Calculating the dissipation in fluid dampers with non-Newtonian fluid models

Arpad Forberger, Gamax Laboratory Solutions Ltd.

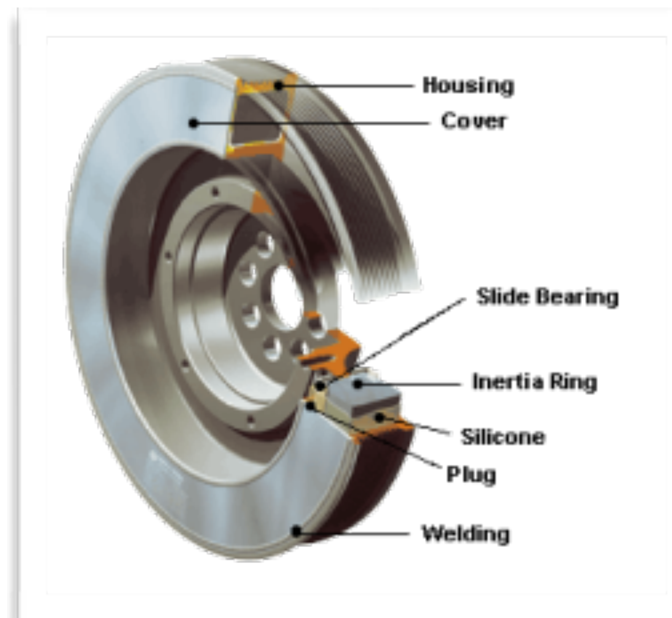
COMSOL CONFERENCE 2015 GRENOBLE

Agenda

- Introduction
- EBM with COMSOL
- Results
- Q&A

Fluid dampers

- Specific damper tuning according to customer requirements
- Damping on a broad frequency range
- Provides noise reduction
- Operating at higher temperature than other damper systems in its application range
- Compact size, integrated solutions with pulley and hub
- Extended service life
- Most cost effective solutions for high powered passenger cars, truck and engines with higher output



Governing equations

- Continuity equation $$\nabla \mathbf{u} = 0$$
- Equation of motion $$\frac{\partial}{\partial t}\rho\mathbf{u} = -\nabla\rho\mathbf{u}\mathbf{u} - \nabla\boldsymbol{\pi} + \rho\mathbf{g}$$
- Energy equation $$\frac{\partial}{\partial t}\rho U = -\nabla\rho U\mathbf{u} - \nabla\mathbf{q} - \boldsymbol{\pi} : \nabla\mathbf{u}$$
- Upper convected Maxwell model $$\boldsymbol{\tau} + \lambda\overset{\nabla}{\boldsymbol{\tau}} = -2\mu_0\mathbf{d}$$
- Equation in COMSOL

$$\frac{\partial\mathbf{u}}{\partial t}\rho + \rho\left(\mathbf{u}\nabla\right)\mathbf{u} = \nabla[-p\mathbf{I} + \mu\left(\nabla\mathbf{u} + \left(\nabla\mathbf{u}\right)^T\right)] + \mathbf{F}$$

Dissipation in polymeric liquids

- Energy equation

$$\rho C_p \frac{DT}{Dt} = -\left(\nabla \mathbf{q}\right) - \left(\frac{\partial ln\rho}{\partial lnT}\right)_p \frac{Dp}{Dt} - \left(\boldsymbol{\tau} : \nabla \mathbf{u}\right)$$

- Rate of strain calculation

$$\mathbf{d} = \dot{\gamma}_d + \dot{\gamma}_s$$

$$\dot{\gamma}_s := \frac{1}{G}\frac{\partial \boldsymbol{\tau}}{\partial t}$$

$$\dot{\gamma}_d = \frac{1}{2}\left(\nabla \mathbf{v} + \nabla \mathbf{v}^T\right) - \frac{1}{G}\left(\frac{\partial \boldsymbol{\tau}}{\partial t} + \mathbf{v}\nabla\boldsymbol{\tau}\right)$$

