

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

3-WP10: Damper Solutions for Future Vehicle Applications

Coordinator of the WP

České vysoké učení technické v Praze: Zdeněk Neusser

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

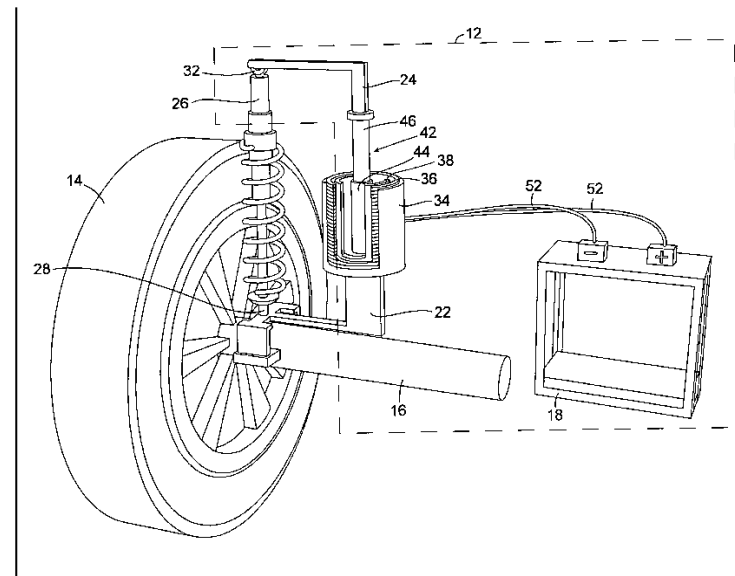
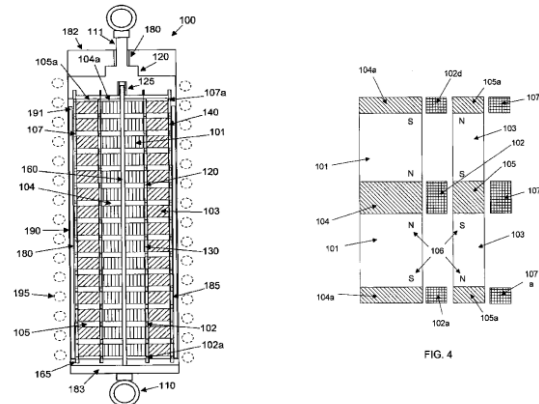
3-WP10-001: Non-tradition damping element with recuperation and energy storage characteristics

- 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 application is ongoing
- Because of patent procedure, the details are confidential

Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

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

- Patent research: Energy recuperation or harvesting from the translational motion of the shock absorbers or similar devices in vehicle chassis
 - US Patent No. 7,261,171 Apparatus and method for converting movements of a vehicle wheel to electricity for charging a battery of the vehicle
 - Cons: The invention does not utilize the conservation of the energy in the form of mechanical energy. The energy of the rotor must be directly transformed into electric or other energy to achieve damping, which in peaks might be difficult.
 - US Patent No. 6,952,060 Electromagnetic linear generator and shock absorber
 - Cons: The „invention“ utilize principle of linear electric motor (which is known, and on the market). The proposed embodiment does results in the low velocity relative motions of the motor which will lead into low efficiency of the energy transformation.





Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

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

- Patent research: Energy recuperation or harvesting from the translational motion of the shock absorbers or similar devices in vehicle chassis
 - US20100219720A1 Harvesting energy from vehicular vibrations using piezoelectric devices
 - Cons: The apparatus is proposed to be placed on leaf springs which are rarely used in current vehicles. The placement on coil springs is also not feasible as deformation of such spring is high and the piezo stack would be broken. The overall motions which can be captured by piezo elements are low and cannot be compared to amount of energy dissipated in traditional dampers. The prize and sensitivity of piezo stack is enormous, so proposed usage is not feasible.
 - US8376100B2 Regenerative shock absorber
 - Cons: The proposed embodiment is fragile, costly, increases the weight of the vehicle significantly. The energy transformation into intermediate form – hydraulic pressure or flow decreases the possible efficiency of the device.

