Contents of Work Package 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11: NVH and Vibration Damping Devices for Future Vehicles

Coordinator of the WP

Brno University of Technology - Ing. Kamil Řehák, Ph.D.

Participants of the WP

Brno University of Technology – prof. Ing. Václav Píštěk, DrSc., doc. Ing. Pavel Kučera, Ph.D., Ing. Ondřej Blaťák, Ph.D.; Tatra Trucks a.s – Ing. Martin Frait; Technical University Liberec - Ing. Robert Voženílek, Ph.D.; Škoda Auto a.s. – Bohuslav Novotný; KAR group, a.s. – Miroslav Konečný, CTU FME – Ing. Zdeněk Neusser, Ph.D.; UWB RTI – Ing. Pavel Žlábek, Ph.D.

Main Goal of the WP

Creation of approach for increase effectivity at future vehicles development.

Partial Goals for the Current Period

Perform concept study and initial measurement, create computational model.

Contents of Work Package 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11: NVH and Vibration Damping Devices for Future Vehicles

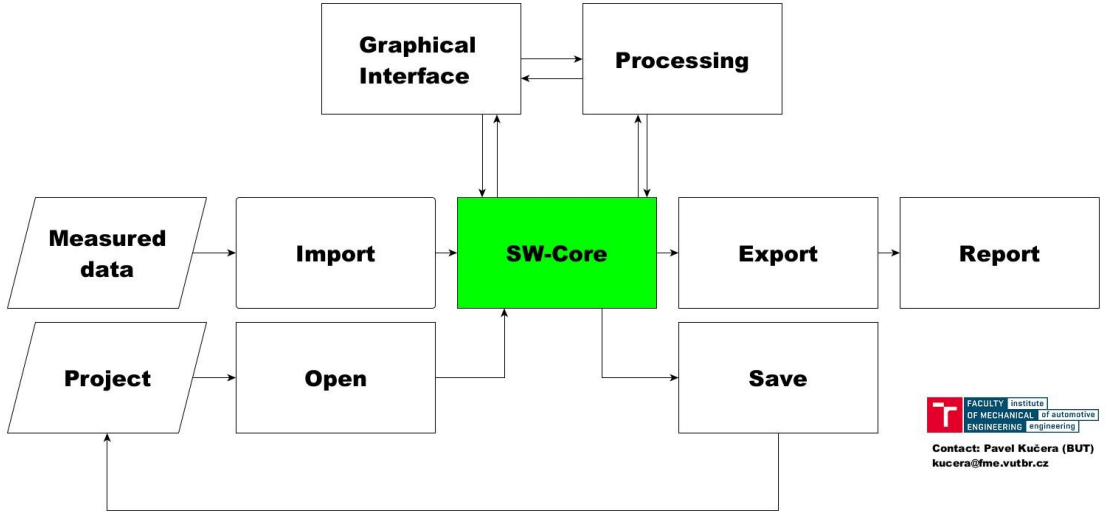
Official 4-WP11 Deliverables:

- 4-WP11-001 | **Software for identification of noise sources of mobile systems**, R-software, BUT 0.9; TATRA 0.05; WBU 0.05
- 4-WP11-002 | **Set for acoustic transmission tests,** G-funk, TUL FME 0.9; Skoda Auto 0.1
- 4-WP11-003 | **Hydraulic damper with new internal architecture for semi-active control,** G-funk, KAR 0.8; BUT 0.15; CTU FME 0.05
- 4-WP11-004 | **Mathematical model of the electronic control system,** O-Ostatní, KAR 0.7; BUT 0.25; CTU FME 0.05
- 4-WP11-005 | **Damping element with innovative damping characteristics**, Gfunk, XII./2025, CTU FME 0.2; BRANO 0.7; BUT 0.1

Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-001: Software for identification of noise sources of mobile systems

- First phase:
  - User requirements and basic software concepts
  - Choice of language (C/C++, Python)
  - Data import (format)
  - Noise measurement on the vehicle to obtain input data
  - Supported operating systems
- Second phase:
  - Analysis of appropriate mathematical data processing
  - Unit tests and software core programming
  - Programming of mathematical methods for the evaluation of noise sources
  - Graphical interface programming
  - Creating the installation package and Testing
- Objectives and benefits
  - User-friendly processing of measured data not only in the automotive field
  - Fast processing
  - Import of the project and its modification, completion, replacement of data
  - Evaluation of noise sources and report generation

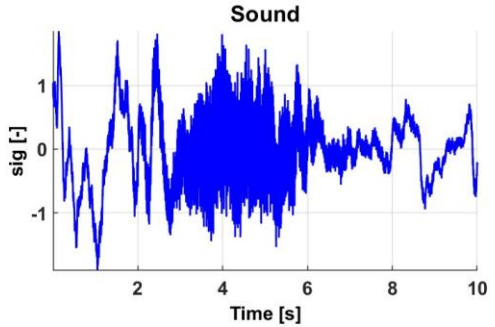


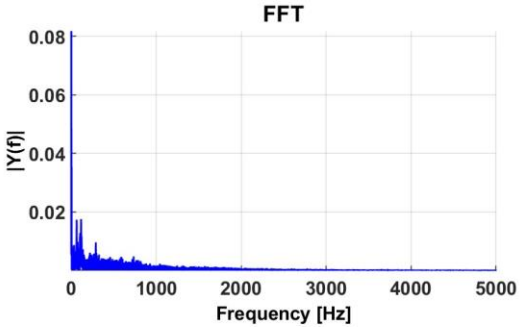
Contact: Pavel Kučera (BUT)
kucera@fme.vutbr.cz

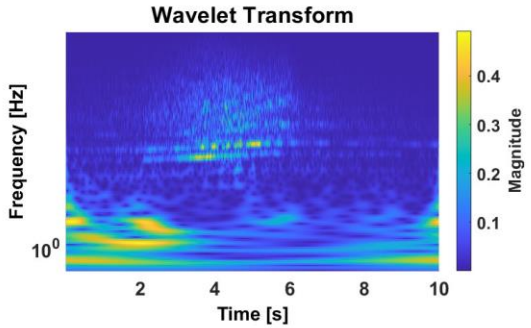
Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

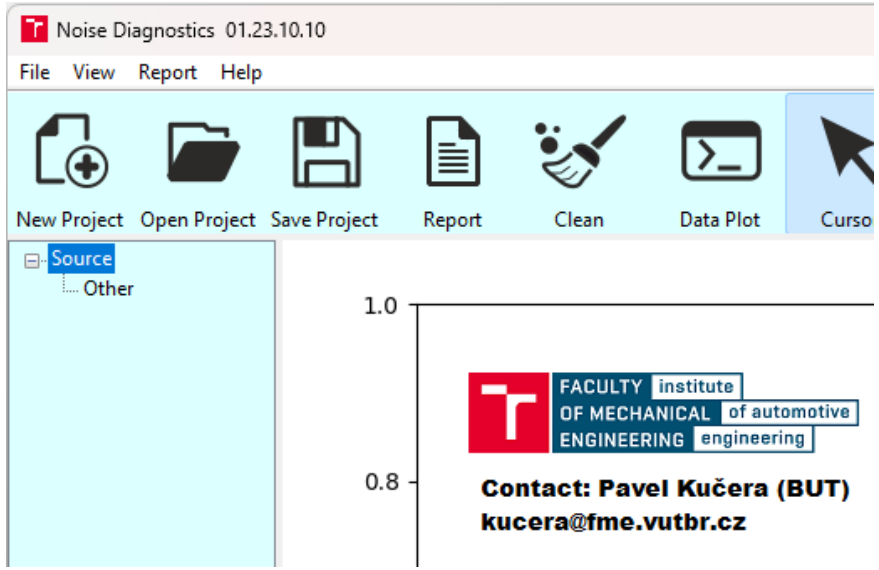
4-WP11-001: Software for identification of noise sources of mobile systems