EBM with COMSOL

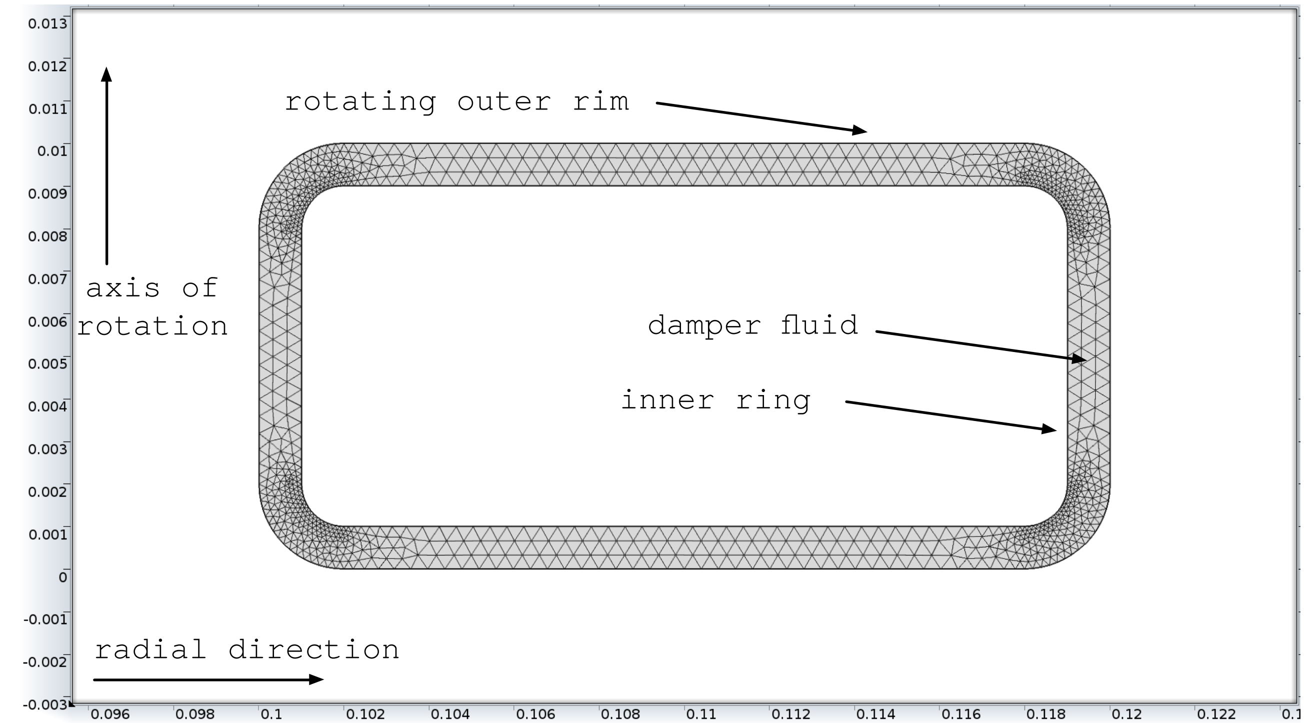
- UCM $$\boldsymbol{\tau} + \lambda \overset{\nabla}{\boldsymbol{\tau}} = -2\mu_0 \mathbf{d}$$
- PDE General form $$e_a \frac{\partial^2 \mathbf{u}}{\partial t^2} + d_a \frac{\partial \mathbf{u}}{\partial t} + \nabla \Gamma = \mathbf{f}$$