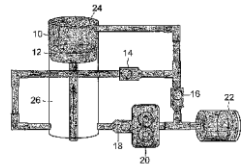
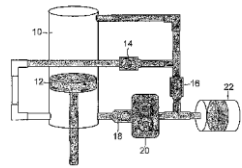
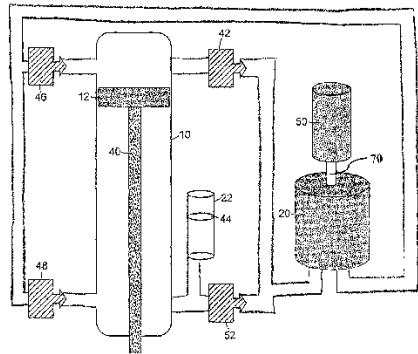
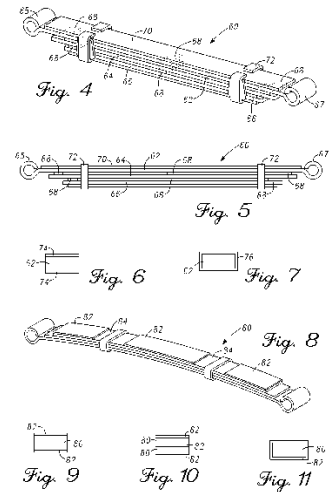
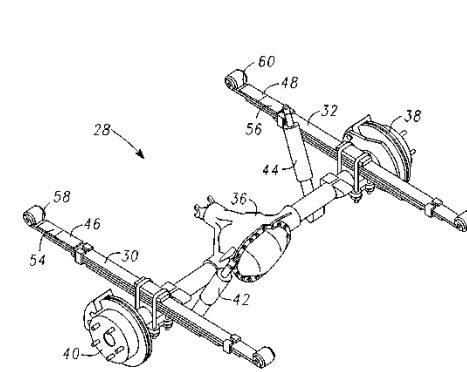
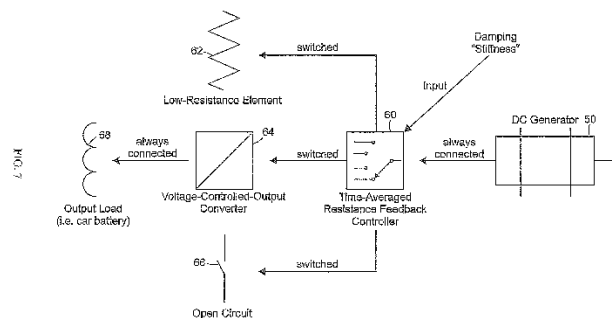