- Analysis of processing methods
  - Signal processing
  - Speed vs. accuracy
  - Resource evaluation
- Software concept
  - Block diagram
  - Flow diagram
  - Import Data
  - Export Result
  - Installation package
- Programming
  - Core SW programming
  - Graphical interface programming





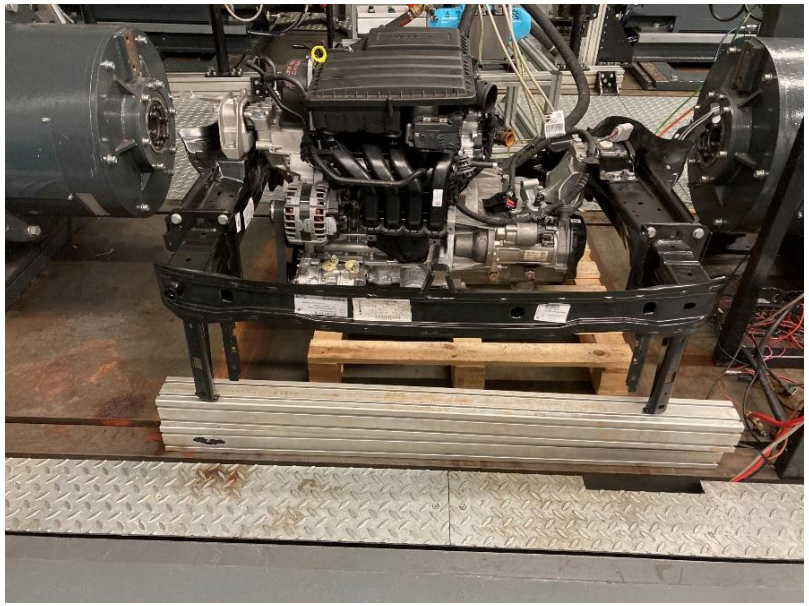




Activities in 4-WP11: NVH and Vibration Damping Devices for Future Vehicles

4-WP11-002: Set for acoustic transmission tests

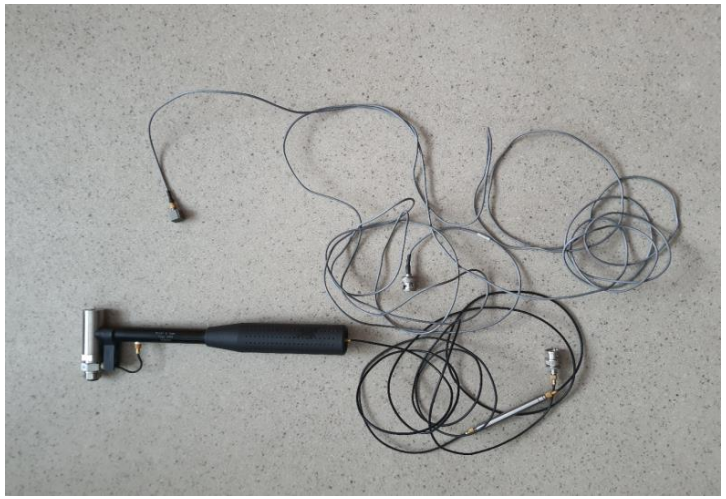
The activity is focused on the creation of a set of parts using the structural parts of a real car to perform acoustic and vibration tests on POWERTRAIN test surfaces. Selected components from the construction of the vehicle will partially be replaced by a universal system for storing drive units in the test facilities. This will achieve a better match between the vibration and noise measurements in the test labs and the real vehicle over a wide range of operating conditions.

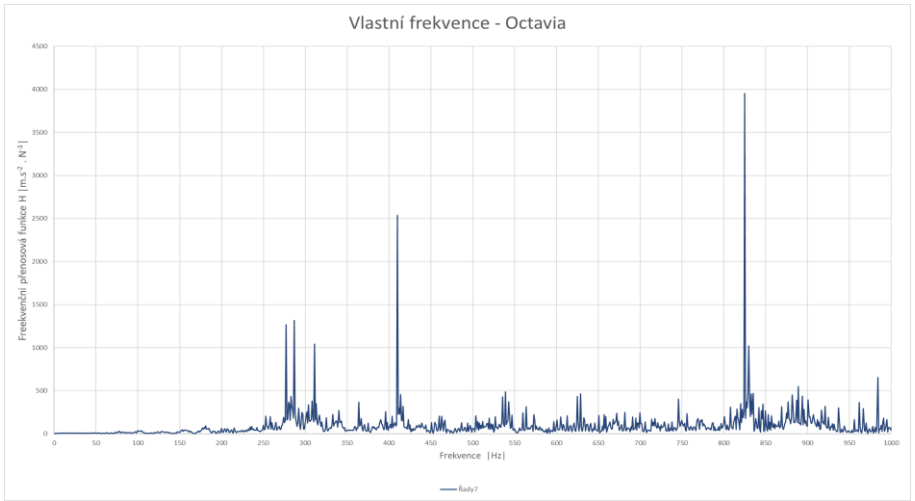


Activities in 4-WP11: NVH and Vibration Damping Devices for Future Vehicles

4-WP11-002: Set for acoustic transmission tests

The measurement of the properties of the real storage of the drive unit was carried out on a Škoda Octavia vehicle of the latest generation, where the storage of the drive unit is comparable to the storage on the Powertrain test cell, the vehicle was at rest and on a horizontal surface. The measurement was performed on the available right-hand storage point (from the point of view of forward travel), which was the only one accessible for measurement. The acceleration sensor was placed near the car body, and a point on the drive unit was excited by an impact hammer (with a built-in force sensor). The frequency transfer function H was evaluated.





Activities in 4-WP11: NVH and Vibration Damping Devices for Future Vehicles

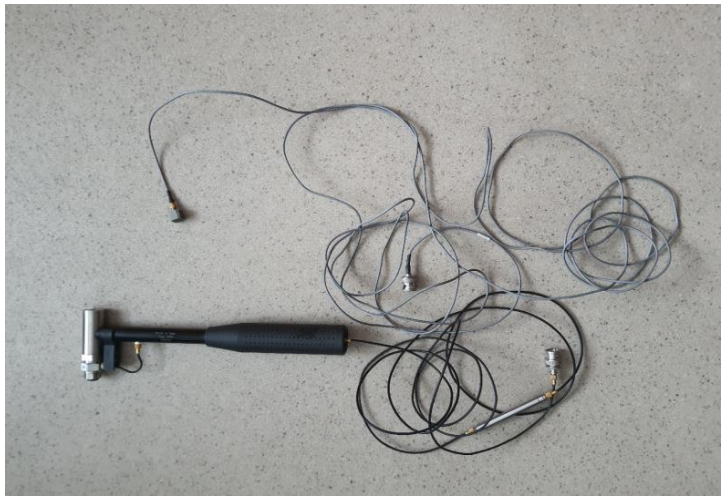
4-WP11-002: Set for acoustic transmission tests

