

Contents of Work Package 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10: Damper Solutions for Future Vehicle Applications

Coordinator of the WP

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Participants of the WP

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Main Goal of the WP

The goal is to use new synergies and technologies to simultaneously improve vehicle stability in critical situations, achieve better load and passenger comfort during normal transport, and finally improve energy consumption of the suspension.

Partial Goals for the Current Period

Detailed simulation models will be applied to optimize & verify the performance for different application cases (e.g., car, rail vehicle) and different operating conditions. Initial experiments will be performed to verify new solutions.

Investigation of non-tradition damper influence on vehicle dynamics behaviour with effective energy recuperation. The analysis of damper effect on motion sickness treatment is performed. Semi-active fast damper for secondary suspension of railway vehicle is investigated and its digital twin is developed by HIL experiment.

Contents of Work Package 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10: Damper Solutions for Future Vehicle Applications

Official 3-WP10 Deliverables:

- 3-WP10-001 | Non-tradition damping element with recuperation and energy storage characteristics, Fuzit, IV./2026, CTU FME 0.7; BRANO 0.2; BUT 0.1
- 3-WP10-002 | Contribution of non-traditional damper to motion sickness treatment, O, IV./2026, CTU FME 0.7; BRANO 0.2; BUT 0.1
- 3-WP10-003 | Semi-active fast damper for secondary suspension of railway vehicle, Gfunk, VI./2024, BUT 0.4; SO 0.3; UPa 0.15; VUKV 0.1; VZU 0.05
- 3-WP10-004 | Control unit for controlling a set of semi-active dampers on a railway vehicle boogie, Gfunk, VI./2024, BUT 0.75; SO 0.1; UPa 0.1; VUKV 0.1; VZU 0.05
- 3-WP10-005 | Digital twin of fast semi-active damper for secondary suspension of railway vehicle boogie, O, XII./2025, BUT 0.3; SO 0.15; UPa 0.4; VUKV 0.1; VZU 0.05

Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-001: Non-tradition damping element with recuperation and energy storage characteristics

- Preparation of patent application, utility model is consequential result
- The proposed solution will enable to utilize currently dissipated energy in dampers into the energy utilizable in the car systems
- Patent and literature research confirms the novelty of the invention core idea
- Formulation of claims and patent formulation is finished
- The patent application is ongoing
- Because of patent procedure, the details are confidential

Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-002: Contribution of non-traditional damper to motion sickness treatment

- The development follows the previous research and also research ongoing (4-WP11-005)
- Question is, whether and how the developed damping elements can help with motion sickness phenomenon
- Literature research is ongoing
 - Literature research
 - ISO NORM 2631: motion sickness occurs at 0.1-0.5 Hz
 - Measured value: vertical acceleration
 - Criterion: MSDV (motion sickness dose value)

$$\text{MSDV}_z = \left\{ \int_0^T [a_w(t)]^2 dt \right\}^{\frac{1}{2}}$$

- Lateral and longitudinal accelerations are covered too
- Influence of angular speed (fore-aft motion) induced motion sickness is investigated