FIG. 1

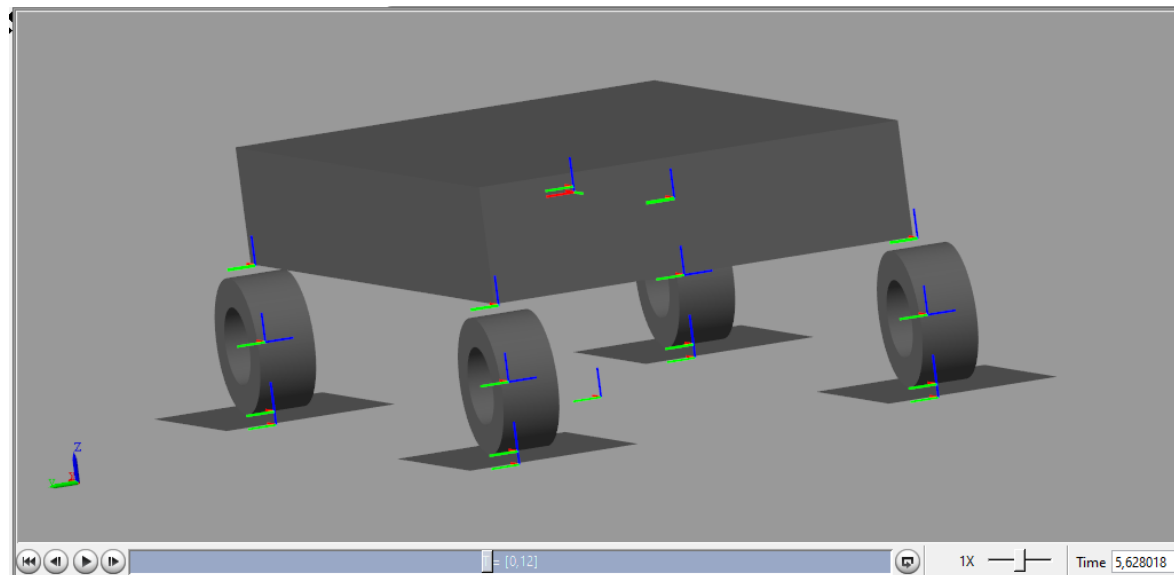
FIG. 2



Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

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

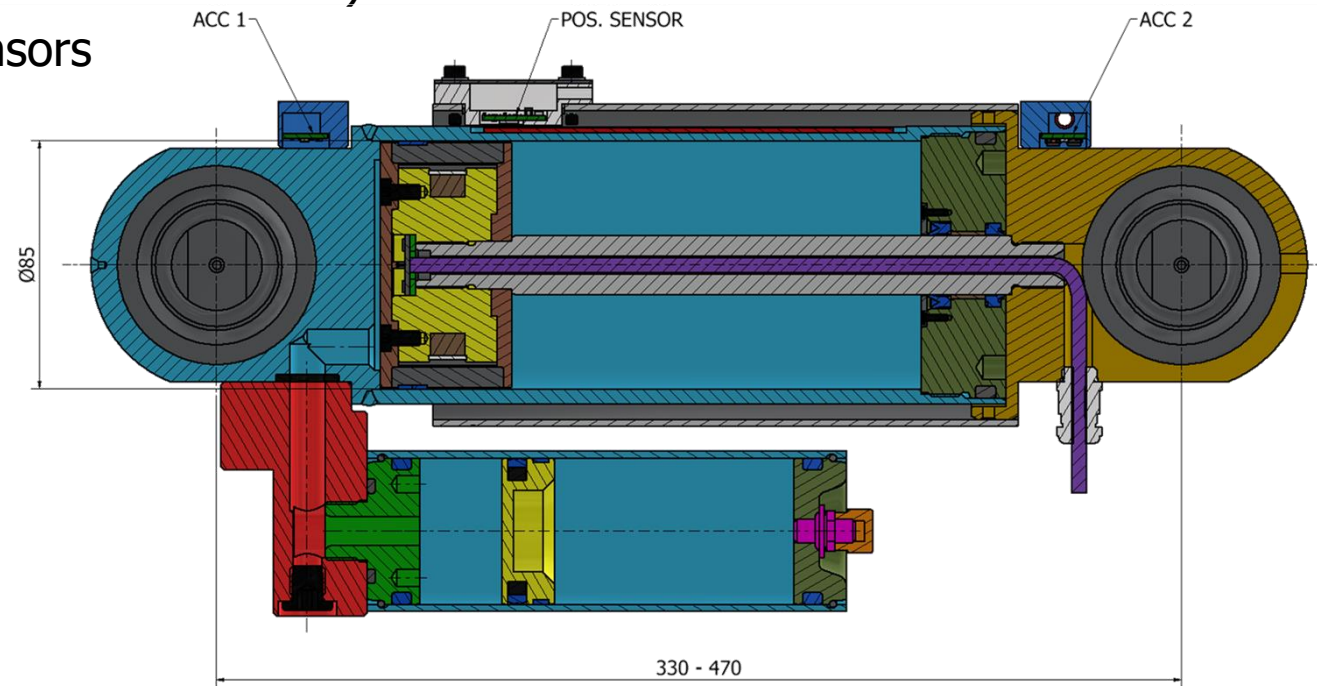
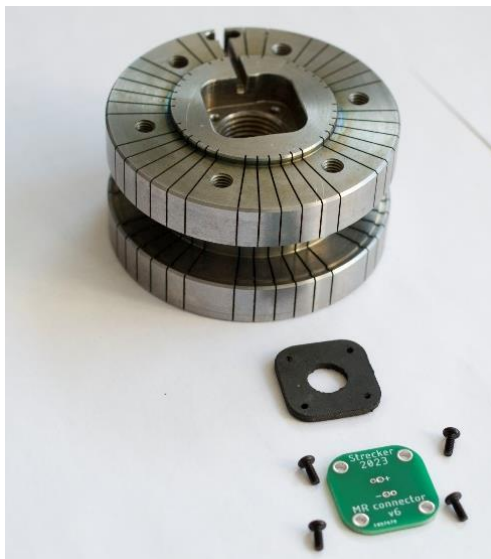
- The development follows the previous research and research ongoing (4-WP11-005)
- Question is, whether and how the developed damping elements can help with motion sickness phenomenon
- Literature research is ongoing
- Preparation of simulation experiment to demonstrate the ability of the motion sickness reduction



Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

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

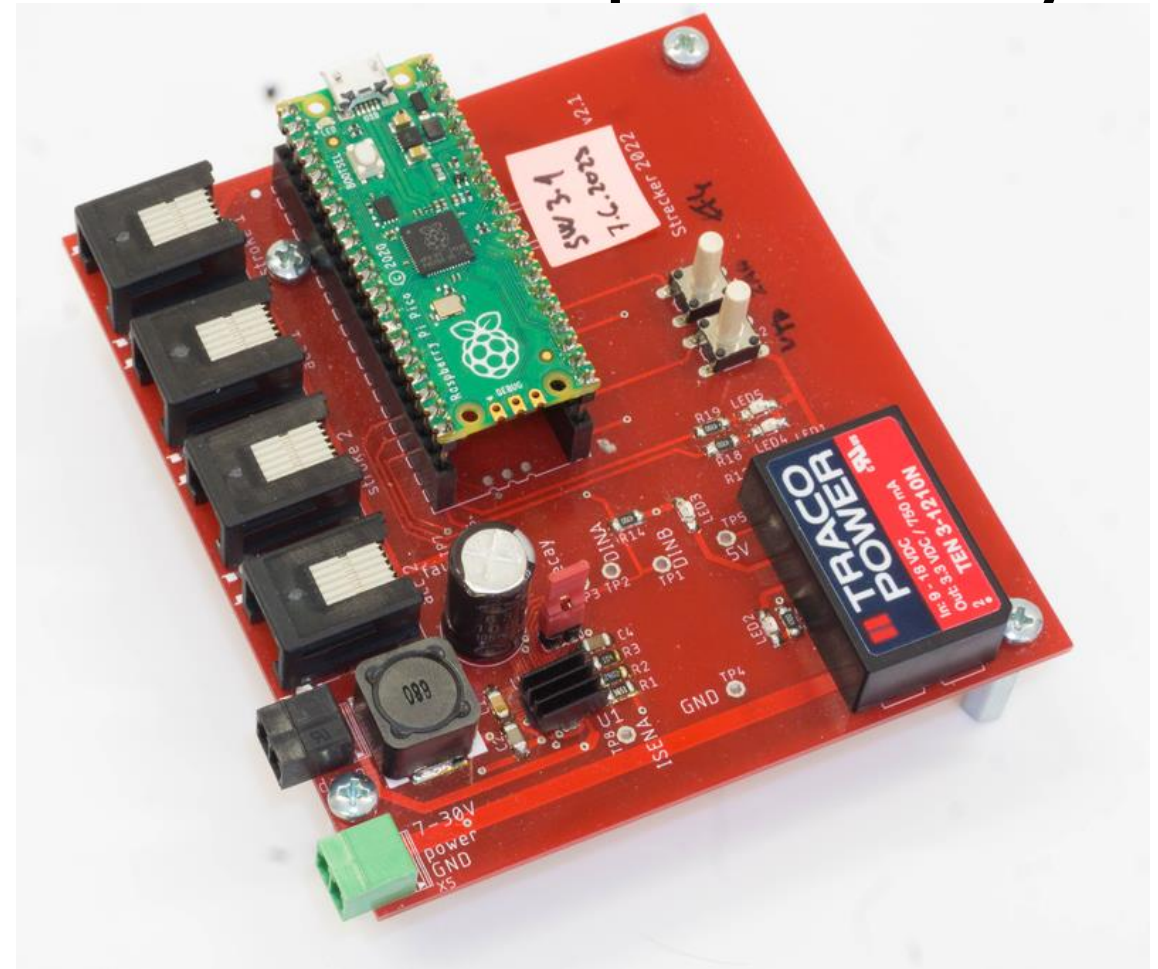
- Experiential MR damper for suburban electric unit
- Design is based on previous MR Damper
 - New MR fluid MRC-S1L instead of LORD 132 DG (change of internal dimensions)
 - Innovative sealing of supply wires (printed circuit board)
 - Inclusion of stroke and acceleration sensors



