

# Magnetorheological suspension damper for aeronautics

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Design

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# Motivation



Launch vehicle

<http://www.bsdspace.it/>



Washing machine

<http://www.bsdspace.it/>



Suspension seat

<http://www.cieb.cz/>

# Introduction to the issue

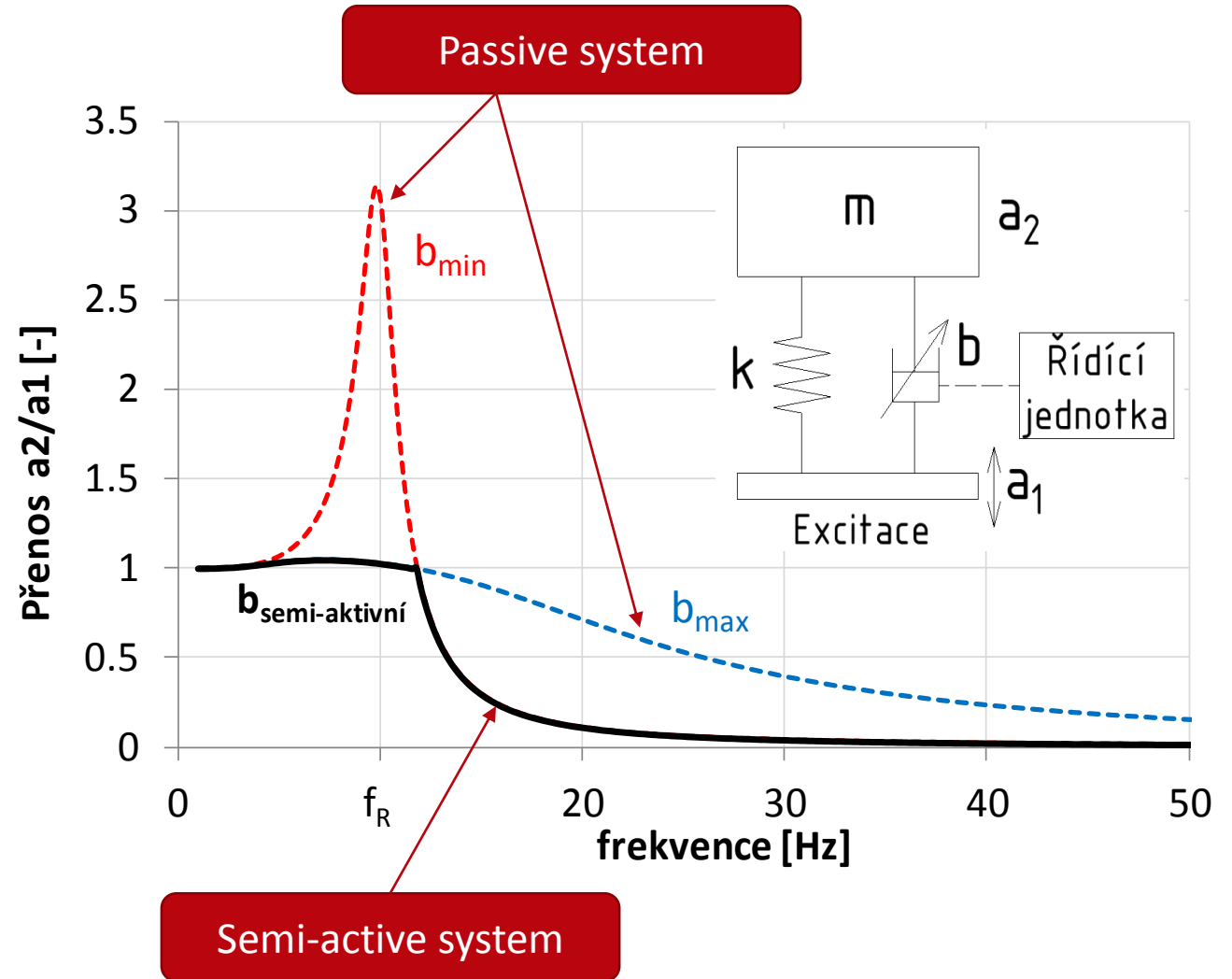
Evaluation of effectiveness of vibro-isolation system