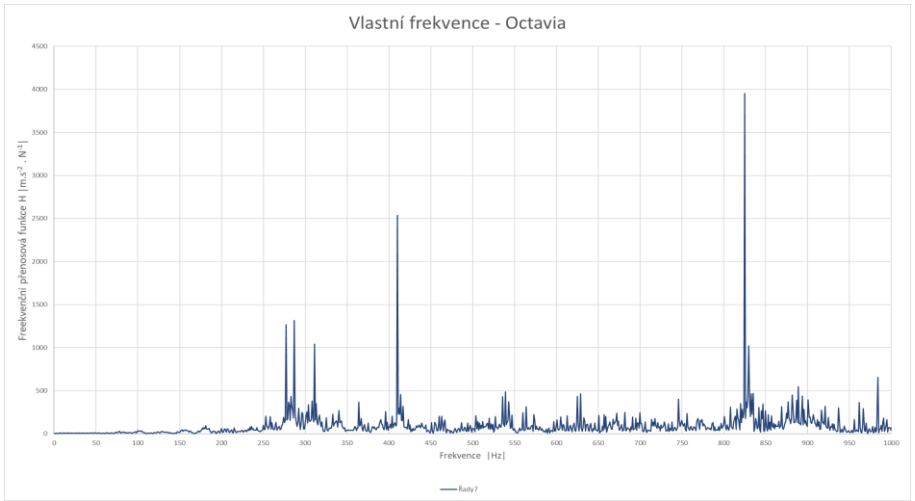
Knowledge gained:

The measurement does not include the influence of the tires and suspension (acceleration sensor and impact hammer) surrounding the powertrain mounting in the body.

The following areas were detected in the H frequency spectrum:

270 Hz to 310 Hz, 410 Hz, 825 Hz, the band below 100 Hz shows a low transmission rate, corresponding to the high damping of the rubber. Frequency peaks are sharp (no sidebands, indicating a low degree of excitation).

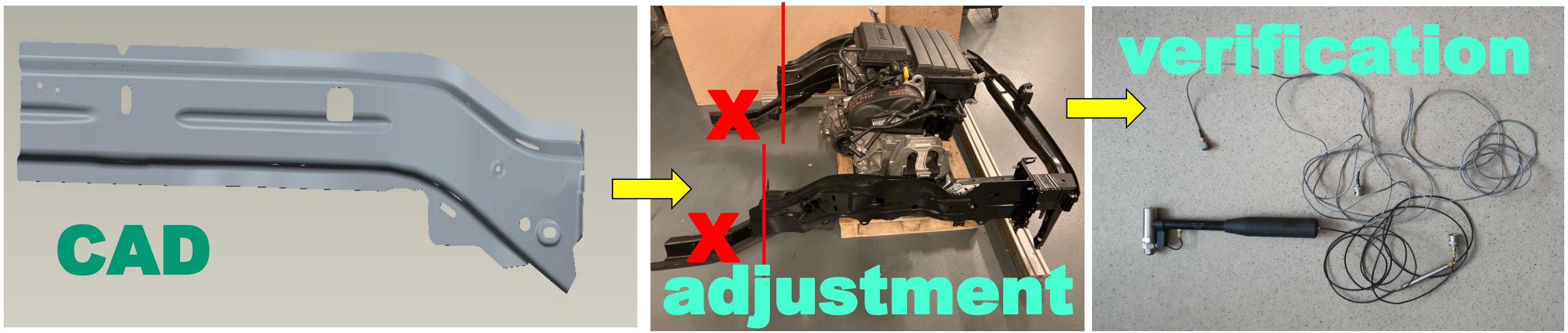




Activities in 4-WP11: NVH and Vibration Damping Devices for Future Vehicles

4-WP11-002: Set for acoustic transmission tests

Currently, the CAD modification of the longitudinal profile for the production of a new storage is underway, and the FEM model of this modified storage will be created. Subsequently, the newly created storage will be verified with a real vehicle and the current storage in the test cells. Multiple iterations are expected.



Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-003: Hydraulic damper with new internal architecture for semi-active control

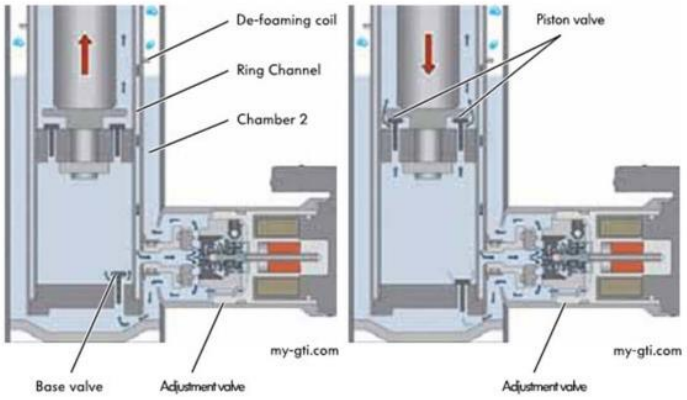
- Main goal is:
  - To build hydraulic damper with fast semi-active control based on standard vehicle damper (monotube or twin tube design).
  - Rebuild standard passive damper to semi-active (electronic) controlled one.
  - *Damper position sensor as the standard part of the damper*.
  - The control of the bypass through the damper rod will be used – control of bump and rebound force.
- Two possible ways to build new type of the damper were studied (different actuators):
  a) Solenoid valve (pilot operated valve)
  b) Rotational actuator – electromotor, servo motor, stepper motor.

Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

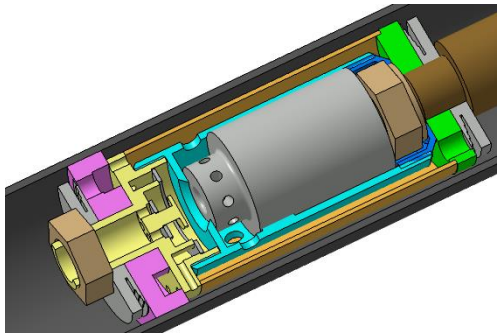
4-WP11-003: Hydraulic damper with new internal architecture for semi-active control

a) Solenoid valve

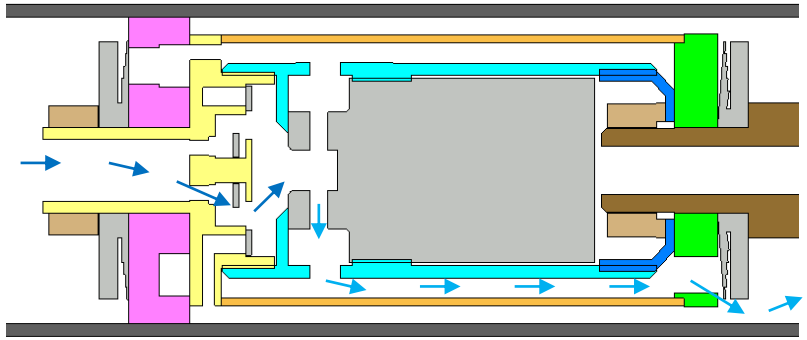
- High internal damper pressure high amount of force creates on the valve area – pilot operated valve.
- The flow through this type of the valve must be only in one direction – leads to special damper design.
- The unidirectionality of the flow can be solved with the use of set of check valves – rod bypass is used.



