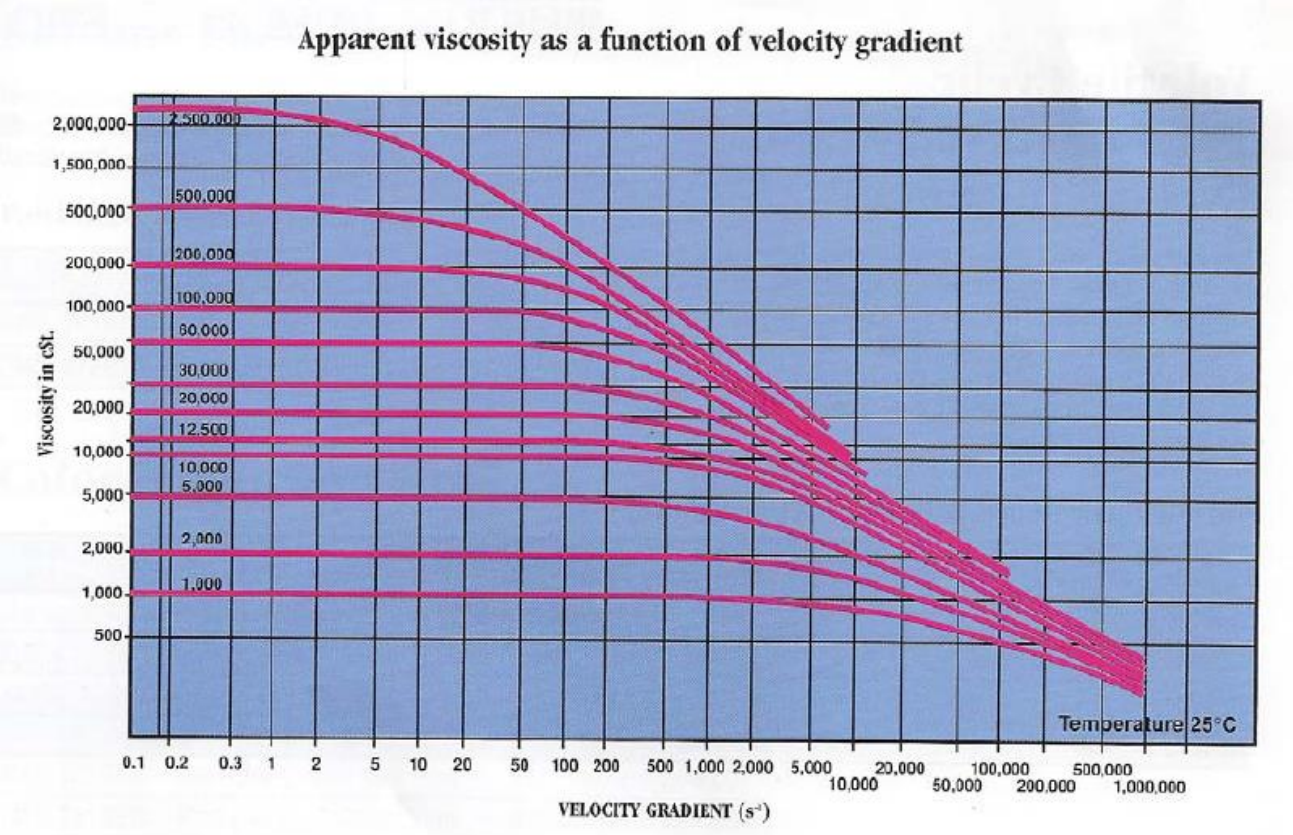
High molecular weight silicone fluids exhibit a reduction in viscosity as the velocity gradient/shear rate within the fluid increases (Non-Newtonian behavior).

The result is a non-linear force-velocity profile for the device.



