SEMI-ACTIVELY CONTROLLED SUSPENSION OF RAILWAY VEHICLE

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INSTITUTE OF **MACHINE**
AND **INDUSTRIAL DESIGN**

CONTENT

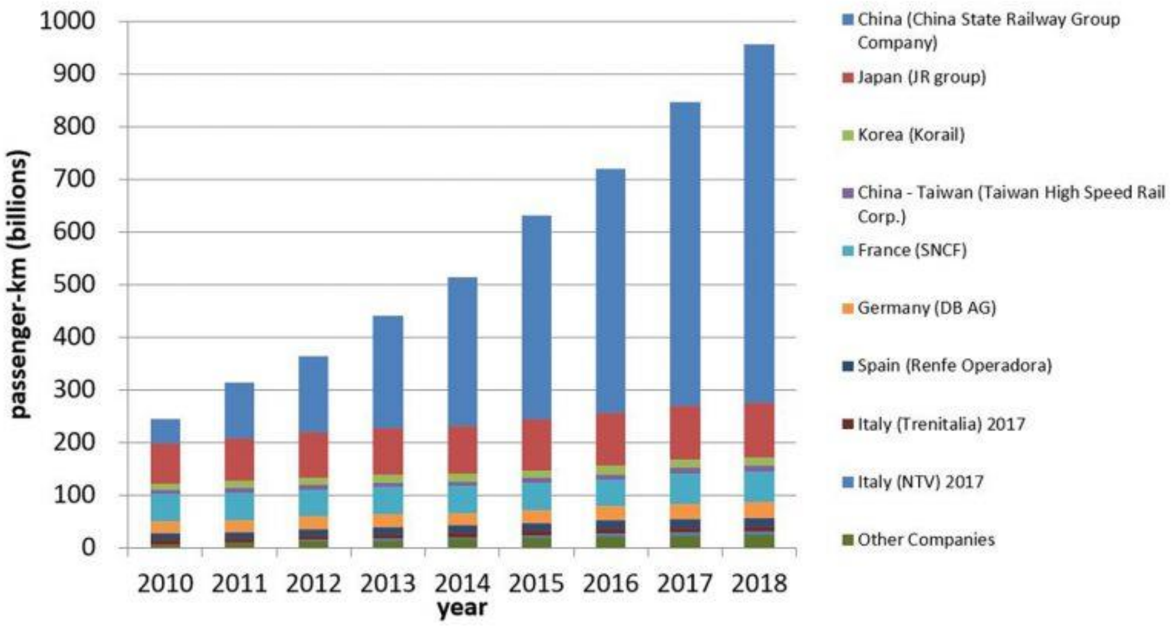
- Motivation
- State of the art
- Aim of the thesis
- Scientific questions and hypothesis
- Materials and methods
- Results
- Conclucion

wikipedia.org

MOTIVATION

- Developing high-speed tracks in Europe
  - passenger and freight transport
  - ecological, economical
  - best for longer intercontinental paths

dopravadnes.cz



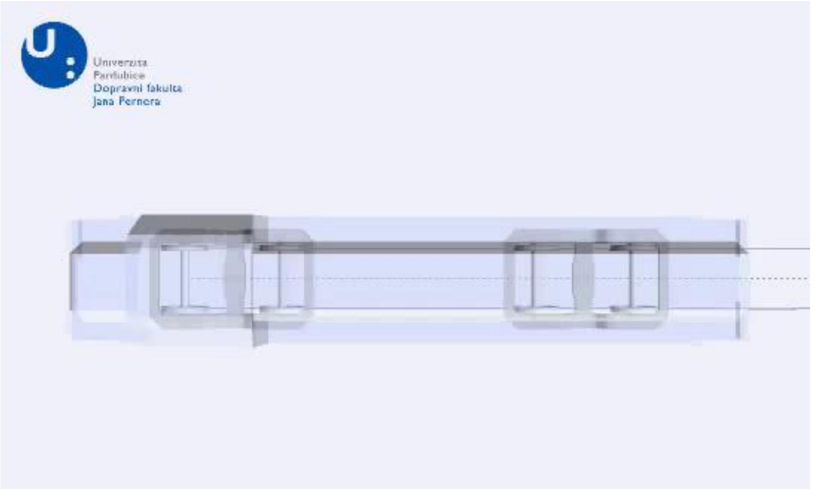
globalrailwayreview.com

MOTIVATION

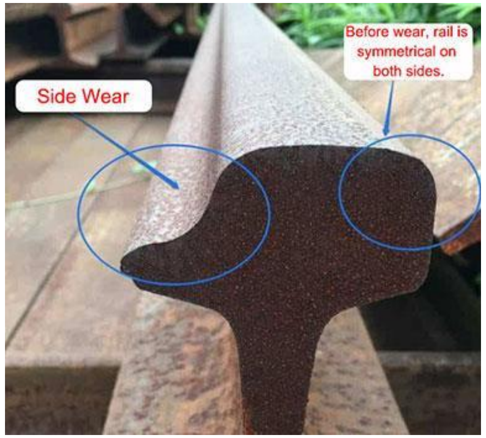
Increasing requirements

- higher speeds
  - safety, stability
- passenger comfort
  - carbody vibration, tilting
- infrastructure requirements
  - wear, fees for track unfriendly vehicles

→ **Higher requirements on damping system**



Unstable ride *youtube.com/DFJP*



Rail wear *rail-fastener.com*

MOTIVATION

Increasing requirements

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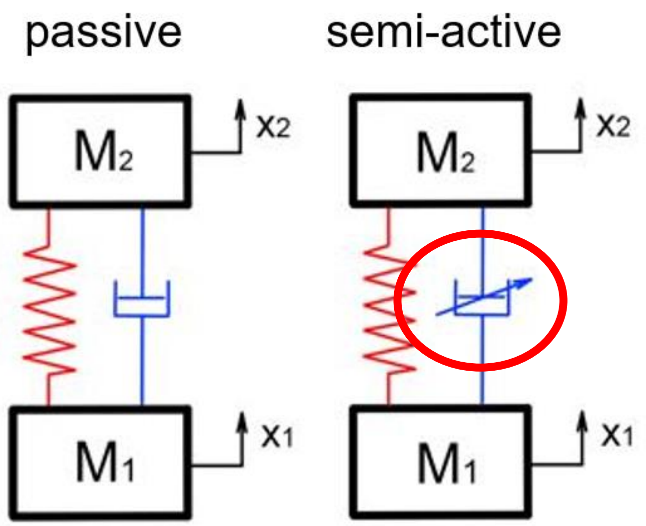
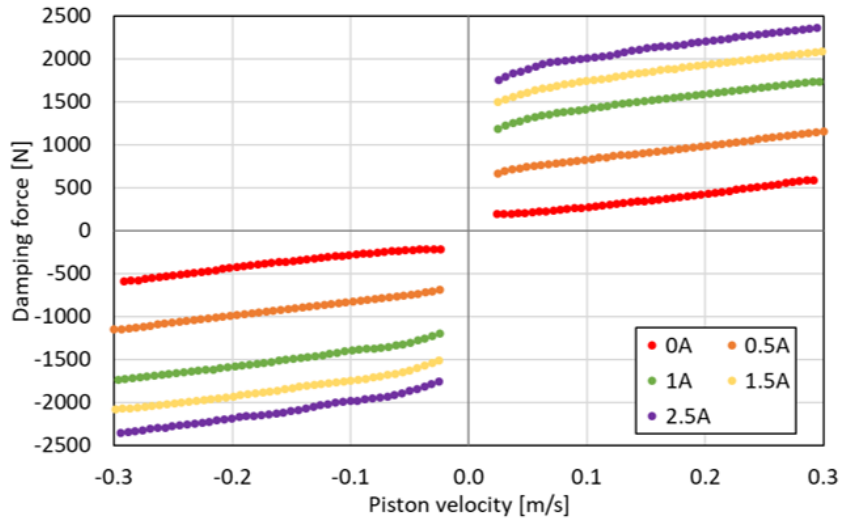




→ **Higher requirements on damping system**

→ semi-active dampers

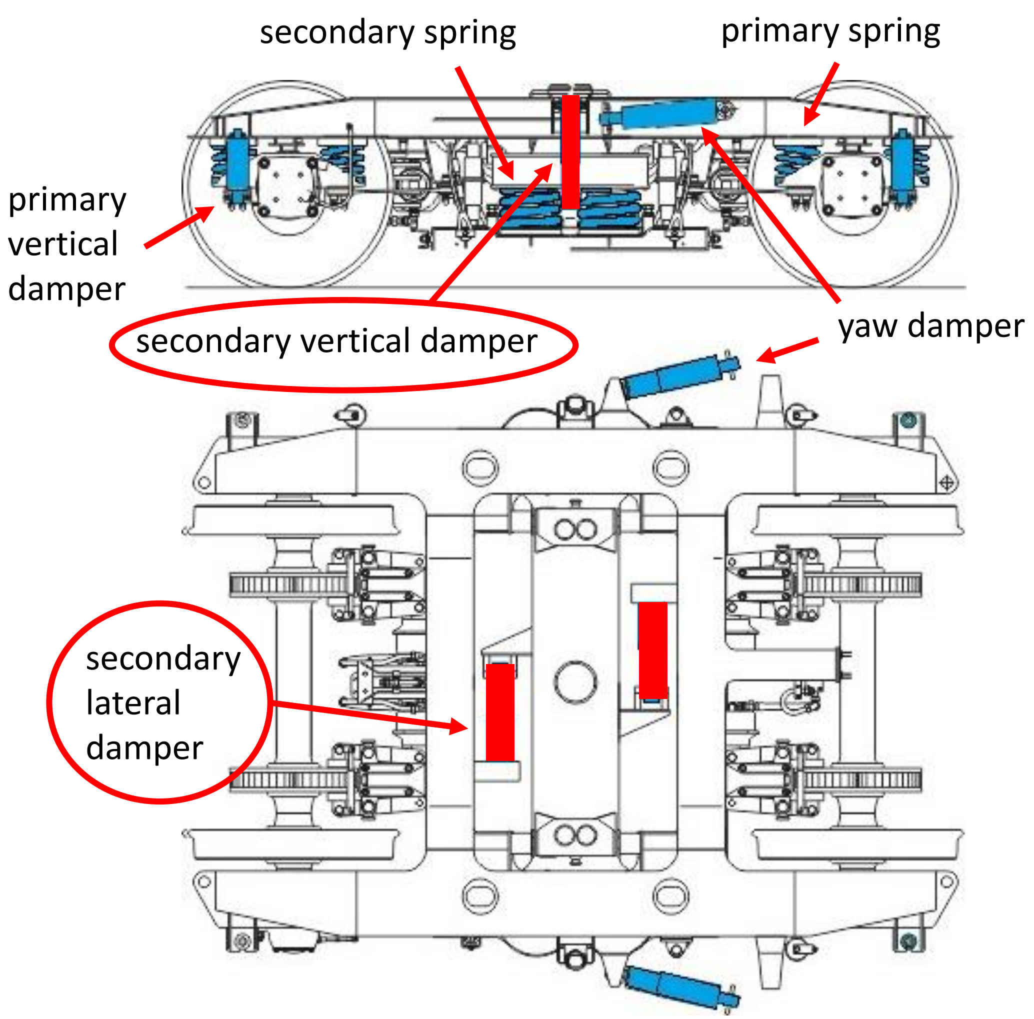
MOTIVATION

Increasing requirements

- higher speeds
  - safety, stability
- **passenger comfort**
  - carbody vibration, tilting
- infrastructure requirements
  - wear, fees for track unfriendly vehicles

→ **Higher requirements on damping system**

→ <u>semi-active dampers</u>



APPROACHES TO IMPROVE PASSENGER COMFORT

2005 — 2011 — 2012 — 2014

Lau et al.
- simulations
- improve 39 %

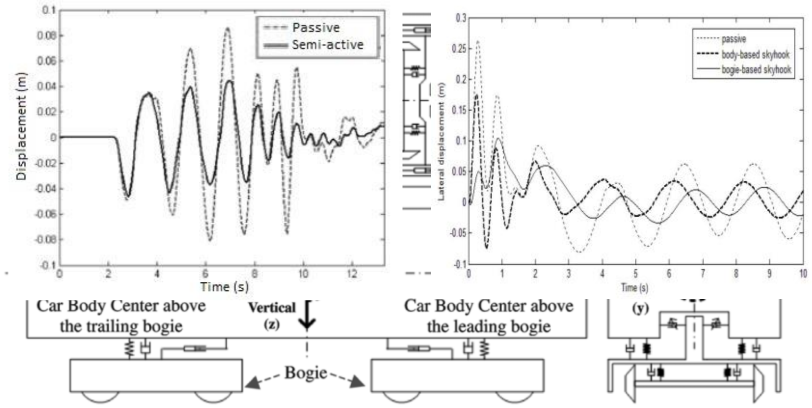
Hudha et al.
- simulations
- Shyhook
- improve 39 %

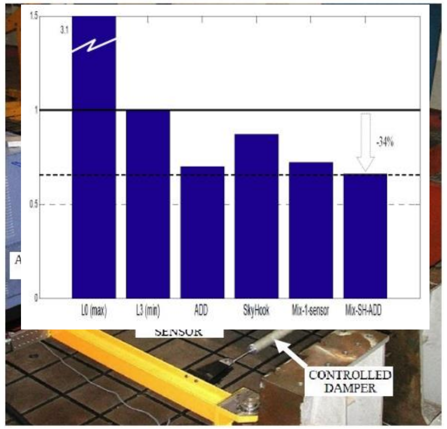
Spelta et al.
- simple real model
- Mix-Skyhook-ADD
- improve 34 %

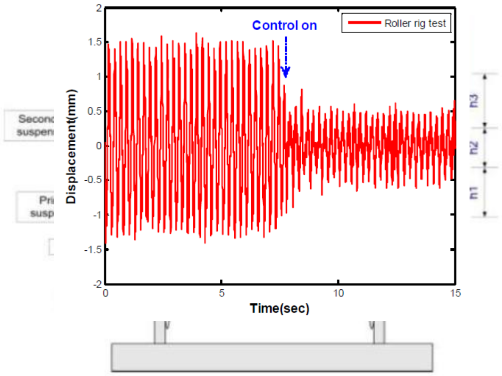
Shin et al.
- simple real model
- Skyhook
- improve 67 %

Sumary:
- lateral dampers
- Skyhook
- improve 30 – 40 %
- neglected or unstated response time
- not verified in real vehicle