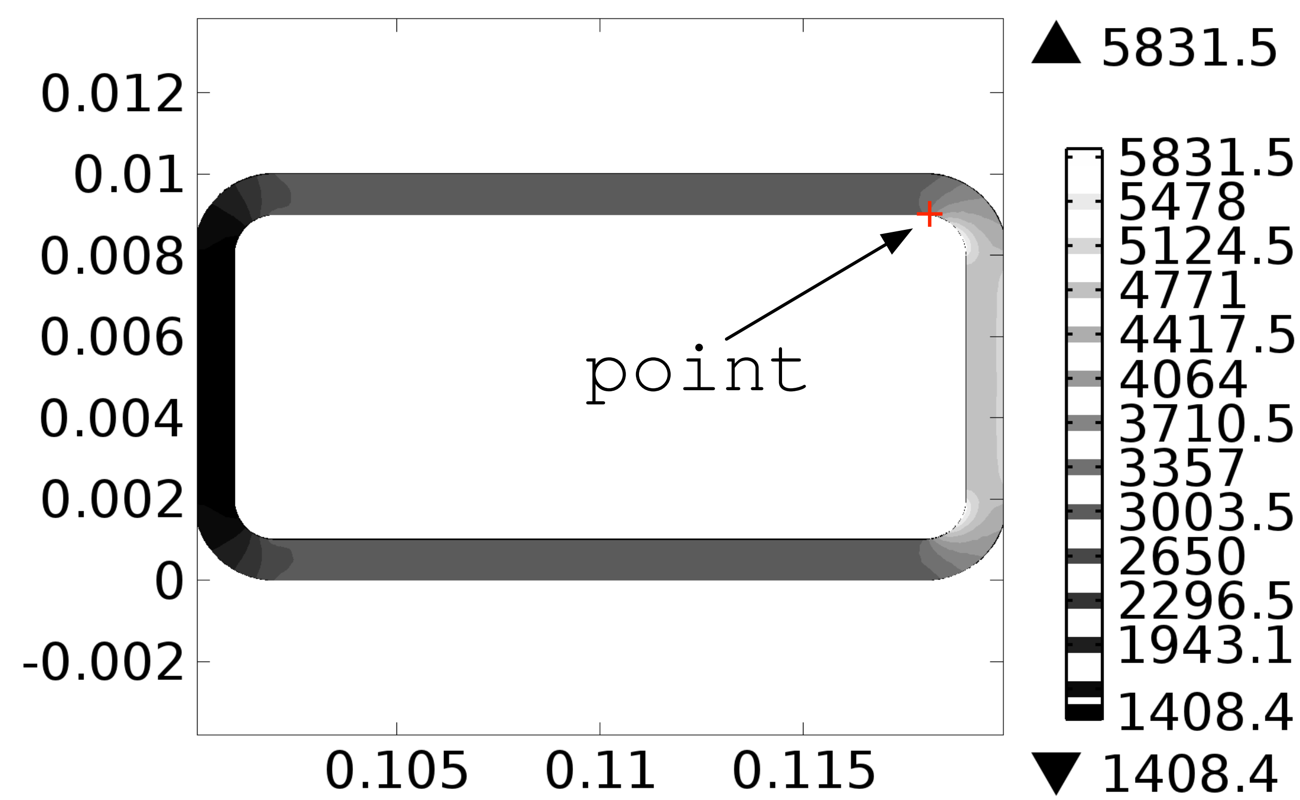
Parameters of the three element material

Parameter	Value
G_1	8053.1 [Pa]
G_2	33.477 [Pa]
G_3	64.353 [Pa]
mu_1	360.910 [Pa s]
mu_2	180.670 [Pa s]
mu_3	41.649 [Pa s]