Damper three tube design



Pilot operated valve controlling
Flow through damper rod bypass



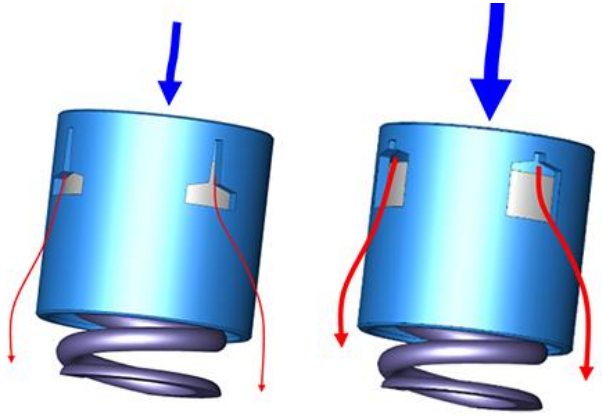
Check valves to keep
unidirectionality of the flow

Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-003: Hydraulic damper with new internal architecture for semi-active control

b) Rotational actuator – electromotor, servo motor, stepper motor

- This technology was already used to build the adaptive damper on IAE.
- This type of actuator can be used inside the standard monotube or twin-tube vehicle damper.
- The problem is the slow change of the valve position. With the special design of the spool valve, the rate of the position change could be fast enough.



Spool valve with special shape orifice

Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-004: Mathematical model of the electronic control system

- The main innovative part of the damper solution will be the control system. Building of the mathematical model was started. R&D activities were focused in:

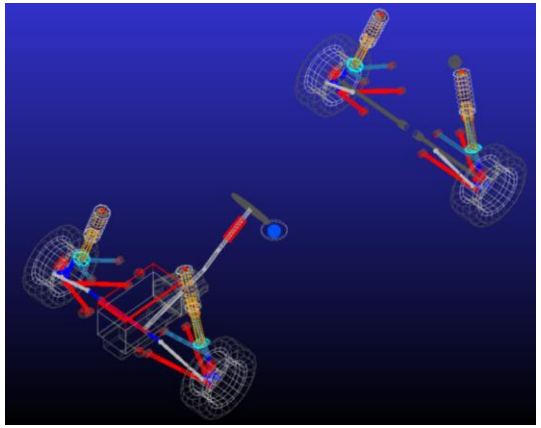
a) Vehicle model

b) Model of measuring system

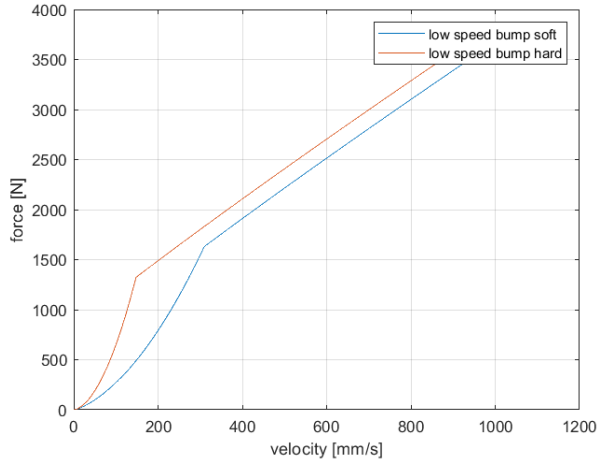
c) Model of the electronic control system

d) Estimator of dynamic quantities

e) Mathematical model of the damper



Multibody model of off-road vehicle

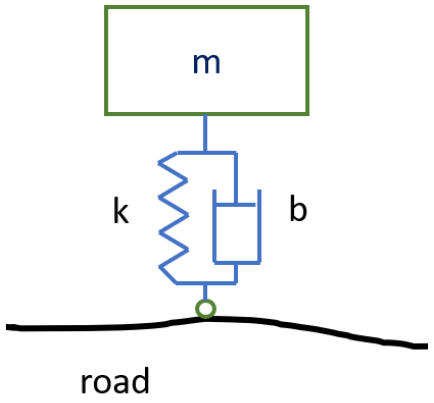


Mathematical model of the damper – low speed valve effect

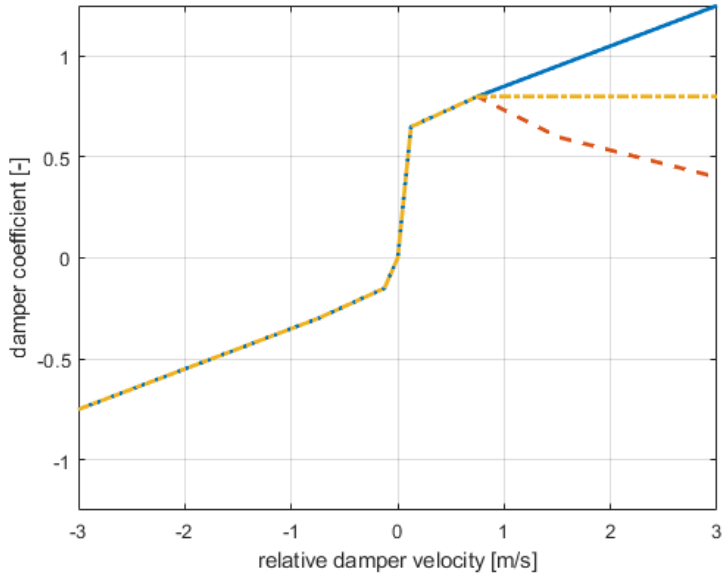
Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-005: Damping element with innovative damping characteristics

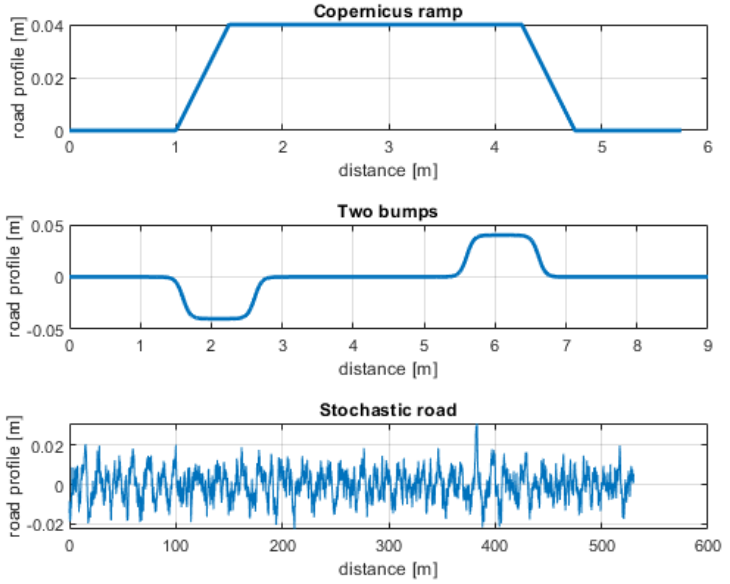
- Motivation: force impacts due to the steep road unevenness cause car body damage
- Simulation experiments are performed: feasibility study
  - One-mass model
  - damping coefficient modifier
  - road profiles for testing



