Contents of Work Package **4-WP05** Tools of Design and Components for Advanced Vehicles - Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# FEFEFOF_4-WP05: Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Coordinator of the WP 05

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## Participants of the WP 05

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DFJP UPa, doc. Ing. Petr Voltr, Ph.D.
Tribotec spol. s r.o., Ing. Pavel Rosendorf

Contents of Work Package **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Main Goal of the WP

- Design of a working sample of a new two-axle bogie for freight wagon. Testing main components of bogie, suspension elements, dampers. Performance of strength calculations and life-time test of materials. Processing of the production documentation of the main components of the new bogie.

- Development of MBS models of a virtual low-floor articulated tram with active elements in bogies.

- Methodology of design of parameters of elements passive safety of railway vehicles.

- Development of a functional sample of a new on-board application unit for liquid and semi-liquid lubrication to control the coefficient of friction between wheels and rails, development of an advanced system to control the coefficient of friction of a roundabout in sharp curves of railway and tram tracks.

All these R&D activities will contribute to shortening the time between conceptual research and the application of an innovative product to the market (time-to-market, TTM) by about 20%, primarily by using the accumulated experience from previous solutions and timely removal of development dead ends in its initial phase.

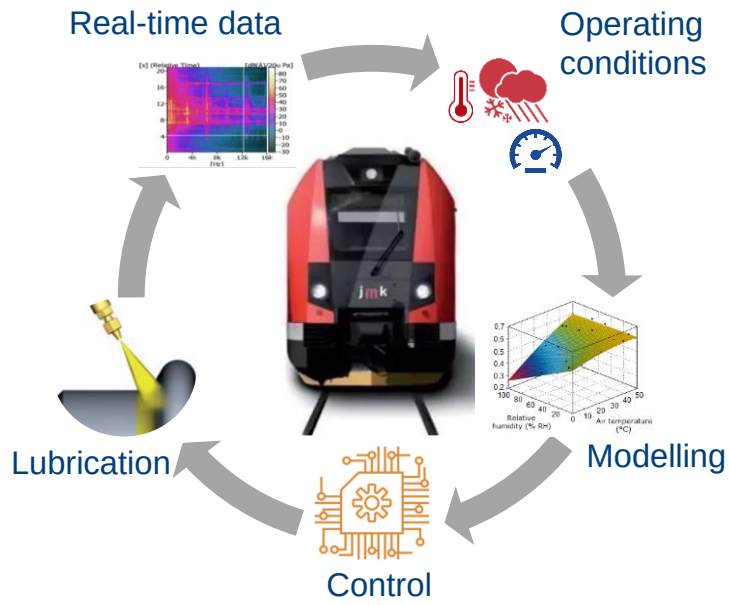
Contents of Work Package **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# Partial Goals for the Current Period

- Development and implementation of friction management technique through the application of a digital twin approach.

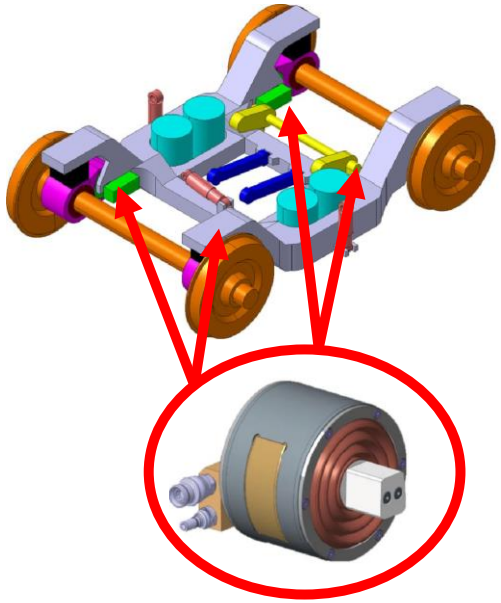
- Control system for the wheel-flange/top-of-rail lubrication based on the combination of:
  - automatic prediction of load, slip and contact area of the wheel-rail contact (based on models, GNSS + map data and operating conditions);
  - prediction of changing properties of the friction layer between the rail and the wheel (based on experimental results and models)
  - feedback from the on-board condition monitoring (noise and vibration);
  - real-time evaluation and optimization of the lubrication control.

The system will be implemented, tested and optimized on a real railway system (Brno-Blansko).



Contents of Work Package **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

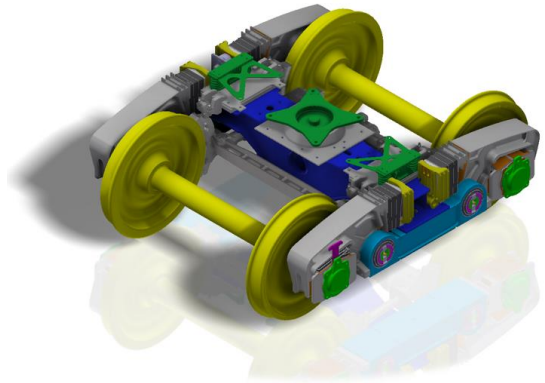
## Partial Goals for the Current Period



- concept design of a low-floor articulated tram with active elements in the tram bogies, development of more accurate MBS models of bogies and trams with actuators, development of actuator control algorithms, simulation of actuator failure states, evaluation of safety risks

- creation of a model of a rail vehicle accident with a car, analysis of the parameters of deformation elements for the consequences of accidents, conceptual design of new crash elements of trams and regional rail vehicles

- selection of suitable sensors for application in the system of measuring the position of wheelset in the track, design of the layout of the sensor system and processing of signals from individual sensors



- design of partial parts, production of functional samples, production and assembly of a functional sample of a new bogie for freight wagons, performance of quasi-static and dynamic tests of bogie and their evaluation

# Contents of Work Package **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## **4-WP05:** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Official 4-WP05 Deliverables:

### Main Goal

- 4-WP05-005 | **Test sample of a key part of the railway bogie**,$G_{funk}$ , (VÚKV 0.2 , TatraVagonka 0.8)
  TN 02000054/004-V19

- 4-WP05-007 | **Onboard lubrication unit for advanced friction management**,$G_{funk}$ ,
  TN 02000054/004-V21 (FME VUT 0.3 , Tribotec 0.7)

# Contents of Work Package **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

**4-WP05:** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Official 4-WP05 Deliverables:

Another goal

- 4-WP05-001 | **MBS model of a virtual low-floor articulated tram with active elements** ,O, (FME CTU 0.75 + STRN 0.2 + VÚKV 0.05)

TN 02000054/004-V15

- 4-WP05-002 | **Methodology of design of parameters of elements passive safety of railway vehicles** ,O, (FME CTU 0.9 + SIEMENS Mobility 0.1)

TN 02000054/004-V16

- 4-WP05-003 | **Methodology of design of shape solution of passive protective elements of given parameters for railway vehicles**,O, (FME CTU 0.9 + SIEMENS Mobility 0.1)

TN 02000054/004-V17

# Contents of Work Package **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

**4-WP05:** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Official 4-WP05 Deliverables:

Another goal

- 4-WP05-004 | **Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track**,O, (FME CTU 0.9 + STRN 0.1)

TN 02000054/004-V18

- 4-WP05-006 | **Report on Milestones - New bogie for freight wagons**,O, (VÚKV 0.8 + Tatravagonka 0.2)

TN 02000054/004-V20

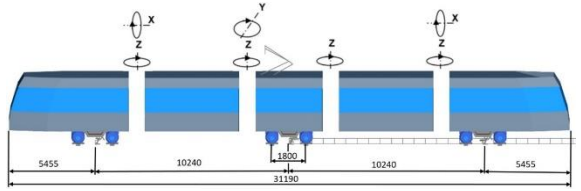
- 4-WP05-008 | **Prediction of friction in the wheel-rail interface**,O, (FME BTU 0.4 + STRN 0.3 + UPa 0.3)

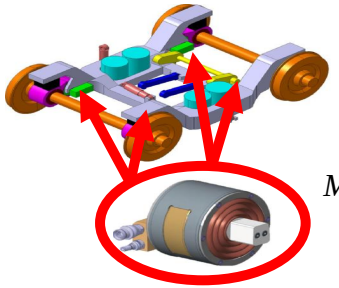
TN 02000054/004-V22

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-001: **MBS model of a virtual low-floor articulated tram with active elements**

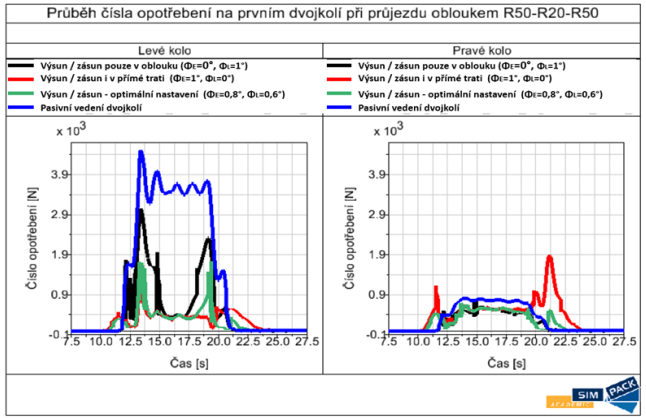
- Driving simulations of a tram vehicle with active and passive suspension on a test track under different boundary conditions were carried out
- Research on the improvement of tram passage in sharp curves of short length and without transitions - passing through an intersection
- A suitable actuator control solution: the actuator starts turning the wheelset into a radial position even before entering the intersection and returns it back before the end of the intersection arc
- Assessment of the influence of the inaccuracy of tram localization in the tram line



*MBS model of articulated low floor tram*

*MBS model of the tram bogie with active elements Liebherr*





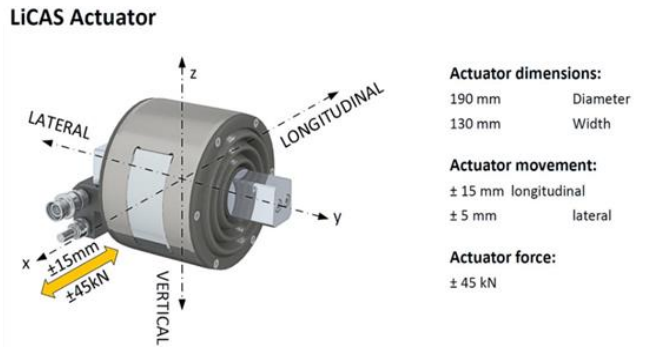
| Chyba lokalizace vozidla | Průměrné číslo opotřebení [N] | To je % oproti pasivnímu vedení | Průměr disipované energie [J] | To je % oproti pasivnímu vedení |
|---|---|---|---|---|
| ±0 | 457 167 | 34.7 | 2 065 343 | 30.0 |
| ±1 | 467 295 | 35.5 | 2 133 174 | 31.0 |
| ±2 | 490 013 | 37.2 | 2 242 867 | 32.6 |
| ±3 | 520 979 | 39.5 | 2 394 941 | 34.8 |
| ±4 | 555 779 | 42.2 | 2 576 104 | 37.4 |
| ±5 | 593 595 | 45.1 | 2 757 182 | 40.1 |
| ±6 | 632 454 | 48.0 | 2 927 480 | 42.5 |
| ±8 | 711 572 | 54.0 | 3 351 308 | 48.7 |
| ±10 | 791 988 | 60.1 | 3 757 187 | 54.6 |
| ±15 | 987 417 | 74.9 | 4 751 485 | 69.1 |
| ±20 | 1 139 679 | 86.5 | 5 492 419 | 79.8 |

*Analysis of the passage of the tram through the intersection - the course of wear and tear in the intersection, i.s. arc R50-R20-R50.*

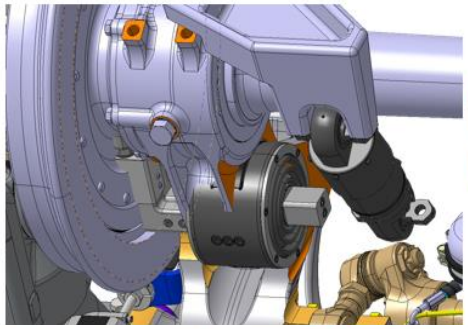
# Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

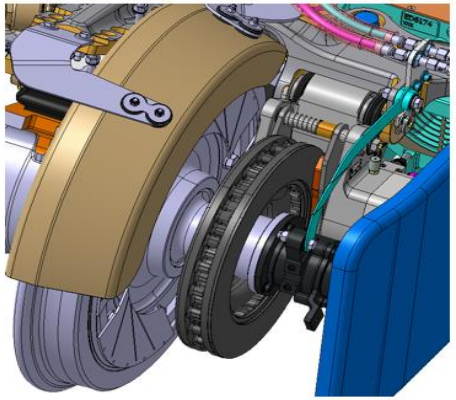
## 4-WP05-001: **MBS model of a virtual low-floor articulated tram with active elements**

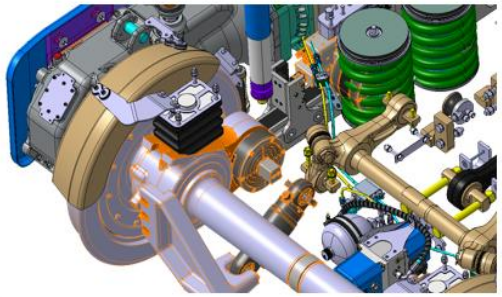
- analysis of the assembly space in the bogies of a low-floor trams
- assesment of the possibility of implementing the actuator into current tram bogies

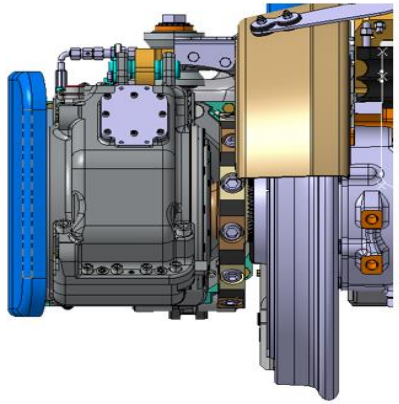


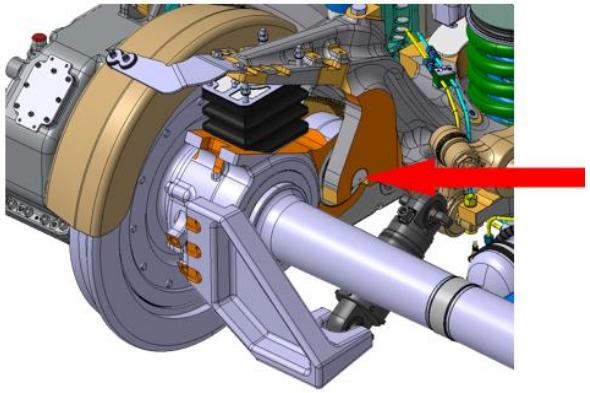

*Use of the LiCAS actuator in the bogie of a passenger wagon*

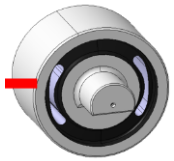


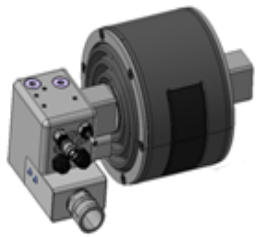












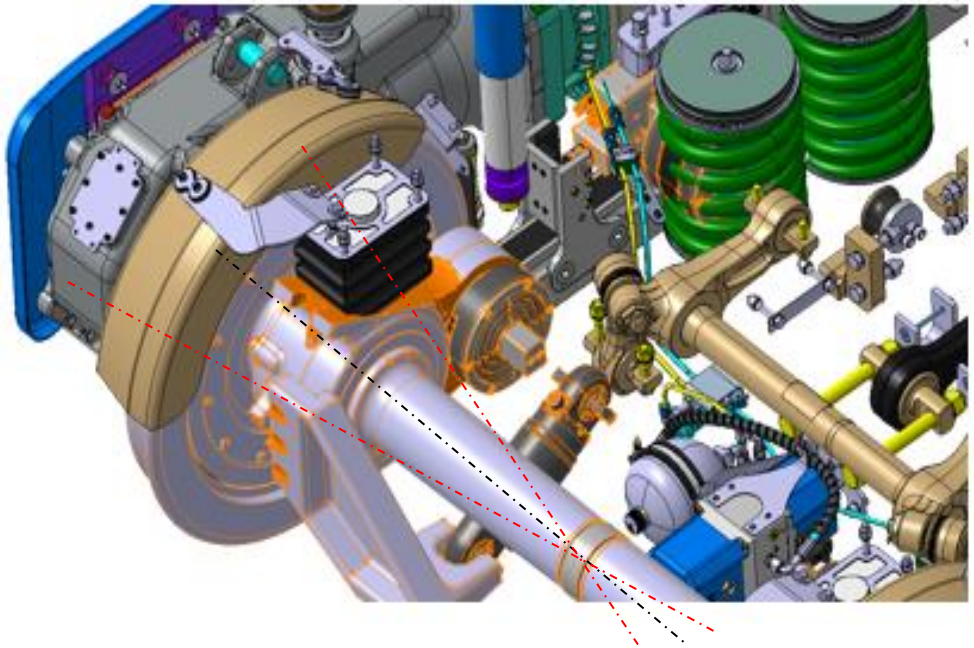
*The pasiv element or the LiCAS actuator?*