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Computational Modelling of Fluid Flow in Viscous Dampers

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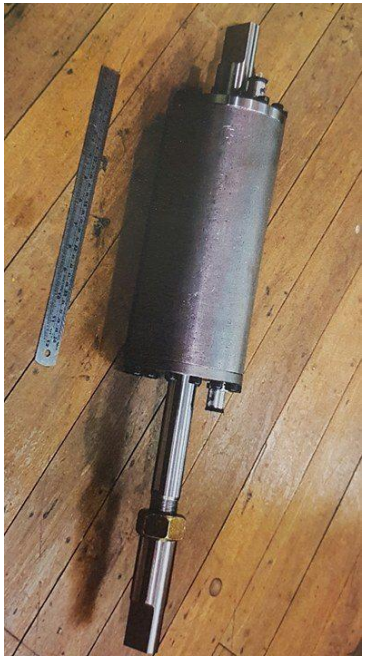

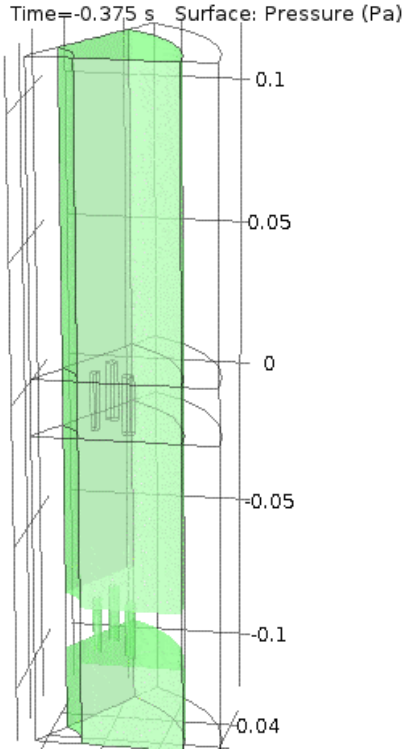

- PROJECT AIM:
  - Establish models of the current device and working fluids
  - Extend these validated models to use silicone fluids with non-Newtonian behavior
  - Provide recommendations for future viscous damper designs

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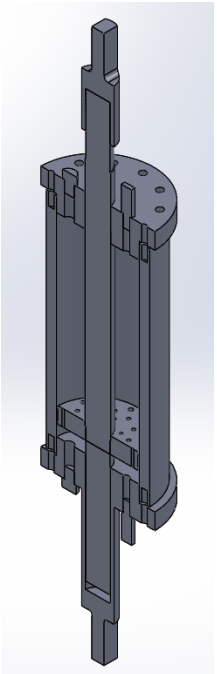
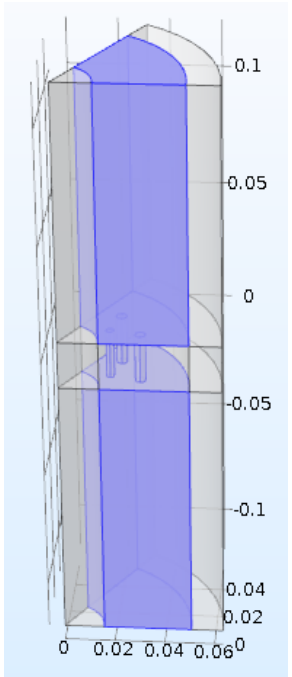
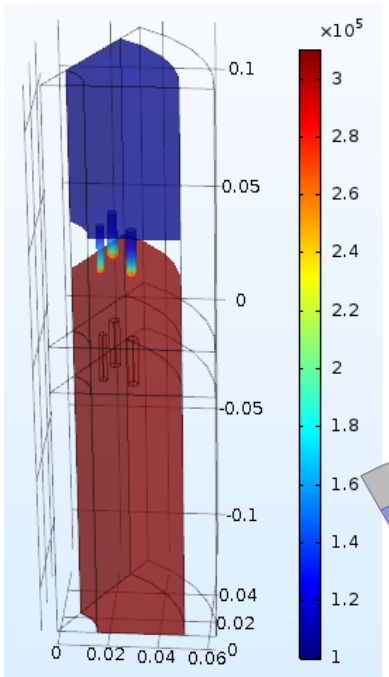
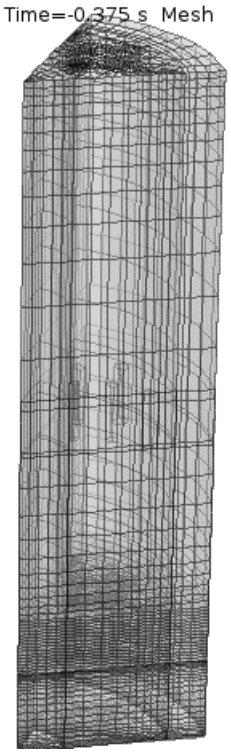
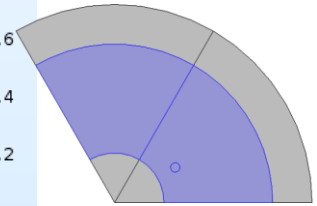
- Model built in COMSOL
- Symmetry exploited by using a wedge of cylinder
- Dynamic mesh
- Pressure and velocity fields solved using Navier-Stokes equations
- Model results compared to experimental data