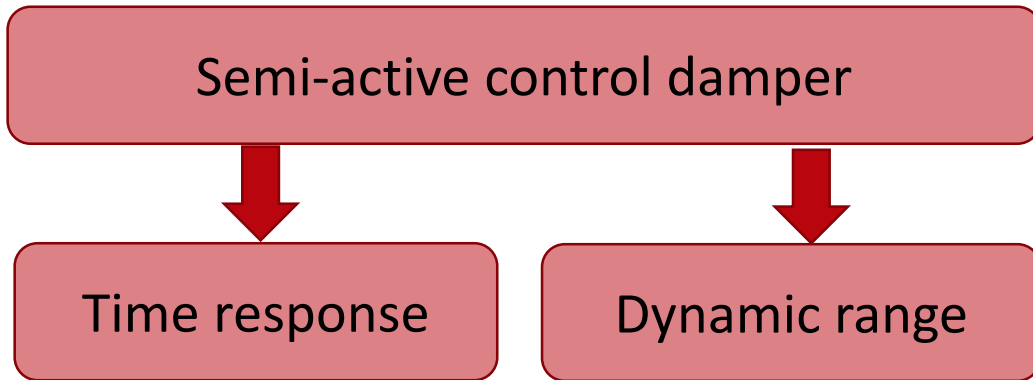
Transfer function of vibro-isolation system