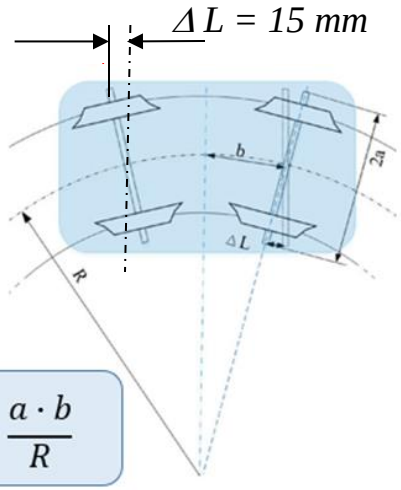
*The use of the LiCAS actuator in the bogie of a low-floor tram is problematic*

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

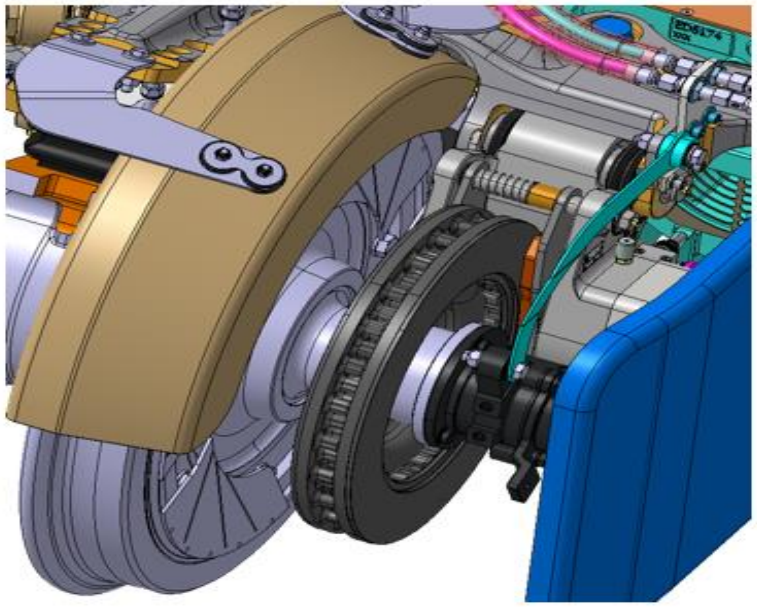
# 4-WP05-001: **MBS model of a virtual low-floor articulated tram with active elements**

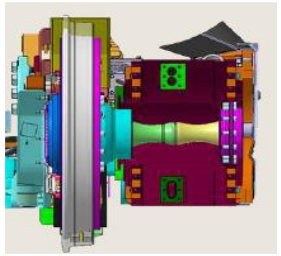
- are we looking for answers to practical design questions?






$$\Delta L = \frac{a \cdot b}{R}$$





*They can compensate for ± ΔL deformation:*

*- the articulated shaft of the wheelset drive unit in the hollow output shaft of the gearbox or traction motor?*

*- the brake unit of the disc brake must be attached to the axis of the tram's two wheels ?*

*- elements of the primary suspension of a tram bogies ?*

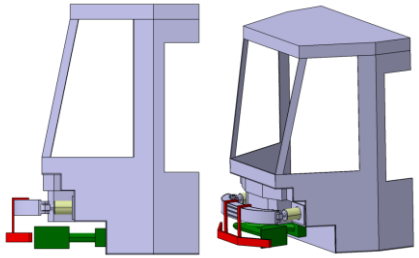
# Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## 4-WP05-002: **Methodology of design of parameters of elements passive safety of railway vehicles**

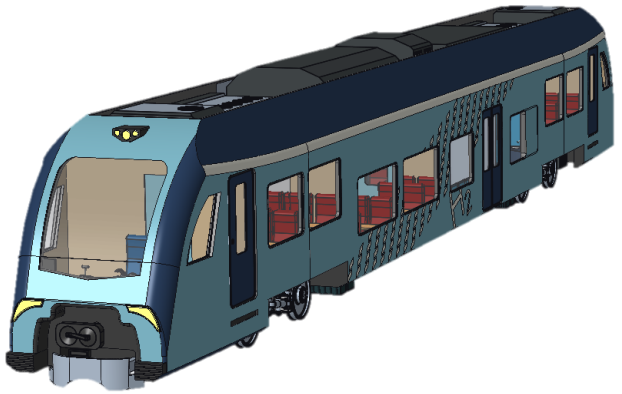
## 4-WP05-003: **Methodology of design of shape solution of passive protective elements of given parameters for railway vehicles**

- Creation of a simulation model of an articulated low-floor tram – LKV Tram - Train
- Application of knowledge from the fields of stiffness compatibility body cars and geometry of road vehicles.

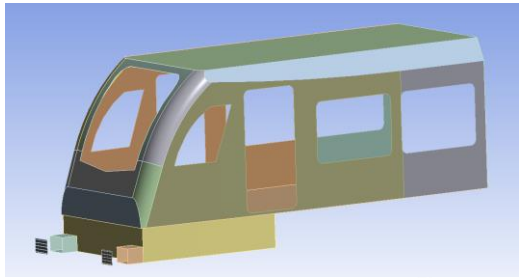
*Models of personal car and articulated low-floor tram*

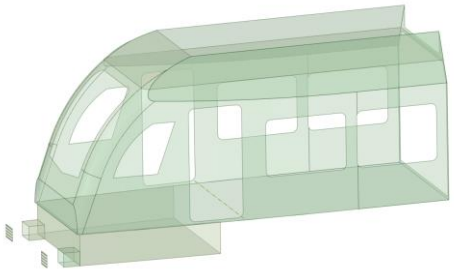


*A model of the driver's cabin of an articulated low-floor tram with a new crash element*



*A model of the driver's cabin of vehicle BEMU 70*



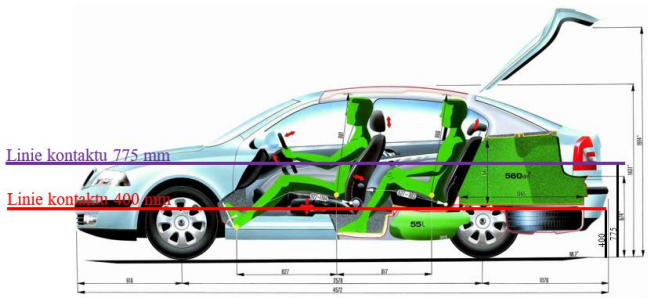


# Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## 4-WP05-002: **Methodology of design of parameters of elements passive safety of railway vehicles**

## 4-WP05-003: **Methodology of design of shape solution of passive protective elements of given parameters for railway vehicles**

- Creation of a simulation model of a rail vehicle BEMU for research into reducing the consequences of regional vehicle accidents with a passenger car at a railroad crossing.




*The area of the height line of the crash side contact*

| Parametr | Charakteristika deformačních prvků [kN/mm] | Svislá pozice nárazníku nad TK [mm] | Výška nárazníku [mm] | Šířka nárazníku [mm] |
|---|---|---|---|---|
| Kombinace 0 | 125,0 | 775 | 170 | 300 |
| Kombinace 1 | 125,0 | 400 | 170 | 300 |
| Kombinace 2 | 125,0 | 400 | 170 | 1 000 |
| Kombinace 3 | 50,0 | 400 | 170 | 300 |

*Considered parameters of deformation elements*

| Rychlost tramvaje [km/h] | Kombinace 0 | Kombinace 1 | Kombinace 2 | Kombinace 3 |
|---|---|---|---|---|
| 25 | 108,6/6,1 | 49,3/0,0 | 47,5/0,0 | 41,5/0,0 |
| 30 | - | 64,8/0,0 | 62,7/0,0 | 59,3/0,0 |
| 35 | - | 77,9/1,5 | 77,3/1,5 | 71,9/0,0 |
| 40 | - | 95,1/4,1 | 94,8/3,9 | 91,1/3,8 |

*Results of the analysis of the combination of parameters of deformation elements*

*To reduce the consequences of accidents between trams or LRV and passengers cars, it is advisable to place the contact points between the rail vehicle and the car at a height of around 400 mm above the above the plane of the rails.*

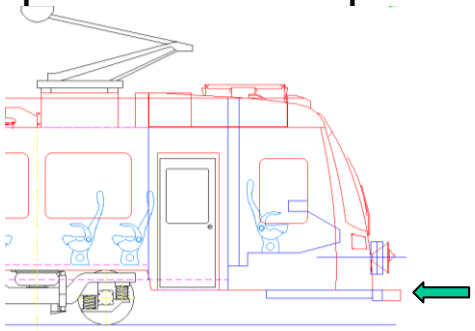
Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

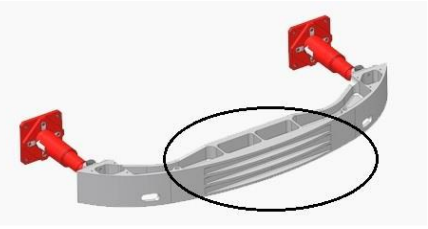
## 4-WP05-002: **Methodology of design of parameters of elements passive safety of railway vehicles**

## 4-WP05-003: **Methodology of design of shape solution of passive protective elements of given parameters for railway vehicles**

- Creation of a simulation model of a rail vehicle BEMU for research into reducing the consequences of regional vehicle accidents with a passenger car at a railroad crossing.
- Determination of the influence of individual parameters on the consequences of accidents:
  - characteristics of deformation elements => improvement of up to 25%,
  - height position of deformation elements above the TK plane => improvement of up to 60%,
  - width of contact area of deformation elements => improvement of up to 50%,
  - contact surface height => negligible improvement.

*It would be appropriate to use a new passive safety element.*

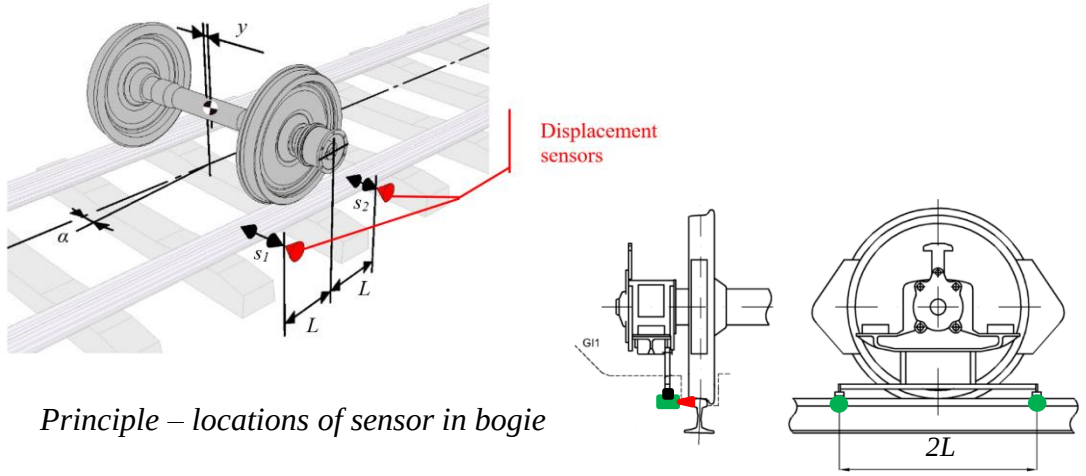




Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-004: **Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track**

- State of the Art – Onboard Axle-Box Placed sensors



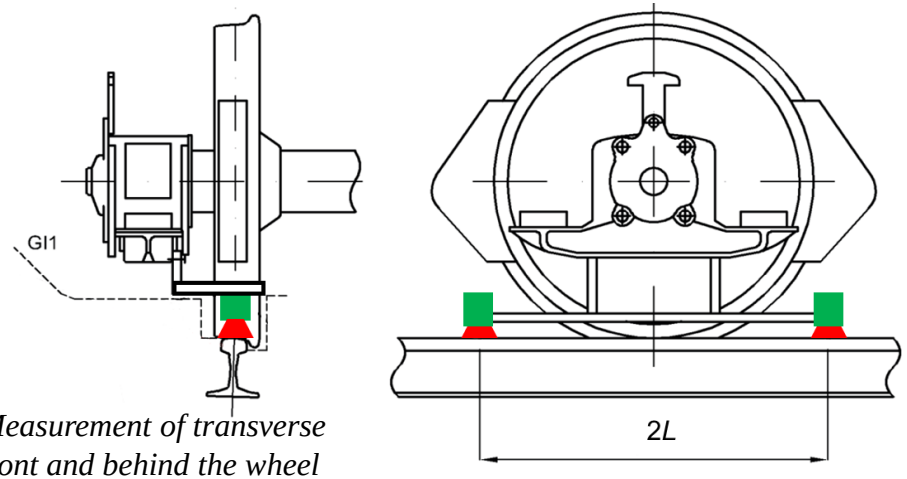

*Principle – locations of sensor in bogie*

- Applicable with contact (rollers) and contactless (laser) sensors.
- Easy calculation of angle of attack.