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 boogie

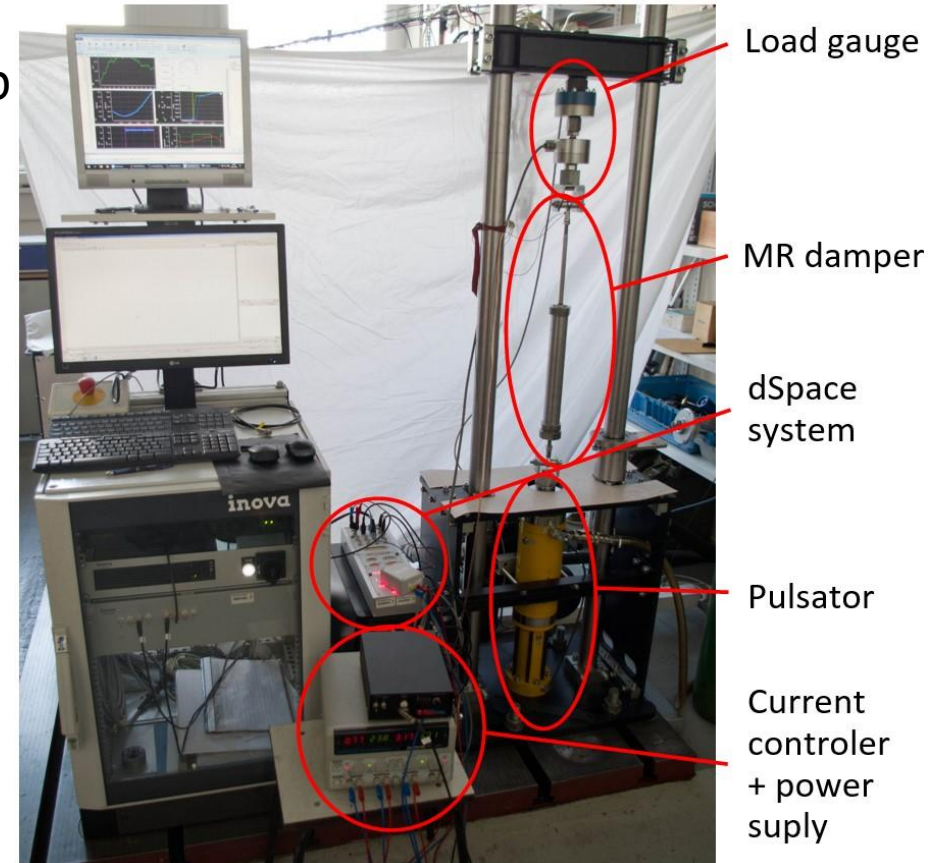
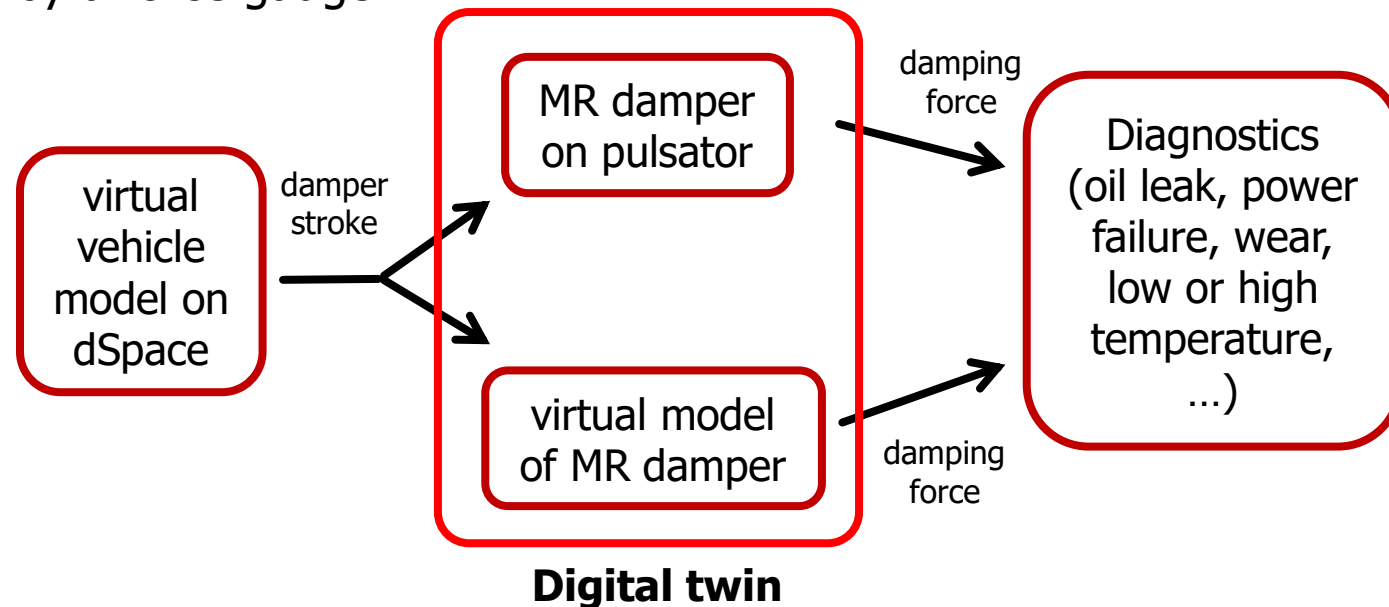
- 1st version of ECU – based on Rpi pico
 - MHL200 digital sensor input
 - MPU6050 digital acceleration sensor
 - Output based on MAX2205
 - Max voltage – 65 V, max current 3 A – too slow for experimental MR damper
 - SW – program for recording data from sensor to SD card, filtering, generating skyhook control signal
- current driver modified to 200 V
 - response time of current up to 2 ms
 - High voltage causing noise
 - Dangerous for tests
- Development of new ECU under progress
 - Voltage up to 48 V / current 7 A
 - Control part same like 1st version