Minimising transmissibility across the frequency range



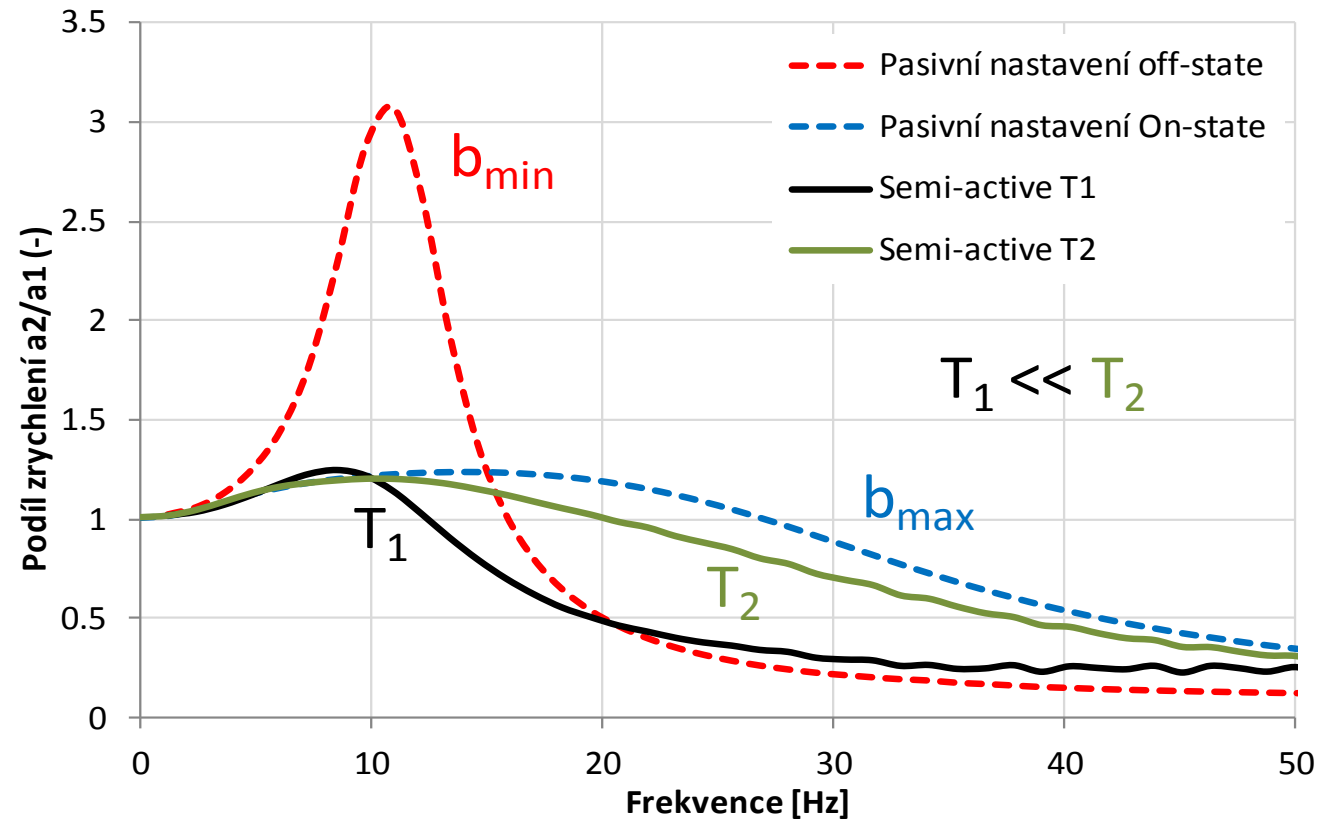
# Introduction to the issue



Magnetorheological damper  
Commercially available MR damper 30 ms

MR damper developed at the BUT 1.5 ms  
(2015)

**A lot of limitation of design!!**



# Methodology design of MR damper



The methodology design of magnetorheological damper with sort time response



Methodology design ??

# Main goal of dissertation thesis

## Main goal

The methodology design of magnetorheological damper with short time response

## Partial goals

- Magnetic models
  - Magnetostatic model
  - Transient magnetic model
- Hydraulic models
  - CFX model of MR damper in OFF state
  - CFX model of bypass gap
  - Analytical model of MR damper in ON state
- Strength model

# Methodology design of MR damper

## Division of Methodology

The mechanical aspects

The magnetic aspects

The hydraulic aspects

The magnetorheological aspects

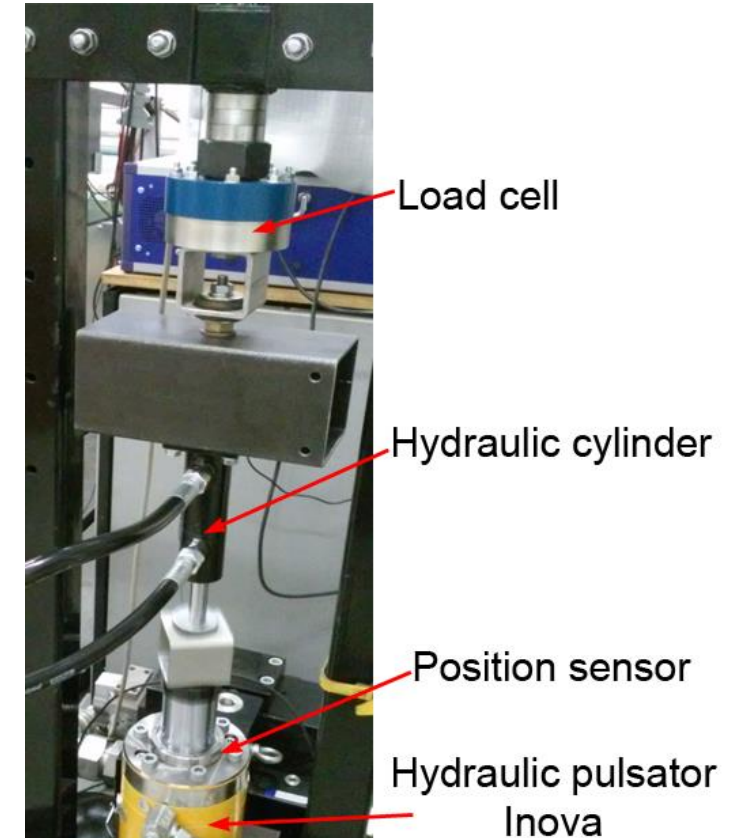
**MR damper seals** ✓  
Experimental rig -> experiment