- Very limited speed (especially contact version)
- Outside of the structure gauge → Incompatible with infrastructure

## NEW PRINCIPLE - GOALS

- contactless measurement that does not limit running speed,
- utilization of mechanically robust sensors allowing attachment to the axle-box,
- placement of the sensors enabling the vehicle to run on the standard railway infrastructure, including switches, crossings, level crossings and other track elements on which current measurement systems are not applicable

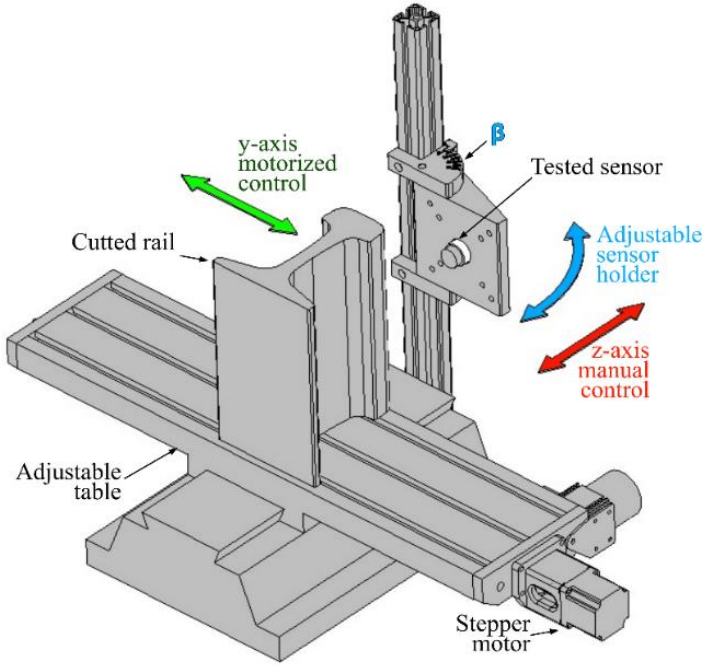



*Principle – Measurement of transverse position in front and behind the wheel*

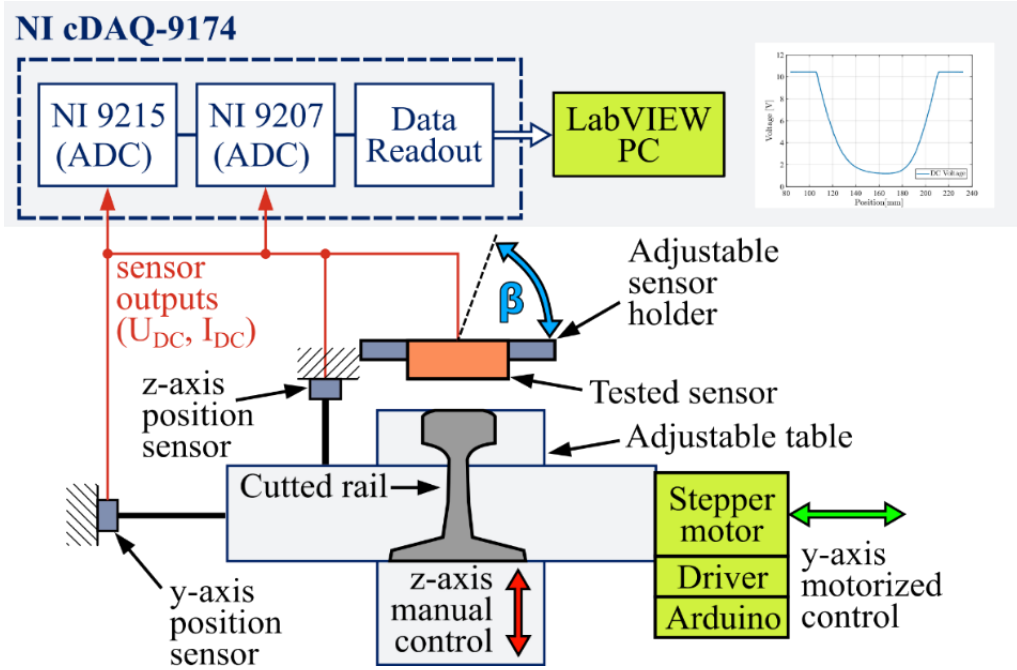
Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-004: **Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track**

- development of a preparation for detailed testing of sensor sensitivity.




*Test Bench and Testing Procedure*



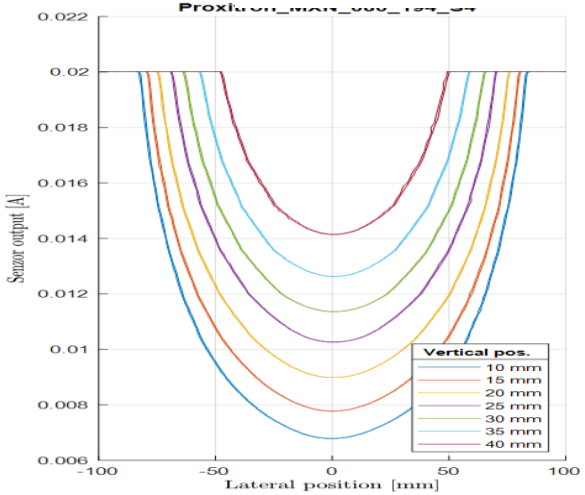

*A test fixture for a basic test of its sensor sensitivity*

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

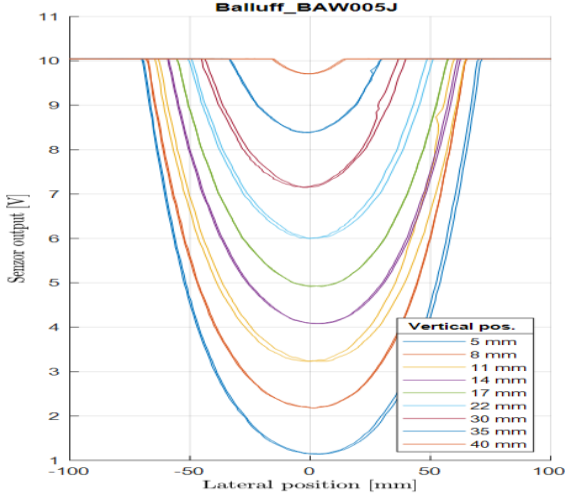
# 4-WP05-004: **Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track**

- development of a preparation for detailed testing of sensor sensitivity.

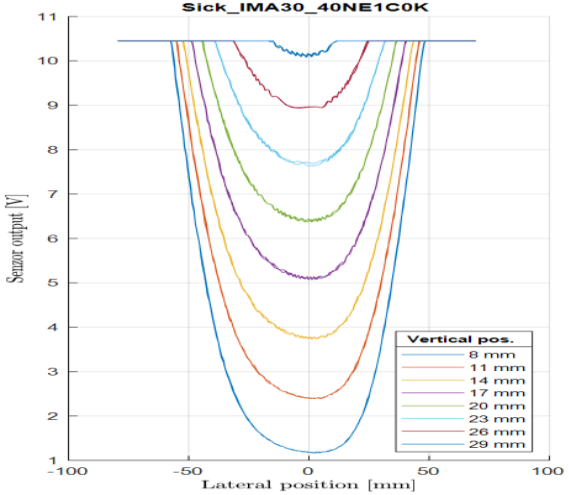
*Proxitron MXN 080.194*




*Balluff BAW 005J*




*Sick IMA30-40NE1ZC0K*

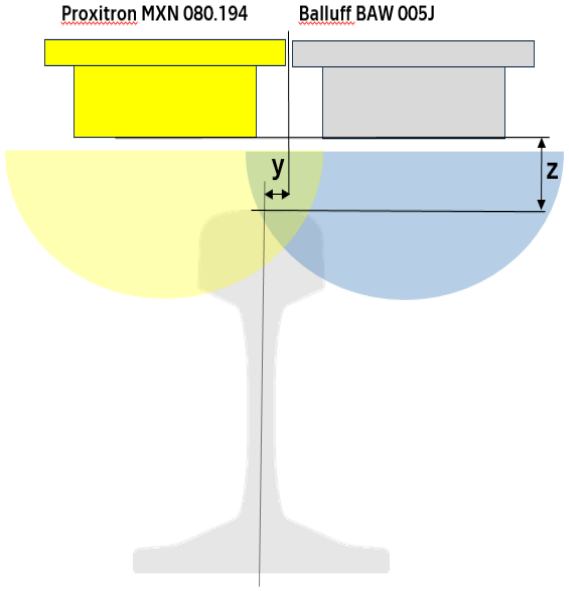


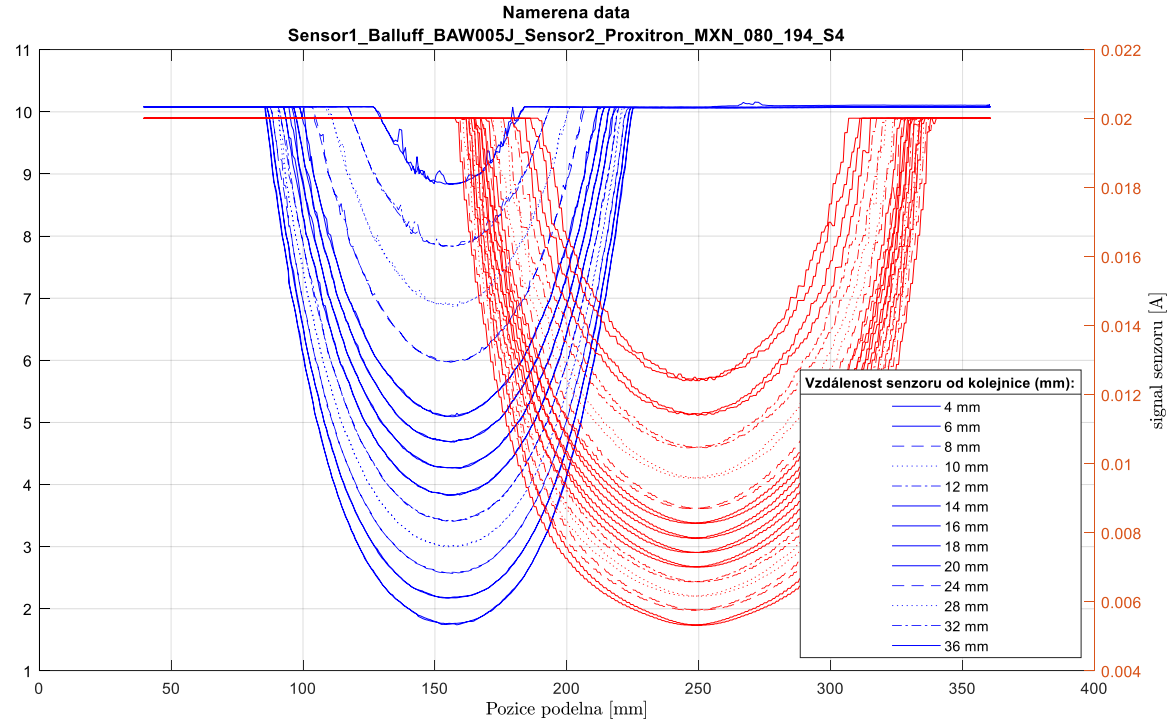

*Measurement of characteristics of three types of sensors - position sensitivity results*

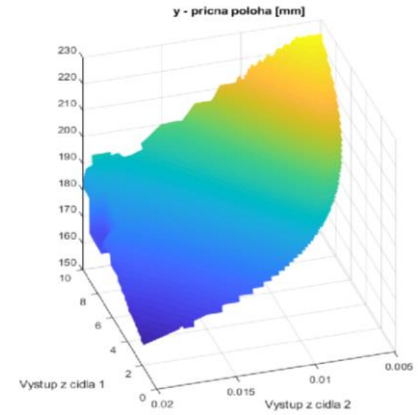
## Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

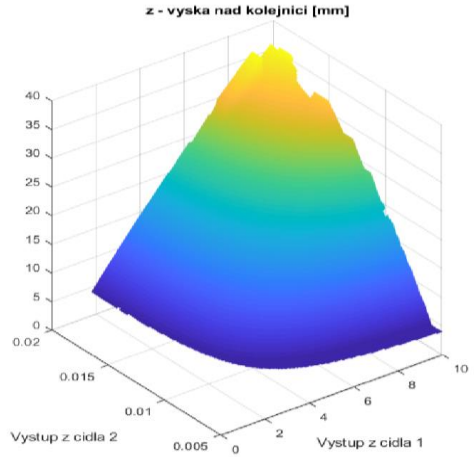
# 4-WP05-004: **Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track**

- development of a preparation for detailed testing of sensor sensitivity.




*Measurement of characteristics of three types of sensors - position sensitivity results*

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

4-WP05-005: **Test sample of a key part of the railway bogie**

4-WP05-006: **Report on Milestones - New bogie for freight wagons**

*Freight bogie Y25*

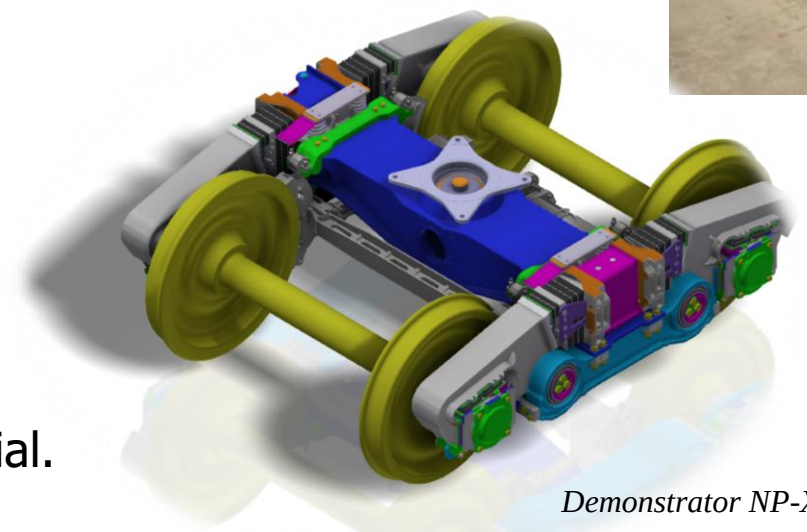
**Motivation:**

- Current standard – freight bogie Y25 (since 1967 in UIC).
- Current (future) requirements – Y25 has problems to fulfil.
- Main problems – noise, wheel-rail contact effects,...

**New solution – bogie NP-X:**

- Identical space and interface as Y25.
- Family of concepts for diverse purposes.
- Rubber suspension oriented horizontally.
- Different wheelset guidance (swing arm).

- International research cooperation.
- Patented solution with high commercial potential.



*Demonstrator NP-X*

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

4-WP05-005: **Test sample of a key part of the railway bogie**

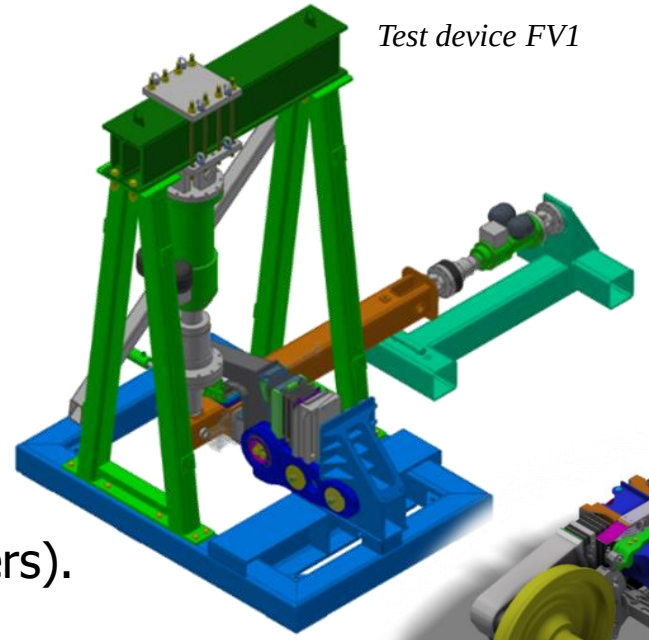
4-WP05-006: **Report on Milestones - New bogie for freight wagons**

## Official results:

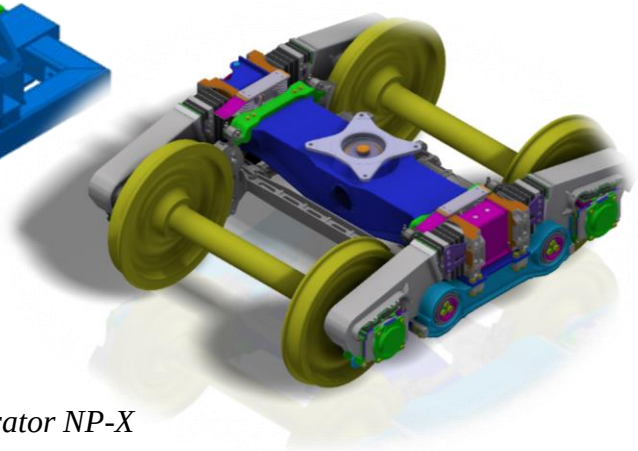
- Test sample $G_{funk}$ in 12/2025 (test rig FV1).
- Test sample $G_{funk}$ in 12/2028 (demonstrator NP-X, FV3).
- Additional reports of type O describing the solutions.

