Simulation of A Rotary Magnetorheological Fluid Damper

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Motivation

- Design a speed-proportional rotary damper with magnetorheological fluid (MRF) inside the damper.
- Create a model to analyze the behavior of the damper.
  - Mathematical description of the MRF
  - Hysteresis modeling of the magnetization with the Jiles-Atherton model

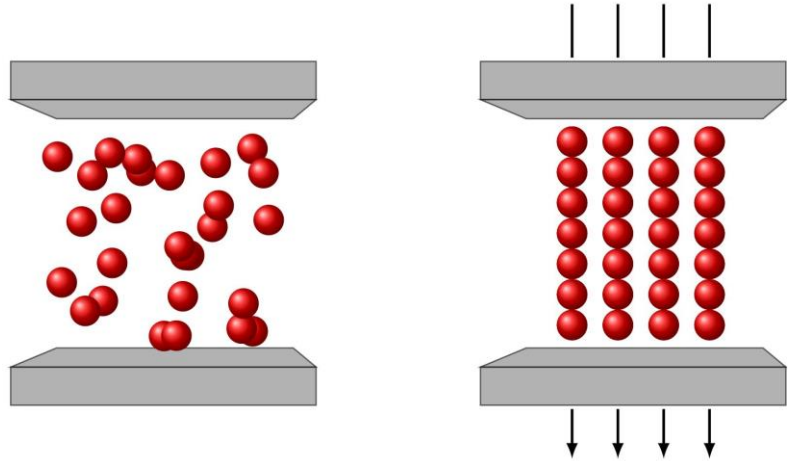
Fundamentals of MRF

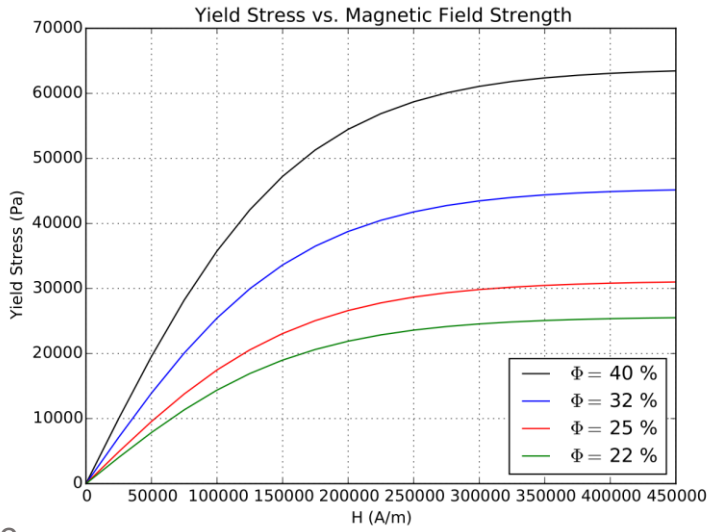
- MRF described as Bingham model
  - $\tau = \tau_H \mathrm{sgn}(\dot{\gamma}) + \underbrace{\eta\dot{\gamma}}$

    Newtonian fluid behavior

    - η – dynamic viscosity
    - $\dot{\gamma}$ –shear rate

  - $\tau_H = C \cdot 271700 \cdot \Phi^{1,5239} \cdot \tanh(6{,}33 \cdot 10^{-6} H)$
    - C – constant for different carrier liquid
    - Φ – particle volume fraction