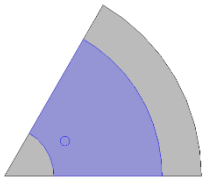




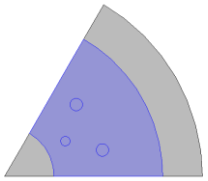




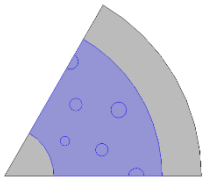
3 open orifices



6 open orifices



18 open orifices



30 open orifices

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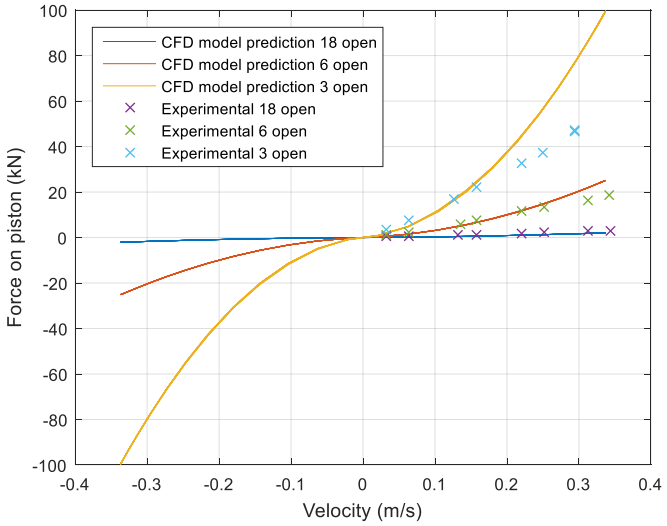
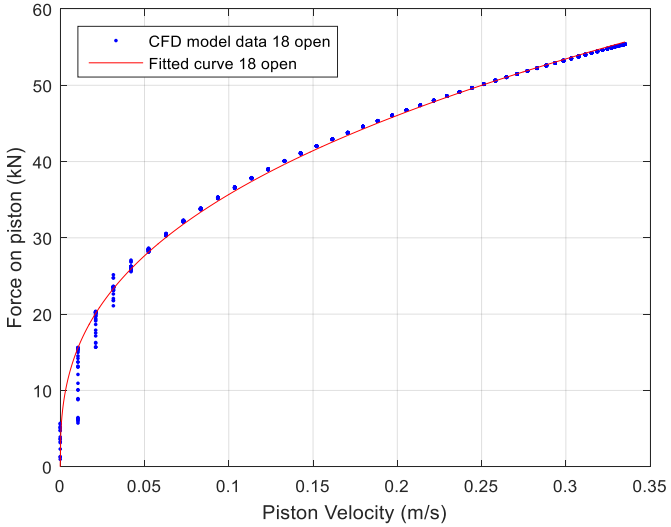
- Agreement between model and experimental for piston velocities < 0.15 m/s
- Model predicts silicone fluids of 2,500,000cSt kinematic viscosity (2.5 m^2/s) will produce desired force response
- Recommended fluids: 100,000cSt - 2,500,000cSt



$$F = CV^n$$

- n = 1 for Newtonian fluid
- n = 0.2 – 0.4 for desired non-Newtonian behaviour
- n = 0.368 for graph on left



FUTURE WORK:

- Experimental testing with silicone fluids
- (Hopefully) developing CFD model to accurately predict behaviour at higher velocities

Focus of Ongoing Work

- Analytical modelling of the multi-level shake table response and comparison with previously developed prediction methods.
- Modelling work and development of a device for potential inclusion within the QuakeCoRE-ILEE tests, if circumstances allow.
- Ongoing discussion with practitioners about system-level integration and potential uptake.