## Activities in 2024:

- Structural design of test sample FV1 (completion).
- Production and assembly of FV1 (completion).
- Initial tests with FV1 (verification of functionality and parameters).
- Start of quasi-static tests campaign with FV1.
- Structural design of the demonstrator FV2 (full bogie).
- Diverse evaluations and computing support - continuously.



*Test device FV1*



*Demonstrator NP-X*

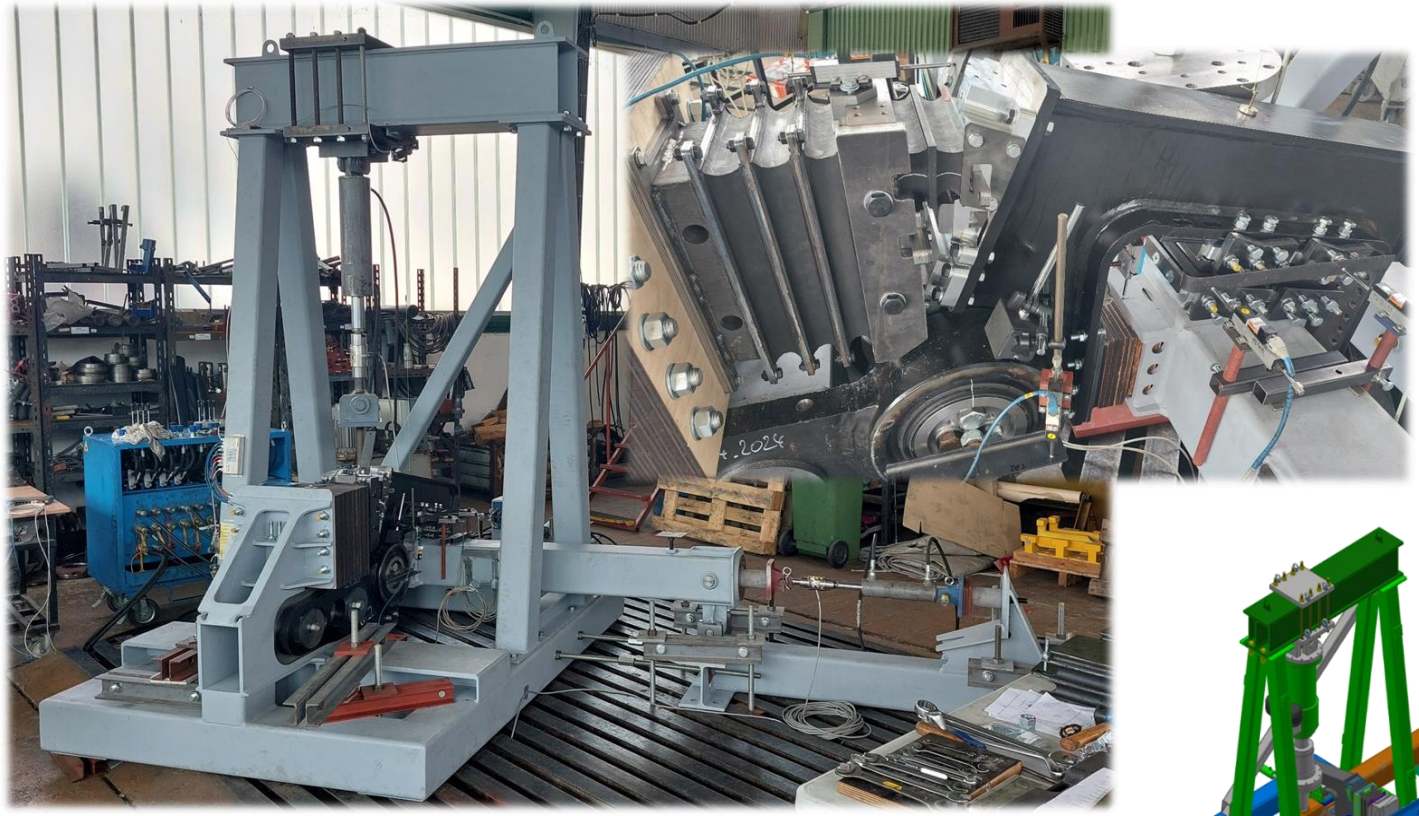
# Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## 4-WP05-005: **Test sample of a key part of the railway bogie**

## 4-WP05-006: **Report on Milestones - New bogie for freight wagons**

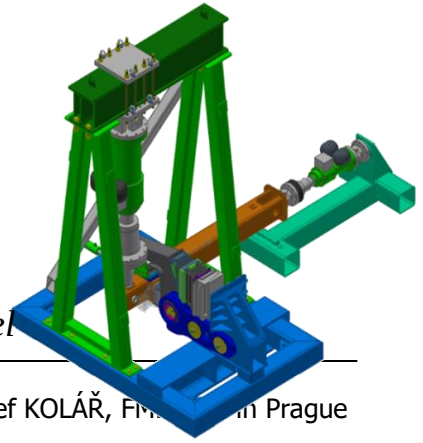
**Test device FV1 – testing of key part of the bogie:**

- Finalising of design.
- Production, assembly.
- Commissioning.



**FV1 – initial tests:**

- Proof of functionality.
- Verification of parameter.
- Verification of measuring chain.



*Test sample FV1 - comparison reality vs. 3D model*

# Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

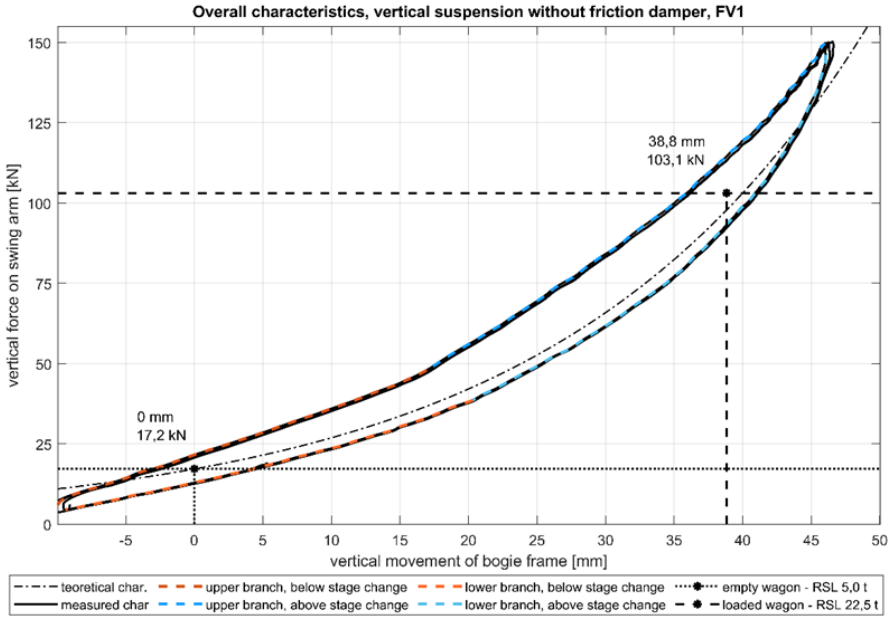
## 4-WP05-005: **Test sample of a key part of the railway bogie**

## 4-WP05-006: **Report on Milestones - New bogie for freight wagons**

VÚKV TATRAVAGÓNKA POPRAD

### **FV1 – quasi-static tests campaign:**

- Measuring devices completed.
- Tests started in 10/2024.



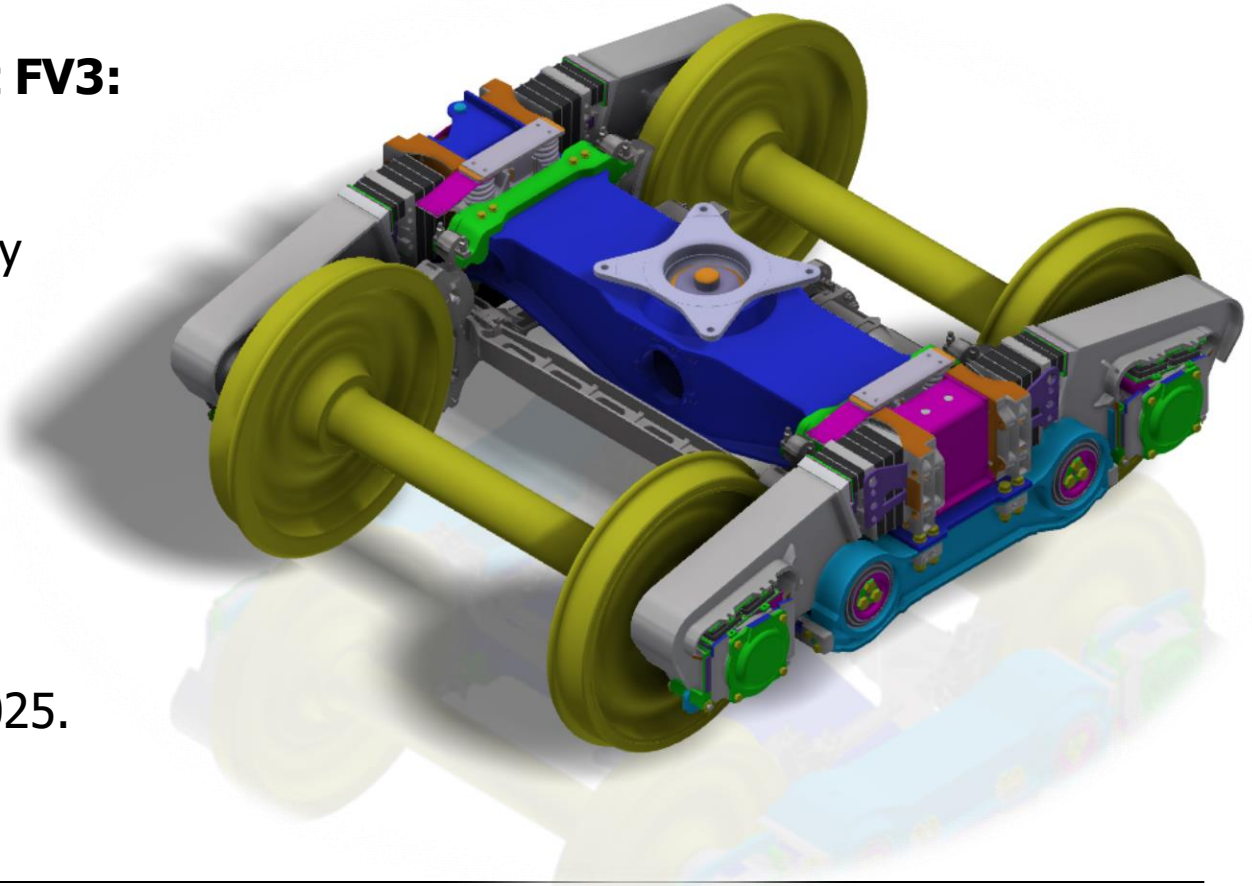

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

4-WP05-005: **Test sample of a key part of the railway bogie**

4-WP05-006: **Report on Milestones - New bogie for freight wagons**

**FV2 – demonstrator and basis for official result FV3:**

- Rubber-metal elements - cooperation with a foreign manufacturer started.
- Main structural parts – analysis of manufacturability with TVP.
- Brake - construction prepared for various brake systems suppliers.
- Loading sensor – investigations relating to its best position, communication with suppliers.
- Other devices – investigation ongoing.
- Calculations and simulations – continuous support.
- Start of production – planned for second half of 2025.



Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

## Motivation

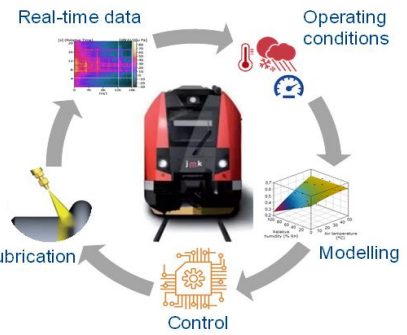
- Lack of an effective solution for wheel-flange and top-of-rail lubrication in curves with small radii (< 300 m).
- Railway corridor between Brno and Blansko with a large number of curves, open after reconstruction in 2023.
- 30y full-service of train units for the South Moravian region operated in the corridor (Skoda Group).

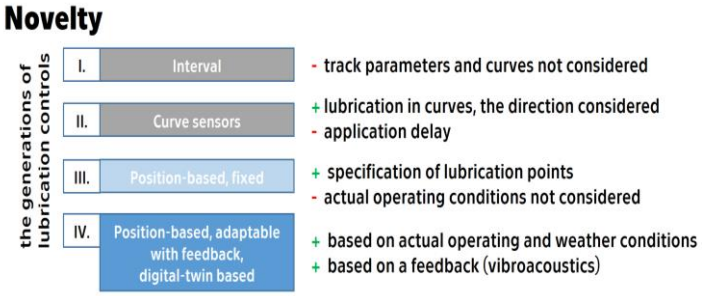
## Goals

- Development and implementation of friction management technique through the application of a digital twin approach.
- The system will be implemented, tested and optimized on a real railway system Brno – Blansko.