**Stiffness of hydraulic system** ✓  
Experimental rig -> experiment

**The guidance of piston rod** ✓



Example of testing seals



Experimental rig for tests of seal

# Methodology design of MR damper

## Division of Methodology

The mechanical aspects

The magnetic aspects

The hydraulic aspects

The magnetorheological aspects

**Magnetostatic model** ✓

FEM model -> experimental verification

**Transient magnetic model** ✓

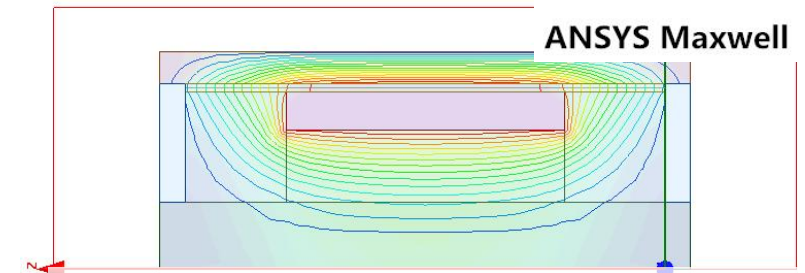
FEM model -> experimental verification

**Material properties** ✓

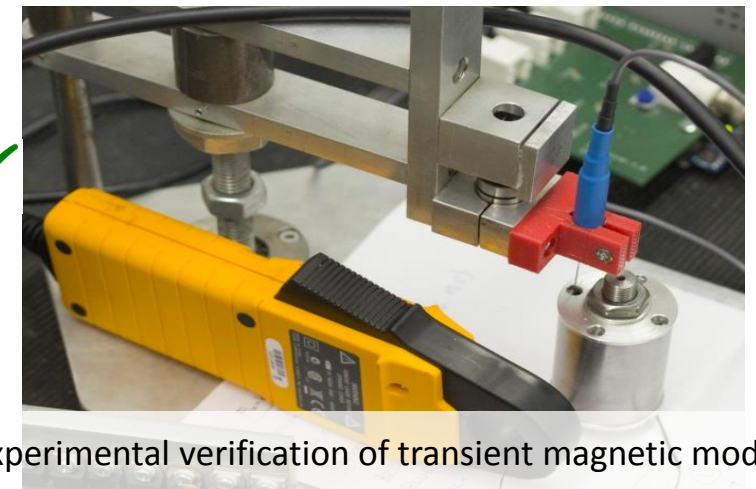
Experiment -> B-H dependency of steels

The arrangement of the magnetic circuit ✓

ANSYS



Magnetostatic model of MR damper



Experimental verification of transient magnetic model

# Methodology design of MR damper

## Division of Methodology

The mechanical aspects

The magnetic aspects

The hydraulic aspects

The magnetorheological aspects