FEM implementation

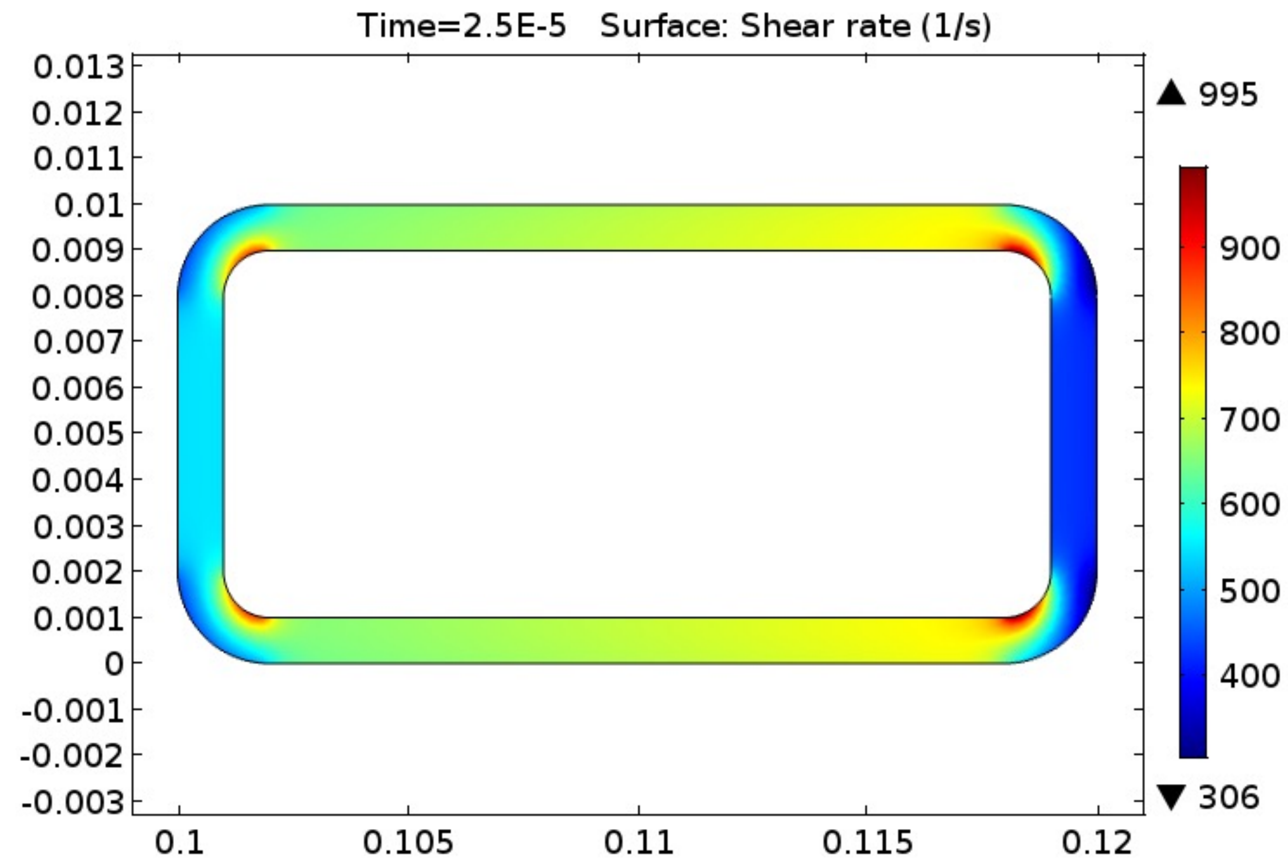
- 2D axial symmetric geometry
- rotating outer housing
- no direct connection between the two disks
- highly non-linear damper fluid inside the channel
- Time dependent and steady state calculation
- Global ODE for calculating the position