One mass model



Damping value modification



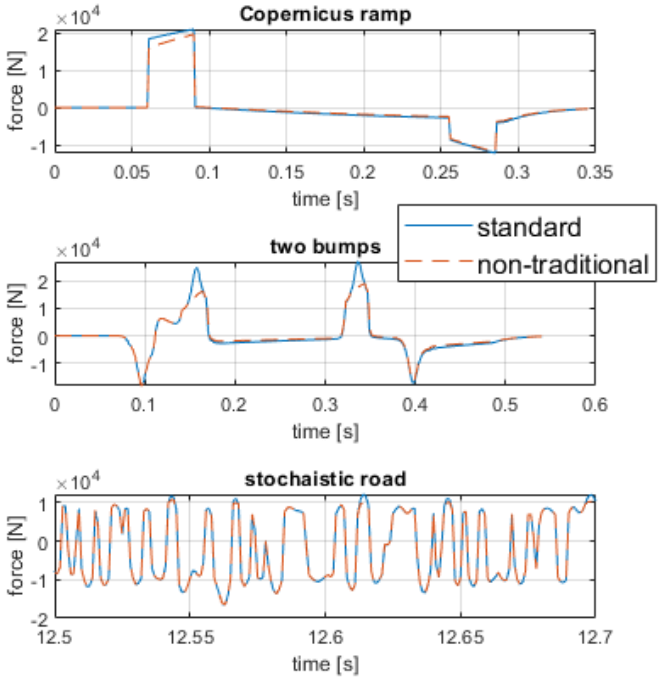
Three road profiles

Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

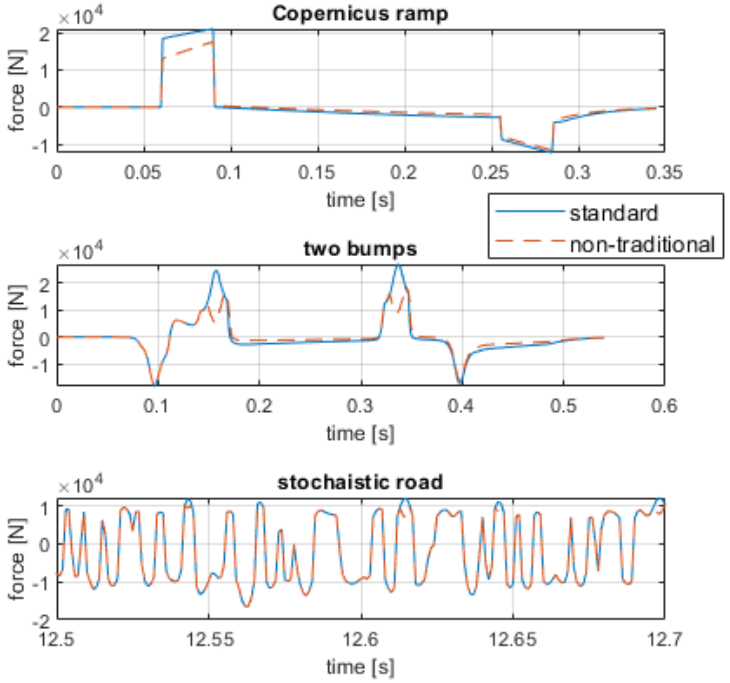
4-WP11-005: Damping element with innovative damping characteristics

- Results of simulation experiment with one-mass model of the car
  - Resulting forces comparison and Root Mean Square evaulation

a) Modified damping characteristics



b) Degressive damping behaviour



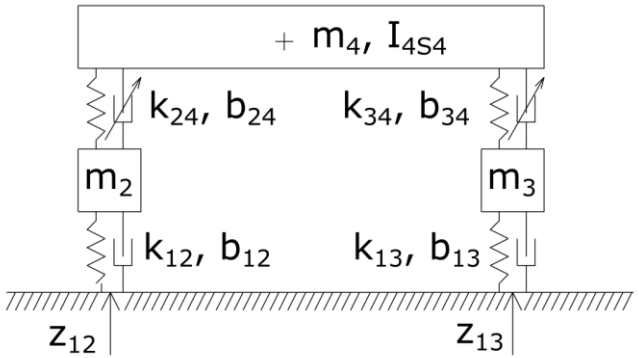
RMS comparison

	Copernicus ramp		Two bumps		Stochastic road	
damper:	RMS	Δ RMS	RMS	Δ RMS	RMS	Δ RMS
standart	2,7		2,9		3,76	
a) modified characteristics	2,5	8%	2,5	14%	3,71	1,3%
b) degressive behaviour	2,2	19%	2,2	24%	3,65	2,7%

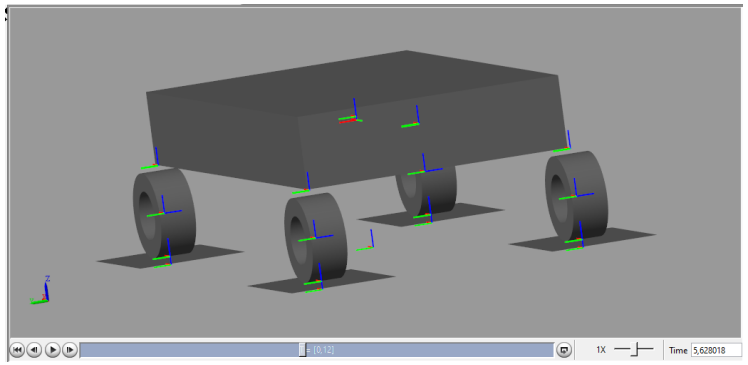
Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-005: Damping element with innovative damping characteristics

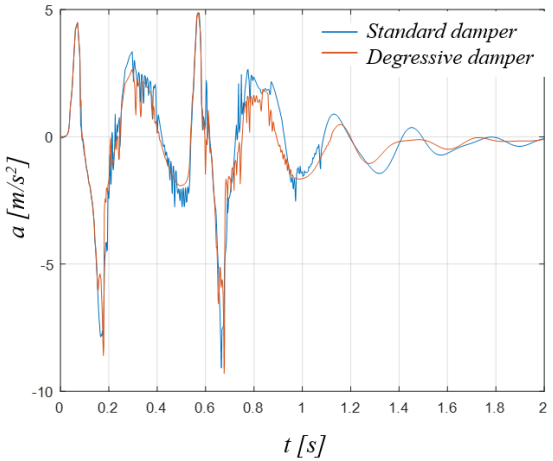
- Simulation experiments with half car model and full car model