Lack of knowledge
- influence of damper dynamic behaviour

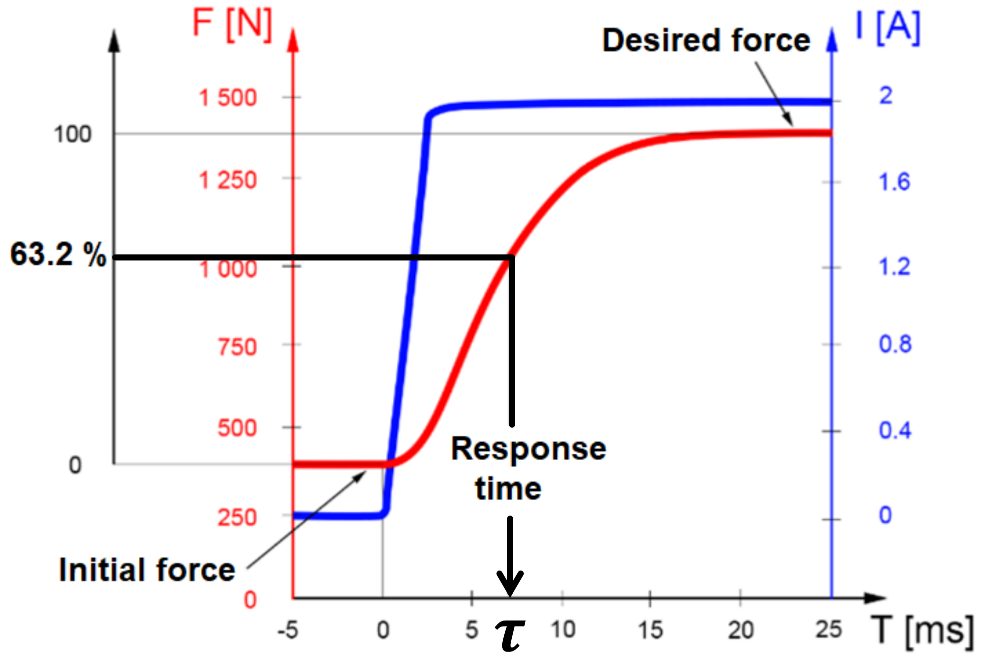




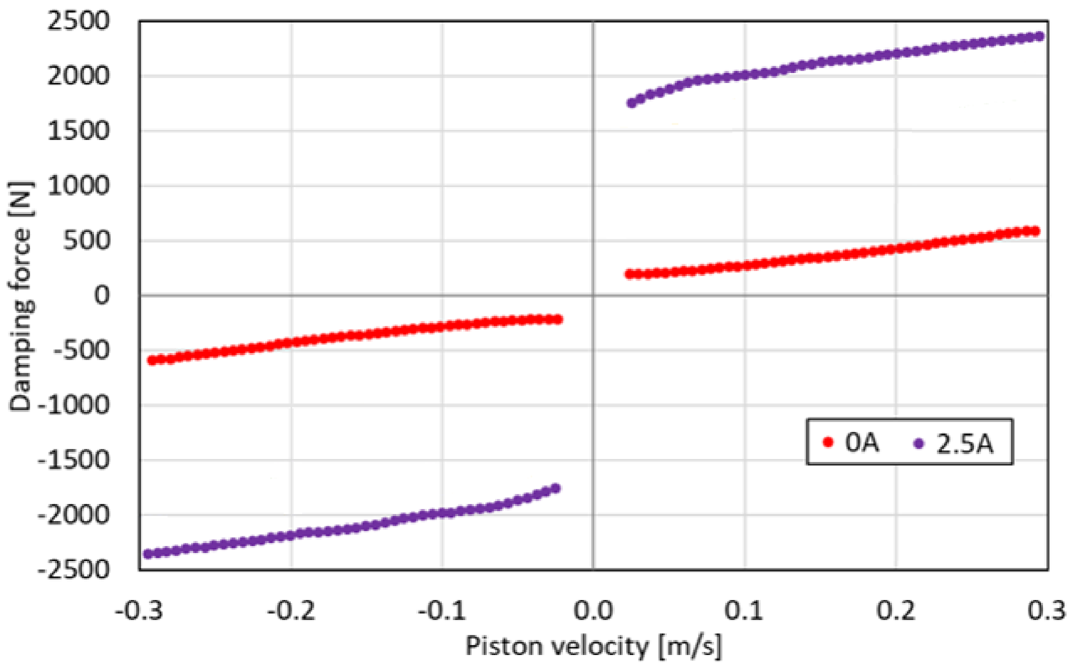


APPROACHES TO IMPROVE PASSENGER COMFORT

Damper force response time

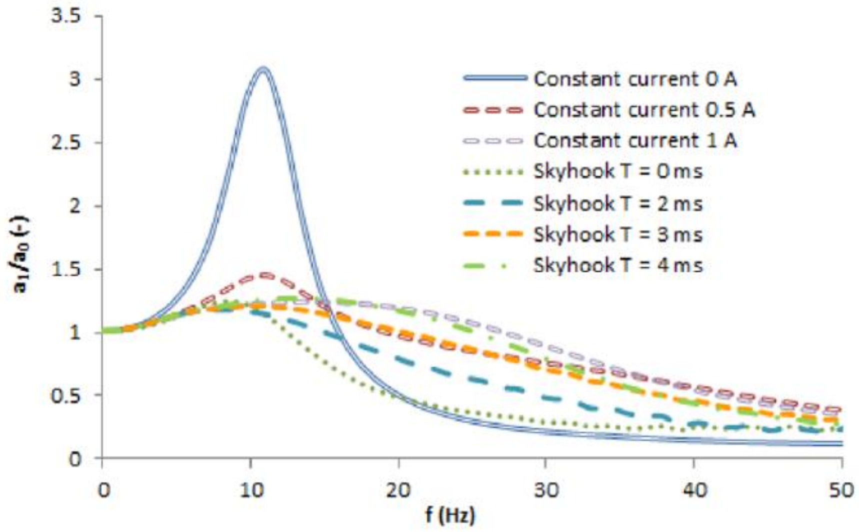


Dynamic force range



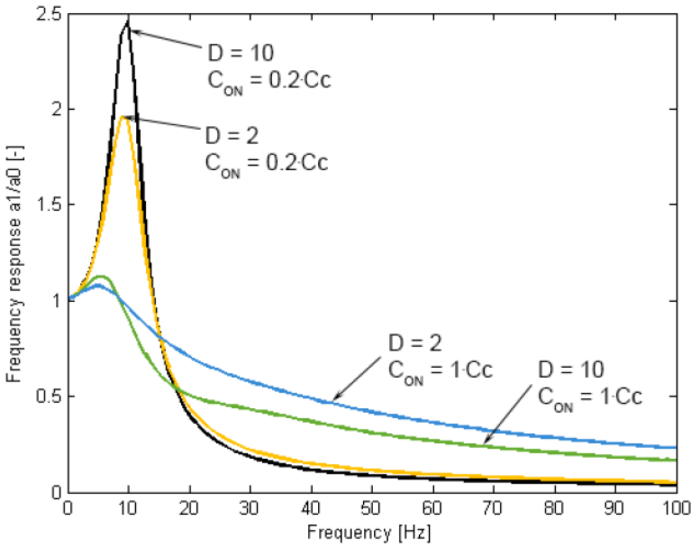
APPROACHES TO IMPROVE PASSENGER COMFORT

Damper force response time



Strecker, 2018

Dynamic force range

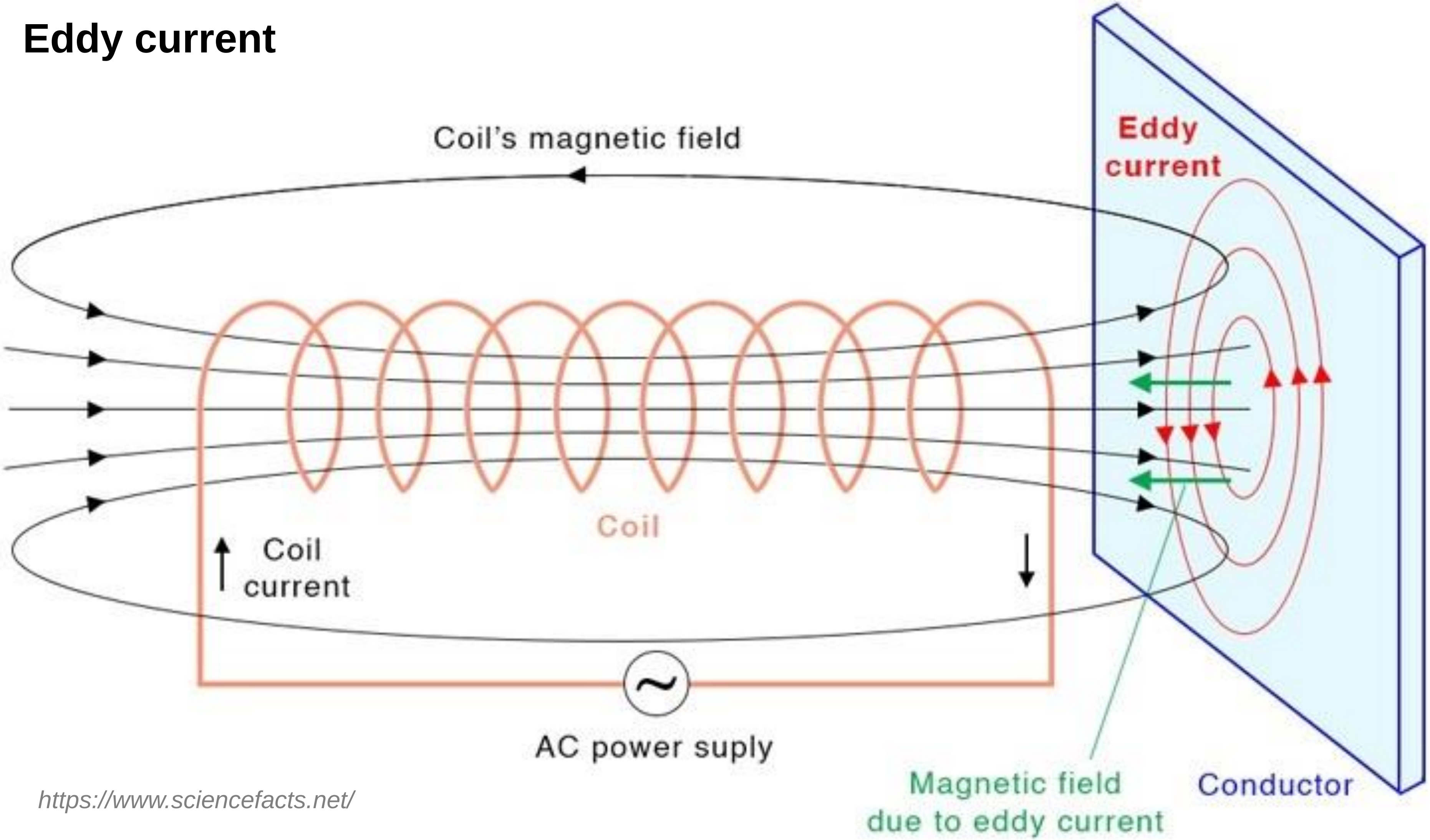


Machacek, 2017

Lack of knowledge: impact and the acceptable value of force response time and dynamic range for different S/A algorithms and for railway vehicle are unknown

APPROACHES TO IMPROVE MR VALVE BEHAVIOUR

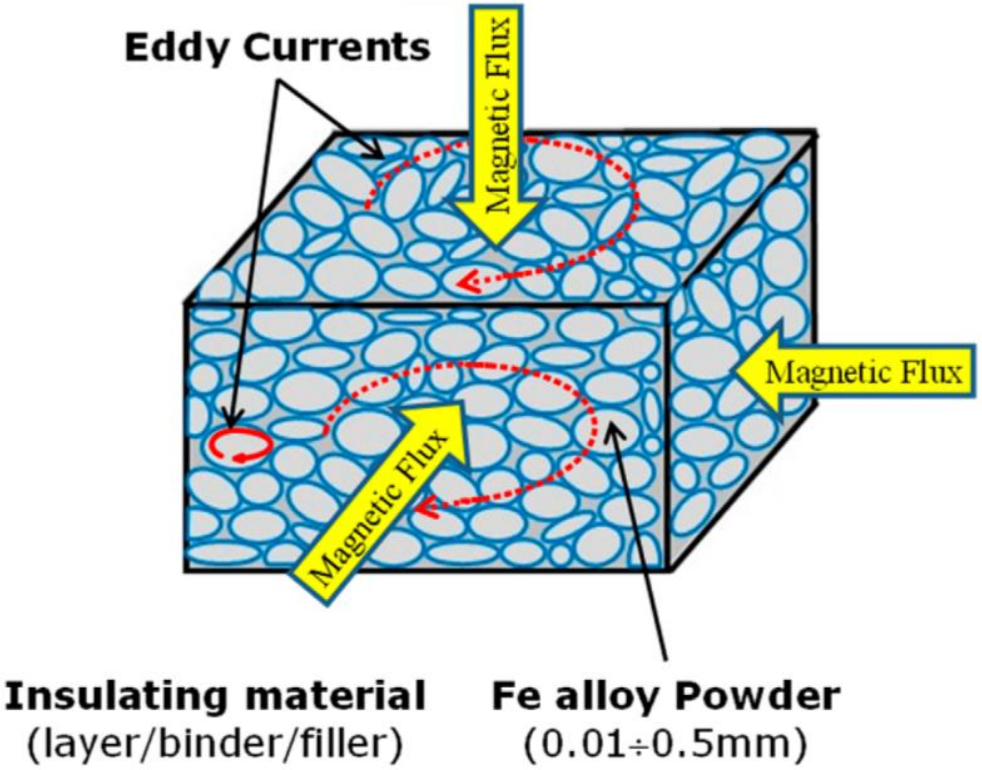
Eddy current

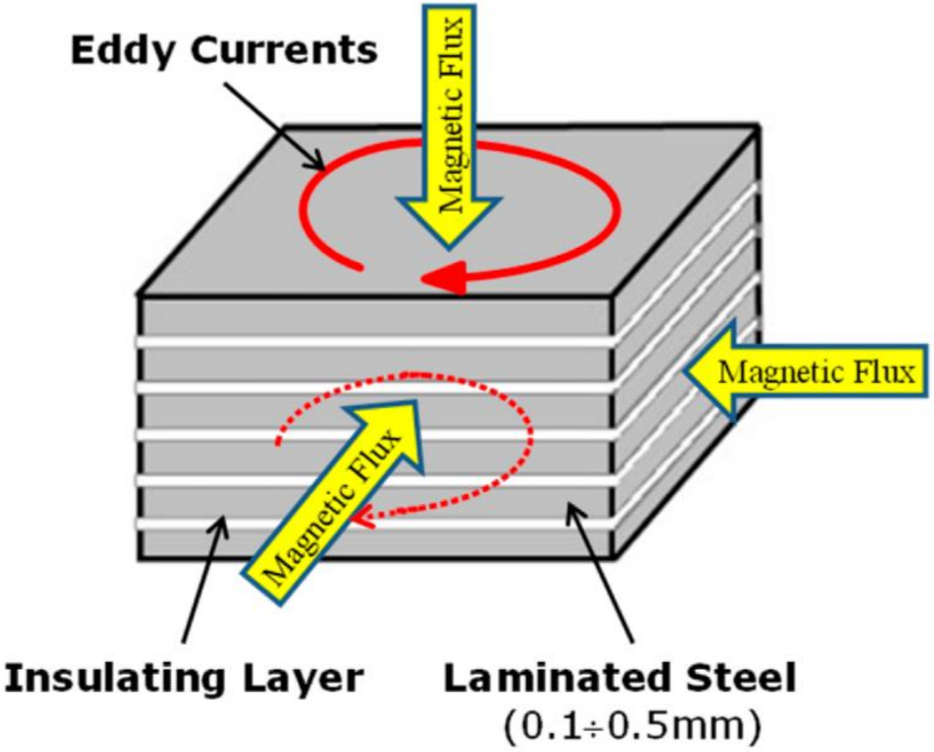


https://www.sciencefacts.net/

APPROACHES TO IMPROVE MR VALVE BEHAVIOUR

Material approach X Shape approach





APPROACHES TO IMPROVE MR VALVE BEHAVIOUR

2013 → 2017 → 2019 → 2019

Goldasz et al.

- laminated stacks
- concept only

Kubík et al.

- external MR valve
- feritte (iron oxid)
- τ = 4 ms, dr = 8

Choi et al.

- grooved
- τ = 2 ms
- dr = 2.5

Strecker et al.