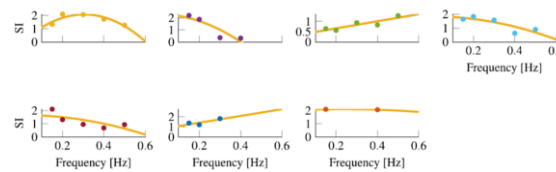


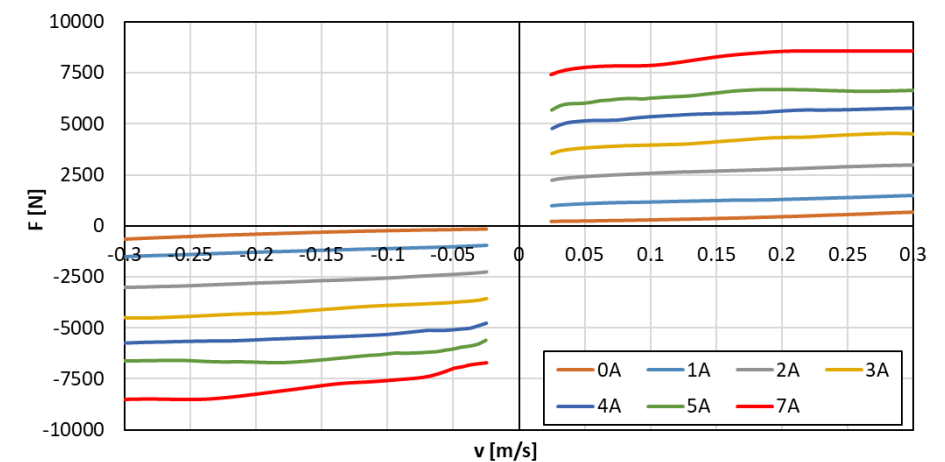
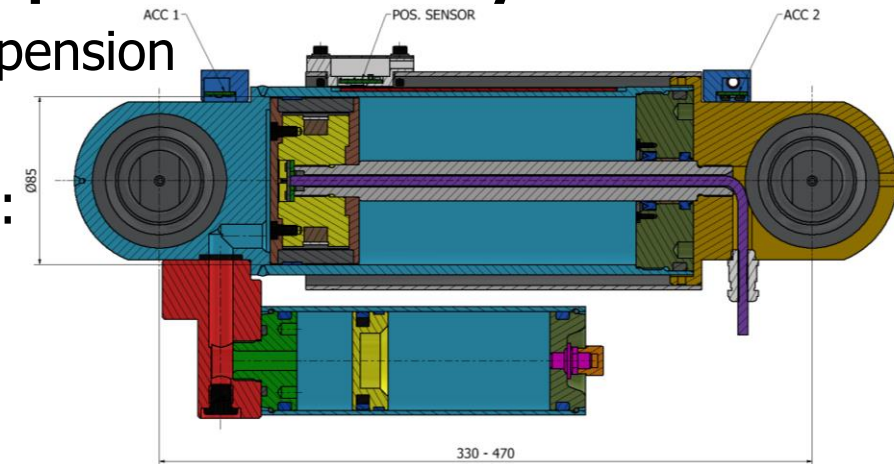
Fig.7 Participant sickness index as a function of frequency, with individual quadratic fits

- Preparation of simulation experiment

Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-003: Semi-active fast damper for secondary suspension of railway vehicle

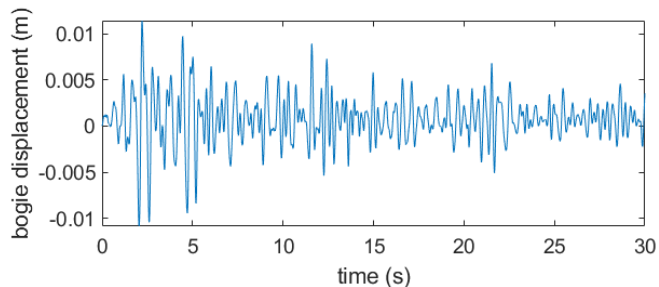
- Vertical magnetorheological (MR) damper for secondary suspension
- The MR damper was developed specifically for this project
- For the DT function, the damper was equipped with sensors:
 - position sensor,
 - acceleration sensors ACC1 and ACC2 (sprung mass).
- Force response time: 7.8 ms
- Dynamic force range (F_{max}/F_{min}): 29 at 0.1 m/s



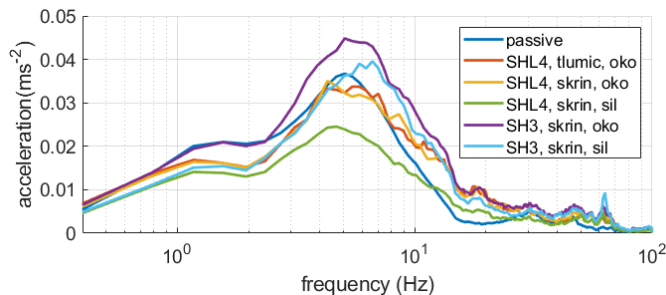
Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-003: Semi-active fast damper for secondary suspension of railway vehicle

- Experimental verification of the S/A damping function at the VZÚ Plzeň model station
 - The test was required by the Czech Rail Authority for approval to operate the experimental vehicle on the tracks
 - A risk analysis of potential HW and SW failures was prepared for the approval process.
 - The tests verified the suspension's behavior under different algorithms and extreme damping conditions