half car model



full car model



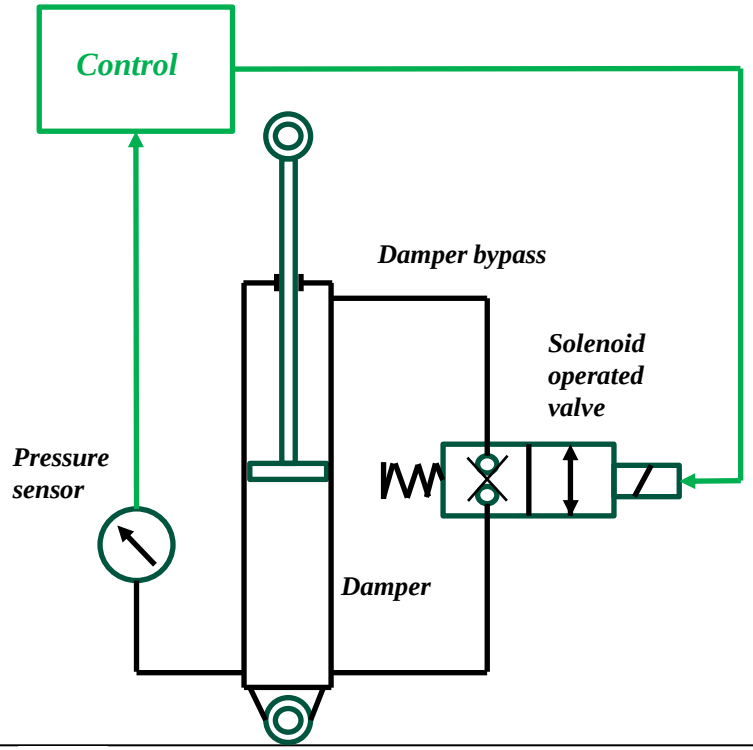
RMS comparison

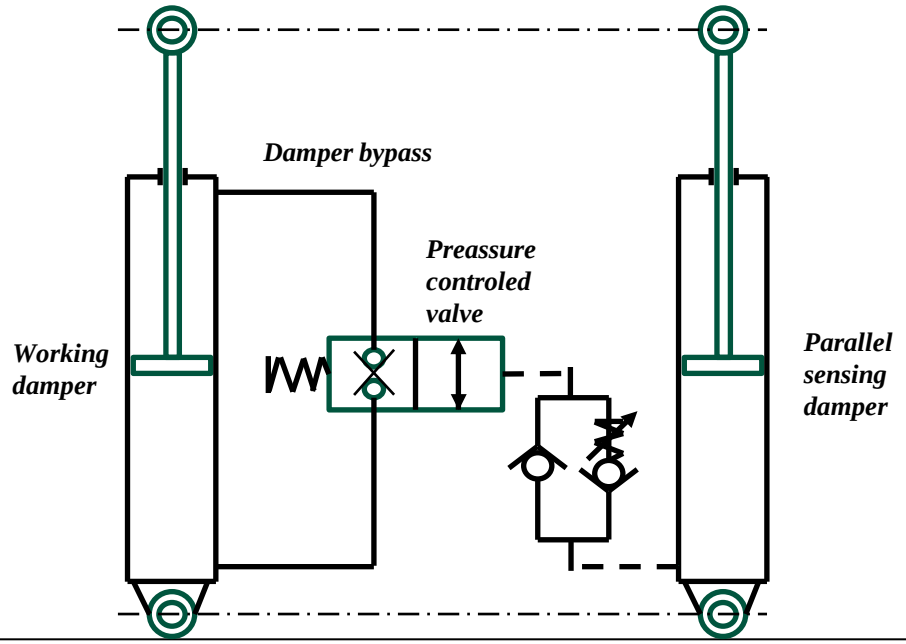
RMS	Standard dampers	Degressive dampers
Half car model	1.78	1.01
Full car model	1.98	1.65

Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-005: Damping element with innovative damping characteristics

- Functional sample – damper with modified characteristics
  - Two setups are considered in mechatronic and pure mechanic manner
  - Pressure controlled bypass





Activities in 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

4-WP11-005: Damping element with innovative damping characteristics

- Functional sample – degressive damper
  - Components and laboratory testing device

Activities in 4-WP11: NVH and Vibration Damping Devices for Future Vehicles

List of Due Deliverables and Their Added Value

- **4-WP11-001** - **Software for identification of noise sources of mobile systems** enables the reduction of costs and the increase of competitiveness of capabilities.
- **4-WP11-002** - deeper inside into testing of drive units of future automotive applications. Close cooperation with industrial partner (Skoda Auto) – both funded R&D projects and commercial ones.
- **4-WP11-003** – concept study of Hydraulic damper for semi-active control
- **4-WP11-004** – creation of mathematical model
- **4-WP11-005** – degresive damper for laboratory testing

Assessment of the Contribution of Deliverables

- Software for identification of noise sources of mobile systems – 4-WP11-001.
- MBS simulation of ICE – (4-WP08-003)
- Development of new components for powertrain - (3-WP13-003), (3-WP09-006), (3-WP09-003)
- All the working package participants (CTU FME, Brano a.s., BUT, …) fulfils the administrative goals.

Activities in 4-WP11: NVH and Vibration Damping Devices for Future Vehicles

Current State of Deliverables and Fulfillment of Goals

- 4-WP11-001 | Software for identification of noise sources of mobile systems, R-software, BUT 0.9; TATRA 0.05; WBU 0.05 **in progress & no major delays:**
  - The concept for the software was laid out, the software design and other follow-up work started to fulfill the output
- 4-WP11-002 | Set for acoustic transmission tests, G-funk, XII./2025, TUL FME 0,9 ; Skoda Auto 0,1 – **in progress & no major delays:**
  - Measurements were made at the location of the storage on a real drive unit.
  - The construction and simulation model is now being prepared, on the basis of which the real longitudinal profile will be adjusted.
  - Then production of the modified drive unit longitudinal profile will begin.
- 4-WP11-003 | Hydraulic damper with new internal architecture for semi-active control, G-funk, KAR 0.8; BUT 0.15; CTU FME 0.05
- 4-WP11-004 | Mathematical model of the electronic control system, O-Ostatní, KAR 0.7; BUT 0.25; CTU FME 0.05 **in progress & no major delays:**
  - Concept study, creation of multibody and mathematical model
- 4-WP11-005 | Damping element with innovative damping characteristics, Gfunk, XII./2025, CTU FME 0.2; BRANO 0.7; BUT 0.1 – **in progress & no major delays**:
  - Simulation experiments – car body force peaks are reduced, RMS value decreases (passenger and payload load is reduced)
  - Functional sample preparation

Current contribution of 4-WP11 Vehicle Noise and Inovative Semi-Active Damper Design

Assessment of the Formal/Administrative Goals of the Work Package

	BUT	ŠKODA AUTO	TATRA TRUCKS	BRANO	WBU	KAR	TUL	CTU FME
Finances (reporting/spending)	OK	OK	OK	OK	OK	OK	OK	OK
Commercialization (the whole organisation)	OK	OK	OK	OK	OK	OK	OK	OK
Deliverables	OK	OK	OK	OK	OK	OK	OK	OK

Current contribution of 4-WP11 NVH and Vibration Damping Devices for Future Vehicles

Acknowledgment

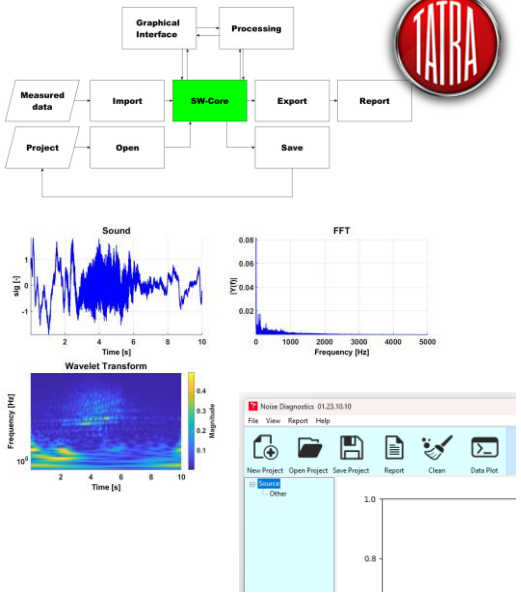
This research has been realized using the support of Technological Agency, Czech Republic, programme National Competence Centres II, project # TN02000054 Božek Vehicle Engineering National Center of Competence (BOVENAC).