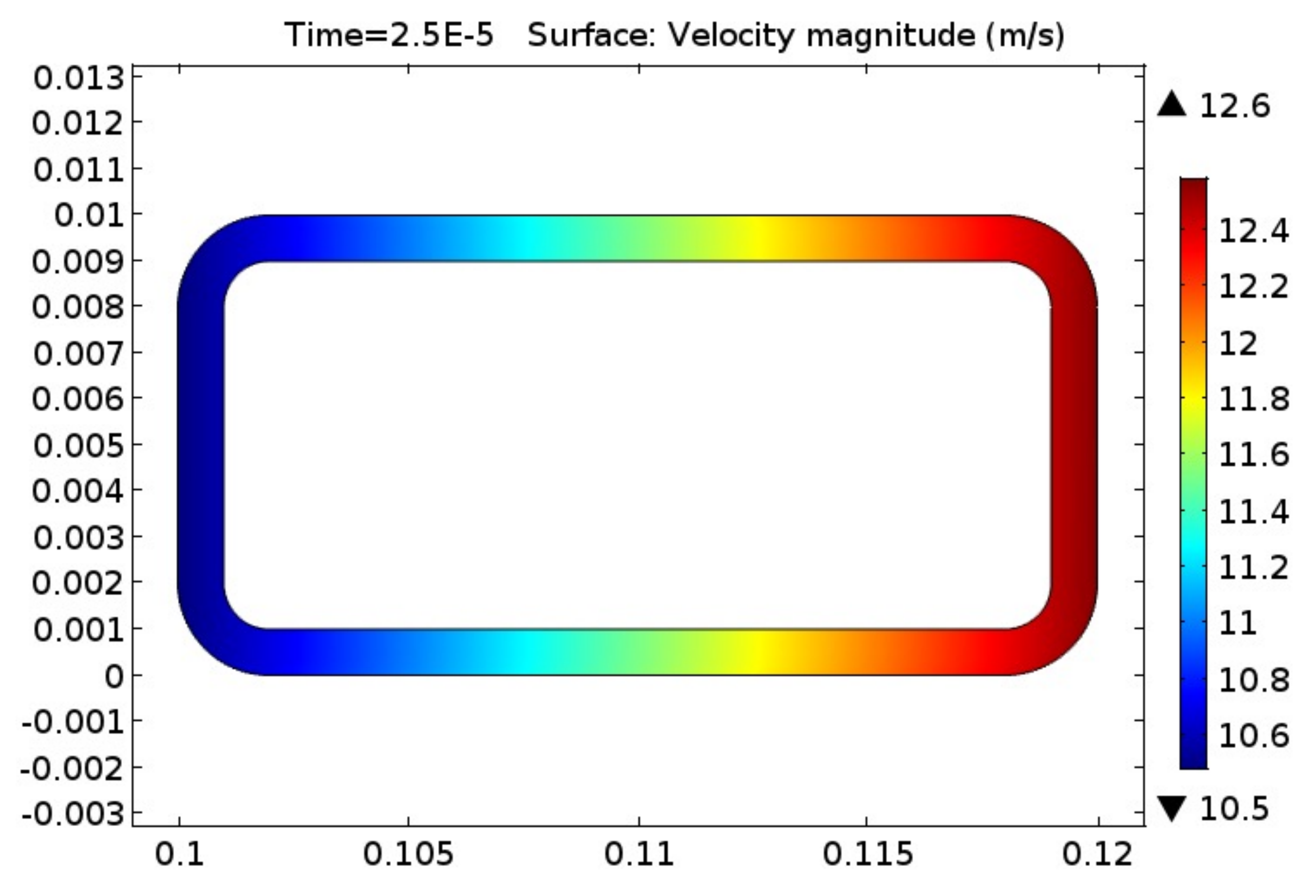




Results

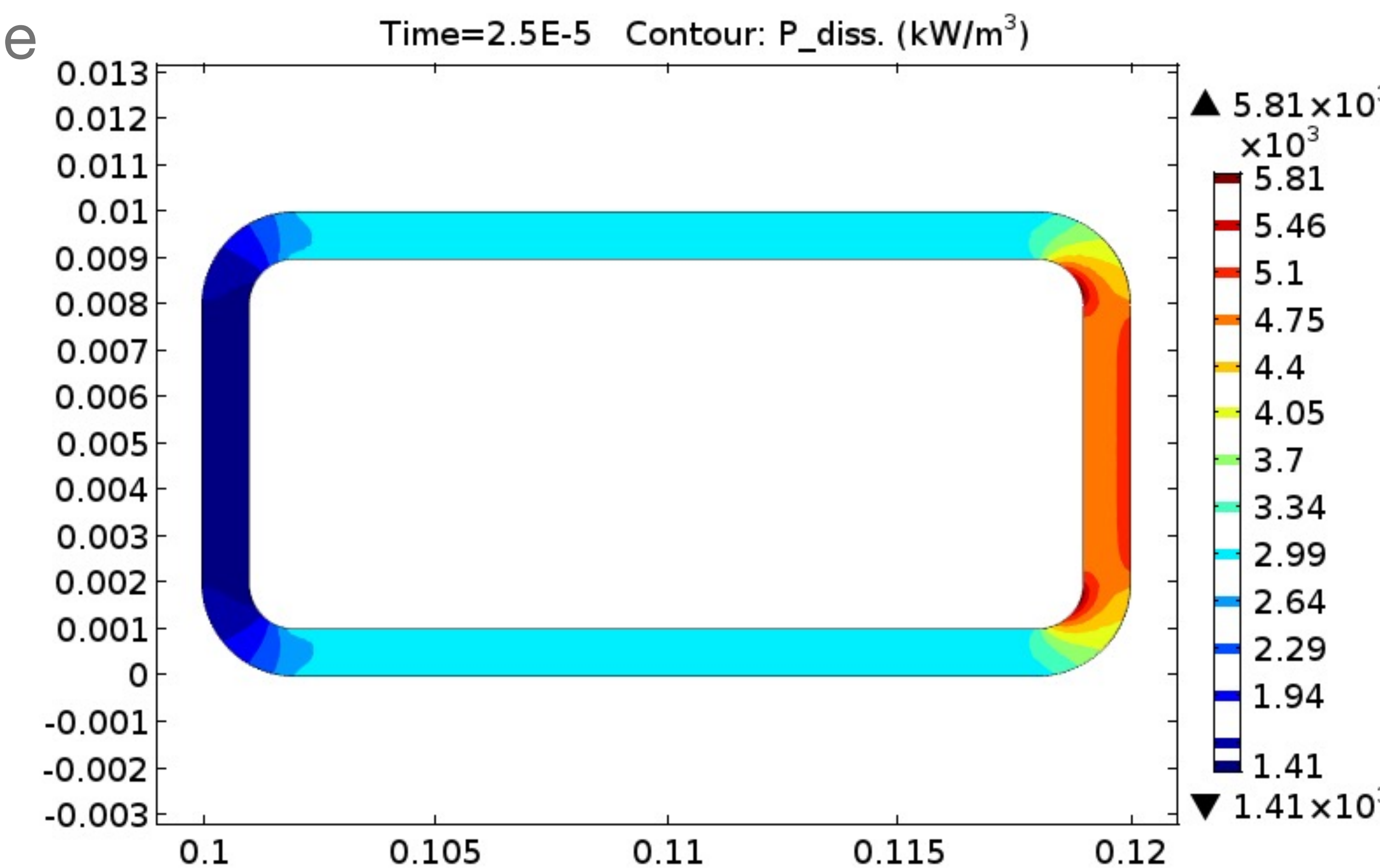
- Higher shear rate occurs at the corners
- Velocity is linearly increasing along the radius





Results

- Calculated dissipation with the correct formula
- Higher values at the outer radius
- Higher temperature occurs at the outer radius