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 boogie

- verification of digital twin functionality using hardware in the loop simulation, verification on a real vehicle would be too expensive
- for use on a vehicle, it will be necessary to equip the damper by a force gauge

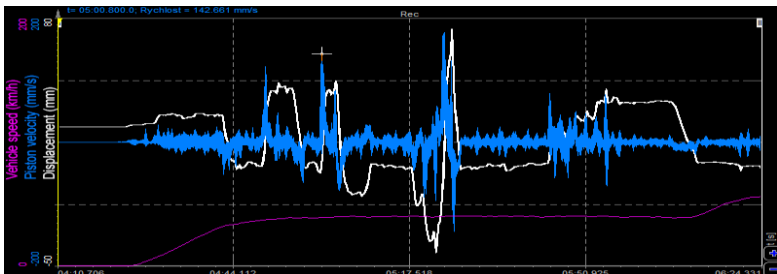


HILS assembly

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 boogie

- Experimentally obtained data for a digital twin
 - Vertical & Lateral damper will be replaced by MR dampers controlled by SA algorithm
 - Preliminary tests were carried out at suburban unit 10Ev to estimate the range of sensors



Experimental measurement unit on vertical secondary damper of 10Ev

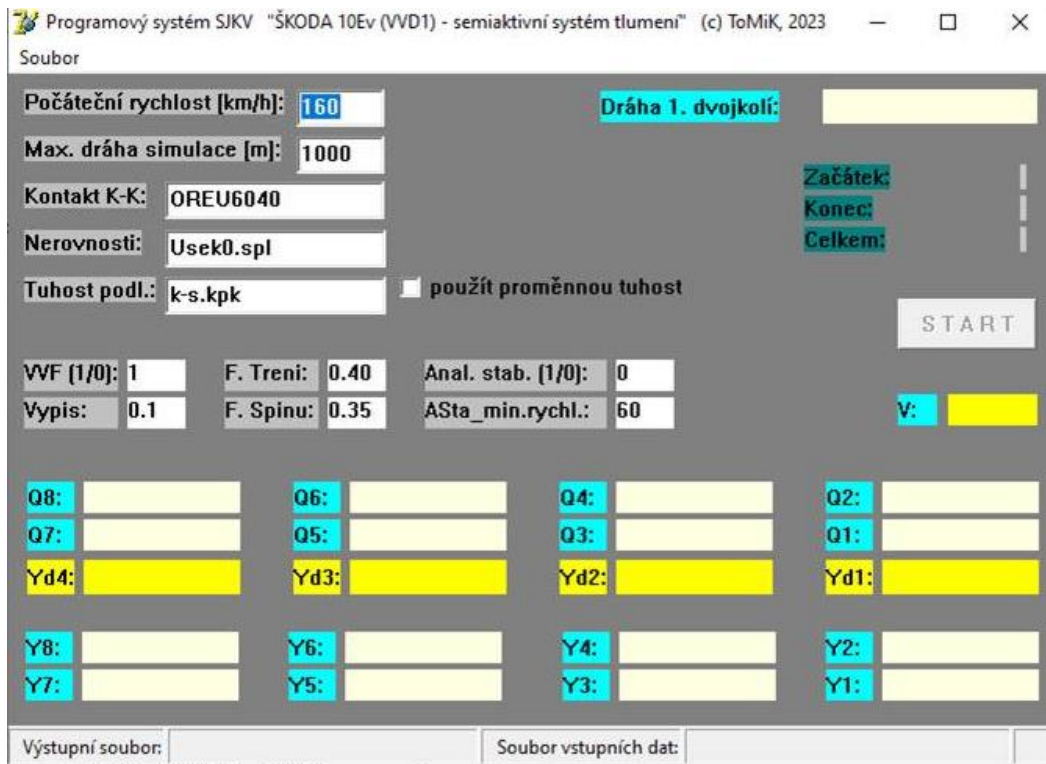
DKV Brno-Maloměřice



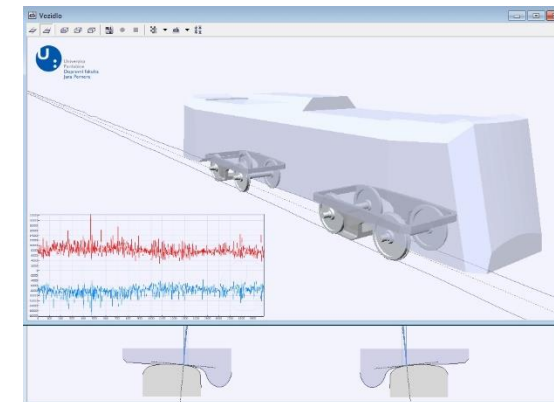
Activities in 3-WP10 Damper Solutions for Future Vehicle Applications

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

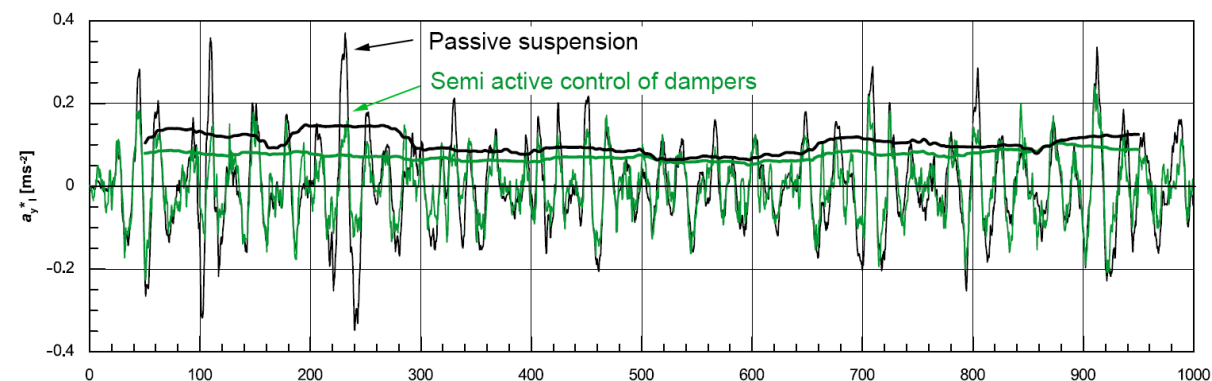
- Implementation of semiactive control to already existing model
 - User interface of the program system SJKV



Visualization



Results



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:**
 - Preparation of patent application
- 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
- 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:**
 - MR damper is designed, based on the previous concept: new MR fluid, innovative sealing, additional sensors incorporated
- 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:**
 - First design of control unit – it verifies the signal processing ability and sensors suitability, vulnerable to noise
 - Design of improved control unit

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 is prepared for digital twin verification

List of Due Deliverables and Their Added Value

- There are no due deliverables yet

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 fulfils the administrative goals.



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

Acknowledgment

This research has been realized using the support of Technological Agency, Czech Republic, programme National Competence Centres II, project # TN02000054 Božek Vehicle Engineering National Center of Competence (BOVENAC).