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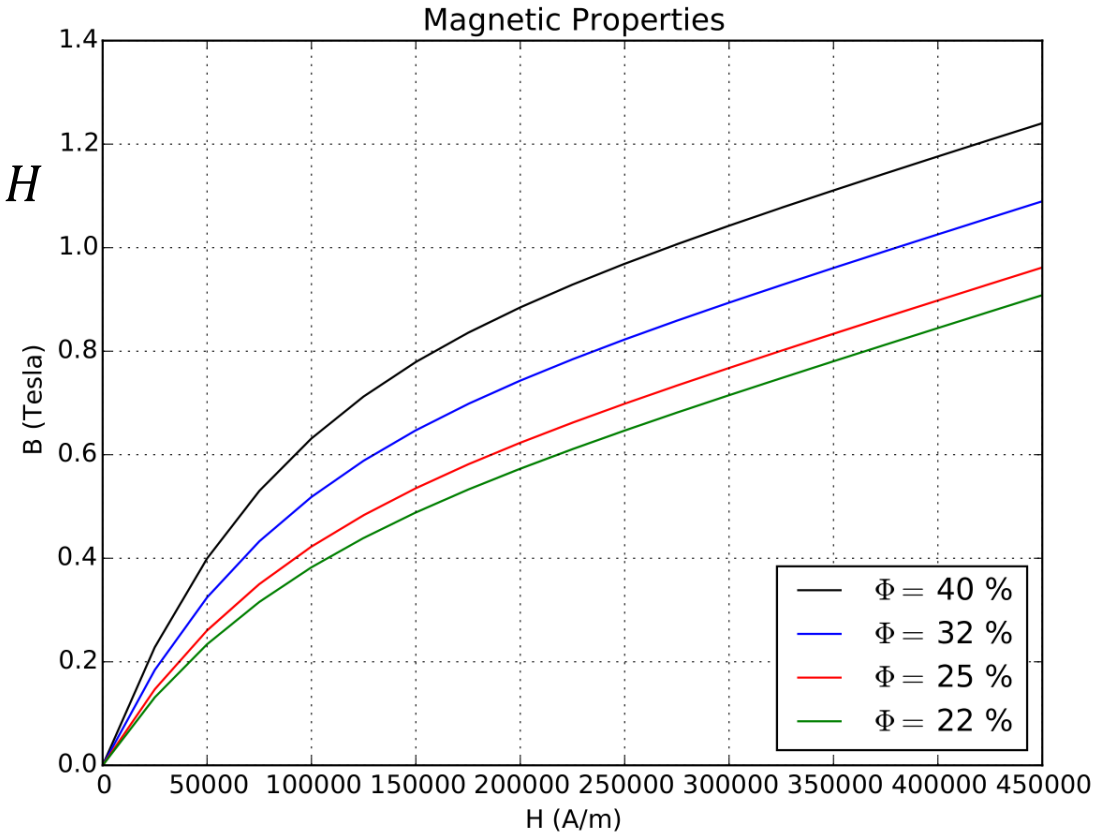
Fundamentals of MRF

- B – H curves of MRF

  - $B = 1{,}91 \cdot \Phi^{1{,}133}[1 - \exp(1 - 10{,}97\mu_0 H)] + \mu_0 H$
    - Φ – particle volume fraction
    - μ_0 – vacuum permeability

  - $H = \frac{1}{\mu_0}\big(0{,}0911577 \cdot W(20{,}9527 \cdot e^{-10{,}97\left(B - 1{,}91 \cdot \Phi^{1{,}133}\right)} \cdot \Phi^{1{,}133}) + B - 1{,}91 \cdot \Phi^{1{,}133}\big)$
    - W – Lambert W function