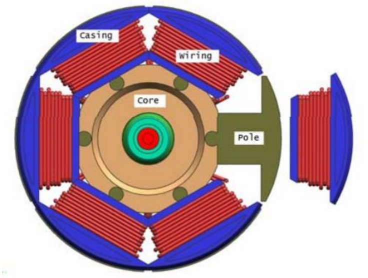
- structured
- τ = 1.3 ms
- dr = 5

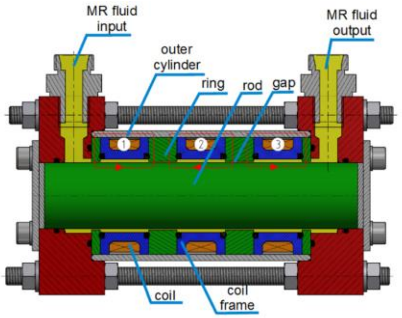
Sumary:

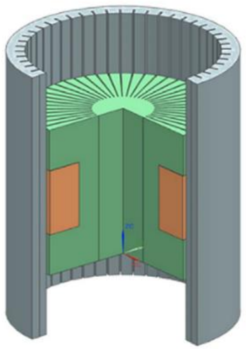
- short response causes small dynamic range?
- common dynamic range 10-20

  (Spelta 2012, Shin 2014),
- common response time 15-100ms

  (Spelta 2012, Koo 2006)
- 300 ms for railway MR damper *(Guo 2015)*







Lack of knowledge: influence of different materials and shapes of magnetic circuit on damper dynamic behaviour

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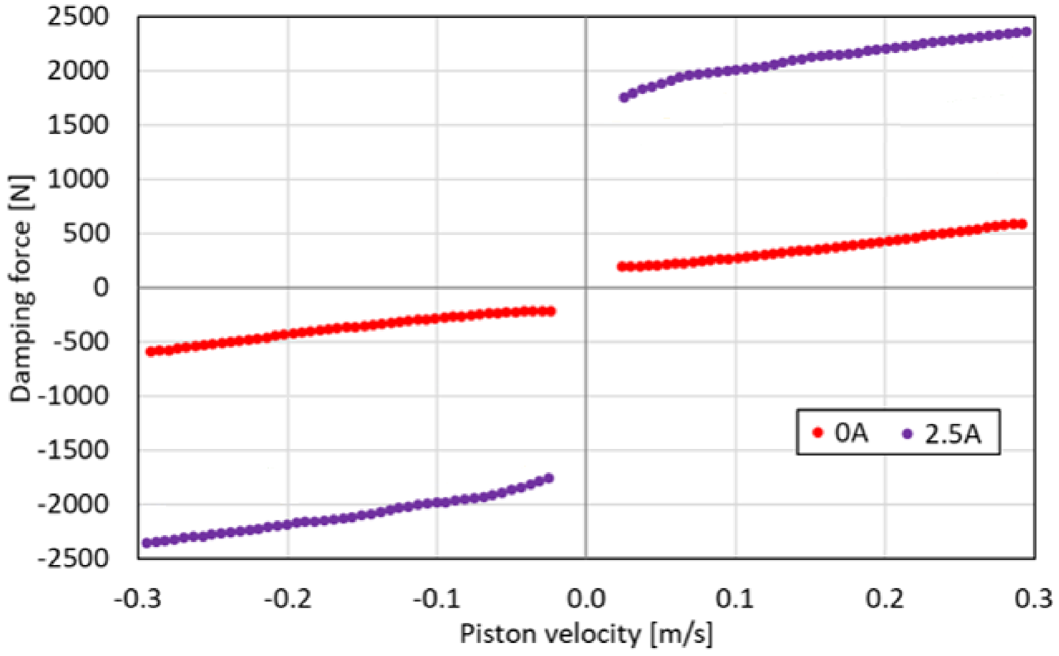
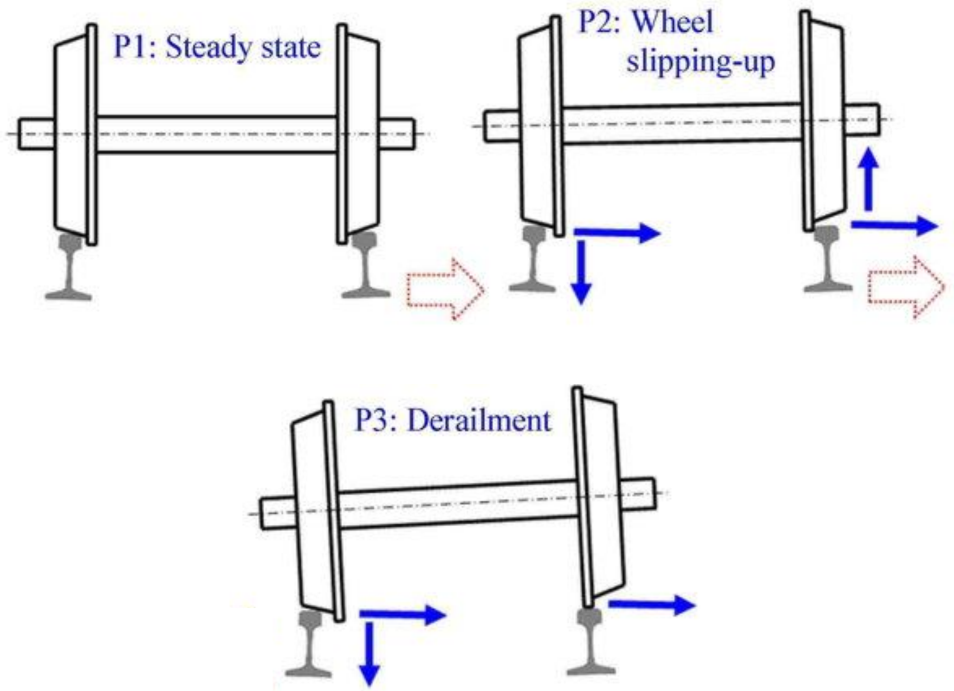
FAIL-SAFE MR DAMPER

Power failure → low damping → dangerous situation (derailment)

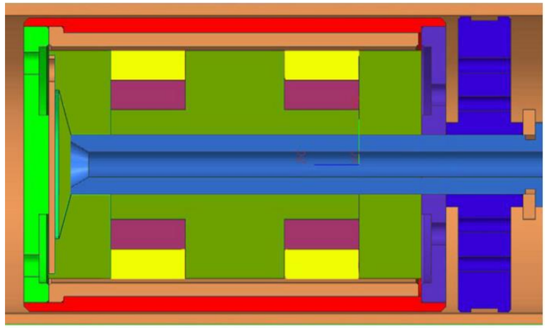


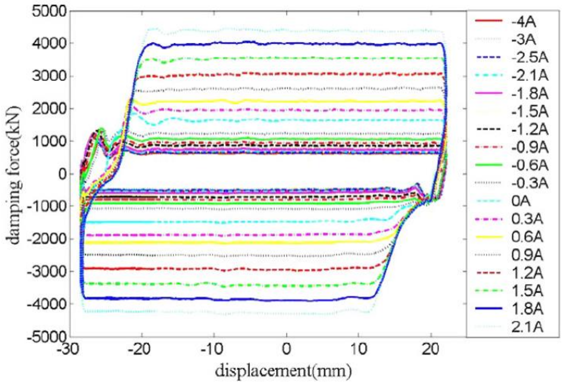


FAIL-SAFE MR DAMPER

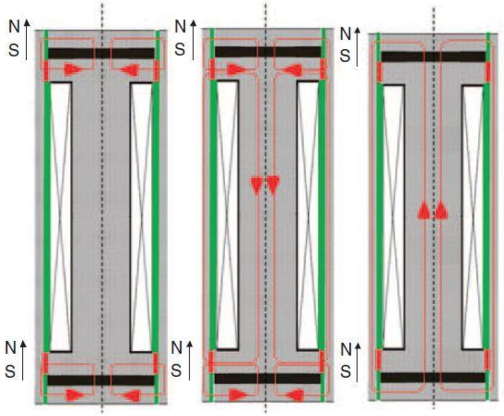
2007 | 2010 | 2011

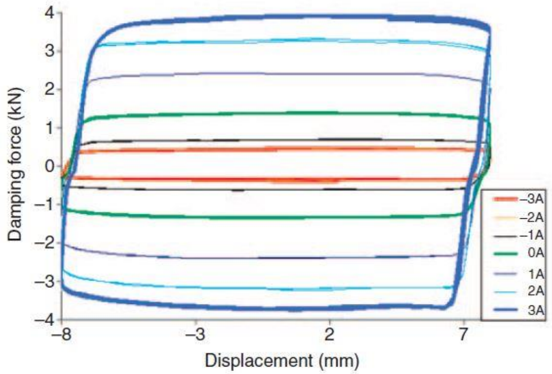
Zhang et al.





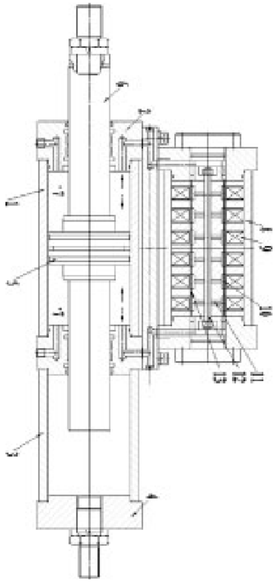
Boese et al.





Wei-ming et al.

- external valve



Sumary:

- permanent magnet in piston core
- fail-safe force – 1/3 of max force

Lack of knowledge

- completely unknown dynamic behaviour of MR damper with permanent magnet

AIM OF THE THESIS

Lack of knowledge:

- influence of different materials and shapes of magnetic circuit on damper dynamic behaviour
- dynamic behaviour of MR damper with permanent magnet
- influence of damper dynamic behaviour on S/A control efficiency

Investigate the possibilities of improving the MR damper dynamic behaviour and the effect of damper dynamic behaviour on the performance of the semi-actively controlled suspension of railway vehicle

AIM OF THE THESIS

Investigate the possibilities of improving the MR damper dynamic behaviour and the effect of damper dynamic behaviour on the performance of the semi-actively controlled suspension of railway vehicle

Scientific questions

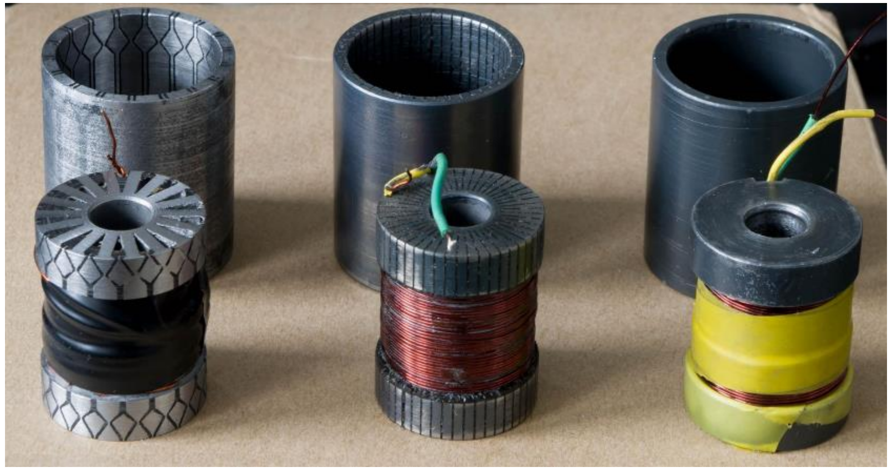
Q1: How does the material and geometry of the MR damper magnetic circuit affect force response time and dynamic range?
Is a shorter damper force response time always associated with a smaller force dynamic range?

H1: Short response time causes small force dynamic range when only material or only shape approach is used.

The highest electrical resistivity → the shortest response time.

The highest magnetic saturation → the highest dynamic range

Shape approach → 5 times shorter response time



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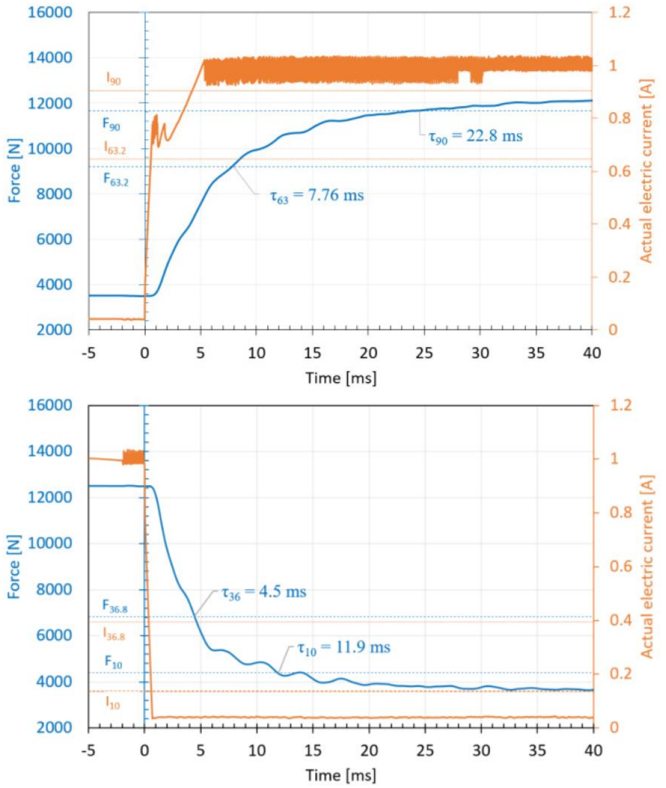
AIM OF THE THESIS

Investigate the possibilities of improving the MR damper dynamic behaviour and the effect of damper dynamic behaviour on the performance of the semi-actively controlled suspension of railway vehicle

Scientific questions

Q2: Will the permanent magnet in the MR valve affect the response time of the MR damper? Will the response time of the force rise and force drop be different?

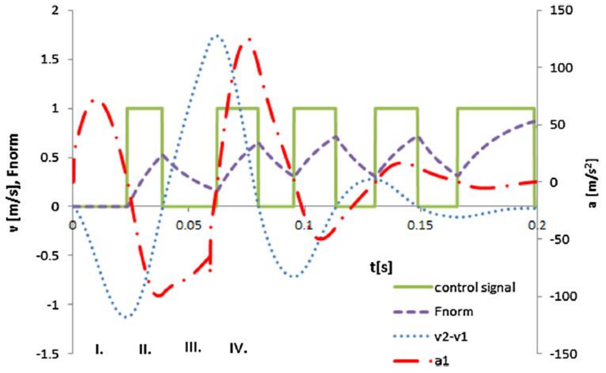
H2: Permanent magnet only shift B-I curve in the gap, but don‘t affect generation of the magnetic field in the magnetic circuit. Response time of the force rise will be slower than the response time of the force drop.



Kubík, 2011

AIM OF THE THESIS

Investigate the possibilities of improving the MR damper dynamic behaviour and the effect of damper dynamic behaviour on the performance of the semi-actively controlled suspension of railway vehicle



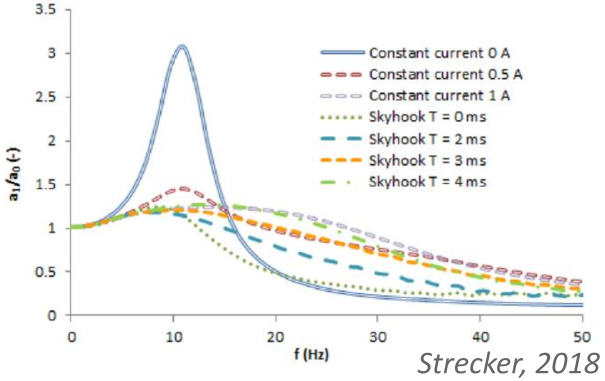
Strecker, 2015

Scientific questions

Q3: How does damper behaviour affect the S/A control of railway vehicle lateral secondary MR dampers? Is there a difference between the effect of the force rise response time and force drop response time? What are the acceptable values of damper force response time and dynamic range for this control?

H3: The algorithms switch once at zero piston velocity and once at non-zero, so that **the response time for force rise will have a different effect than the response time for force drop**. An acceptable force **dynamic range is assumed to be about 10**. An acceptable **force response time is assumed to be about 10 ms**, due low vibration frequency of railway vehicle carbody.

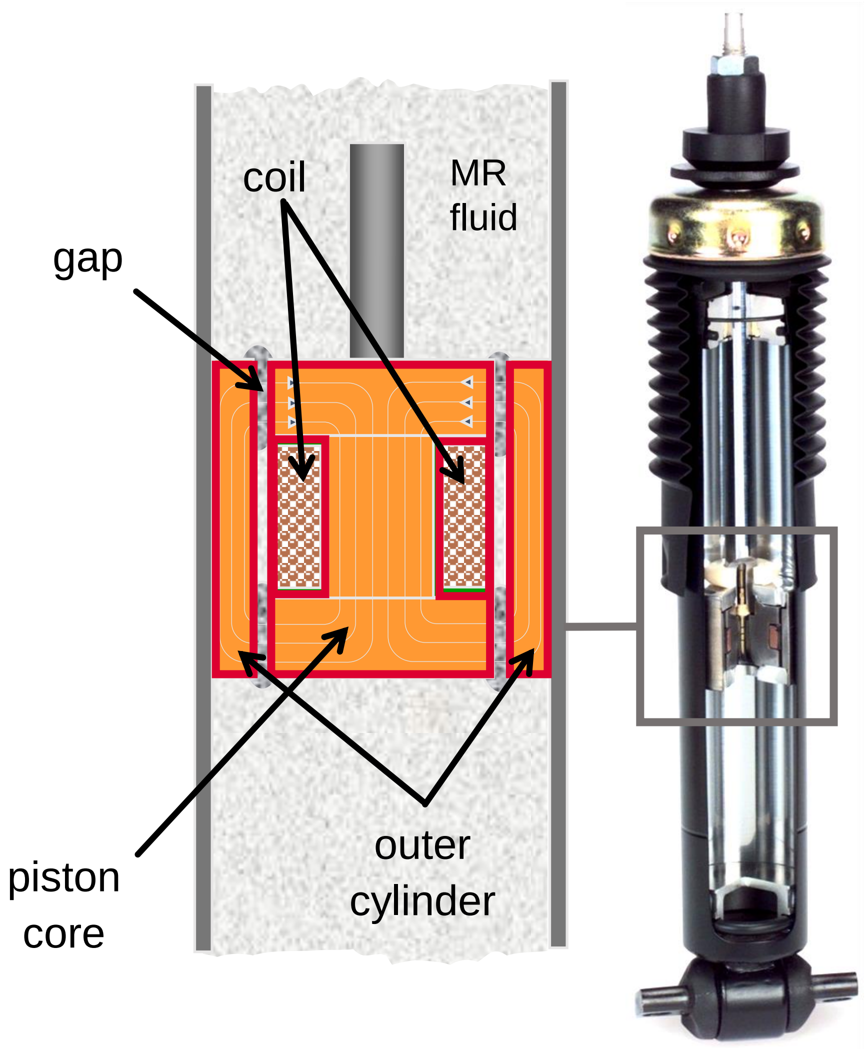
- **Necessary to answer these 3 questions before designing an MR damping system for a railway vehicle**



Strecker, 2018

MATERIALS AND METHODS

Geometry of magnetic circuit



Q1: What is the effect of the material and the shape approach?