*The electrical unit Regio Panter for the South Moravian*

*View of part of the curved railway track Brno - Blansko*




*Concept solution of a digital twin electric unit.*

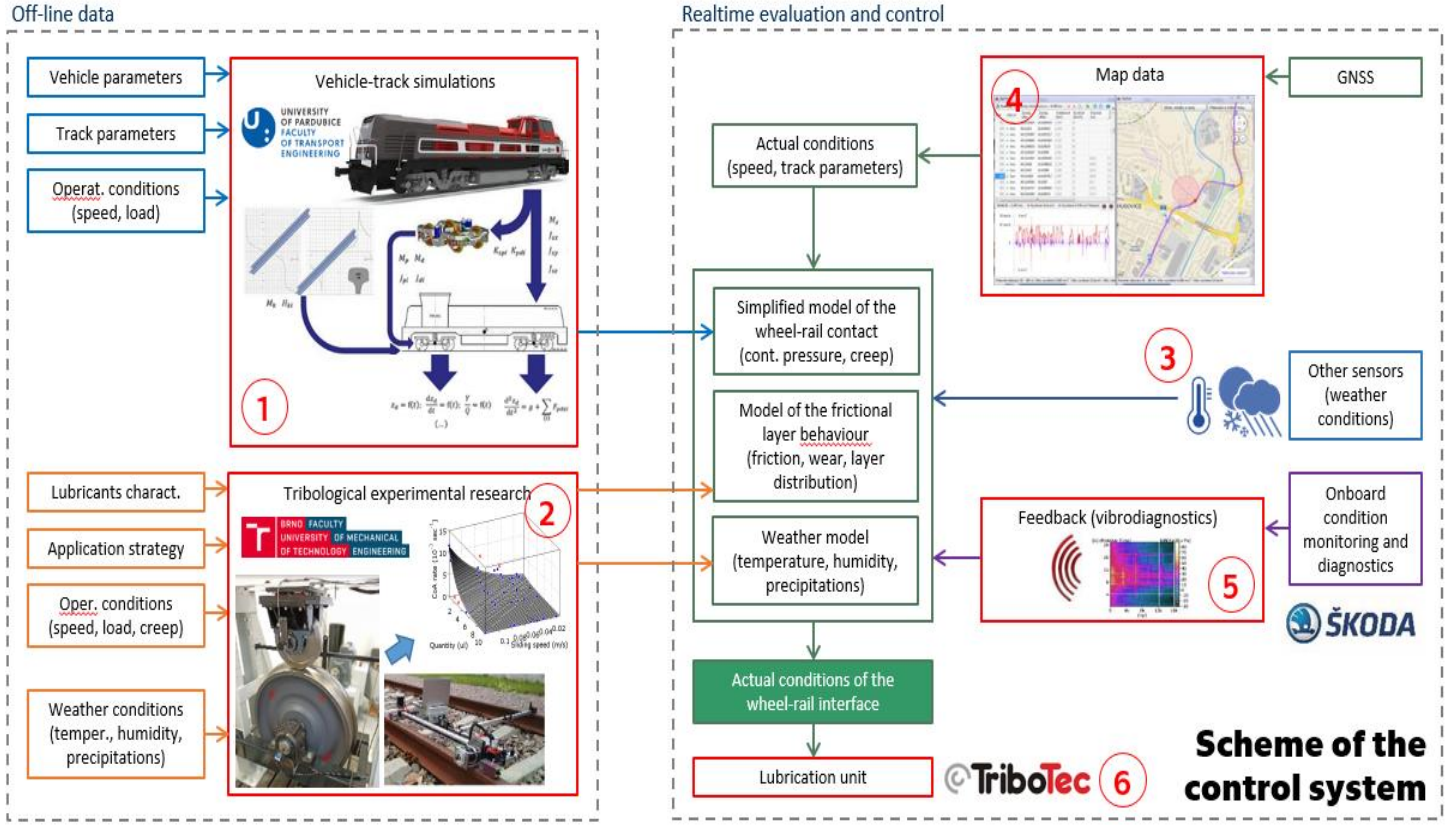
Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

## Activities in 2024

- Development of simulation tools for Skoda 18Ev and the first set of simulations
- Regression model of retentivite as a result of laboratory experiments
- Design of diagnostic data processing
- Implementation of the first level of erasure maps to 18Ev
- Development of the lubrication unit according to current requirements



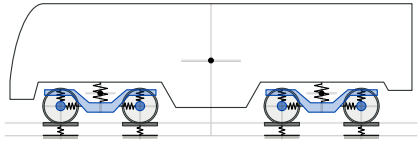
Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

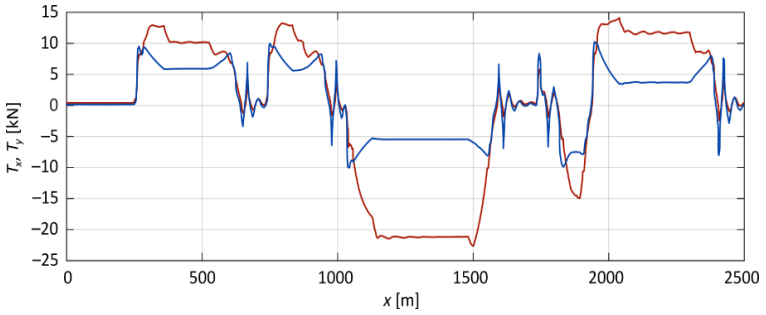
# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

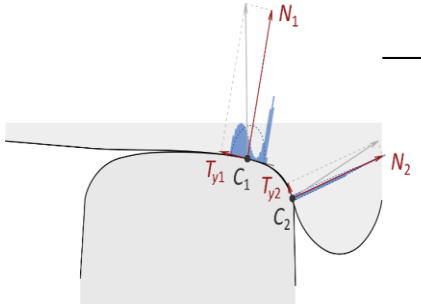
## ① *Vehicle dynamics simulations*

*Vehicle and track parameters* → *Multibody simulation model* → *Curving simulations* → *Detailed outputs characterizing the contact conditions* → *Simplified model of contact conditions affecting flange lubrication*



- Model of the ŠKODA 18Ev EMU created based on design specifications and parameters from the producer
- Track geometry parameters, wheel and rail contact geometry available
- Use of the SJKV system („Simulace jízdy kolejového vozidla“) – in-house simulation software of the University of Pardubice




*Curving simulations* → *Detailed outputs characterizing the contact conditions*

- Simulation of running through curves of small radii
- Extracting detailed outputs on contact conditions – position and size of the contact area, creeppages, normal and creep forces

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

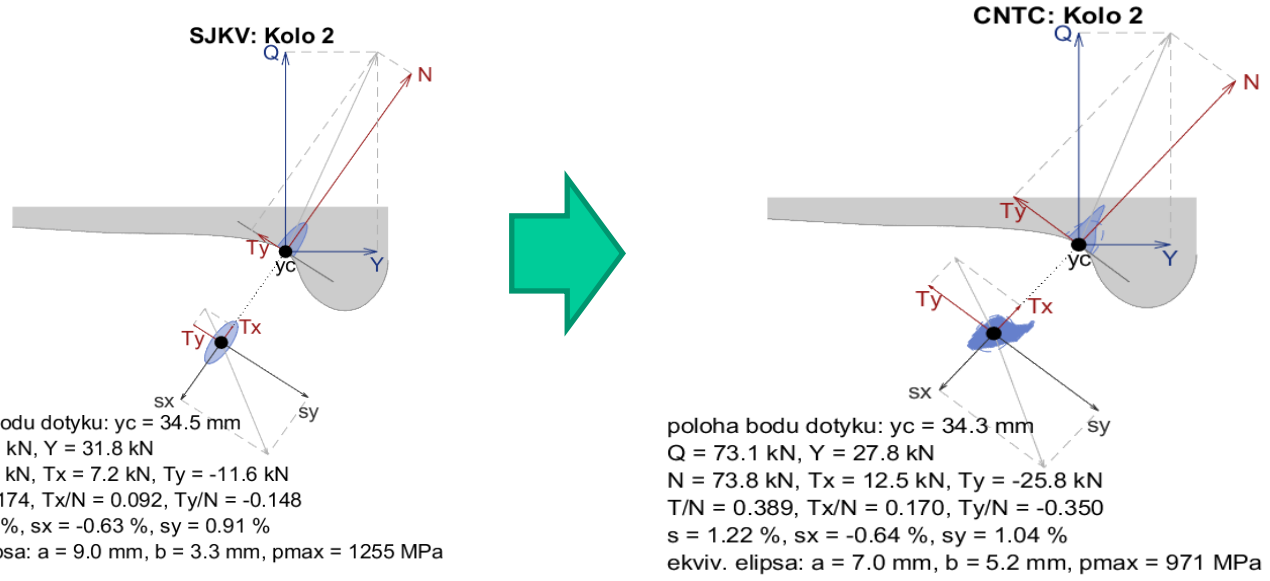
# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

## ① *Vehicle dynamics simulations*

*Vehicle and track parameters* → *Multibody simulation model* → *Curving simulations* → *Detailed outputs characterizing the contact conditions* → *Simplified model of contact conditions affecting flange lubrication*

- 2nd iteration using „CONTACT" wheel-rail contact SW
- Refinement of the calculation in the contact area with the same external forces



Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

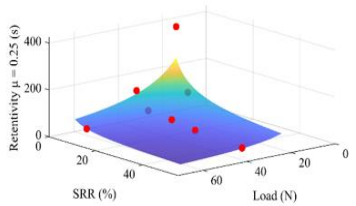
# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

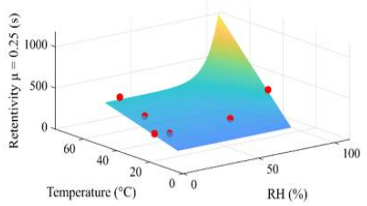
## ② *Wheel-rail experimental research*

**Regression model**

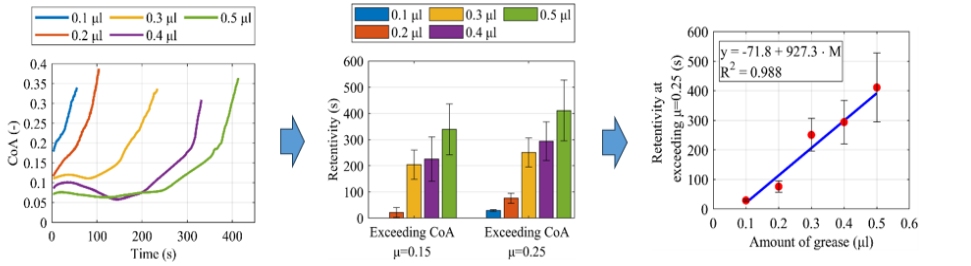
$$ret = b_1 \cdot W^{b_2} \cdot U^{b_3} \cdot SRR^{b_4} \cdot (b_5 + b_6 \cdot M) \cdot (b_7 + b_8 \cdot T) \cdot \left(b_9 + b_{10} \cdot e^{b_{11} \cdot RH}\right)$$

**Load** $W = \frac{\varepsilon' \cdot F}{E' \cdot R_x^2 \cdot (k')^{\frac{1}{3}}}$ **Speed** $U = \frac{\eta \cdot v_e}{E' \cdot R_x \cdot (k')^{\frac{2}{3}}}$ **Creep** (Stick, Slip) **Quantity** $M = \frac{V_m}{b \cdot l \cdot R_x \cdot (k')^{\frac{2}{3}}}$ **Temperature** **Humidity** $H_2O$

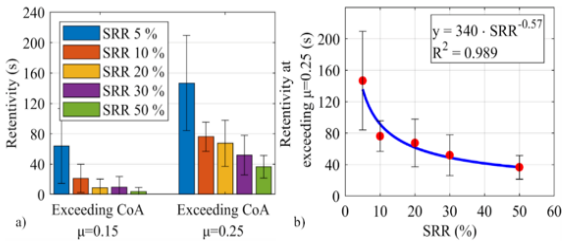


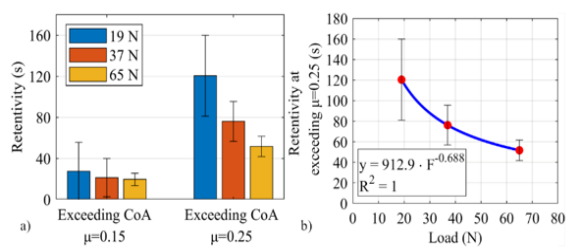

**Lubricant quantity**



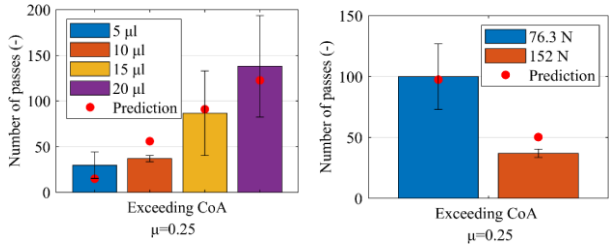

**Slip**

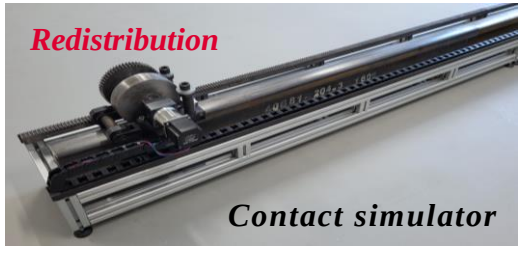


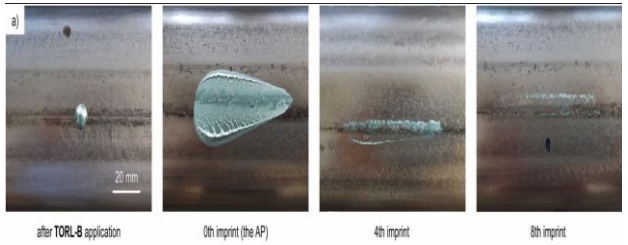

**Load**







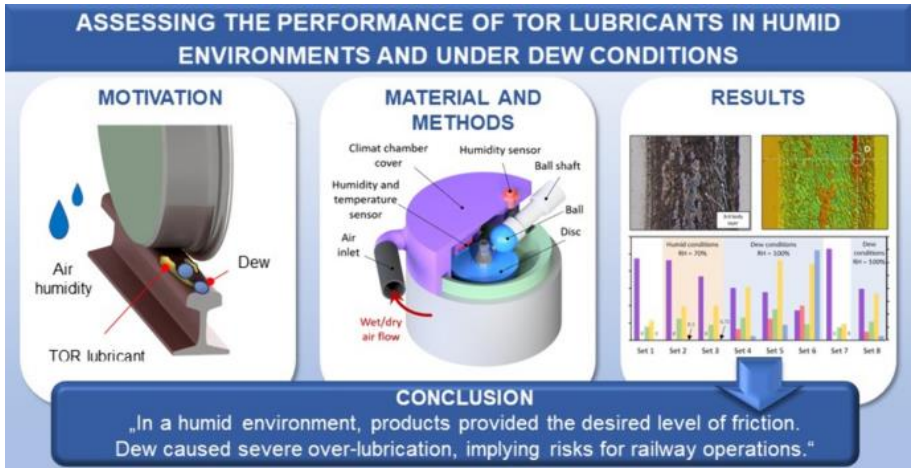



Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

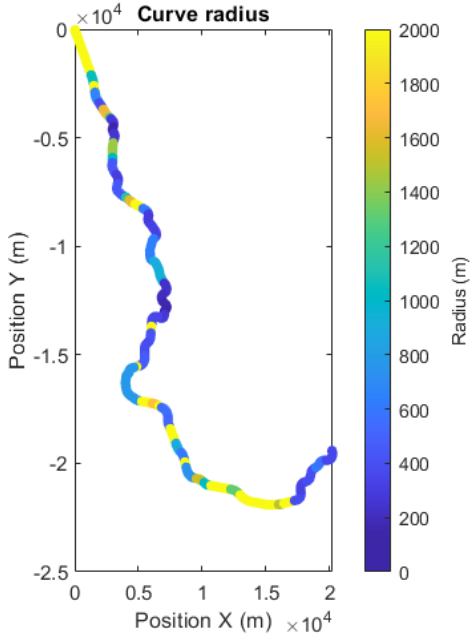
4-WP05-007: **Onboard lubrication unit for advanced friction management**