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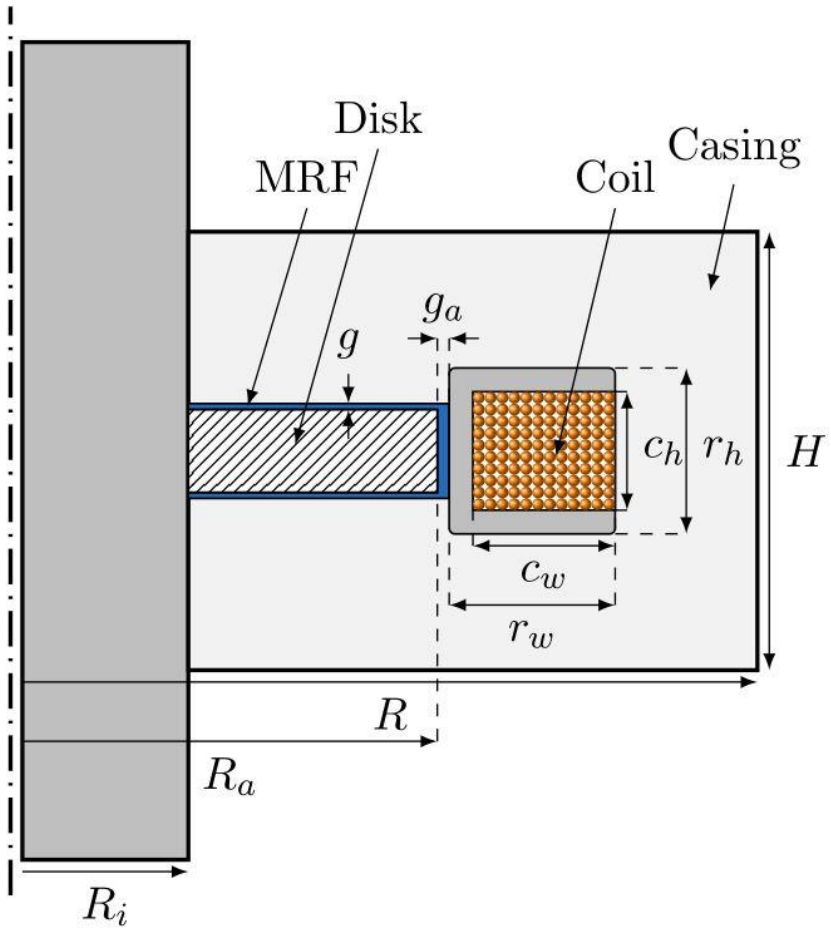
Model of the rotary damper

- The shaft and the ring around the coil are modeled as non magnetic material.
- The disk and the casing material was defined as steel with two different cases.
  - Without hysteresis
  - With hysteresis



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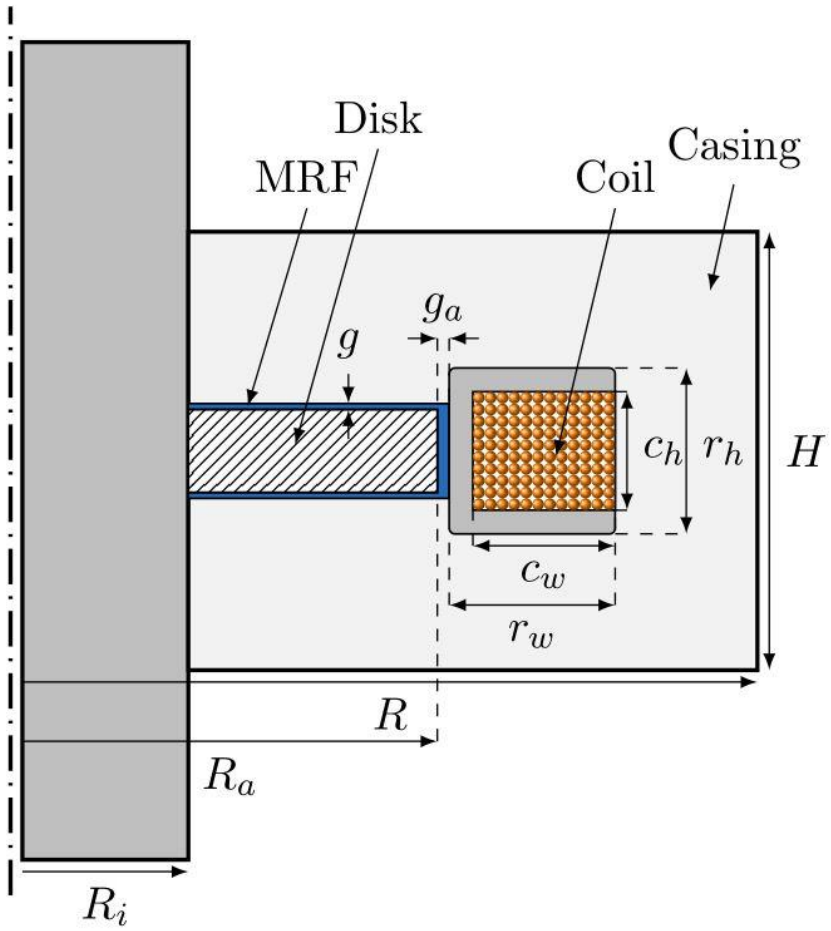
Model of the rotary damper