Výtah z prací 2023-2025 na 4-WP11 NVH a zařízení pro tlumení vibrací pro budoucí vozidla

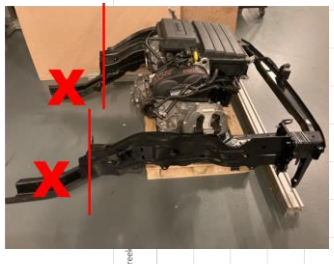
4-WP11-001 Software pro identifikaci zdrojů hluku mobilních systémů

(Pavel Kučera – kucera@fme.vutbr.cz)

FACULTY OF MECHANICAL ENGINEERING institute of automotive engineering

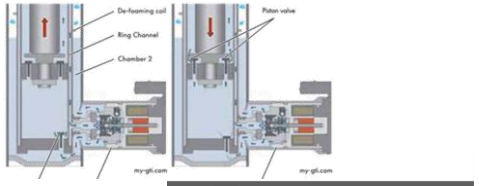


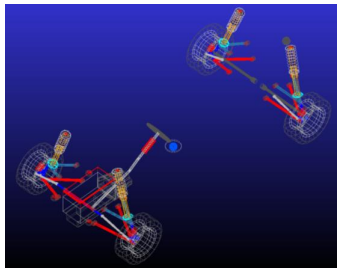
4-WP11-002 Sada pro akustické testování převodovky

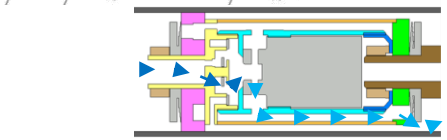


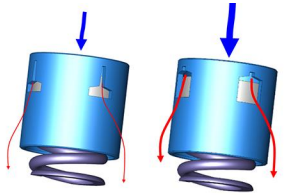
4-WP11-003 Hydraulický tlumič s novou vnitřní architekturou pro semiaktivní ovládání

4-WP11-004 Matematický model elektronického řídicího systému

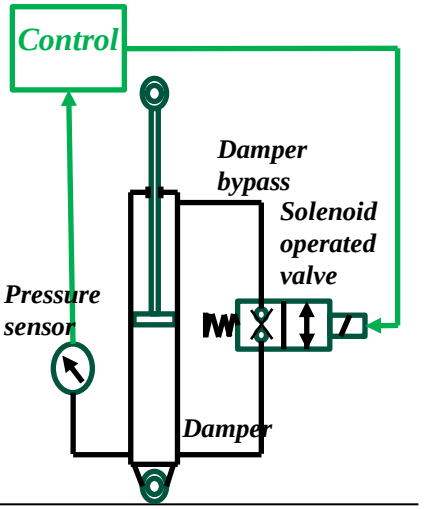








4-WP11-005 Tlumicí prvek s inovativní charakteristikou tlumení

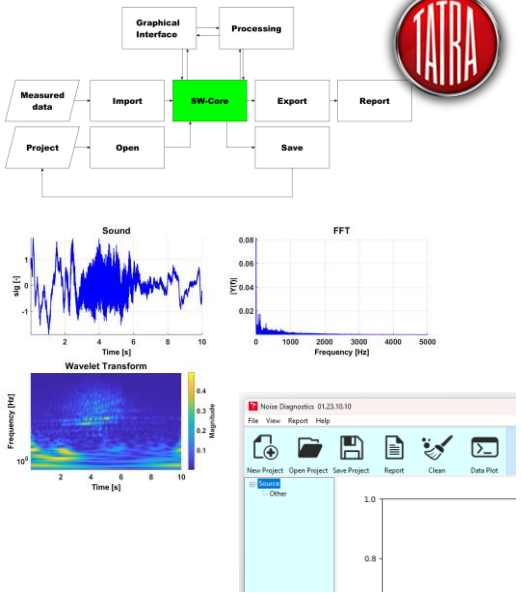


Results of 4-WP11 NVH and Vibration Damping Devices for Future Vehicles–Achieved 2023-2025

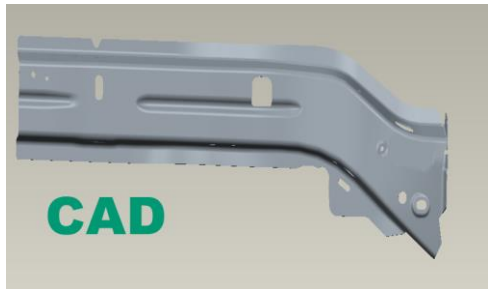
4-WP11-001 Software for identification of noise sources of mobile systems

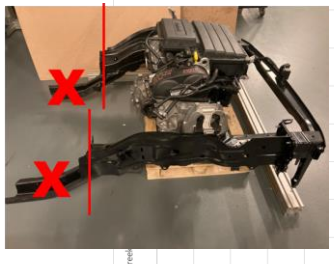
(Pavel Kučera – kucera@fme.vutbr.cz)

FACULTY OF MECHANICAL ENGINEERING institute of automotive engineering



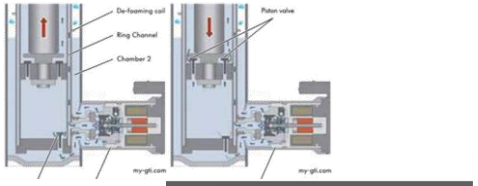
4-WP11-002 Set for acoustic transmission tests

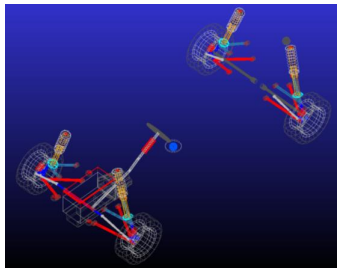


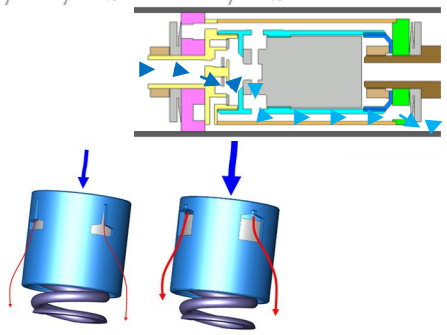


4-WP11-003 Hydraulic damper with new internal architecture for semi-active control

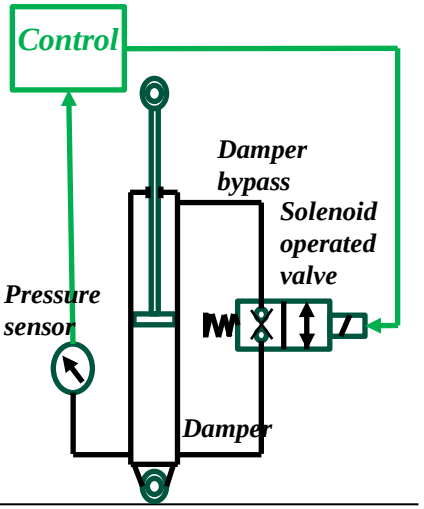
4-WP11-004 Mathematical model of the electronic control system







4-WP11-005 Damping element with innovative damping characteristics

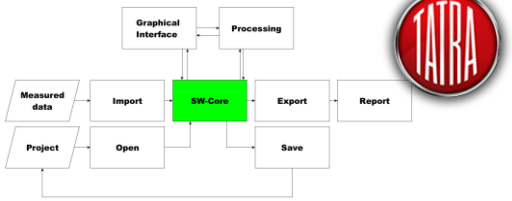


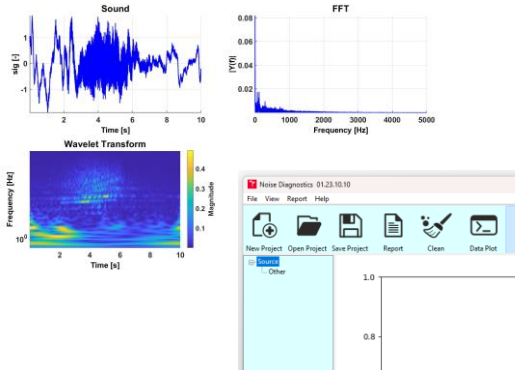
Výtah z prací 2023 na 4-WP11 NVH a zařízení pro tlumení vibrací pro budoucí vozidla