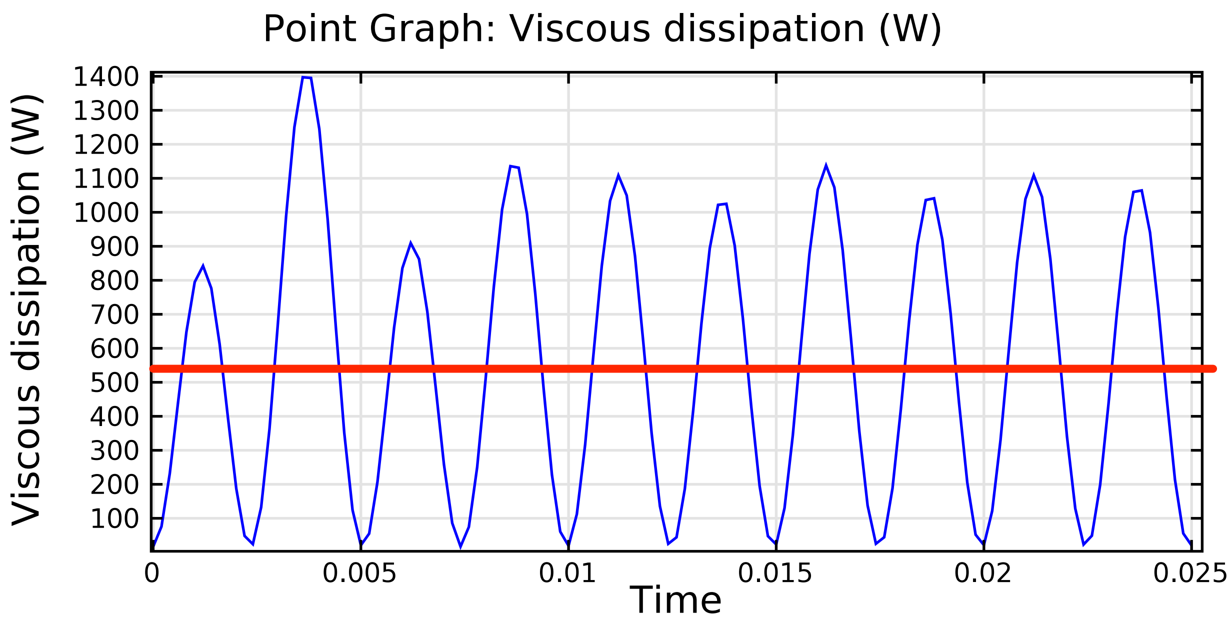


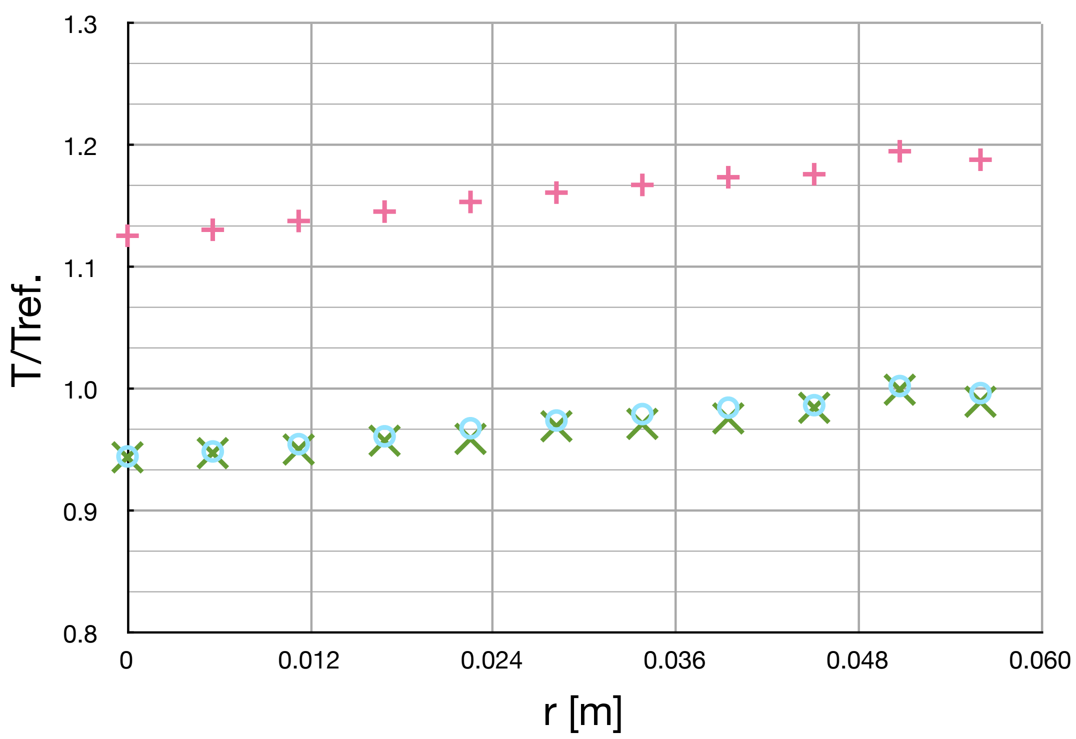
Results

- Time dependent calculation for the viscous dissipation

- Time averaged power calculated as the input for steady state simulation

- Reference temperature is cyan circle, UCM with new formula is green x and UCM with standard formula is red cross





Summary

- Easy to implement any material model with EBM
- Correct calculation of dissipated heat for damper fluids
- Validation with measured data is user friendly

Q&A

Thank you for your attention!