Q1

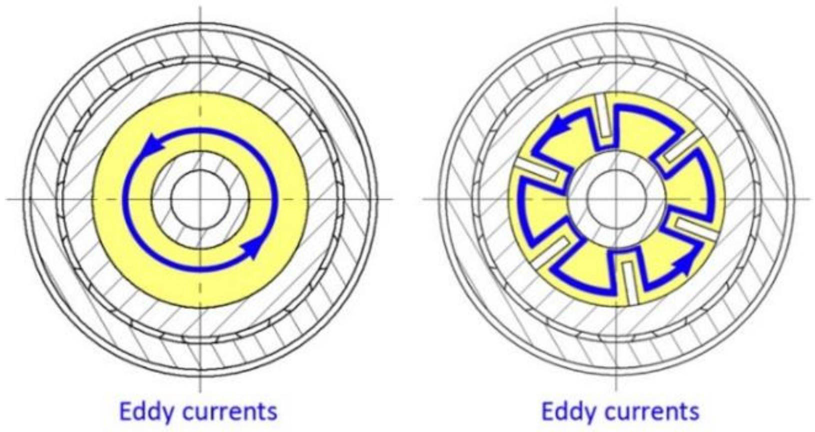
MATERIALS AND METHODS

Material approach

Material	Electrical resistivity (10^{-6} Ω·m)	Magnetic saturation (T)
11SMn30 – cutting steel	0.17	1.9
N87 ferrite – iron oxide	**10,000,000**	**0.5**
Sintex SMC – soft magnetic composites	2800	1.45
AISI 420A – stainless steel	0.5	1.6
Pure iron – SLM	**0.13**	1.7
Vacoflux 50 – CoFe alloy	0.42	**2.35**

Shape approach

- for materials with low electrical resistivity
- grooved core and cylinder of damper piston
- grooves intersect the flow of eddy curents
- final variant was selected using FEM analysis



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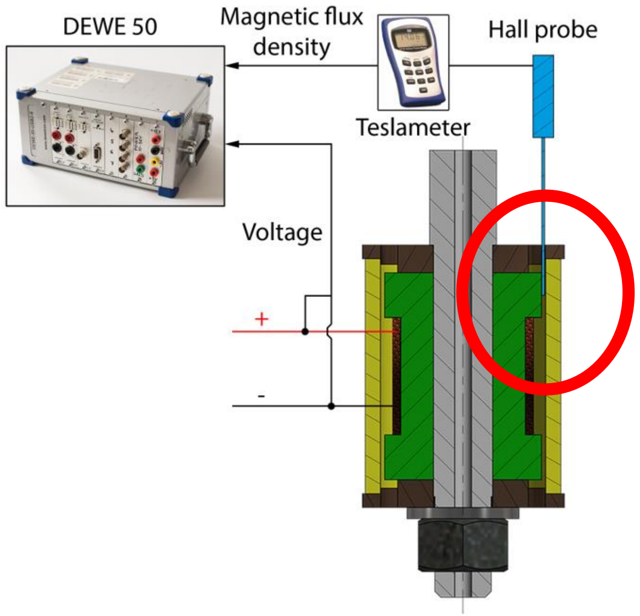
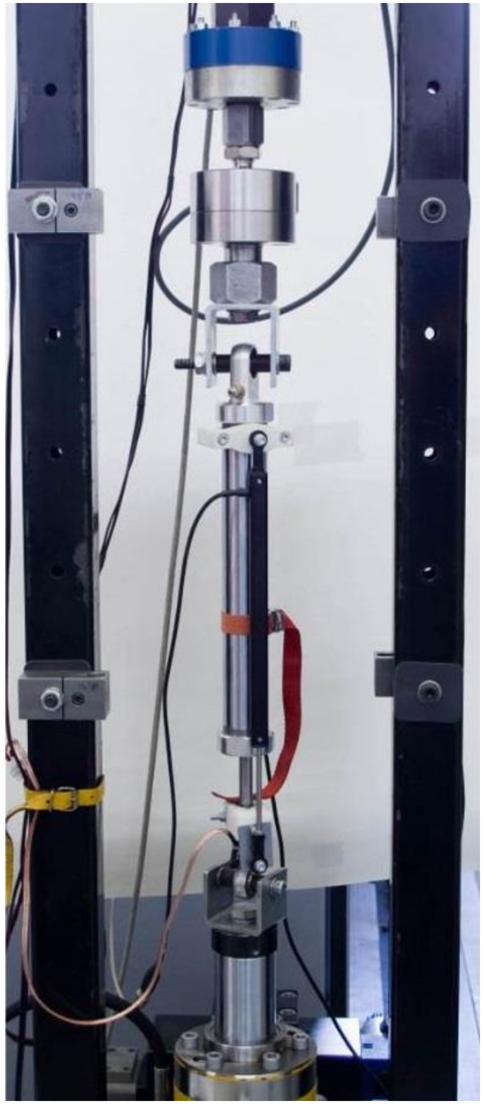
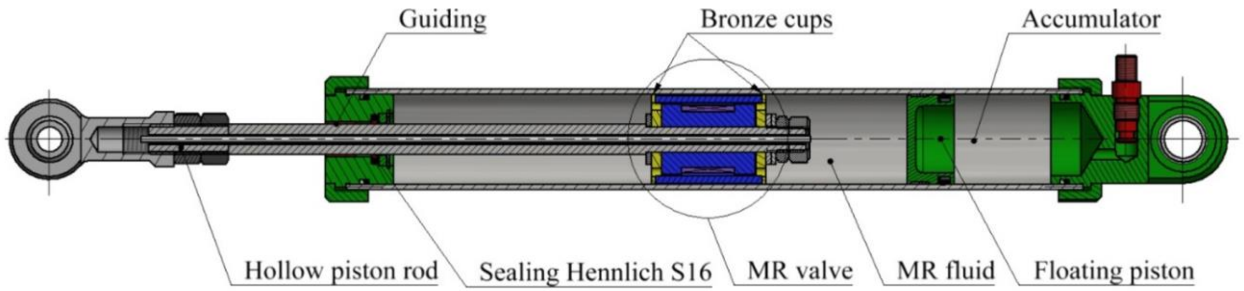
MATERIALS AND METHODS

Measuring of magnetic flux density and MR damper dynamic behaviour

- magnetic flux in the gap
  - Hall probe, teslameter
- pistons → MR damper
  → hydralulic pulsator







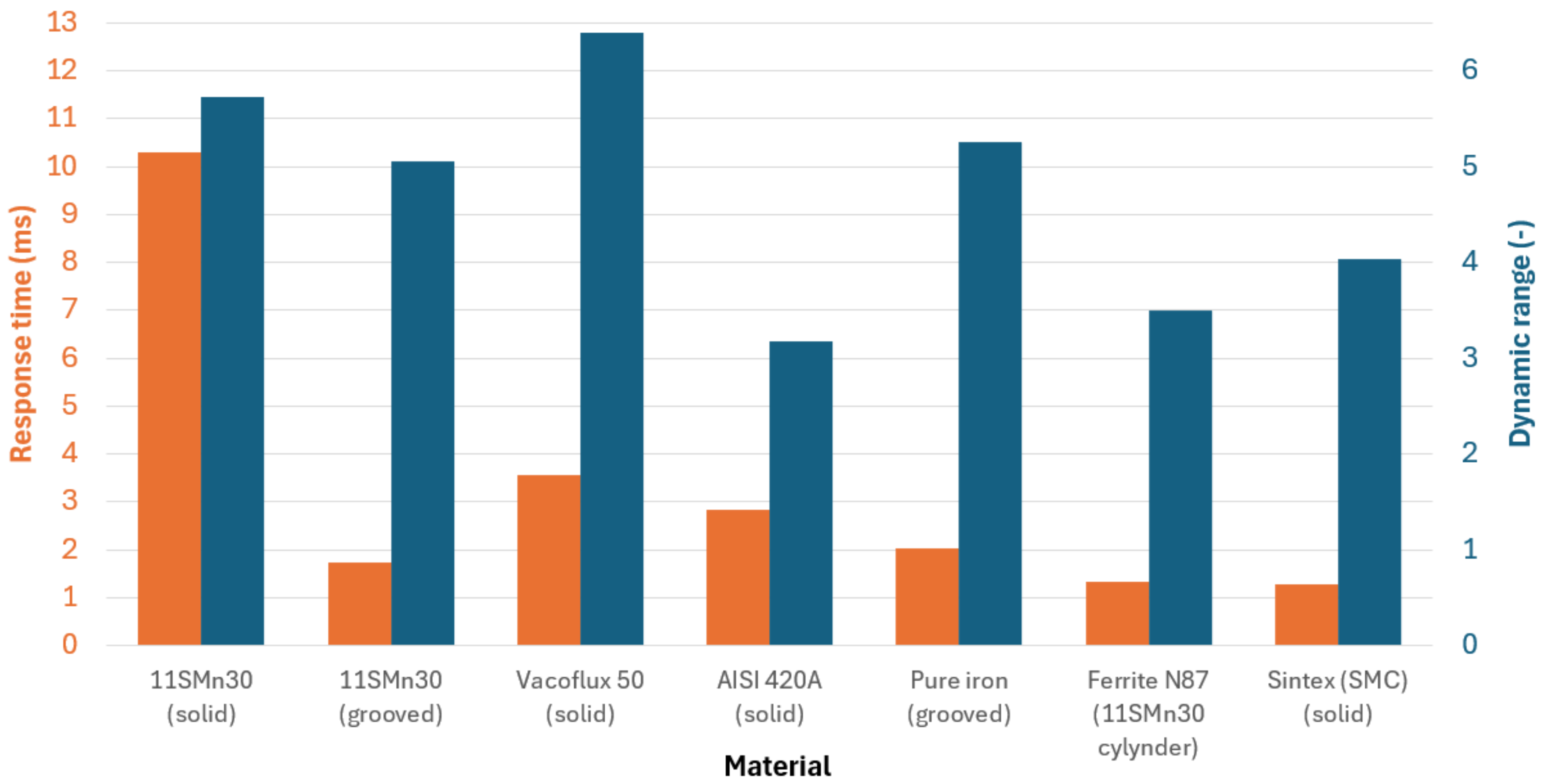
Q1: Effect of the material and the shape approach

Q1

RESULTS AND DISCUSIONS

Damper force response time and dynamic range

- Ferrite and SMC: the shortest force response time
  - the highest electric resistivity
  - bad mechanical properities
- Vacoflux: the highest dynamic range
  - the highest magnetic saturation
- 11SMn30 – 6 times shorter force response time by grooves



Conclusion

- H1: verified
- Best option: SMC, grooved 11SMn30

Q1: What is the effect of the material and the shape approach?

Q1

RESULTS AND DISCUSIONS

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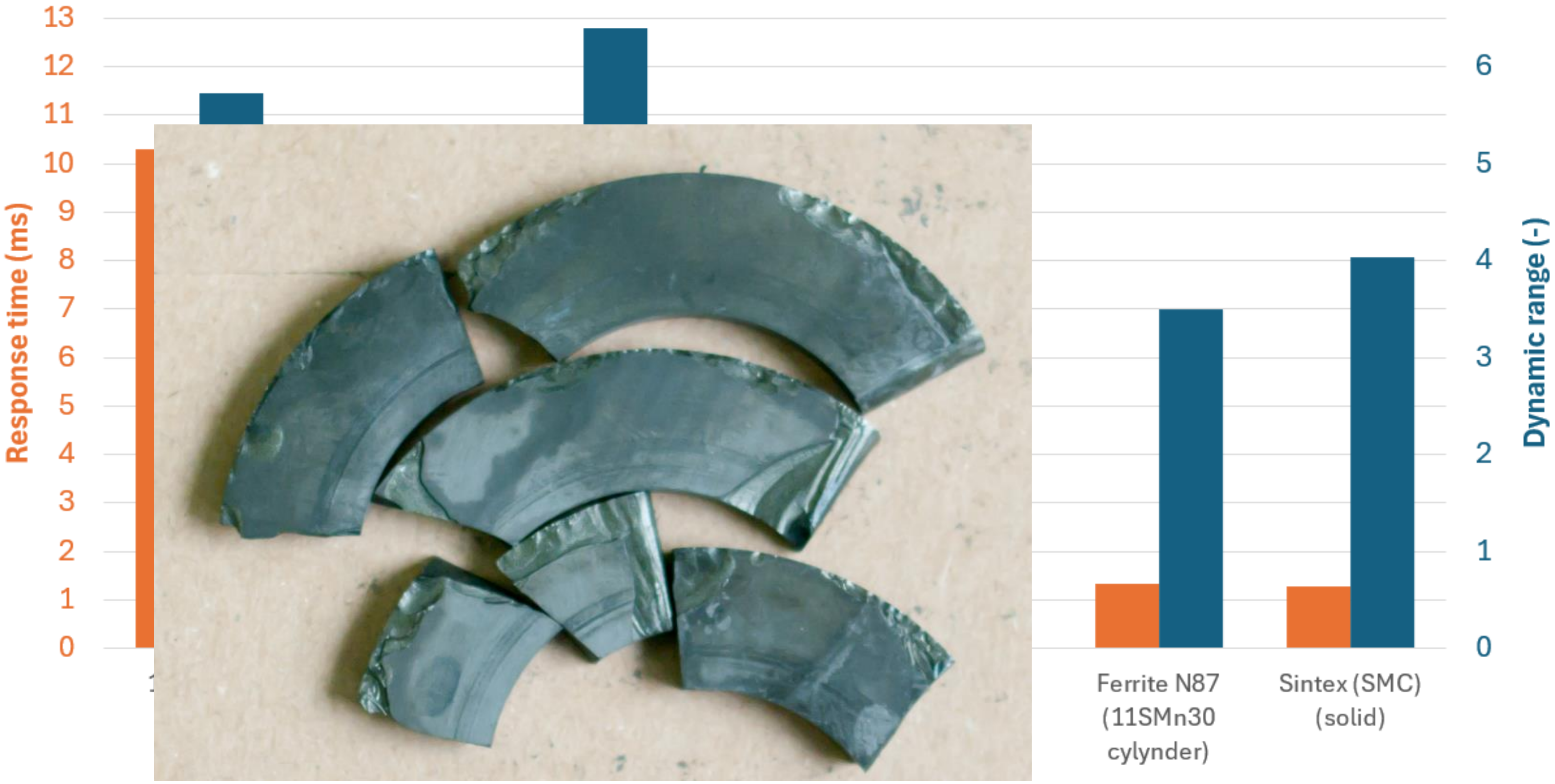

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RESULTS AND DISCUSIONS

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Conclusion

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materials (IF 3.4) MDPI

Article

Novel Approaches to the Design of an Ultra-Fast Magnetorheological Valve for Semi-Active Control

Zbyněk Strecker [1,*], Filip Jeniš [1], Michal Kubík [1], Ondřej Macháček [1] and Seung-Bok Choi [2,*]

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2 Department of Mechanical Engineering, The State University of New York at Korea (SUNY Korea), Incheon 21985, Korea
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Abstract: This article presents a list of suitable techniques and materials leading to the design of an ultra-fast magnetorheological (MR) valve. Two approaches for achieving the short response time are proposed: (a) by means of material, and (b) by means of the shape. Within the shape approach, the revolutionary technique of 3D metal printing using a selective laser melting (SLM) method was tested. The suitability of the materials and techniques is addressed based on the length of the response time, which is determined by the FEM. The simulation results determine the response time of the magnetic flux density on the step signal of the current. Subsequently, the response time is verified by the measurement of the simple magnetorheological valve. The following materials were tested: martensitic stainless steel AISI 420A (X20Cr13), cutting steel 11SMn30, pure iron for SLM, Sintex SMC STX prototyping material, ferrite N87, and Vacoflux 50. A special technique involving grooves was used for preventing eddy currents on materials with a high electrical conductivity. The simulation and experimental results indicate that a response time shorter than 2.5 ms can be achieved using materials such as Sintex SMC prototyping, ferrite N87, and grooved variants of metal pistons.