4-WP11-001 Software pro identifikaci zdrojů hluku mobilních systémů

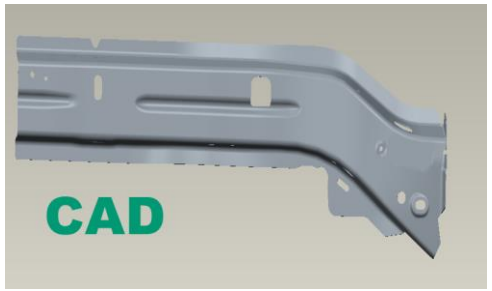
(Pavel Kučera – kucera@fme.vutbr.cz)

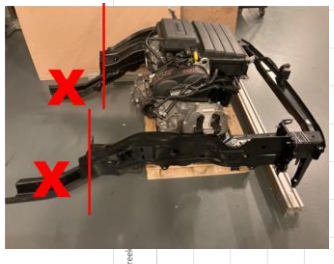
FACULTY OF MECHANICAL ENGINEERING institute of automotive engineering





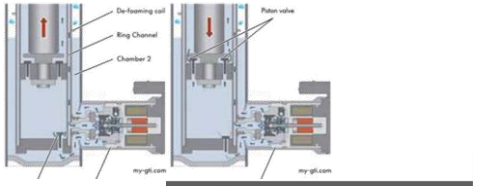
4-WP11-002 Sada pro akustické testování převodovky

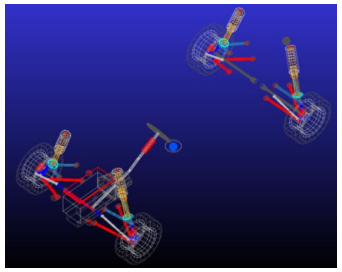


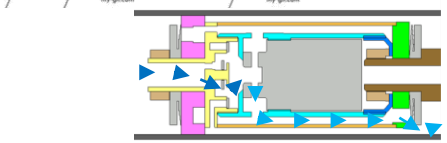


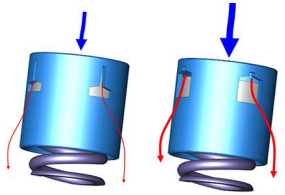
4-WP11-003 Hydraulický tlumič s novou vnitřní architekturou pro semiaktivní ovládání

4-WP11-004 Matematický model elektronického řídicího systému

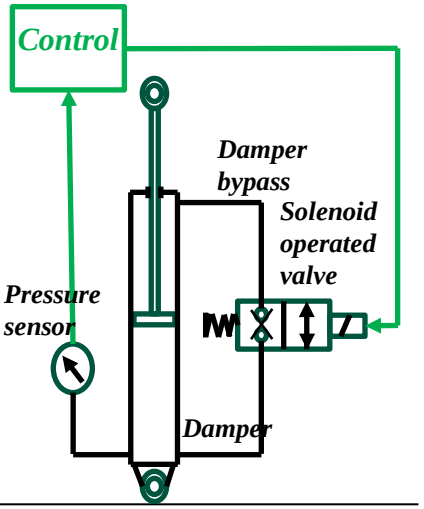








4-WP11-005 Tlumicí prvek s inovativní charakteristikou tlumení



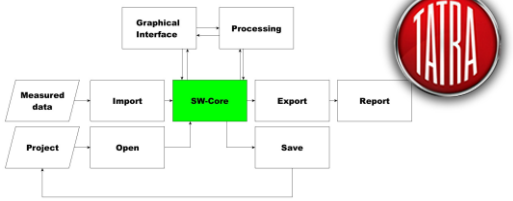
Results of 4-WP11 NVH and Vibration Damping Devices for Future Vehicles Design–Achieved 2023

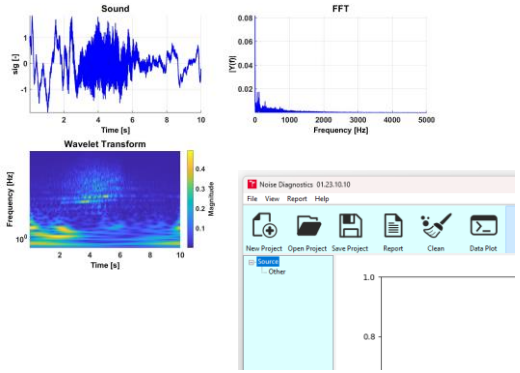
4-WP11-001 Software for identification of noise sources of mobile systems

(Pavel Kučera – kucera@fme.vutbr.cz)

FACULTY OF MECHANICAL ENGINEERING institute of automotive engineering

TATRA

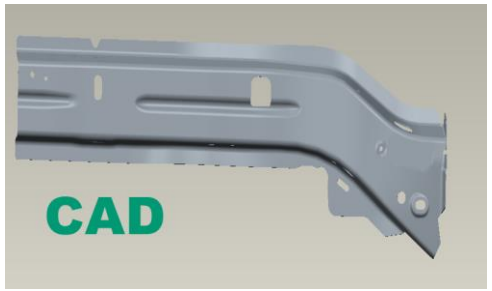


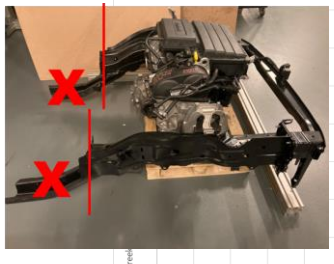


4-WP11-002 Sada pro akustické testování převodovky

ŠKODA

TUL



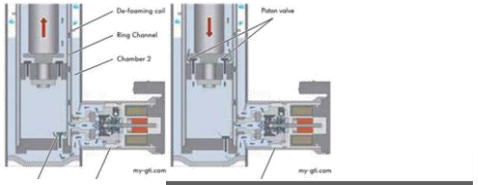


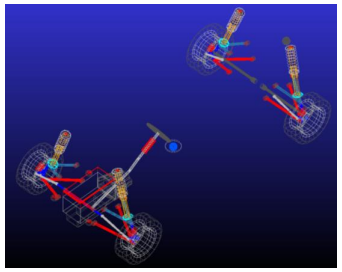
4-WP11-003 Hydraulický tlumič s novou vnitřní architekturou pro semiaktivní ovládání

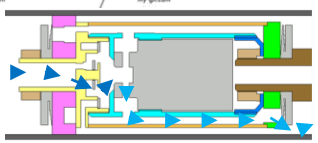
4-WP11-004 Matematický model elektronického řídicího systému

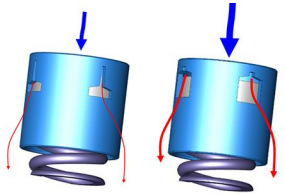
KAR

FAKULTA STROJNÍ ČVUT V PRAZE









4-WP11-005 Tlumicí prvek s inovativní charakteristikou tlumení

FAKULTA STROJNÍ ČVUT V PRAZE

BRANO GROUP