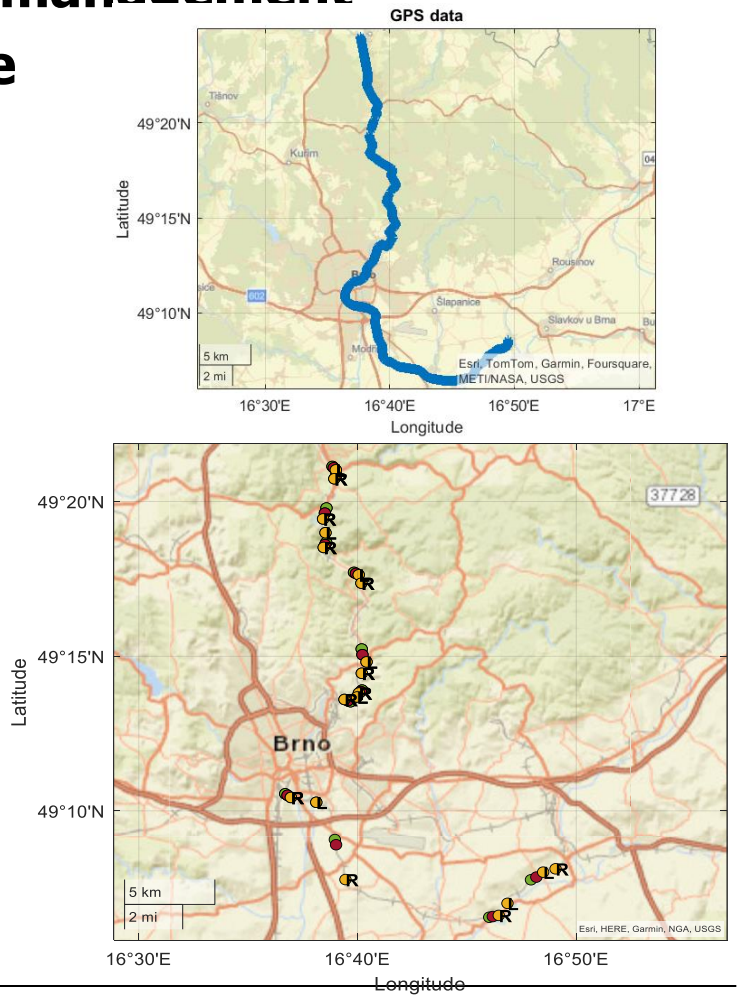
4-WP05-008: **Prediction of friction in the wheel-rail interface**

## 3 *Weather conditions*




## 4 *Map data*



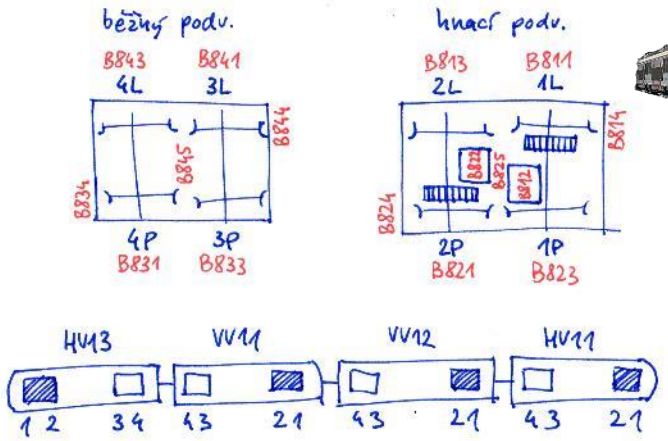
Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

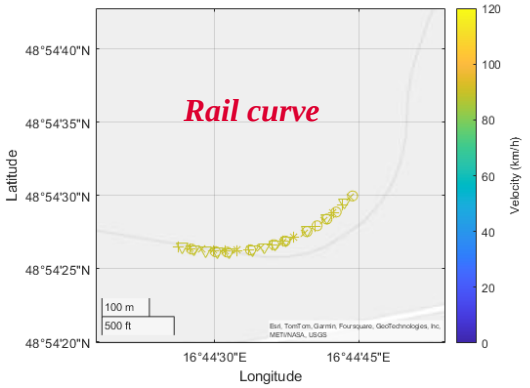
# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

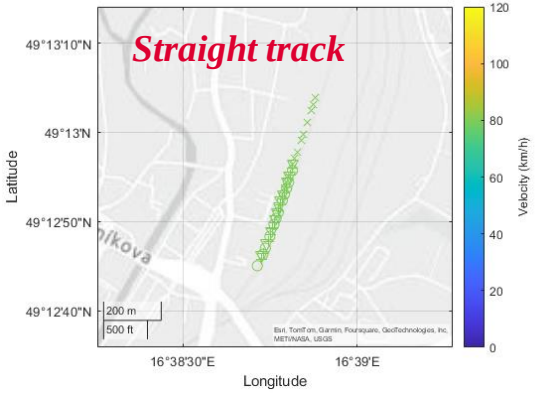
## 5 *Vibrodiagnostics*

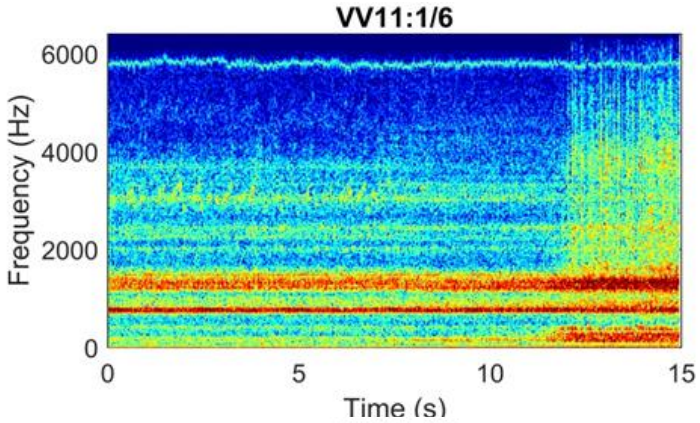
- *Accelerometers installed in ŠKODA 18Ev vehicles*
- *„Wheel-flange contact" use case – feasibility study*
- *According to the lubrication map*

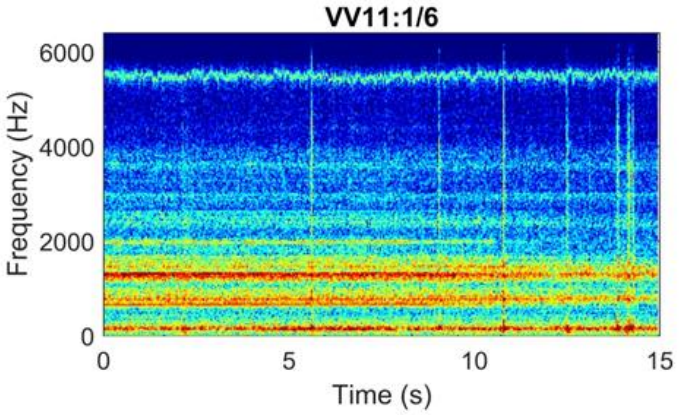



*Accelerometers on bogie*




*Velocity of electric unit in straight track and rail curve and spectrograms*

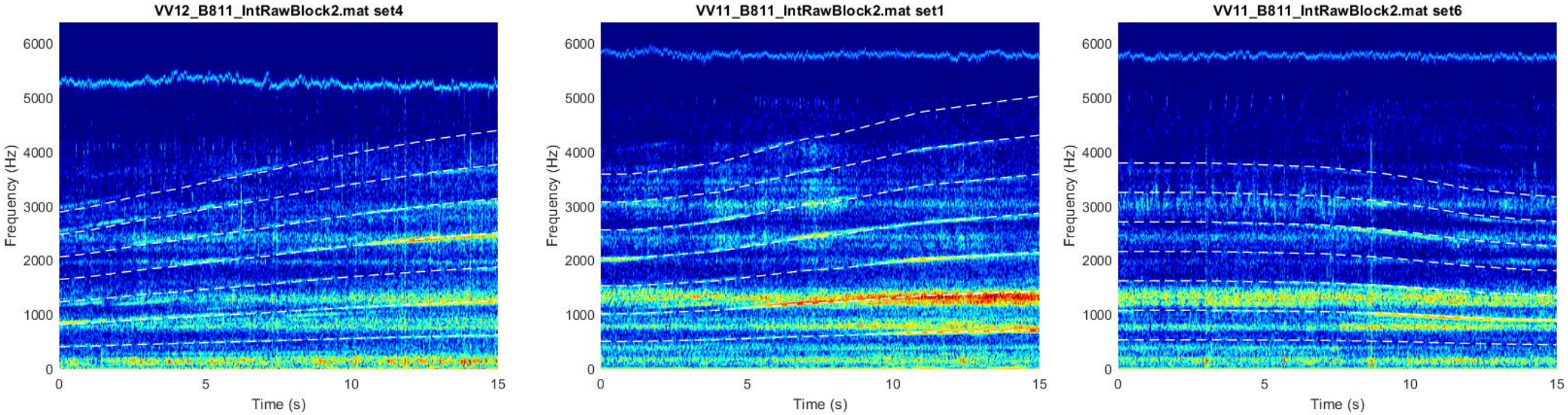
Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

4-WP05-007: **Onboard lubrication unit for advanced friction management**

4-WP05-008: **Prediction of friction in the wheel-rail interface**

## 5 *Vibrodiagnostics*

### *The effect of tooth frequencies*




*Spectrograms with predictions for tooth frequencies and their harmonic multiples (wheel diameter 0.85 m, z1=20, z2=81, records from 03-06-2024)*

Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

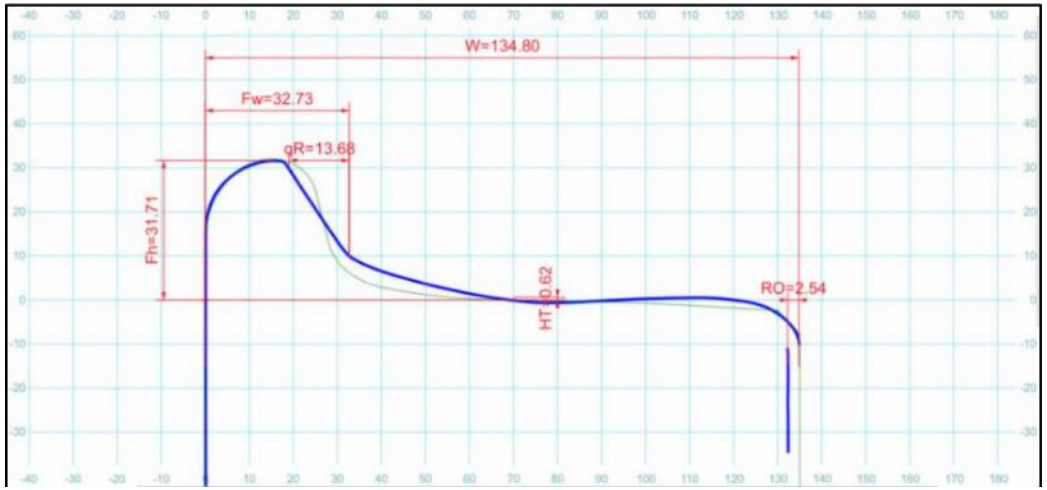
## *Other feedback*

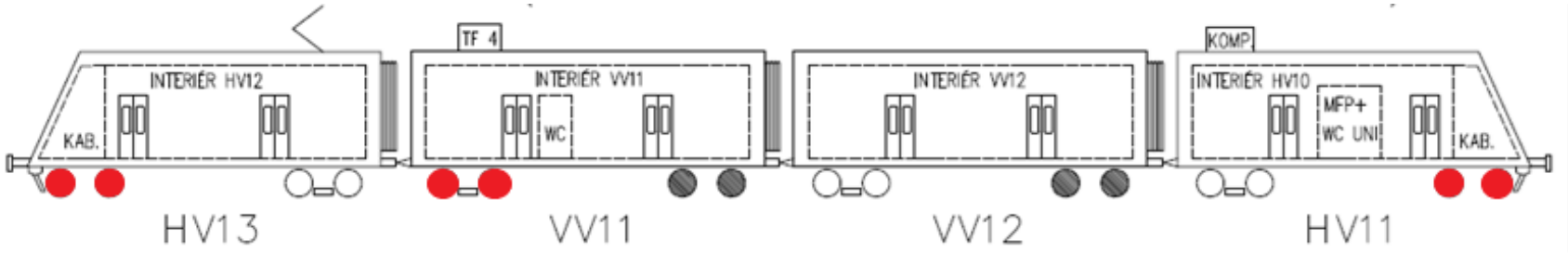
4-WP05-007: **Onboard lubrication unit for advanced friction management**

4-WP05-008: **Prediction of friction in the wheel-rail interface**

### 5 *Vibrodiagnostics*

- *Wear of wheel profile measurement*
- *long-term assessment of the lubrication impact*



Activities in **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

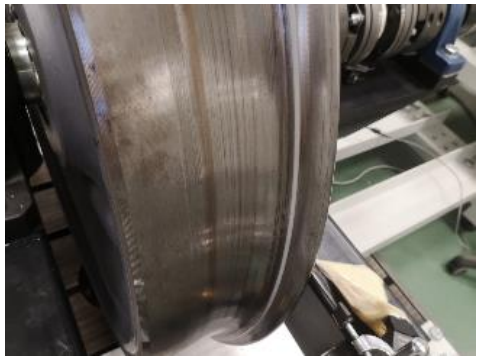
# 4-WP05-007: **Onboard lubrication unit for advanced friction management**

# 4-WP05-008: **Prediction of friction in the wheel-rail interface**

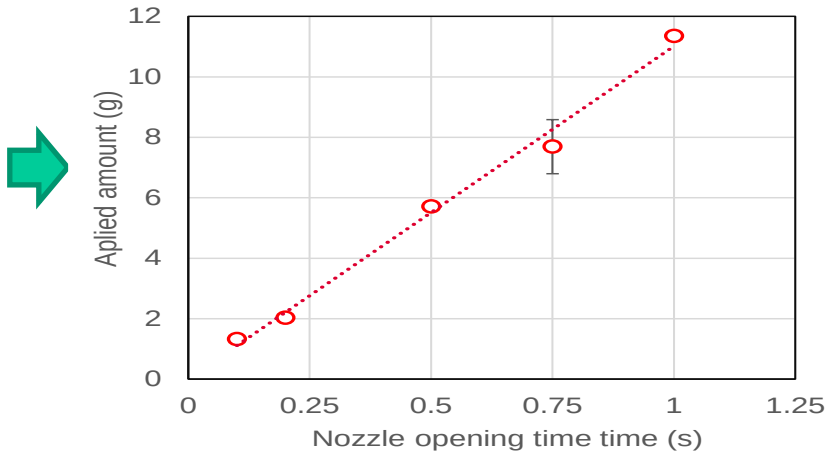
## 6 *Lubrication unit*

***Requirments***

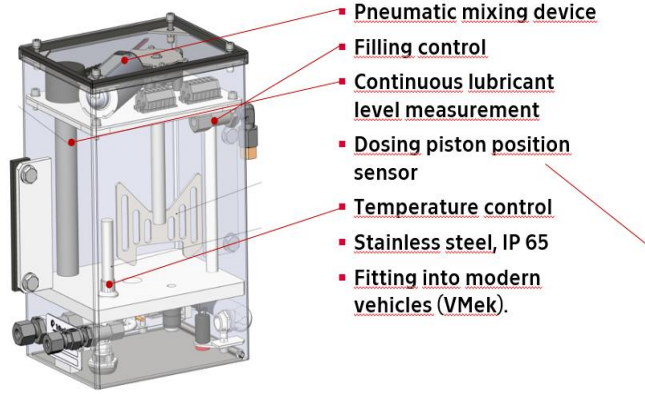
- *Precise dosing*
- *Application feedback*
- *Continuous monitoring*



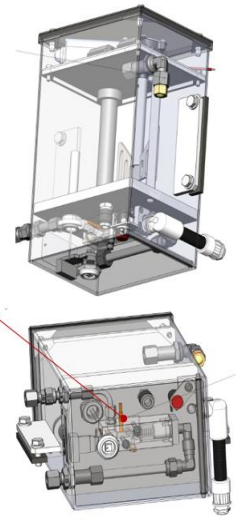
*Development of design a new lubrication unit*




**Lubrication unit**



- Pneumatic mixing device
- Filling control
- Continuous lubricant level measurement
- Dosing piston position sensor
- Temperature control
- Stainless steel, IP 65
- Fitting into modern vehicles (VMek).