Keywords: magnetorheological valve; response time; eddy currents; magnetic simulations; SMC material

check for updates

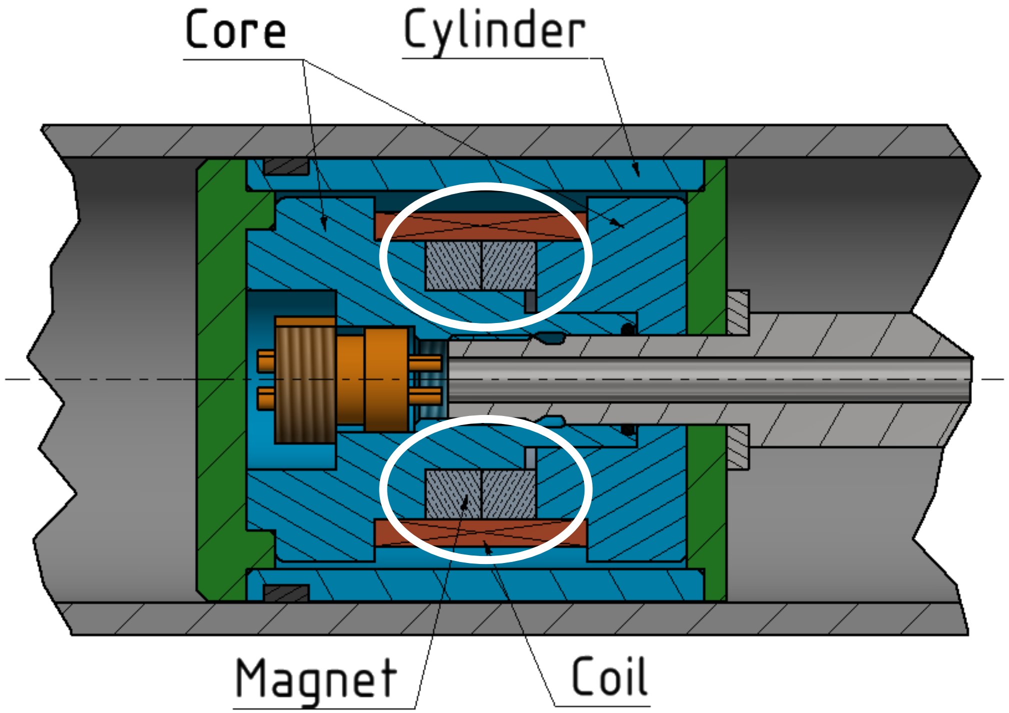
Citation: Strecker, Z.; Jeniš, F.; Kubík, M.; Macháček, O.; Choi, S.-B. Novel Approaches to the Design of an Ultra-Fast Magnetorheological Valve for Semi-Active Control. *Materials* **2021**, *14*, 2500. https://doi.org/10.3390/ma14102500

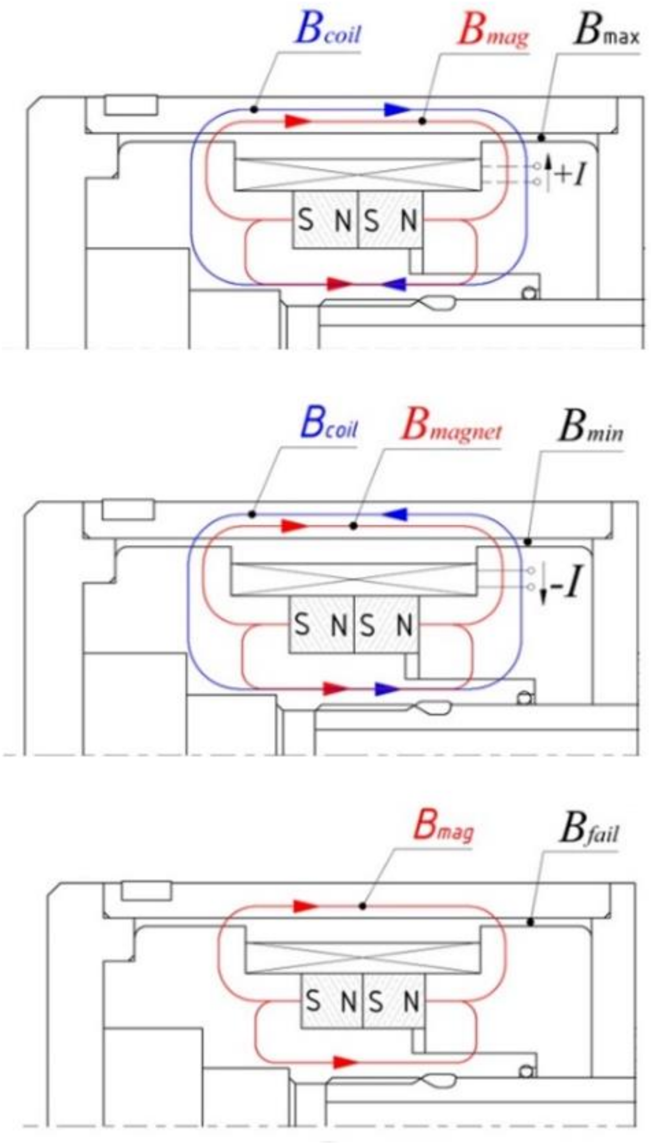
MATERIALS AND METHODS

Geometry of magnetic circuit

- core and cylinder from 11SMn30
- two neodymum magnets

$$B_{max} = B_{mag} + B_{coil}$$
$$B_{min} = B_{mag} - B_{coil}$$
$$B_{fail} = B_{mag}$$





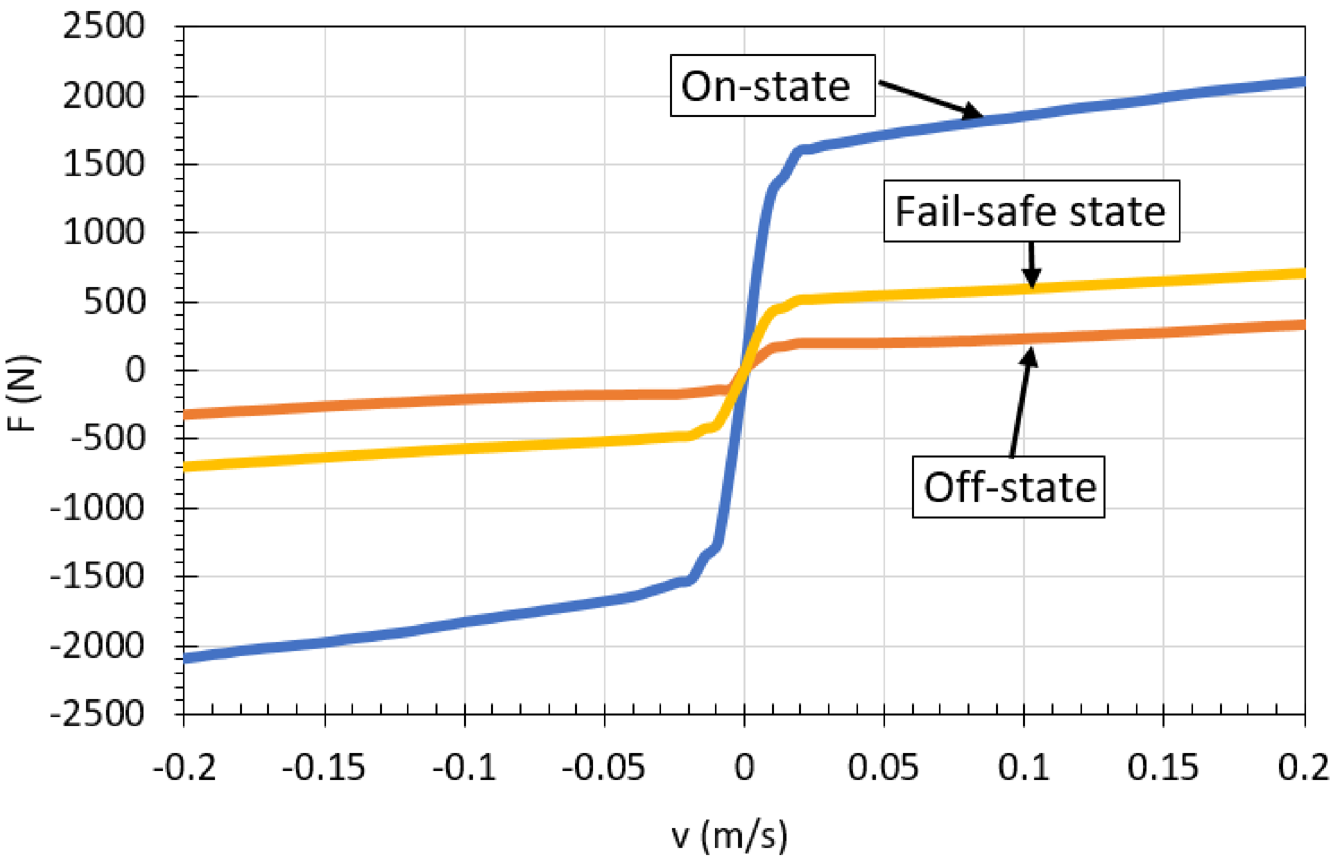
Q2: What is the effect of the permanent magnet in the fail-safe MR damper?

Q2

RESULTS AND DISCUSIONS

Damper dynamic behaviour

- fail-safe force is 1/3 of on-state force



Q2: What is the effect of the permanent magnet in the fail-safe MR damper?

Q2

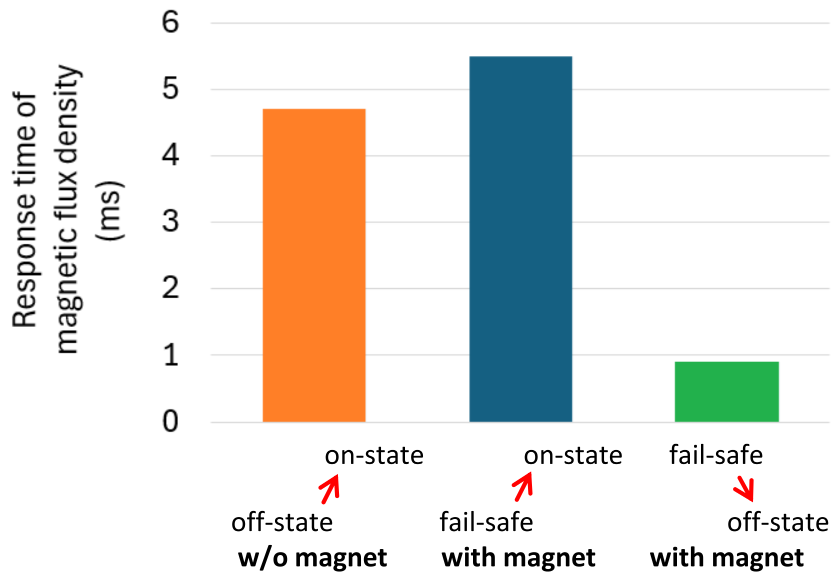
RESULTS AND DISCUSIONS

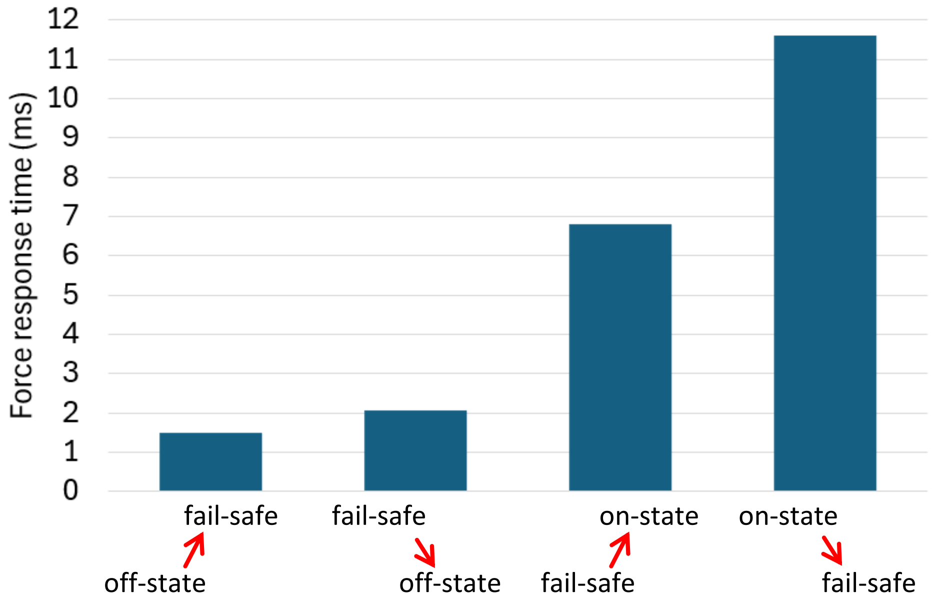
Damper dynamic behaviour

- fail-safe force is 1/3 of on-state force
- permanent magnet influence but does not degrade transient behaviour of MR damper
- **damping force rise is faster than force drop**

Conclusion

- H2: falsified





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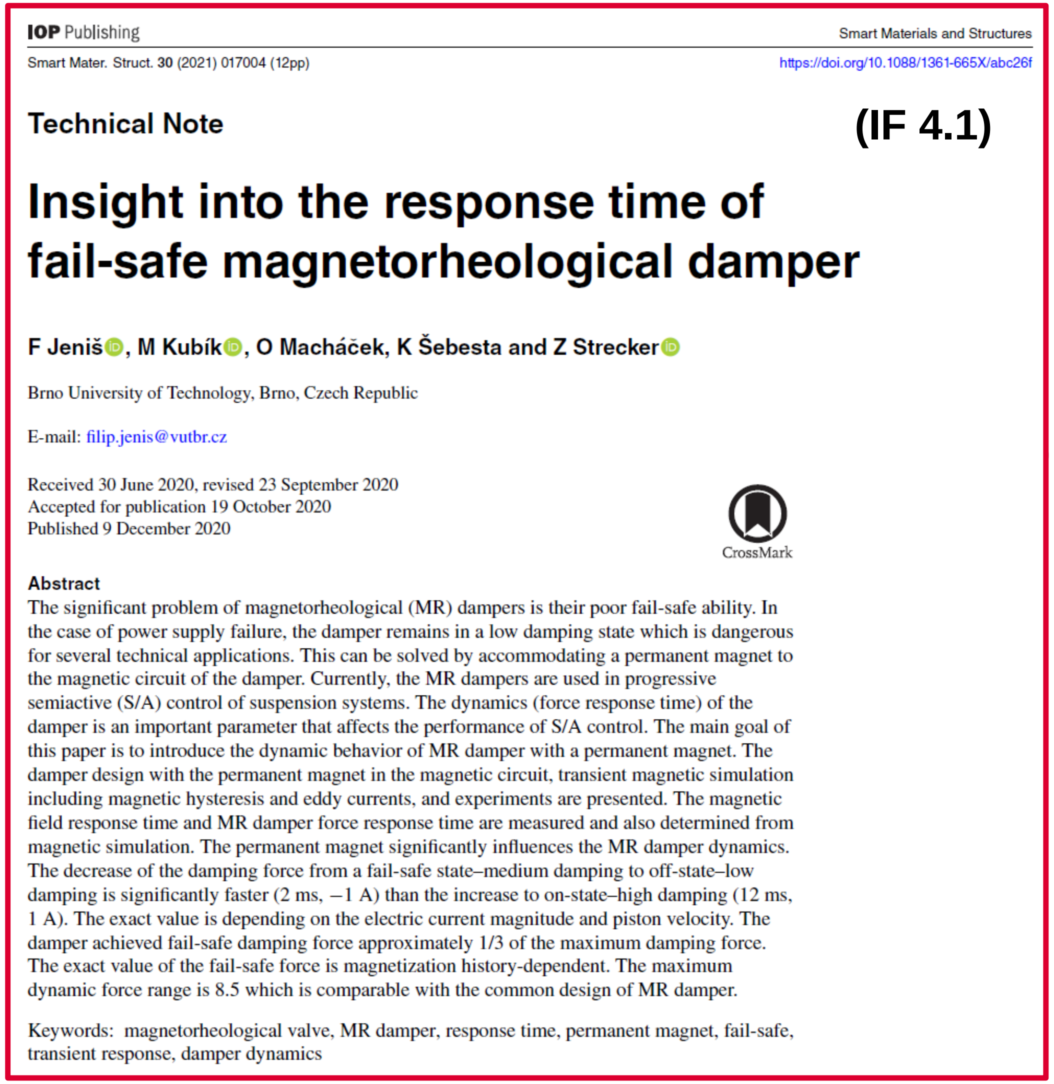
Q2

RESULTS AND DISCUSIONS



IOP Publishing Smart Materials and Structures

Smart Mater. Struct. 30 (2021) 017004 (12pp) https://doi.org/10.1088/1361-665X/abc26f