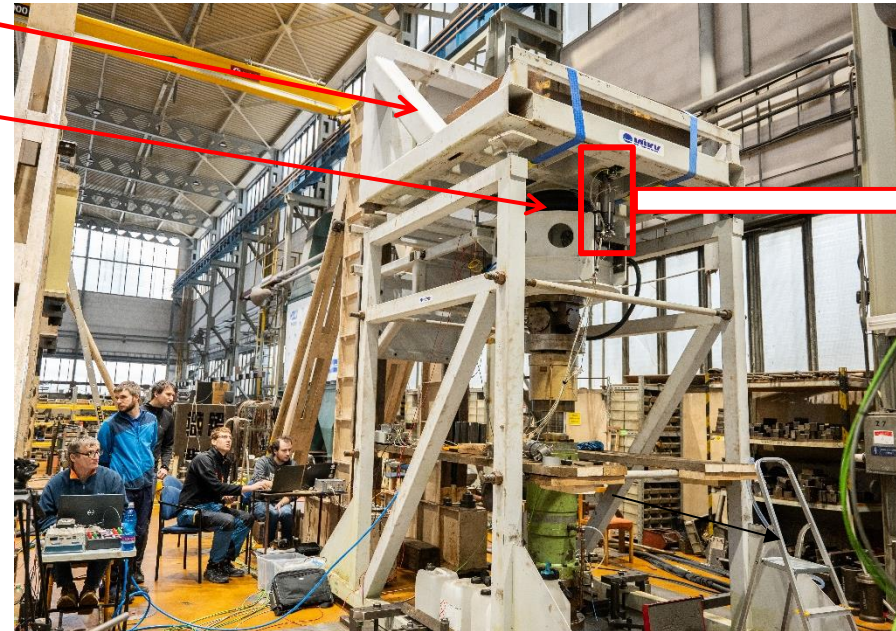
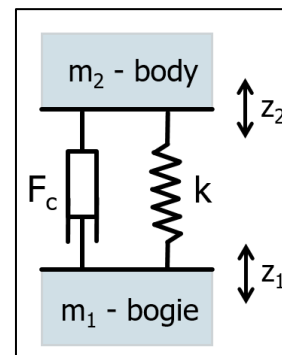


Real track excitation z_1



Sprung mass (7t)

Air spring



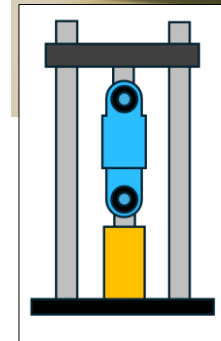
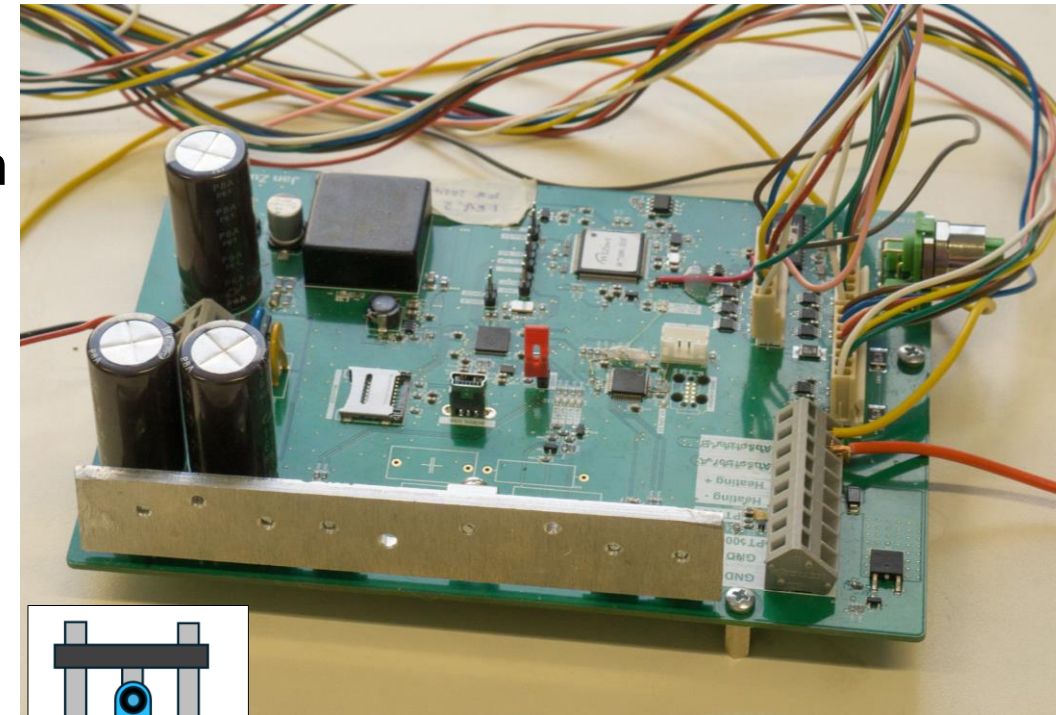
Results: FFT of sprung mass acc

Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-004: Control unit for controlling a set of semi-active dampers on a railway vehicle bogie

Redesign of the first version

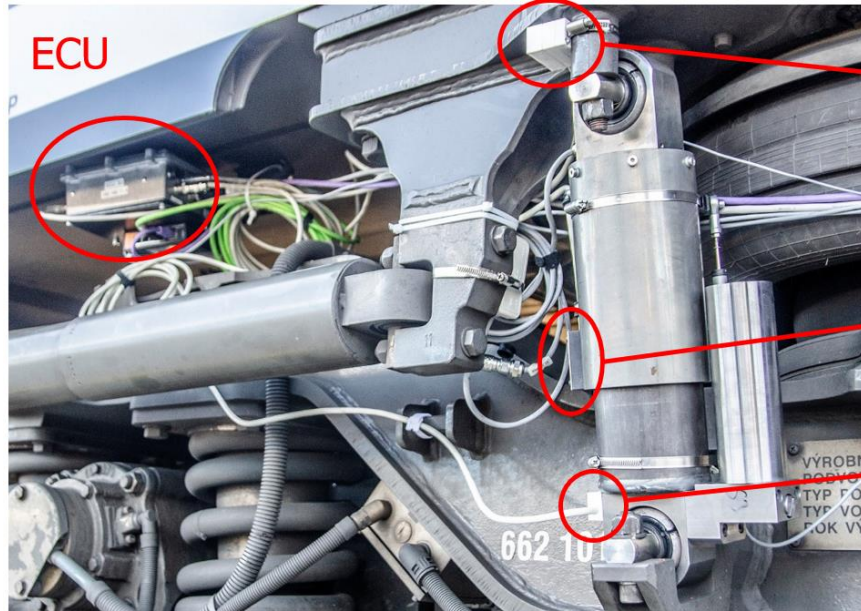
- For laboratory HIL tests of railway damper digital twin
- Inputs modified for connection with dSpace system
- SD-card for recording of all measured and calculated signals
- LAN output for connecting to PC with control application
- Increased resistance to interference of sensors
- PCB design and fabrication in cooperation with EGM medical company
- Power supply redesigned to industrial standard 48V



Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-005: Digital twin of fast semi-active damper for secondary suspension of railway vehicle bogie

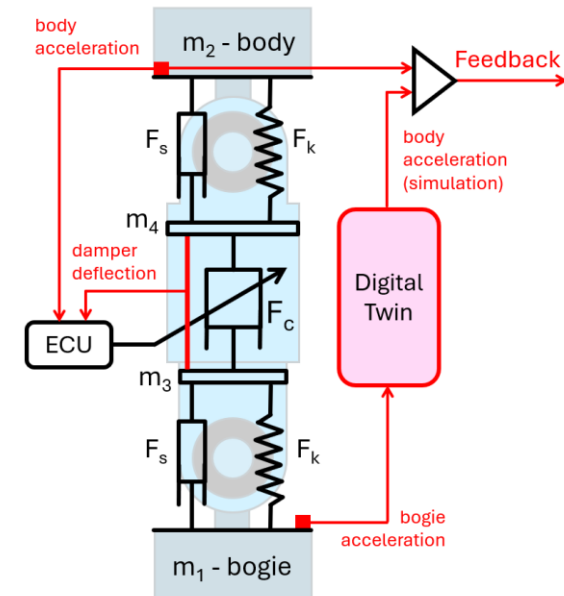
- DT will be used for condition monitoring of S/A damping of secondary suspension
- DT works with a virtual model of the whole S/A group (MR damper, silentblocks, ECU + software)
- DT predicts the transfer of vibrations from the bogie to the body
- If the measured body vibration deviates significantly from the predicted value, a damping correction is triggered