- Calculating the braking torque
  - $T = T_H \mathrm{sgn}(\dot{\gamma}) + T_\eta(\dot{\gamma})$
  - with $T_H = 2\pi N_{disk} \int_{R_i}^{R_a} r^2 \, \tau_H \, dr$
  - and $T_\eta = 2\pi N_{disk} \int_{R_i}^{R_a} r^2 \, \eta \, \dot{\gamma} \, dr$
- Calculating the shear rate
  - $\dot{\gamma} = \frac{r\omega}{g}$
  - with $\omega = \int \frac{M_a - T(\dot{\gamma})}{J_s} dt$



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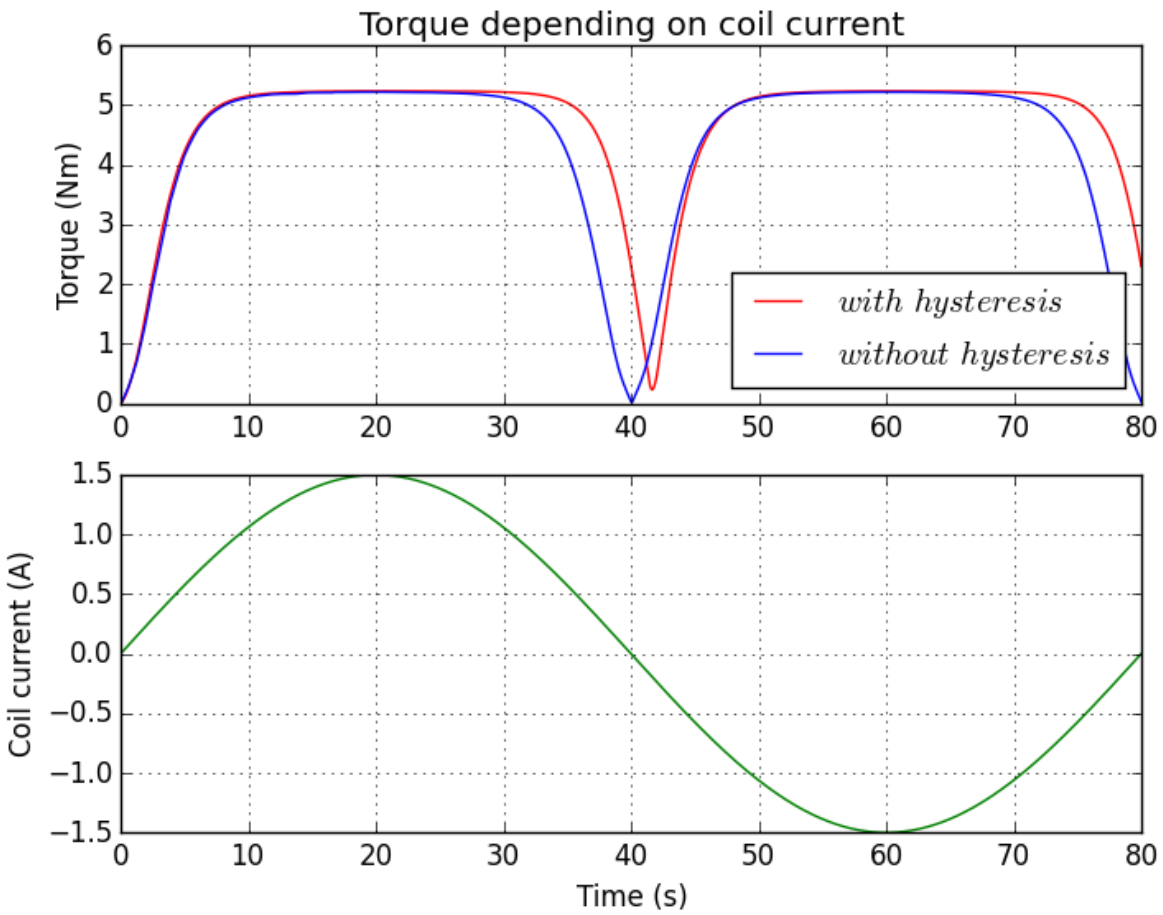
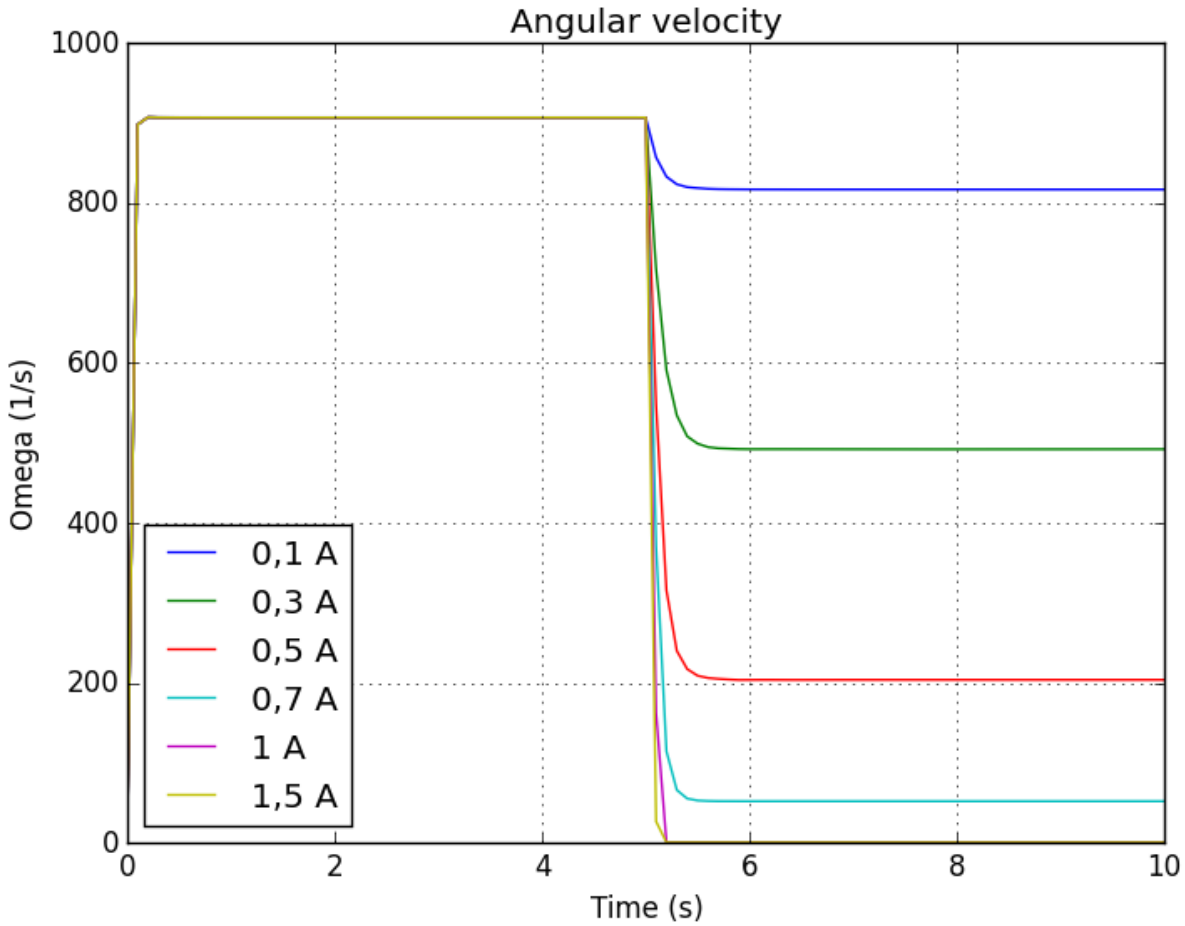
Simulation Results





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Conclusion and Outlook

- Create a model to analyze the behavior of the rotary damper.
  - Mathematical description of the MRF
    - Different MRFs can quickly implemented by changing only two variables
  - Hysteresis modeling of the magnetization with the Jiles-Atherton model
- In future projects this simulation model can be used to study different scenarios in more detail.

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