Technical Note **(IF 4.1)**

Insight into the response time of fail-safe magnetorheological damper

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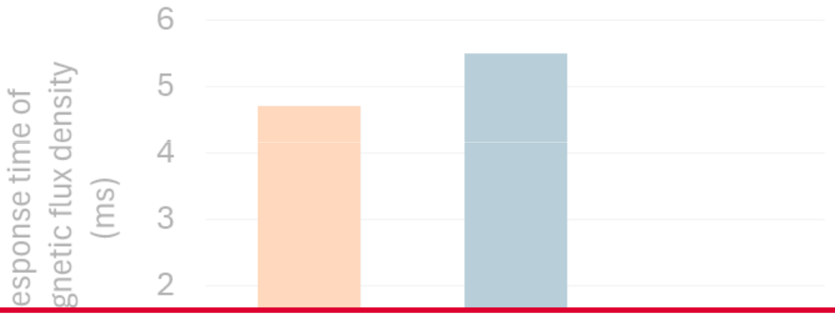
CrossMark

Abstract

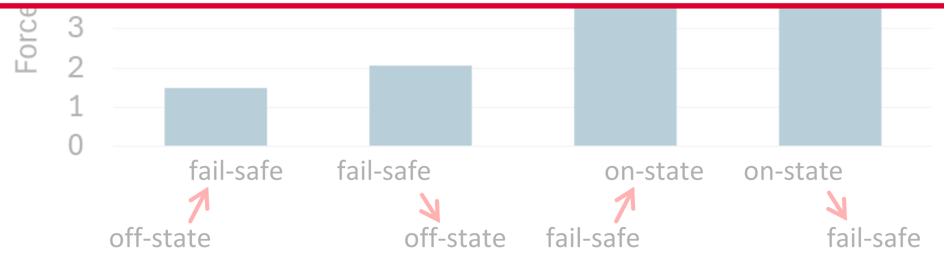
The significant problem of magnetorheological (MR) dampers is their poor fail-safe ability. In the case of power supply failure, the damper remains in a low damping state which is dangerous for several technical applications. This can be solved by accommodating a permanent magnet to the magnetic circuit of the damper. Currently, the MR dampers are used in progressive semiactive (S/A) control of suspension systems. The dynamics (force response time) of the damper is an important parameter that affects the performance of S/A control. The main goal of this paper is to introduce the dynamic behavior of MR damper with a permanent magnet. The damper design with the permanent magnet in the magnetic circuit, transient magnetic simulation including magnetic hysteresis and eddy currents, and experiments are presented. The magnetic field response time and MR damper force response time are measured and also determined from magnetic simulation. The permanent magnet significantly influences the MR damper dynamics. The decrease of the damping force from a fail-safe state–medium damping to off-state–low damping is significantly faster (2 ms, −1 A) than the increase to on-state–high damping (12 ms, 1 A). The exact value is depending on the electric current magnitude and piston velocity. The damper achieved fail-safe damping force approximately 1/3 of the maximum damping force. The exact value of the fail-safe force is magnetization history-dependent. The maximum dynamic force range is 8.5 which is comparable with the common design of MR damper.

Keywords: magnetorheological valve, MR damper, response time, permanent magnet, fail-safe, transient response, damper dynamics



H2.2: 11SMn30 cutting steel causes excessive eddy current development and a longer response time. A combination of the eddy current effect and the permanent magnet effect probably causes the behaviour described.

The response time could behave as hypothesis H2, i.e., the **force drop could be faster than the force rise** if the 11SMn30 cutting steel was **grooved** or if the magnetic circuit was made of a material more resistant to eddy currents, such as **SMC.**



Q2: What is the effect of the permanent magnet in the fail-safe MR damper?

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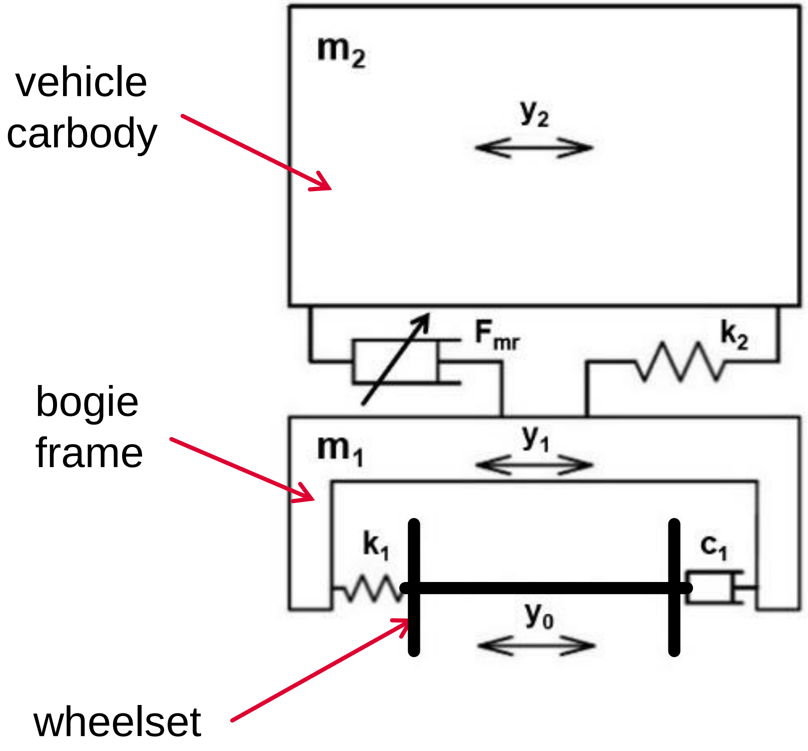
MATERIALS AND METHODS

Vehicle model

- lateral movement of railway vehicle suspension
- 2 degrees of freedom
- 1 wheelset, ½ of bogie frame, ¼ of vehicle carbody
- kinematic excitation y_0
- 1:5 scale

Parameter	Symbol	Original	1:5 scale
½ bogie frame weight	m1	5000 kg	1000 kg
¼ carbody weight	m2	13,750 kg	2750 kg
wheelset-bogie frame bond stiffness	k1	10 kN/mm	2 kN/mm
bogie frame-carbody bond stiffness	k2	1 kN/mm	0.2 kN/mm
wheelset-bogie frame bond damping	c1	10 kNs/m	2 kNs/m

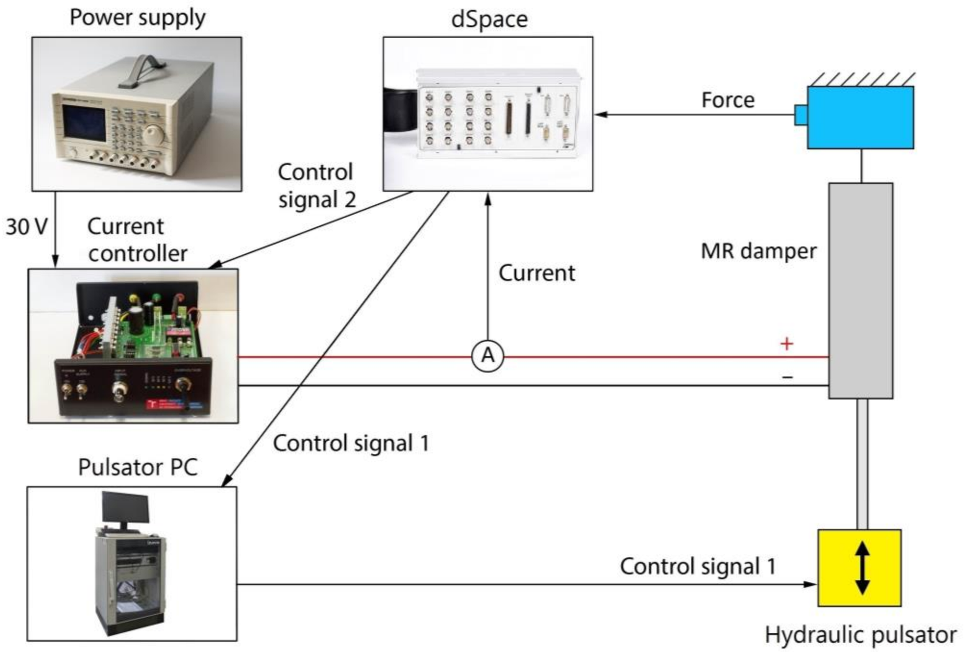


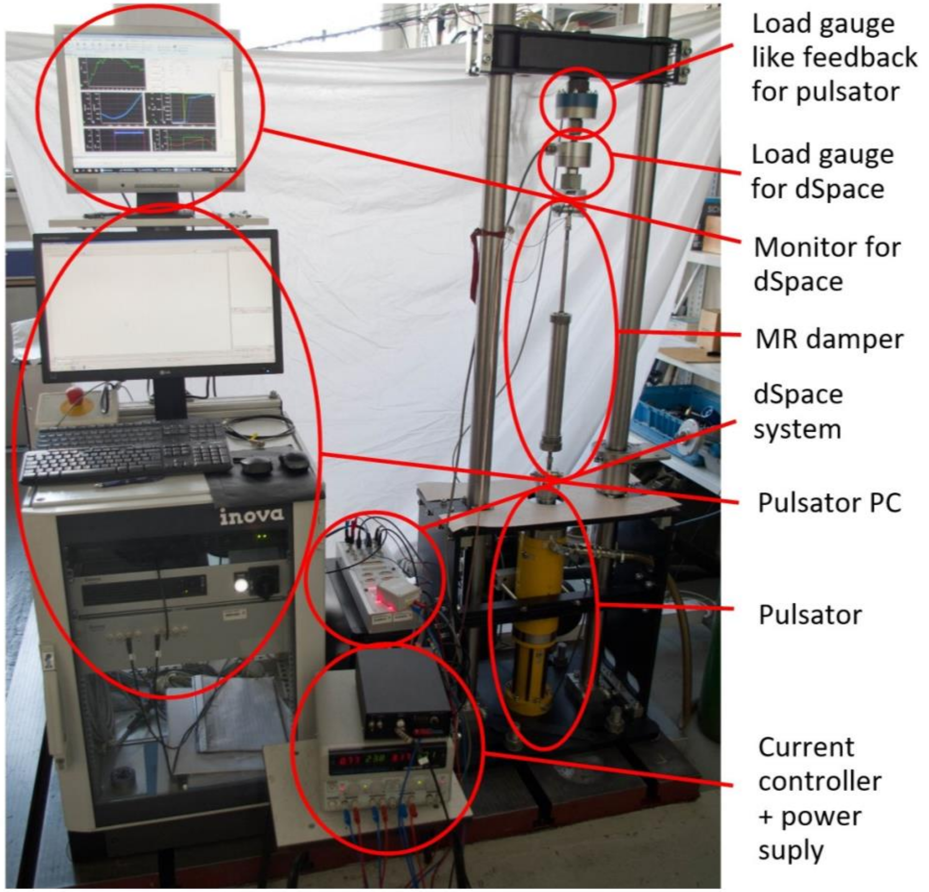
Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

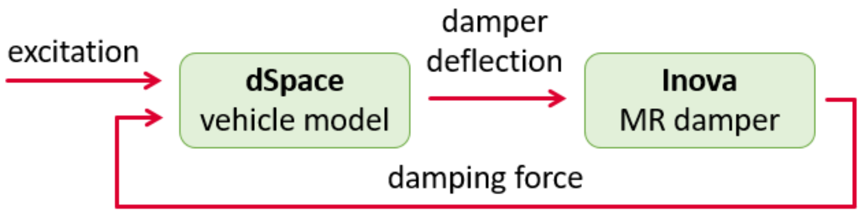
MATERIALS AND METHODS

Hardware-in-the-loop simulation

- real damper on pulsator
- virtual model on dSpace







Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

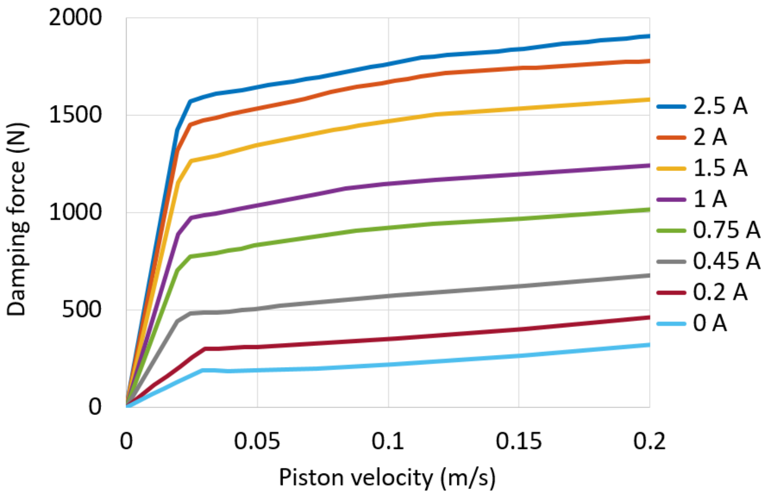
Q3

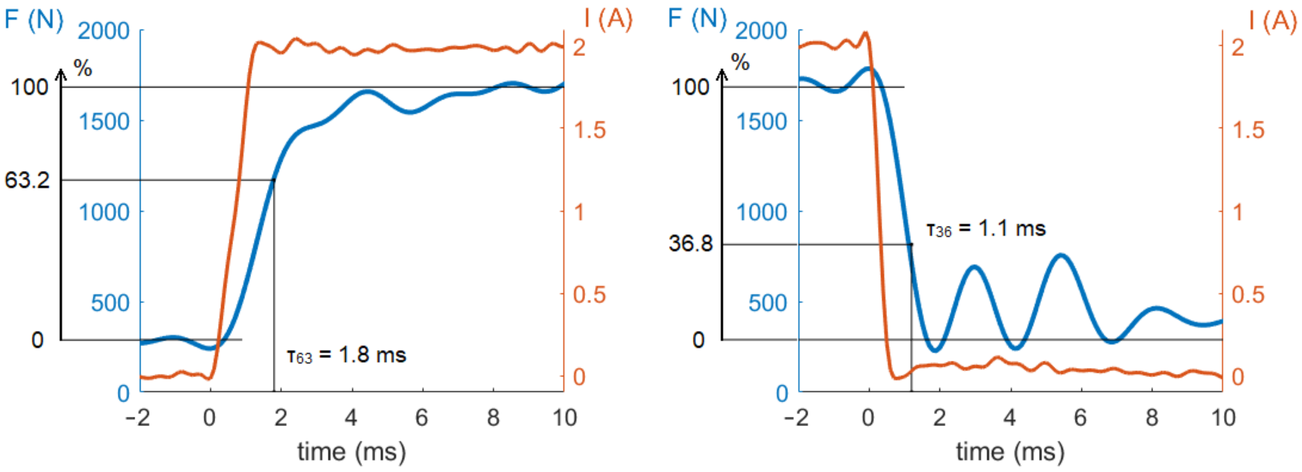
MATERIALS AND METHODS

MR damper

- magnetic circuit from SMC
- max. force of 1900 N (0.2 m/s)
- dynamic range of 7.6 (0.1 m/s)
- force rise response time of τ = 1.8 ms
- force drop response time of τ = 1.1 ms

- tested response time
    - 1.8 ms – 56 ms
- tested dynamic range
    - 2 – 7.8





Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

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Q3

MATERIALS AND METHODS

Semi-active control

- four S/A strategies
- Shyhook – two states

$$F(v) = \begin{cases} F_{max}(v), & \dot{y}_2(\dot{y}_2 - \dot{y}_1) \geq 0 \\ F_{min}(v), & \dot{y}_2(\dot{y}_2 - \dot{y}_1) < 0 \end{cases}$$

- Skyhook – linear

$$I = \begin{cases} sat\left(\frac{I_{max} \cdot \dot{y}_2}{(\dot{y}_2 - \dot{y}_1)}\right), & \dot{y}_2(\dot{y}_2 - \dot{y}_1) \geq 0 \\ I_{min}, & \dot{y}_2(\dot{y}_2 - \dot{y}_1) < 0 \end{cases}$$

- Acceleration Driven Damper – two states

$$F(v) = \begin{cases} F_{max}(v), & \ddot{y}_2(\dot{y}_2 - \dot{y}_1) \geq 0 \\ F_{min}(v), & \ddot{y}_2(\dot{y}_2 - \dot{y}_1) < 0 \end{cases}$$

- **Acceleration Driven Damper – linear**

$$I = \begin{cases} sat\left(\frac{I_{max} \cdot \dot{y}_2}{(\dot{y}_2 - \dot{y}_1)}\right), & \ddot{y}_2(\dot{y}_2 - \dot{y}_1) \geq 0 \\ I_{min}, & \ddot{y}_2(\dot{y}_2 - \dot{y}_1) < 0 \end{cases}$$