Fulfillment of goals and deliverables of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# Current State of Deliverables and Fulfillment of Goals

- 4-WP05-001 | MBS model of a virtual low-floor articulated tram with active elements,O, XII/2025

  FME CTU 0.75 + STRN 0.2 + VÚKV 0.05

  – **in progress & no major delays:**
  - Active silent block technology brings the possibility of applying active wheel guidance technology to modern trams, for which the technology is very suitable
  - A control principle has been proposed that does not incur additional costs for equipping the vehicle with sensors and enables the verification of input values for actuator control from two independent sources
  - The results of MBS calculations of the passage of an articulated modern tram along a real track brought a significant (73%) reduction in the wear index or energy dissipated in the contact between wheel and rail
  - Active wheel guidance technology thus has great potential:
    - reduce the costs of operating trams,
    - increase the comfort of passengers and people moving around the tram line,
    - reduce vehicle energy consumption,
    - enable the wider deployment of cheaper and more capable vehicles with non-rotating chassis even on lines with curves of smaller radii and thus contribute to the further development of tram transport

Fulfillment of goals and deliverables of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

# Current State of Deliverables and Fulfillment of Goals

- 4-WP05-002 | Methodology of design of parameters of elements passive safety of railway vehicles, O, III/2025 — FME CTU 0.9 + SIEMENS Mobility 0.1
- 4-WP05-003 | Methodology of design of shape solution of passive protective elements of given parameters for railway vehicles,O, XII/2025 — FME CTU 0.9 + SIEMENS Mobility 0.1
  - **in progress & no major delays:**
    - a model of a side collision between a middle-class passenger car and a low-floor tram was created
    - findings from the field of compatibility of car body stiffness and road vehicle geometry were evaluated
    - the doctoral thesis of J. Seidl was defended: Methodology for the design of the front of the tram to reduce the consequences of accidents on passenger cars
    - a model of a side collision between a medium-class passenger car and a light rail regional vehicle is being developed
- 4-WP05-003 Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track, XII/2025 — FME CTU 1.0
  - **in progress & no major delays**:
    - suitable sensors were selected, the development of a product for detailed sensor sensitivity testing began

# Fulfillment of goals and deliverables of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Current State of Deliverables and Fulfillment of Goals

- 4-WP05-005 | Test sample of a key part of the railway bogie, $G_{Funk}$, XII/2025,
  VUKV 0.2 + Tatravagonka Poprad 0.8
- 4-WP05-006 | Report on Milestones - New bogie for freight wagons,O, XII/2025
  VUKV 0.8 + Tatravagonka Poprad 0.2

– **in progress & no major delays:**

- activities within the FEFEFOV project extend results received within the CKDV WP02 project (2012-2019)
- agreed an overview of planned activities and outputs within the FEFEFOV project (2023 - 2028)
- prepared preliminary plan o testing (test devices => validation program)
- development of rubber suspension elements and communication with supplier is underway
- development of the FV1 test device and procurement of its main components is underway
- production of steel components of FV1 is started in cooperation with TVP and VÚKV
- development of the FV2 test device (conceptual proposal), preliminary discussions about casting parts

Fulfillment of goals and deliverables of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Current State of Deliverables and Fulfillment of Goals

- 4-WP05-007 | Onboard lubrication unit for advanced friction management,$G_{funk}$ , XII/2025,
  FME VUT 0.3 , Tribotec 0.7
- 4-WP05-008 | Prediction of friction in the wheel-rail interface,O, XII/2025
  FME BTU 0.4 + STRN 0.3 + UPa 0.3

– **in progress & no major delays:**

- the development and implementation of the friction and adhesion control technique by applying the digital twin approach of the Regio Panter electric unit supplied by Skoda Transportation for the South Moravian Region was started.
- a computer map of the railway line Brno - Blansko is created
- tribological models of the wheel-rail interface are improved
- on-board vibration and noise monitoring – methods of identifying vibration and noise monitoring are specified

Fulfillment of goals and deliverables of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## List of Due Deliverables and Their Added Value

- **4-WP05-001** – Research into the use of active elements in low-floor trams enables STRN to maintain its market position. Modern trams with active elements can significantly reduce track wear (approx. 70%) and vehicle noise, especially when driving in curves.
- **4-WP05-002, 4 – WP05-003** – Research and development of new impact elements on the fronts of low-floor trams and regional vehicles is made possible by STRN and Siemens Mobility to contribute to the fulfillment of the goals of the Vision "O" project and to maintain its position on the market. Modern rolling stock meeting EN 12 663 and EN 15227 standards can reduce the consequences of collisions with passenger cars at level crossings by using a flexible passive crash element and thus become friendly to road vehicles.
- **4-WP05-004** – The development of a sensor for the instantaneous position of two wheels in the track can contribute to the acceleration of the introduction of active elements into the bogies of rail vehicles, reducing the guiding forces and the wear of wheels and rails.
- **4-WP05-005, 4 – WP05-006** – Research and development of new two-axle bogie for freights wagons will allow the manufacturer Tatravagónka Poprad to maintain its important position on the world market and will contribute to the reduction of noise, guiding forces and wear of wheels and rails.

Fulfillment of goals and deliverables of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## List of Due Deliverables and Their Added Value

- **4-WP05-007, 4 – WP05-008** – The development and implementation of the friction and adhesion control technique through the application of the digital twin approach to the Regio Panter electric units will enable the Skoda Group manufacturer to optimize costs for a 30-year full service and will contribute to a number of findings leading to the reduction of guiding forces and wear of wheels and rails.

Current contribution of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Assessment of the Contribution of Deliverables

- The issue of partial research works carried out in this package cooperates with and follows on from the partial research works carried out in packages 4-WP01-001 (FEFEFOF).
- Realized research activities should contribute to improving the efficiency of rail vehicles.
- The activities contribute to the expansion of knowledge about new ways of driving rail vehicles, their investigation into driving dynamics and reliability/lifetime.
- New findings and outputs can be applied in the construction of bogies for new rail vehicles, e.g. in Skoda Transportation, Siemens Mobility, Tatravagonka Poprad and others.
- The knowledge gained is regularly presented at professional conferences.

Current contribution of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles

## Assessment of the Formal/Administrative Goals of the Work Package

*We assume that the use of allocated funds, the commercialization of research, and the fulfillment of contractual research will be fulfilled by all partners participating in the implementation of 4-WP05 during the years 2023-2026.*

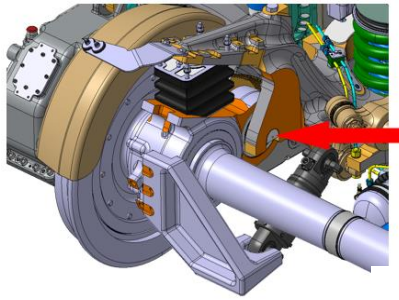
***Acknowledgment***

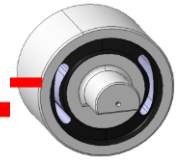
*This research has been realized using the support of Technological Agency, Czech Republic, programme National Competence Centres II, project # TN02000054 Bozek Vehicle Engineering National Center of Competence (BOVENAC).*

# Výtah z prací 2023-2025 na DP4-WP05 Bezpečnost, design, aktivní řízení a mazání okolků u budoucích kolejových vozidel – dosaženo 2023

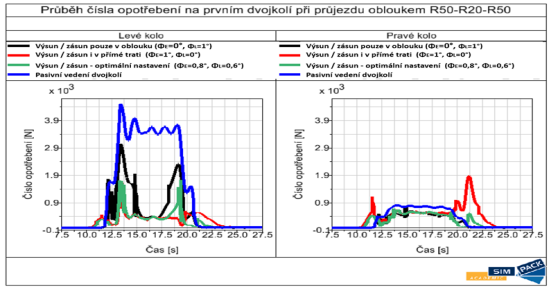
## 4 – WP05 - 001 (O) (ČVUT FS 0.75 + STRN 0.20 + VUKV 0.05)

***MBS model virtuální článkové nízkopodlažní tramvaje s aktivními prvky***





*Pasivní prvek nebo LiCAS actuator ?*

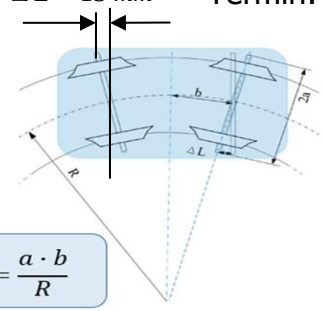



*Výsledky simulací jízdy model článkové nízkopodlažní tramvaje v obloucích*

| Chyba lokalizace vozidla | Průměrné číslo opotřebení [N] | To je % oproti pasivnímu vedení | Průměr disipované energie [J] | To je % oproti pasivnímu vedení |
|---|---|---|---|---|
| ±0 | 457 167 | 34.7 | 2 065 343 | 30.0 |
| ±1 | 467 295 | 35.5 | 2 133 174 | 31.0 |
| ±2 | 490 013 | 37.2 | 2 242 867 | 32.6 |
| ±3 | 520 979 | 39.5 | 2 394 941 | 34.8 |
| ±4 | 555 779 | 42.2 | 2 576 104 | 37.4 |
| ±5 | 593 595 | 45.1 | 2 757 182 | 40.1 |
| ±6 | 632 454 | 48.0 | 2 927 480 | 42.5 |
| ±8 | 711 572 | 54.0 | 3 351 308 | 48.7 |
| ±10 | 791 988 | 60.1 | 3 757 187 | 54.6 |
| ±15 | 987 417 | 74.9 | 4 751 485 | 69.1 |
| ±20 | 1 139 679 | 86.5 | 5 492 419 | 79.8 |

$\Delta L = 15$ mm

Termín: 1.12.2025



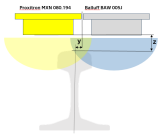

$$\Delta L = \frac{a \cdot b}{R}$$

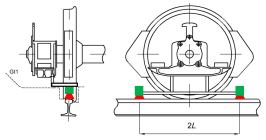
*Analýza , jak řešit posuv ΔL s ohledem na pohon a brzdu ?*

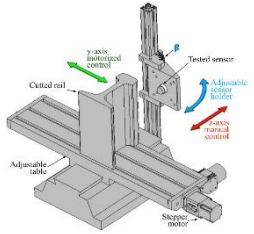
*Posouzení zástavby aktivního prvku do podvozku tramvaje*

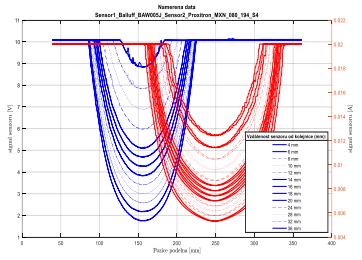
## 4 – WP05 - 004 (O), ČVUT FS 1.0 Termín:1.12.2025

***Rozbor možností koncepčního řešení snímačů pro zjišťování aktuální polohy dvojkolí v koleji***







*Přípravek pro základní test citlivosti senzoru*

## 4 – WP05 - 002 (O), (ČVUT FS 0.9 + SIEMENS Mobility 0.1)

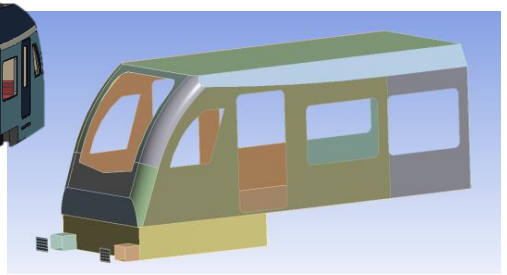
Termín: 1.3.2025

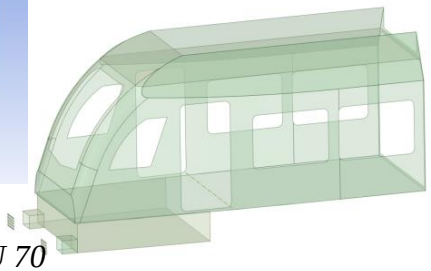
***Metodika návrhu parametrů prvků pasivní bezpečnosti kolejových vozidel***

## 4 – WP05 - 003 (O), (ČVUT FS 0.9 + SIEMENS Mobility 0.1)

Termín: 1.12.2025

***Metodika návrhu tvarového řešení pasivních ochranných prvků daných parametrů pro kolejová vozidla***





*Tvorba crashového modelu čela a kabiny vozidla BEMU 70*

# Božek Vehicle Engineering National Center of Competence

Colloquium Božek 2024 – BOVENAC 19. 11. 2024, CVUM Roztoky

Programme National Competence Centres

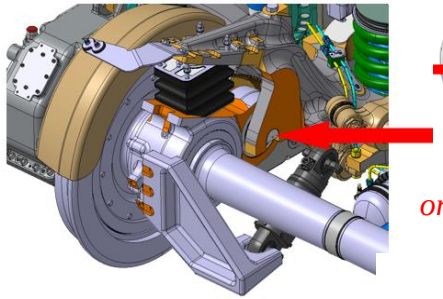
Národní centrum kompetence inženýrství pozemních vozidel Josefa Božka

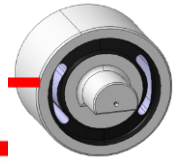
## Results of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles – Achieved 2023

### **4 – WP05 - 001** (O) (CTU FME 0.75 + STRN 0.20 + VUKV 0.05)

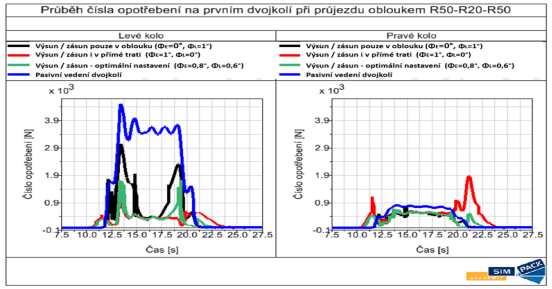
***MBS model of a virtual low-floor articulated tram with active elements***

*Project deadline:* 1.12.2025





*Pasiv element or LiCAS actuator ?*




| Chyba lokalizace vozidla | Průměrné číslo opotřebení [N] | To je % oproti pasivnímu vedení | Průměr disipované energie [J] | To je % oproti pasivnímu vedení |
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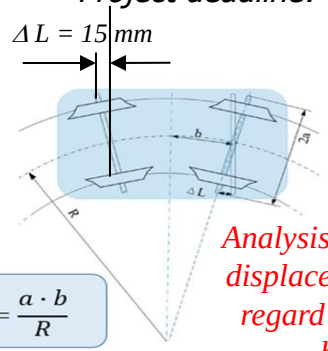



*Analysis, how to solve displacement ΔL with regard to drive and brake?*

*Assessment of the installation of an active element in the tram bogies*

### **4 – WP05 - 002** (O), (CTU FME 0.9 + SIEMENS Mobility 0.1)

*Project deadline:* 1.3.2025

***Methodology of design of parameters of elements passive safety of railway vehicles***

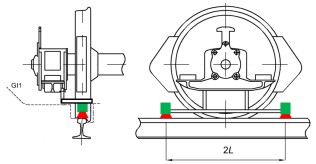
### **4 – WP05 - 003** (O), (CTU FME 0.9 + SIEMENS Mobility 0.1)

*Project deadline:* 1.12.2025

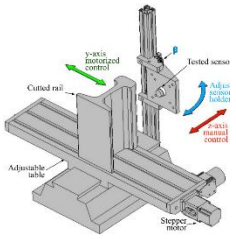
***Methodology of design of shape solution of passive protective elements of given parameters for railway vehicles***

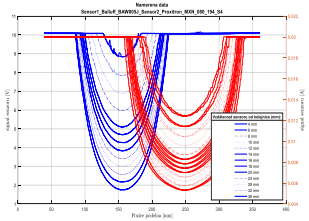
### **4 – WP05 - 004** (O), CTU FME 1.0 *Project deadline:* 1.12.2025