Body
accelerometer

Displacement
sensor

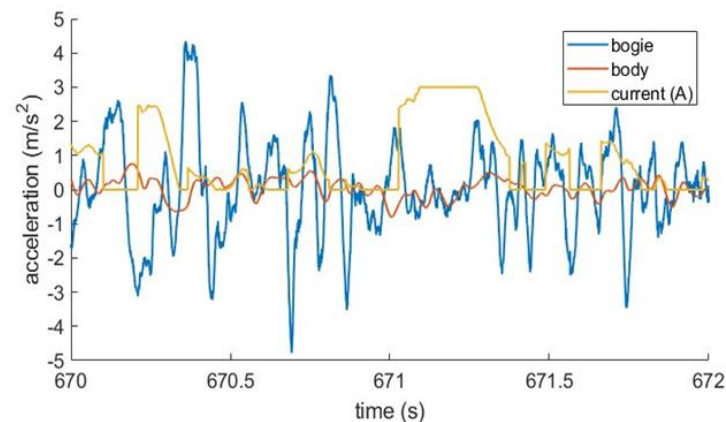
Bogie
accelerometer



Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-005: Digital twin of fast semi-active damper for secondary suspension of railway vehicle bogie

- Experimentally obtained data for a digital twin
 - Vehicle: Škoda InterPanter 10Ev
 - Data collection period: V.-VII. 2024
 - Driven during tests: cca 500 km

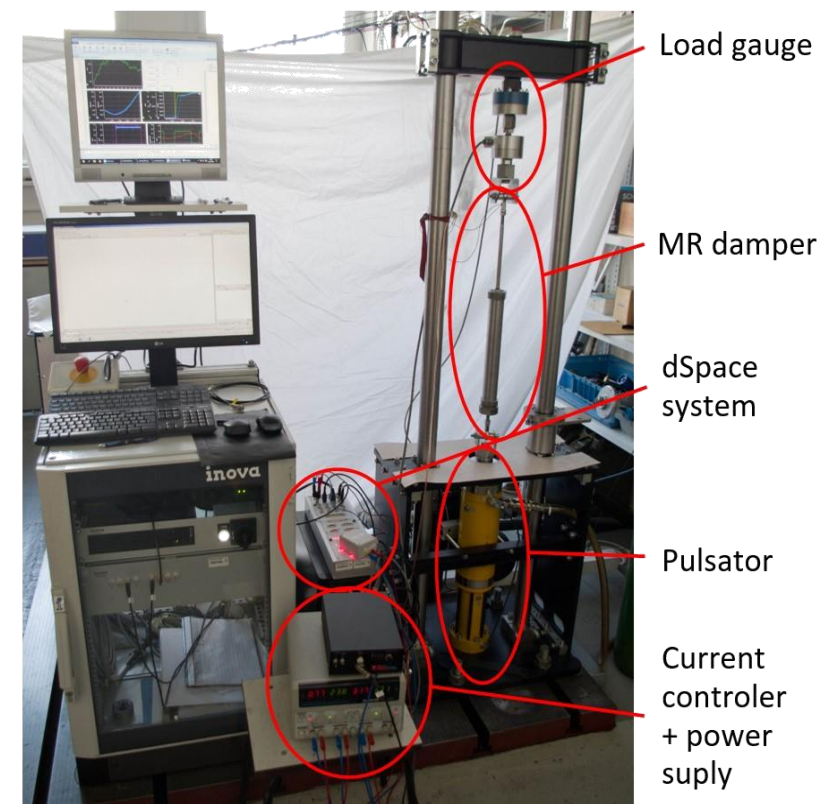
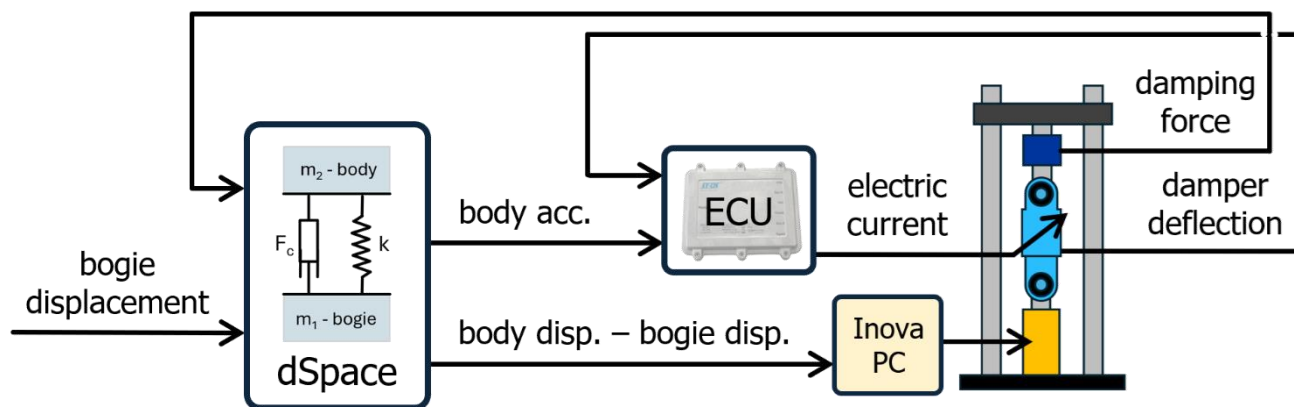


Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

3-WP10-005: Digital twin of fast semi-active damper for secondary suspension of railway vehicle bogie

- Simulation of the behaviour of the secondary vertical suspension in the Hardware-in-the-loop
 - HIL simulation enables the combination of a virtual vehicle model and a real S/A damper
 - The virtual model runs on the dSpace platform
 - The ECU is completely autonomous, the acceleration signal on the body is replaced by a simulation from dSpace
 - The driving tests provided a lot of data to validate the HIL function

Hardware-in-the-loop simulation:



Fulfillment of goals and deliverables of 3-WP10 Damper Solutions for Future Vehicle Applications

Current State of Deliverables and Fulfillment of Goals

- 3-WP10-001 | Non-tradition damping element with recuperation and energy storage characteristics, Fuzit, IV./2026, CTU FME 0.7; BRANO 0.2; BUT 0.1 – **in progress & no major delays:**
 - The patent application is ongoing
- 3-WP10-002 | Contribution of non-traditional damper to motion sickness treatment, O, IV./2026, CTU FME 0.7; BRANO 0.2; BUT 0.1 – **in progress & no major delays:**
 - Literature research and simulation experiment
- 3-WP10-003 | Semi-active fast damper for secondary suspension of railway vehicle, Gfunk, VI./2024, BUT 0.4; SO 0.3; UPa 0.15; VUKV 0.1; VZU 0.05 – **in progress & no major delays:**
 - Development of vertical magnetorheological (MR) damper for secondary suspension is finished
 - Testing is performed
- 3-WP10-004 | Control unit for controlling a set of semi-active dampers on a railway vehicle boogie, Gfunk, VI./2024, BUT 0.75; SO 0.1; UPa 0.1; VUKV 0.1; VZU 0.05 – **in progress & no major delays:**
 - Control unit design is finished and it is used with semi-active magneto-rheological dampers

Fulfillment of goals and deliverables of 3-WP10 Damper Solutions for Future Vehicle Applications

Current State of Deliverables and Fulfillment of Goals

- 3-WP10-005 | Digital twin of fast semi-active damper for secondary suspension of railway vehicle boogie, O, XII./2025, BUT 0.3; SO 0.15; UPa 0.4; VUKV 0.1; VZU 0.05 – **in progress & no major delays:**
 - Digital twin parameters are tuned by experimental data
 - HIL simulation uses a MR damper and control unit to tune the digital twin

List of Due Deliverables and Their Added Value

- 3-WP10-003 – semi-active magneto-rheological damper reduces horizontal vibrations of the sprung mass
- 3-WP10-004 – ensures appropriate control of magneto-rheological fluid based damper in the HIL environment

Current contribution of 3-WP10 Damper Solutions for Future Vehicle Applications

Assessment of the Contribution of Deliverables

- Vehicle energy recuperation – 3-WP03, 4-WP06, 4-WP07
- Damping elements – 3-WP10, 4-WP11
- Motion thickness treatment – 3-WP11, 4-WP01

Assessment of the Formal/Administrative Goals of the Work Package

- All the working package participants (CTU FME, Brano a.s., BUT, ...) fulfils the administrative goals.

Current contribution of 3-WP10 Damper Solutions for Future Vehicle Applications

Acknowledgment

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