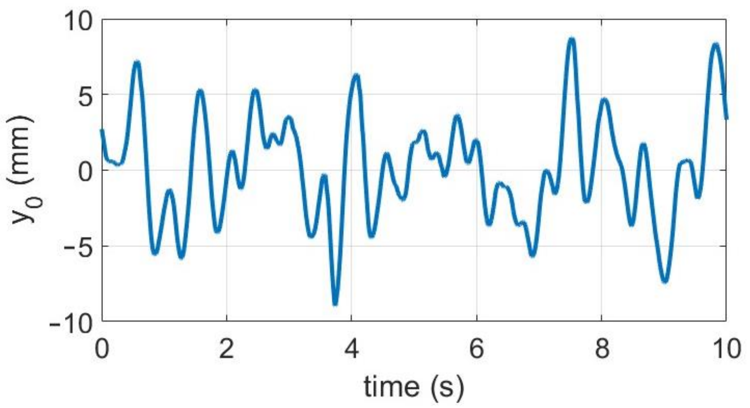
Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

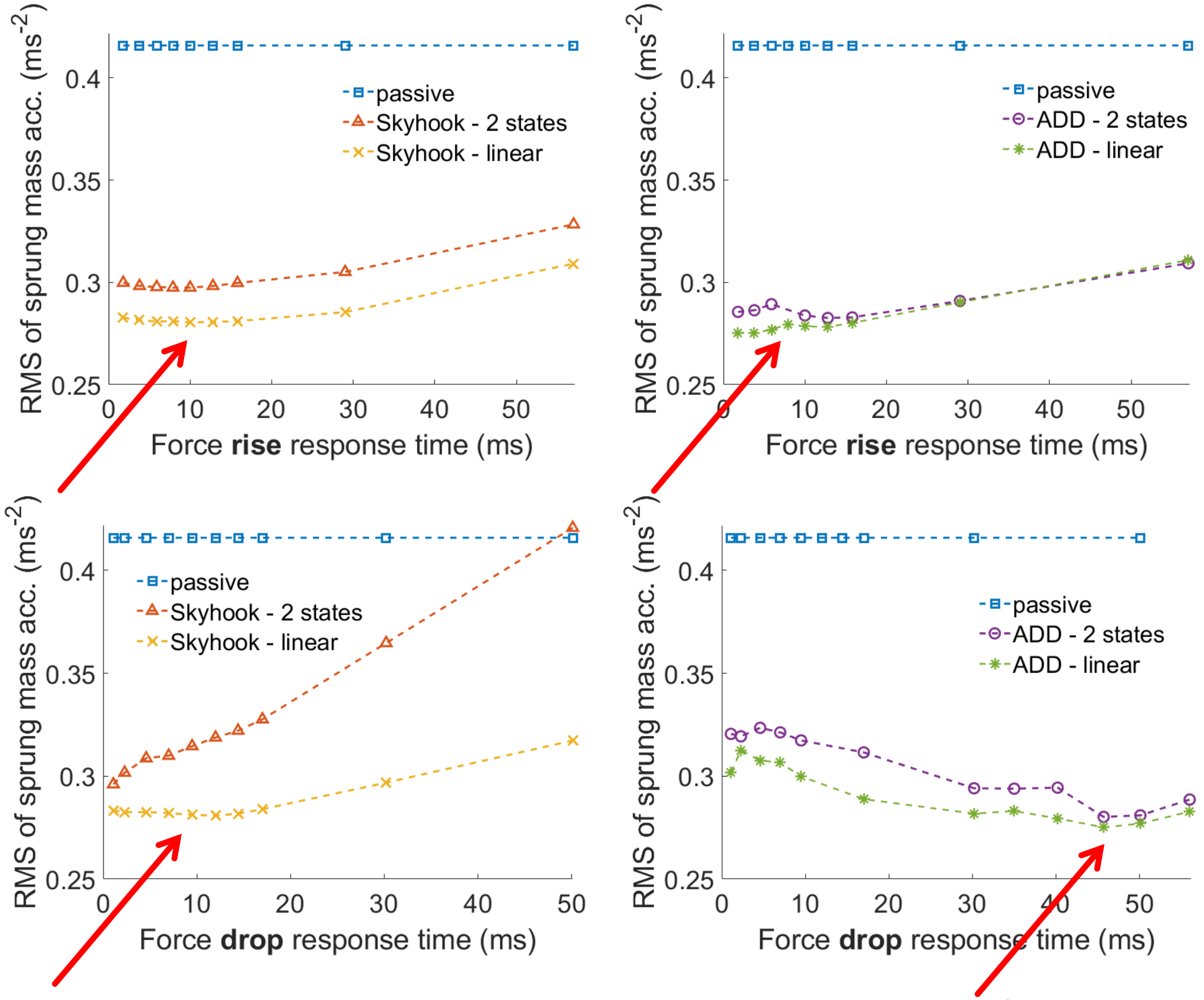
RESULTS AND DISCUSIONS

Q3

Results

- excitation: straight track, 160 km/h
- force **drop** response time more important than the force **rise** response time
- ideal response time about τ = 8 ms
- best force-drop response time for ADD τ = 45 ms





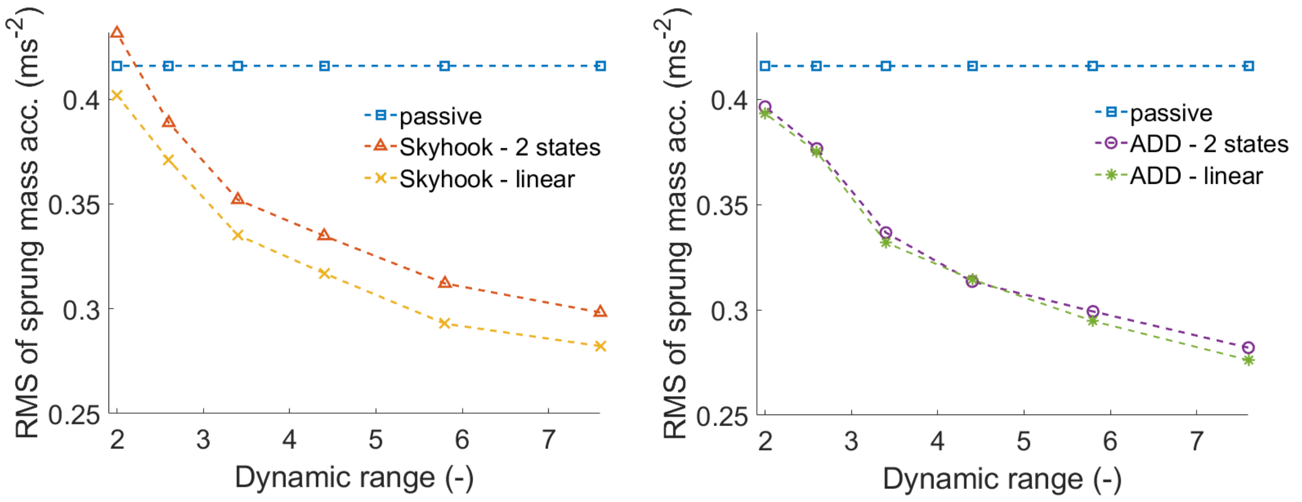
Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

Q3

RESULTS AND DISCUSIONS

Results

- excitation: straight track, 160 km/h
- force **drop** response time more important than the force **rise** response time
- ideal response time about τ = 8 ms
- best force-drop response time for ADD τ = 45 ms
- improve 34 % by ADD-L



Mode	RMS (m/s^2)	Improvement (%)
passive	0.416	0
SH-2	0.298	28.3
SH-L	0.282	32.2
ADD-2	0.282	32.2
ADD-L	**0.276**	**33.6**

Conclusion

- H3: verified

Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

Q3

RESULTS AND DISCUSIONS

Results

- excitation: straight track, 160
- force **drop** response time m than the force **rise** response
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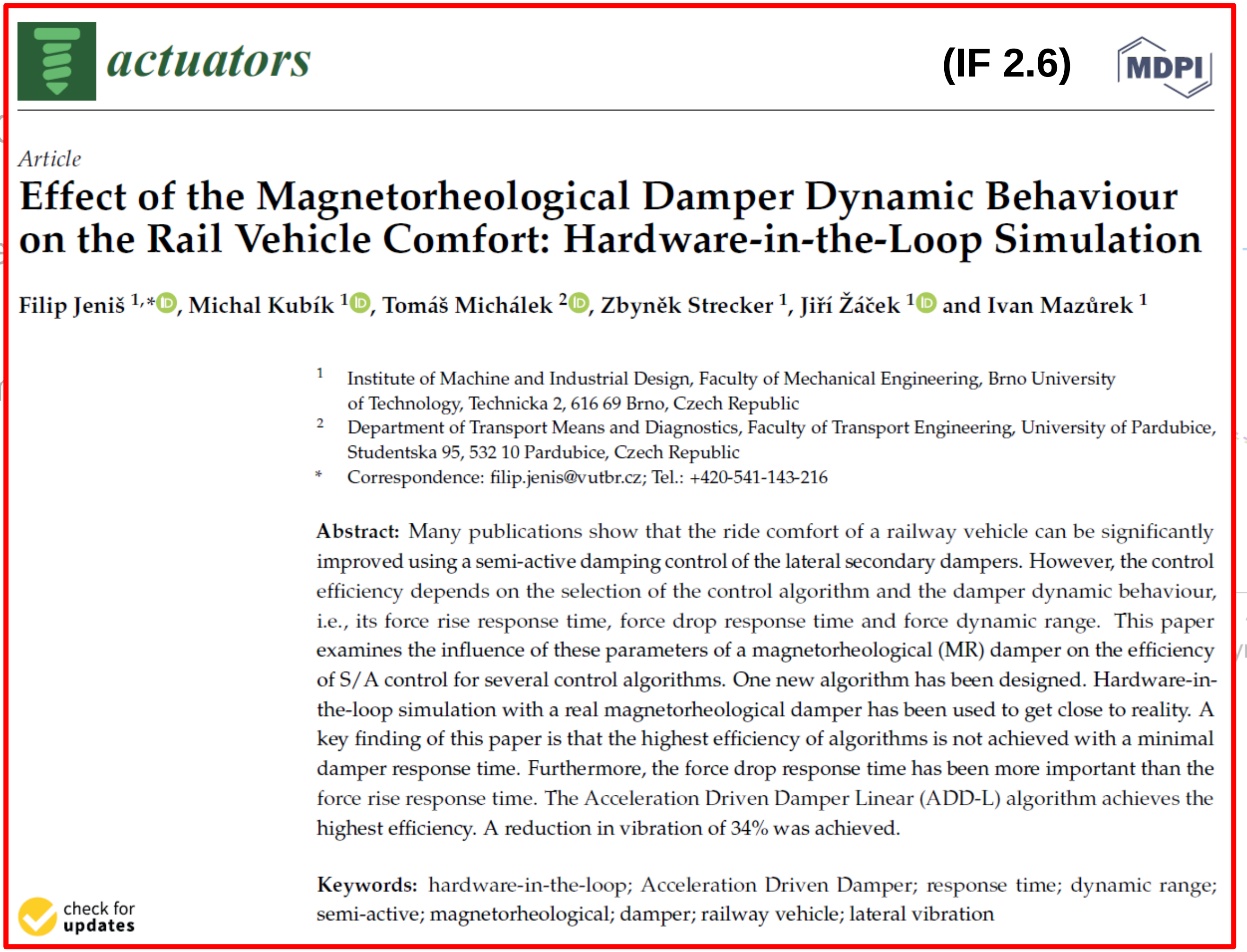

actuators (IF 2.6) MDPI

Article

Effect of the Magnetorheological Damper Dynamic Behaviour on the Rail Vehicle Comfort: Hardware-in-the-Loop Simulation

Filip Jeniš [1,*], Michal Kubík [1], Tomáš Michálek [2], Zbyněk Strecker [1], Jiří Žáček [1] and Ivan Mazůrek [1]

1 Institute of Machine and Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2, 616 69 Brno, Czech Republic
2 Department of Transport Means and Diagnostics, Faculty of Transport Engineering, University of Pardubice, Studentska 95, 532 10 Pardubice, Czech Republic
* Correspondence: filip.jenis@vutbr.cz; Tel.: +420-541-143-216

Abstract: Many publications show that the ride comfort of a railway vehicle can be significantly improved using a semi-active damping control of the lateral secondary dampers. However, the control efficiency depends on the selection of the control algorithm and the damper dynamic behaviour, i.e., its force rise response time, force drop response time and force dynamic range. This paper examines the influence of these parameters of a magnetorheological (MR) damper on the efficiency of S/A control for several control algorithms. One new algorithm has been designed. Hardware-in-the-loop simulation with a real magnetorheological damper has been used to get close to reality. A key finding of this paper is that the highest efficiency of algorithms is not achieved with a minimal damper response time. Furthermore, the force drop response time has been more important than the force rise response time. The Acceleration Driven Damper Linear (ADD-L) algorithm achieves the highest efficiency. A reduction in vibration of 34% was achieved.

Keywords: hardware-in-the-loop; Acceleration Driven Damper; response time; dynamic range; semi-active; magnetorheological; damper; railway vehicle; lateral vibration

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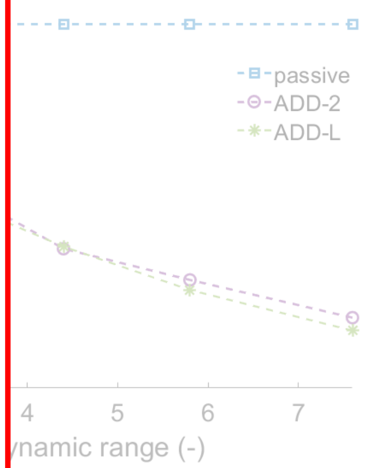

Conclusion

- H3: verified

Q3: What is the effect of the MR damper dynamic behaviour on the S/A control efficiency?

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CONCLUSION

S/A control of railway vehicle suspension significantly improves passenger comfort

- MR damper with great response time and dynamic range
- improvement using the material and the shape approach
- permanent magnet in fail-safe damper does not degrade damper behaviour

- damper scaled 1:5 was used → larger railway MR damper – longer response time!!

CONCLUSION

MR bogie yaw damper

- grooved 11SMn30

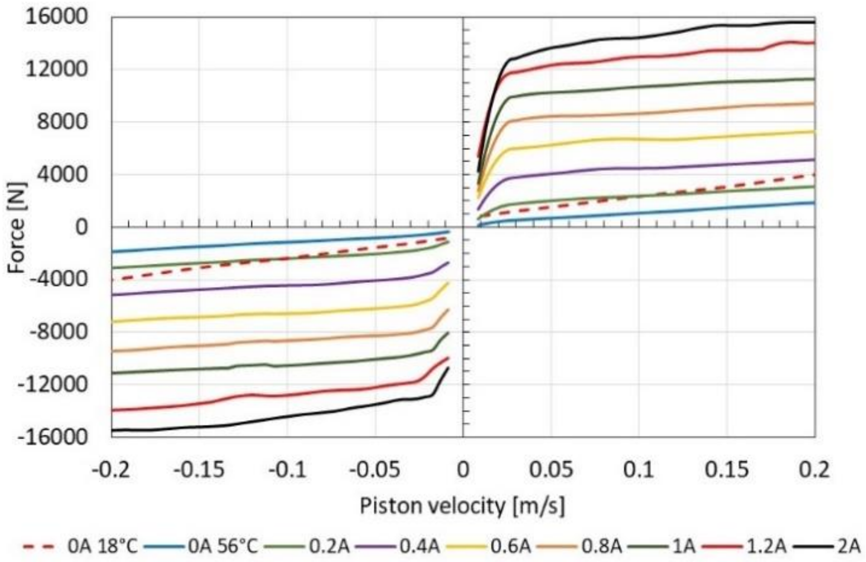
CONCLUSION

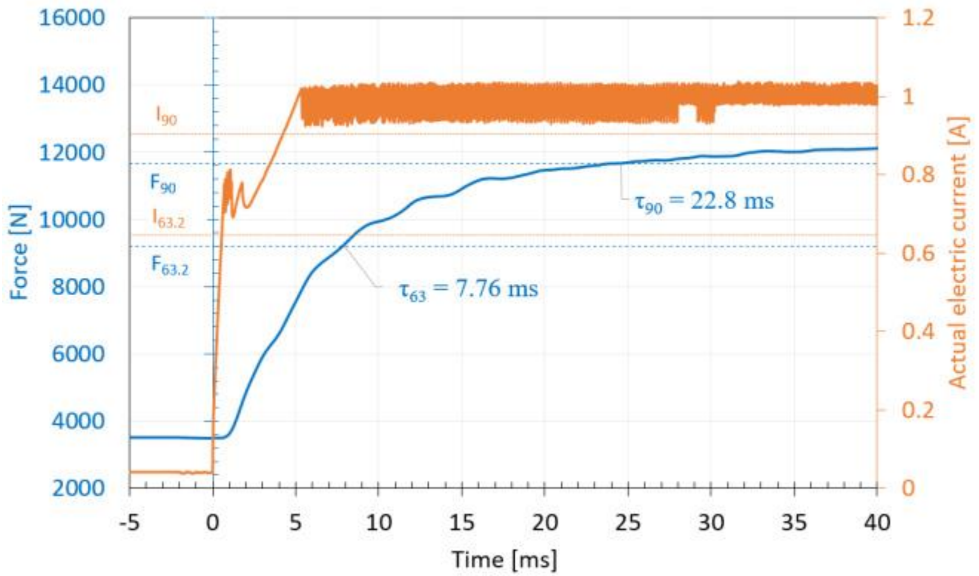
MR bogie yaw damper

- grooved 11SMn30
- dynamic range of **25 – 8.5**
- response time τ = **7.8** ms

  (Guo 2015, 300 ms)