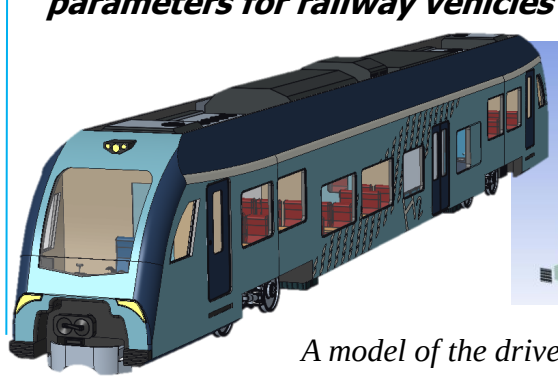
***Analysis of the possibilities of the conceptual solution of sensors for determining the current position of the wheelset in the track***

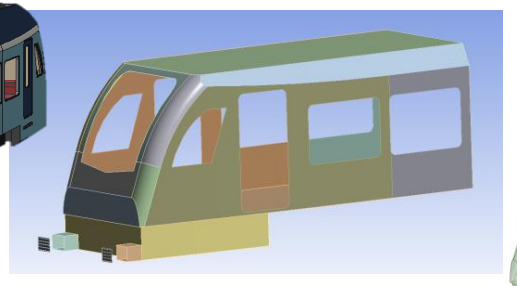


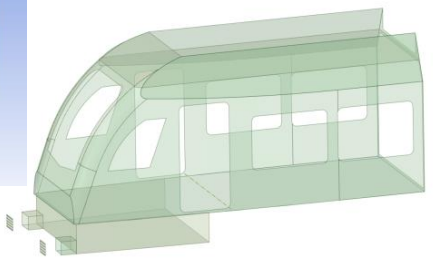
*A stand for a basic sensor sensitivity test*









*A model of the driver's cabin of vehicle BEMU 70*

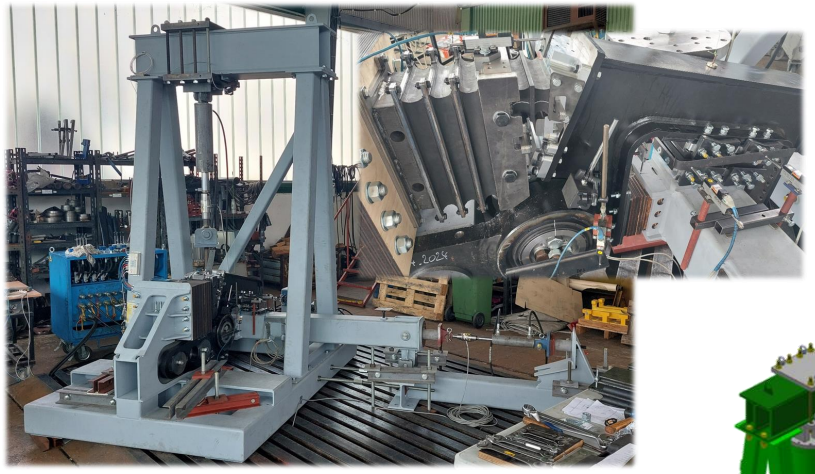
# Výtah z prací 2023-2025 na DP4-WP05 Bezpečnost, design, aktivní řízení a mazání okolků u budoucích kolejových vozidel – dosaženo 2023

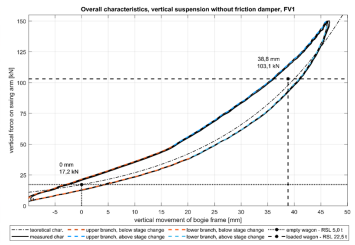
**4 – WP05 - 005** (Gfunk) (VÚKV 0.2, TatraVagónka 0,8) Termín: 1.12.2025

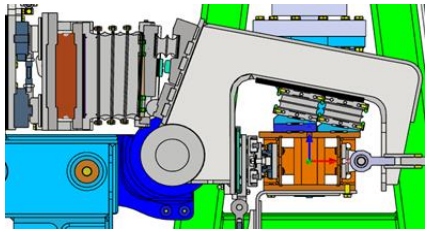
***Testování zkušebních vzorků klíčové části železničního podvozku***

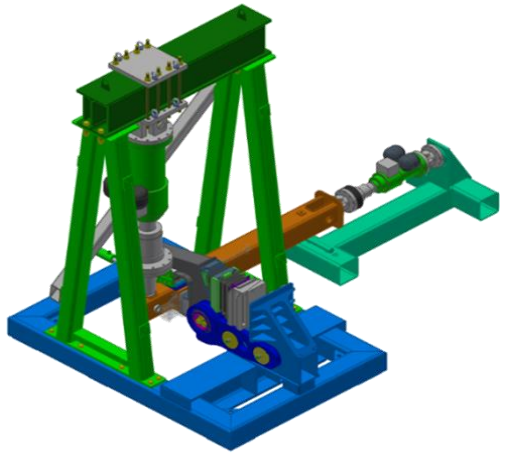
**4 – WP05 - 006** (O) (VÚKV 0.8, Tatra Vagónka 0,2) Termín: 1.12.2025

***Zpráva o milnících – nový podvozek pro nákladní vozy***







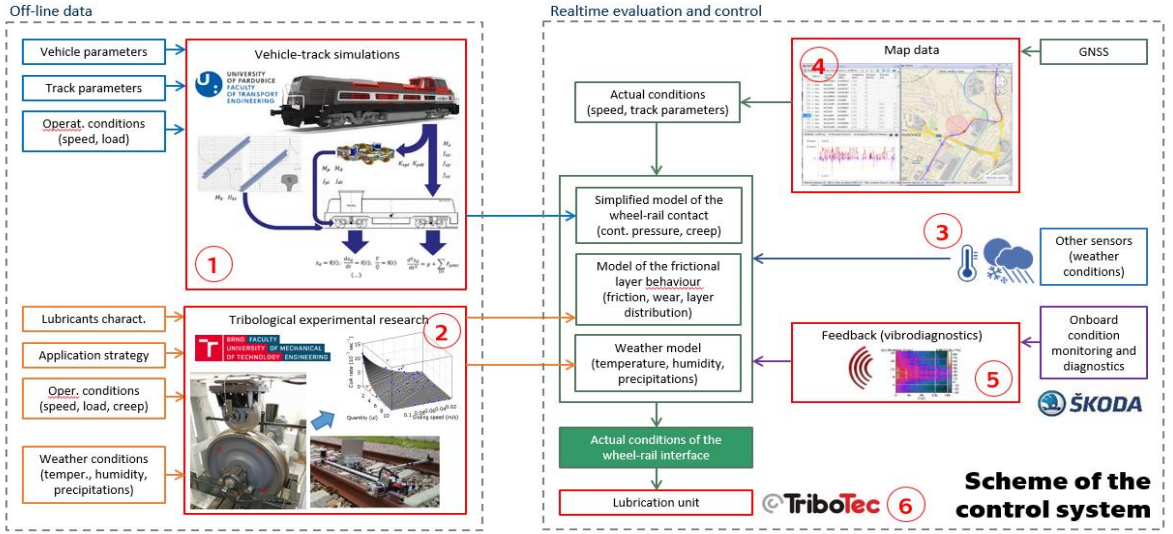
*Testování funkčního vzorku FV1 – porovnání reality vs. 3D model*

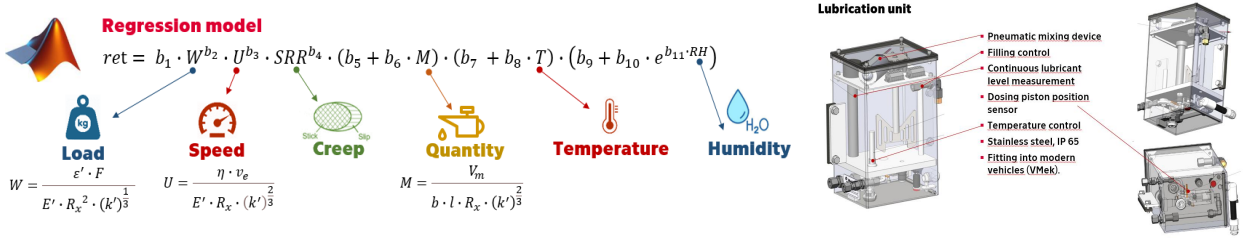
**4 – WP05 - 007** (Gfunk) (FSI VUT 0.3 , Tribotec 0.7) Termín: 1.12.2025

***Palubní mazací jednotka pro pokročilé řízení tření a adheze***

**4 – WP05 - 008** (O) (FSI VTU 0.4 + STRN 0.3 + UPa 0.3) Termín: 1.12.2025

***Predikce tření na rozhraní kolo-kolejnice***




*Koncept řešení digitálních dvojčat elektrické jednotky a vývoj mazací jednotky.*

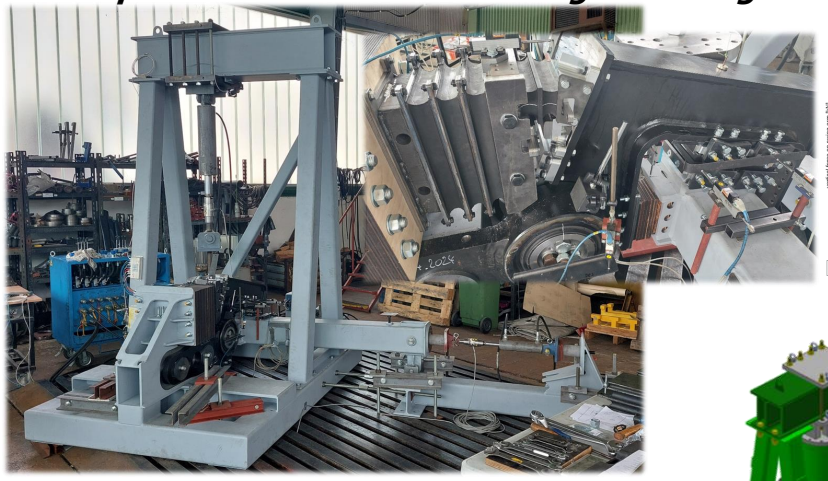
## Results of **4-WP05** Safety, Design, Active Control and Lubrication of Future Rail Vehicles – Achieved 2023

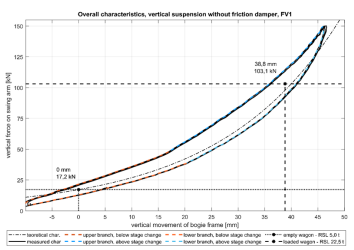
**4 – WP05 - 005** (Gfunk) (VUKV 0.2, Tatra Vagonka 0.8) Project deadline: 1.12.2025

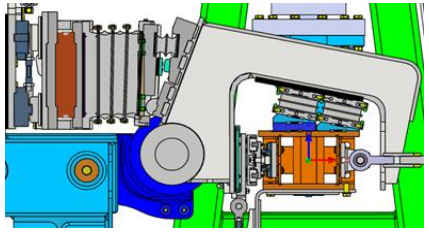
***Test sample of a key part of the railway bogie***

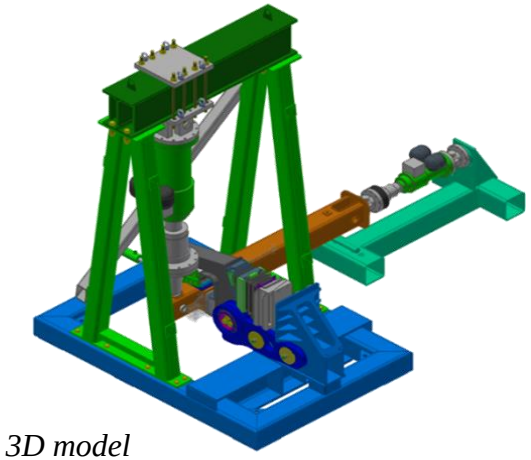
**4 – WP05 - 006** (O) (VUKV 0.8, Tatra Vagonka 0,2) Project deadline: 1.12.2025

***Report on Milestones - New bogie for freight wagons***







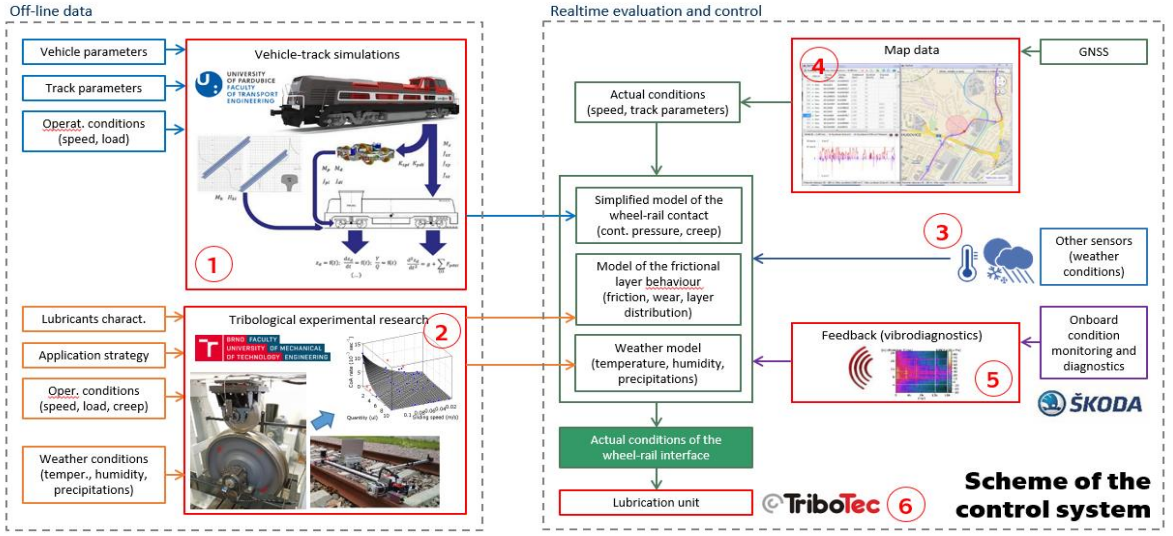
*Test sample FV1 - comparison reality vs. 3D model*

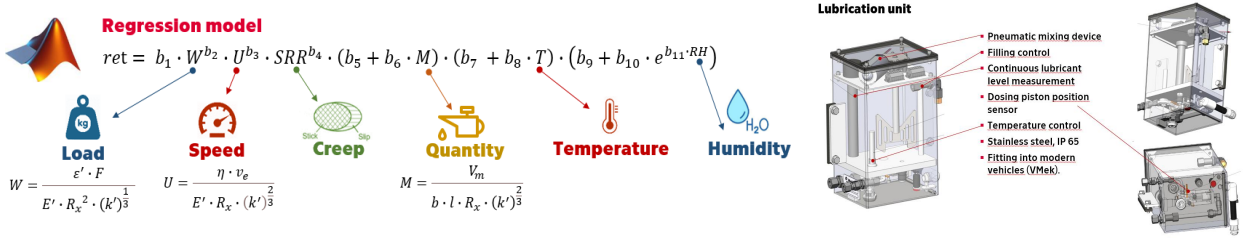
**4 – WP05 - 007** (Gfunk) (FME BTU 0.3 , Tribotec 0.7) *Project deadline:* 1.12.2025

***Onboard lubrication unit for advanced friction management***

**4 – WP05 - 008** (O) (FME BTU 0.4 , STRN 0.3, UPa 0.3) *Project deadline:* 1.12.2025

***Prediction of friction in the wheel-rail interface***




*Schema of Electric unit digital twin solution concept and lubrication unit development.*