**Bypass gap of active zone** ✓

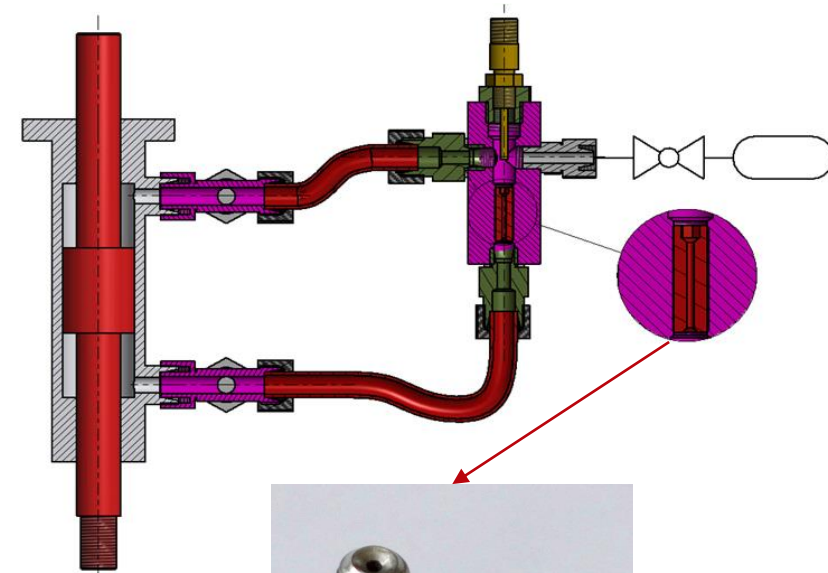
CFD model -> experimental verification

**MR damper in OFF state** ✗

Model -> experimental verification

**Material properties** ✓

Temperature dependency of viscosity MRF



Experimental rig of bypass gap

# Methodology design of MR damper

## Division of Methodology

The mechanical aspects

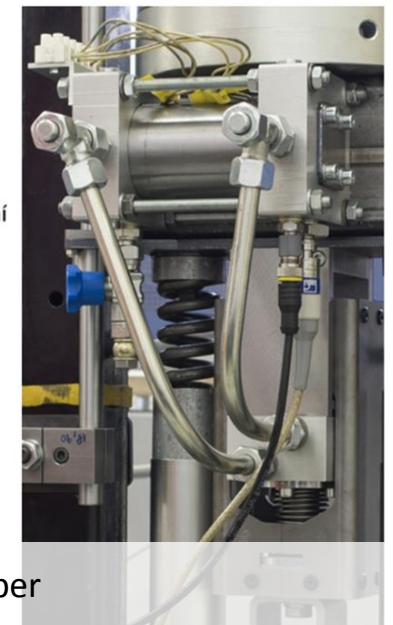
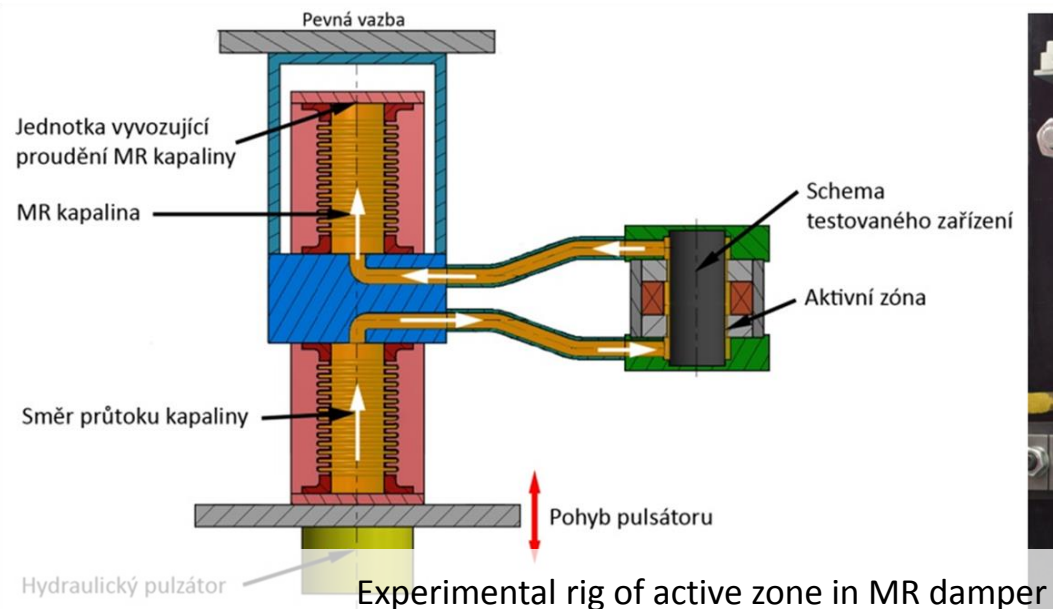
The magnetic aspects

The hydraulic aspects

The magnetorheological aspects

**MR damper in ON state** ✓  
Model -> experimental verification

**Yield stress of MR fluid** ✓



# Current state of dissertation

## Partial goals

- Magnetic models
  - Magnetostatic ✓
  - Transient magnetic model ✓
- Hydraulic models
  - CFX model of MR damper in OFF state ✗
  - CFX model of bypass gap ✓
  - Analytical model of MR damper in ON state ✓
- Strength models ✗