- <u>suitable for use on a railway vehicle!</u>





APPLICATION

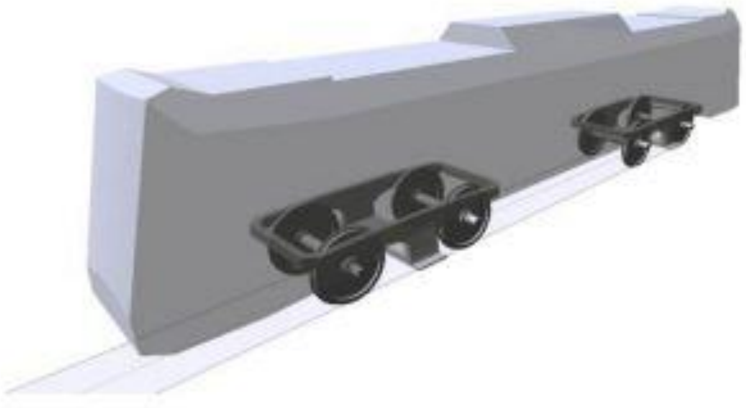
MR bogie yaw damper

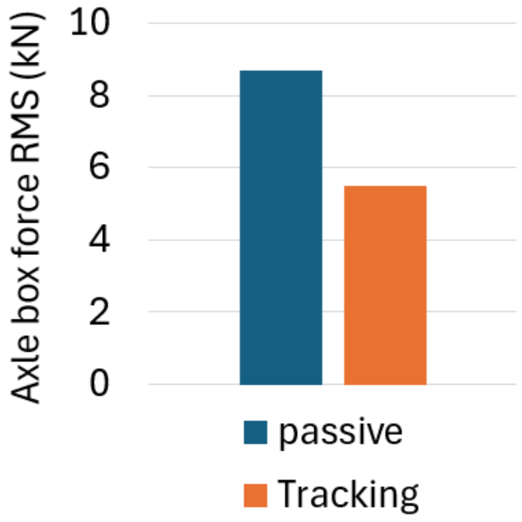
- grooved 11SMn30
- dynamic range of **25 – 8.5**
- response time τ = **7.8** ms

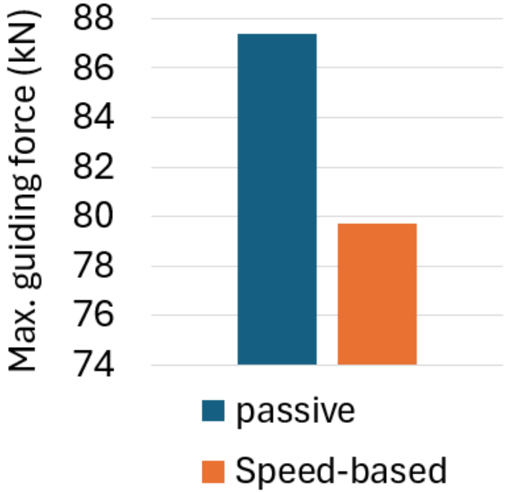
  (Guo 2015, 300 ms)
- suitable for use on a railway vehicle

Simulations and tests

- reduction of axle box force RMS on straight track by 40 % (stability)
- reduction of maximal guiding forces in S-curce by 9 % (wear)







APPLICATION

Semi-active yaw dampers in locomotive running gear: new control algorithms and verification of their stabilising effect

Filip Jeniš[1], Tomáš Michálek[2], Michal Kubík[1], Aleš Hába[2], Zbyněk Strecker[1], Jiří Žáček[1] and Ivan Mazůrek[1]

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Abstract

It is generally accepted that semi-actively controlled dampers can significantly improve the behaviour of a road or rail vehicle. In the case of a railway vehicle, this offers the possibility of solving a contradiction in the damping requirements for different driving modes. This paper deals with applying magnetorheological dampers with semiactive control in the locomotive bogie to reduce hunting oscillation. The magnetorheological bogie yaw damper design, selected algorithms for its control, and application on a complex multi-body locomotive model that simulates fast running on a real straight track are shown. The important part of the paper is focused on the effect of the damping force level and the damper force response time. The results have shown that using the semi-active control of the yaw dampers makes it possible to reduce carbody lateral oscillation by 60 % and wear in the wheel-rail contact by 80 % and improve running stability for higher equivalent conicity and subcritical speed. The critical speed can be increased by more than 60 km/h. The efficiency of the proposed semi-active control increases with increasing damping force level and decreasing response time. The control is most effective under conditions of low equivalent conicity.

Keywords: semi-active, magnetorheological, damper, hunting oscilation, railway vehicle, bogie, running stability

The Influence of Semi-actively Controlled Magnetorheological Bogie Yaw Dampers on Guiding Behaviour of a Railway Vehicle in an S-Curve: Simulation and On-track test

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Michal Kubík, Brno University of Technology, Technická 2, Brno, Czechia
Zbyněk Strecker, Brno University of Technology, Technická 2, Brno, Czechia
Jiří Šlapák, University of Pardubice, Faculty of Transport Engineering, Studentská 95, Pardubice, Czechia
Mazůrek Ivan, Brno University of Technology, Technická 2, Brno, Czechia

Abstract

Many publications have shown that semi-actively controlled dampers could significantly improve the behaviour of a road or rail vehicle. In the case of a railway vehicle, these dampers can solve a contradiction in the damping requirements for the different driving modes. This paper explores the application of magnetorheological bogie yaw dampers in the locomotive bogie to reduce guiding forces and wear in wheel–rail contact when the vehicle runs through the S-curve. The paper describes the magnetorheological damper, damper model and the strategies for its semi-active control, followed by the results from simulations on a complex multi-body locomotive model and from the on-track test with a real vehicle. The simulations and on-track tests have shown that using the semi-active control of the yaw dampers leads to a reduction of the guiding force and so-called “combined loading force” by around 10 %. The reduction of these forces will lead to a decrease in wear in the wheel–rail contact.

Keywords

semi-active, magnetorheological, yaw, damper, railway vehicle, S-curve, guiding force, wear

10
8
passive
Speed-based

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APPLICATION

MR lateral and vertical damping system

- Škoda 10Ev – InterPanter
- best algorithm Shykook-linear
- comfort increased by 50 %
- first test runs May 2024

LIST OF PUBLICATIONS

Papers published in journals with impact factor

- **JENIŠ, Filip**; KUBÍK, Michal; MICHÁLEK, Tomáš; STRECKER, Zbyněk; ŽÁČEK, Jiří; MAZŮREK, Ivan. Effect of the magnetorheological damper dynamic behaviour on the rail vehicle comfort: hardware-in-the-loop simulation. *Actuators,* 2023, **12**(47), 1-14. **(IF 2.6)**
- STRECKER, Zbyněk; **JENIŠ, Filip**; KUBÍK, Michal; MACHÁČEK, Ondřej; CHOI, Seung Bok. Novel Approaches to the Design of an Ultra-Fast Magnetorheological Valve for Semi-Active Control. *Materials,* 2021, **14**(10), 1-20. **(IF 3.4)**
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- KUBÍK, Michal; VÁLEK, Josef; ŽÁČEK, Jiří; JENIŠ, Filip; BORIN, Dmitry; STRECKER, Zbyněk; MAZŮREK, Ivan. Transient response of magnetorheological fluid on rapid change of magnetic field in shear mode. *Scientific Reports*, 2022, **12**(1), 1-10. **(IF 4.6)**
- KUBÍK, Michal; ŠEBESTA, Karel; STRECKER, Zbyněk; JENIŠ, Filip; GOLDASZ, Janusz; MAZŮREK, Ivan. Hydrodynamic response time of magnetorheological fluid in valve mode: model and experimental verification. *Smart Materials and Structures*, 2021, **30**(12), 1-13. **(IF 4.1)**
- ROUPEC, Jakub; JENIŠ, Filip; STRECKER, Zbyněk; KUBÍK, Michal; MACHÁČEK, Ondřej. Stribeck Curve of Magnetorheological Fluid within Pin-on-Disc Configuration: An Experimental Investigation. *Materials*, 2020, **13**(20), 1-11. **(IF 3.4)**

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LIST OF PUBLICATIONS

Papers in conference proceedings (12x)

- MICHÁLEK, Tomáš; JENIŠ, Filip. Modelling of secondary suspension for electric multiple unit. In. *Computational Mechanics 2023, 38th conference with international participation*. Srní: University of West Bohemia. s. 116-118.
- JENIŠ, Filip; MICHÁLEK, Tomáš. The effect of semi-active control of bogie yaw dampers on the railway vehicle critical speed. In*, 26th International Conference Current Problems in Rail Vehicles 2023.* Žilina: Scientific and Technical Society at the University of Žilina. s. 213-220. **(expected WOS)**
- BASARGAN, Hakan; JENIŠ, Filip; MIHÁLY, András; GÁSPÁR, Péter. Fault-tolerant control of semi-active suspension in case of oil leakage of magnetorheological damper. In *2023 EUROPEAN CONTROL CONFERENCE, ECC.* Bucharest, Romania: IEEE, 2023. **(WOS)**
- KUBÍK, Michal; STRECKER, Zbyněk; JENIŠ, Filip; MACHÁČEK, Ondřej; PŘIKRYL, Matěj; ŠPALEK, Petr. Magnetorheological Yaw Damper with Short Response Time for Railway Vehicle Bogie. In *Actuators 2021*. BERLIN: VDE VERLAG GMBH, 2021. s. 1-4. **(Scopus)**
- JENIŠ, Filip; MICHÁLEK, Tomáš; MAZŮREK, Ivan. Benefit of a semi-actively conntroled magnetorheological damper for a railway vehicle. In *Current Problems in Rail Vehicles 2021, 25th conference with international participation.* Pardubice: Faculty of transport engineering University of Pardubice, 2021. s. 85-92. **(expected WOS)**
- JENIS, Filip; STRECKER, Zbyněk; MAZUREK, Ivan. A new method for on-board car suspension testing. In *Proceedings of the Engineering Mechanics 2020*. Brno: Brno University of Technology Institute of Solid Mechanics, Mechatronics and Biomechanics, 2020. s. 238-241. **(WOS)**
- ZINDULKA, Martin; STRECKER, Zbyněk; JENIŠ, Filip. *Semiactive seat suspension for agricultural machines*. In Proceedings of the Engineering Mechanics 2020. Brno: Brno University of Technology Institute of Solid Mechanics, Mechatronics and Biomechanics, 2020. s. 548-551. **(WOS)**
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- KUBÍK, Michal; ROUPEC, Jakub; JENIŠ, Filip; MAZŮREK, Ivan. *The settings of CFD model with magnetorheological fluid and its influence on the results*. In Engineering Mechanics 2019, 25th International Conference. Praha: Institute of Thermomechanics of the Czech Academy of Sciences, 2019. s. 223-226. **(WOS)**
- JENIŠ, Filip; ROUPEC, Jakub; ŽÁČEK, Jiří; KUBÍK, Michal; MACHÁČEK, O.; SMILEK, J.; SMILKOVÁ, M.; MAZŮREK, Ivan. *Abrasion of Magnetorheological Fluids.* In Engineering Mechanics 2019, 25th International Conference. Praha: Institute of Thermomechanics of the Czech Academy of Sciences, 2019. s. 169-172. **(WOS)**
- JENIS, Filip; MAZUREK, Ivan. Mechatronicaly controlled bogie of high speed train. In *Conference proceedings of the 60th International Conference of Machine Design Departments. Brno Universtiy of Technology*, 2019.

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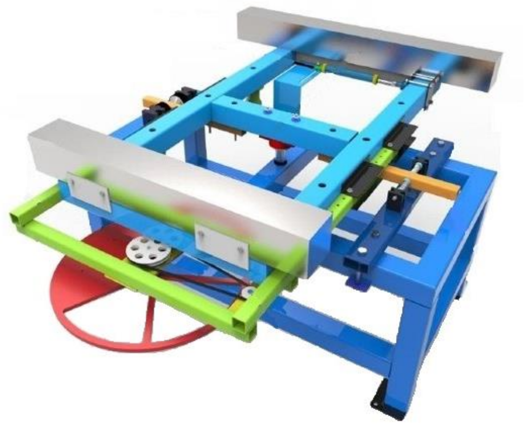
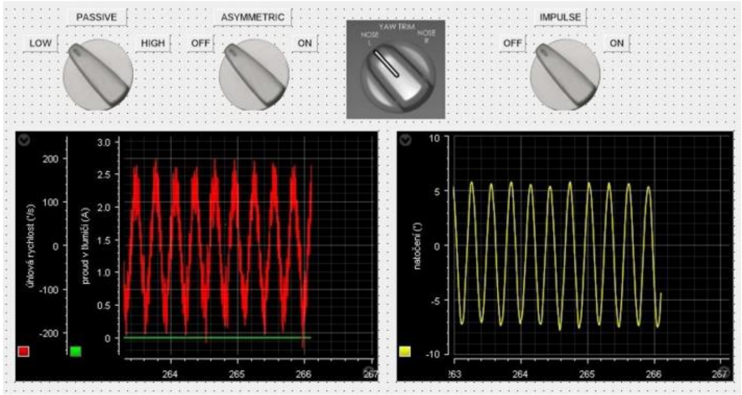
Other results

- JENIŠ, Filip; DANIEL, Pavel; MAZŮREK, Ivan: SW Demo; *Program for semi-active MR damper regulation*. **Software** (RIV-R)
- STRECKER, Zbyněk; MAZŮREK, Ivan; MACHÁČEK, Ondřej; JENIŠ, Filip: *Controller for the semi-active MR damper.* **Functional specimen** (RIV-G)
- JENIŠ, Filip; ŠEBESTA, Karel; DANIEL, Pavel; MAZŮREK, Ivan: *Demonstrator for verifying the functionality of a fast-response MR damper.* **Functional specimen** (RIV-G)
- JENIŠ, Filip; MAZŮREK, Ivan: *Simulation model of the dynamic structure of the vehicle suspension during the over-crossing test.* **Software** (RIV-R)
- JENIŠ, Filip; MAZŮREK, Ivan; SKUHRAVÝ, Pavel: *Control and analysis program of the over-crossing tester.* **Software** (RIV-R)
- MAZŮREK, Ivan; JENIŠ, Filip; SKUHRAVÝ, Pavel: *Inertial measurement unit for sensing carbody movement.* **Functional specimen** (RIV-G)
- MAZŮREK, Ivan; JENIŠ, Filip; SKUHRAVÝ, Pavel: *Universal over-crossing obstacle.* **Functional specimen** (RIV-G)



Demonstrator of MR damper function
ustavkonstruovani.cz

Inertial measurement unit
ustavkonstruovani.cz



Program for S/A MR damper control
ustavkonstruovani.cz

LIST OF PUBLICATIONS

Project participations

- 2023 – Present, Semiactive damping system for single deck electric multiple unit (Technology Agency of the Czech Republic – CK04000210)
- 2023 – Present, Božek Vehicle Engineering National Center of Competence (Technology Agency of the Czech Republic – TN02000054)
- 2022 – Present, Hydraulic semi-active damper for intelligent rail bogie (Technology Agency of the Czech Republic – CK03000052)
- 2020 – 2022, Study of the magnetorheological fluid response time (Czech Science Foundation – 20-23261Y)
- 2019 – 2022, National Competence Centre of Mechatronics and Smart Technologies for Mechanical Engineering (Technology Agency of the Czech Republic – TN01000071)
- 2018 – 2021, Developement of Magnetorheological Damping System for Railway Vehicles (Czech Ministry of Industry and Trade – FV30310)
- 2020, Development of a fail-safe magnetorheological damper (university grant – FEKT/FSI-J-20-6260)
- 2017 – 2019, Studies on Magnetorheological Fluid with High Sedimentation Stability (Czech Science Foundation – GC17-10660J)
- 2017 – 2019, Electronic car suspension tester (Technology Agency of the Czech Republic – TH02010663)

THANK YOU FOR YOUR ATTENTION

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