# Opponent

## Ing. Janusz Gołdasz, D.Sc.

- Head of development of MR dampers in the company BWI group
- Cracow University
- The world's largest manufacturer of MR dampers
- Chevrolet, Ford, Cadillac, Ferrari, Audi, Range rover



Audi R8 [wikipedia.org](https://en.wikipedia.org/wiki/Audi_R8)



Ford Mustang [wikipedia.org](https://en.wikipedia.org/wiki/Ford_Mustang)



Range Rover Evoque [wikipedia.org](https://en.wikipedia.org/wiki/Range_Rover_Evoque)

# Publications

## ● Impacted articles (2x co-author)

STRECKER, Z.; MAZŮREK, I.; ROUPEC, J.; MACHÁČEK, O.; KUBÍK, M.; KLAPKA, M. Design of magnetorheological damper, with short time response. *JOURNAL OF INTELLIGENT MATERIAL SYSTEMS AND STRUCTURES*, 2015, vol. 26, no. 17, p. 1951-1958. ISSN: 1045-389X. **IF 1,975, Počet citací: 2**

KLAPKA, M.; MAZŮREK, I.; MACHÁČEK, O.; KUBÍK, M. Twilight of the EUSAMA diagnostic methodology. *Meccanica* [online], 2016, ISSN 0025-6455 **IF 1,949**  
(článek prošel recenzním řízením)

## ● Articles in Scopus (2x author, 3x co-author)

**KUBÍK, M.; MACHÁČEK, O.; MAZŮREK, I.** A study of hydraulic resistance of viscous bypass gap in magnetorehological damper. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 2016, vol. 64, no. 4, p. 1199-1203. ISSN: 1211-8516.

MACHÁČEK, O.; KUBÍK, M.; MAZŮREK, I.; STRECKER, Z.; ROUPEC, J. Frictionless Bellows Unit Connected with the Magnetorheological Valve. In *ENGINEERING MECHANICS 2016. First edition, 2016. Praha: Institute of Thermomechanics Academy of Sciences of the Czech Republic, 2016. p. 354-357. ISBN: 978-80-87012-59- 8.*

**KUBÍK, M.; MACHÁČEK, O.; STRECKER, Z.; ROUPEC, J.; MAZŮREK, I.** Hydraulic resistance of magnetorheological damper viscous bypass gap. In *Engineering Mechanics 2016. Engineering mechanics 2017. first edition. Praha: Institute of Thermomechanics Academy of Sciences of the Czech Republic, 2016. s. 330-333. ISBN: 978-80-87012-59- 8. ISSN: 1805-8178.*

STRECKER, Z.; ČÍPEK, P.; ROUPEC, J.; MACHÁČEK, O.; KUBÍK, M. Testing of Car Suspension With Fast MR Damper, Controlled by Modified Groundhook Algorithm. In *Engineering Mechanics 2016. Engineering mechanics 2017. First edition. Prague: Institute of Thermomechanics Academy of Sciences of the Czech Republic, v.v.i., 2016. s. 526-529. ISBN: 978-80-87012-59- 8. ISSN: 1805-8178.*

# Publications

- **Submitted article**

Magnetorheological valve with ferrite magnetic circuit

Smart Material and Structures **IF 2.769 (author)**

Novel method for measurement of MR fluid sedimentation and its experimental verification

Smart Material and Structures **IF 2.769 (co-author)**

- **Submitted patent**

Magnetický obvod potlačující vířivé proudy



# Other activities

- Teaching
  - 5KS – Machine Design – Machine Elements
  - 6KT – Machine Design – Mechanical Drives
  - ZKP – Team Project
  - QEM – Experimental methods
- HS
  - Development of actuator for automotive
  - Damper testing of belt tensioner
- Academic Senate (September 2016)



6KT - Planetary gear of starter (Magnetron)

Thank you for your attention

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