

## Contents of Work Package **3-WP09: New Solutions for Automotive Transmissions**

### **3-WP09: New Solutions for Automotive Transmissions**

#### **Coordinator of the WP**

České vysoké učení technické v Praze, doc. Dr. Ing. Gabriela Achtenová

#### **Participants of the WP**

VŠB – Technická univerzita Ostrava

ŠKODA AUTO a. s.

CompoTech Plus

#### **Main Goal of the WP**

Research into new materials, production or technological procedures, structural elements, as well as completely new concepts of transmission mechanisms with the primary goal of reducing vibrations and noise. Support for structural design and experimental measurement using simulation and calculation methods.

#### **Partial Goals for the Current Period**

Composite shaft design for use in vehicles. Design of microgeometry of automotive transmission gearing to reduce transmission error and for final grinding of asymmetric powder metal gearing. Development of a simulation tool for gear stiffness measurement

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## **3-WP09: New Solutions for Automotive Transmissions**

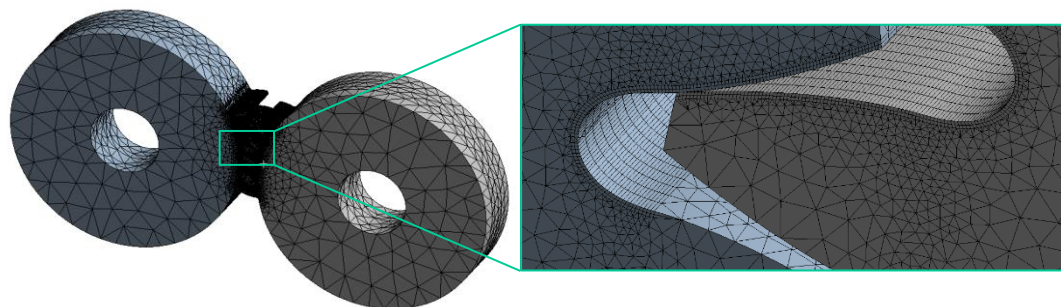
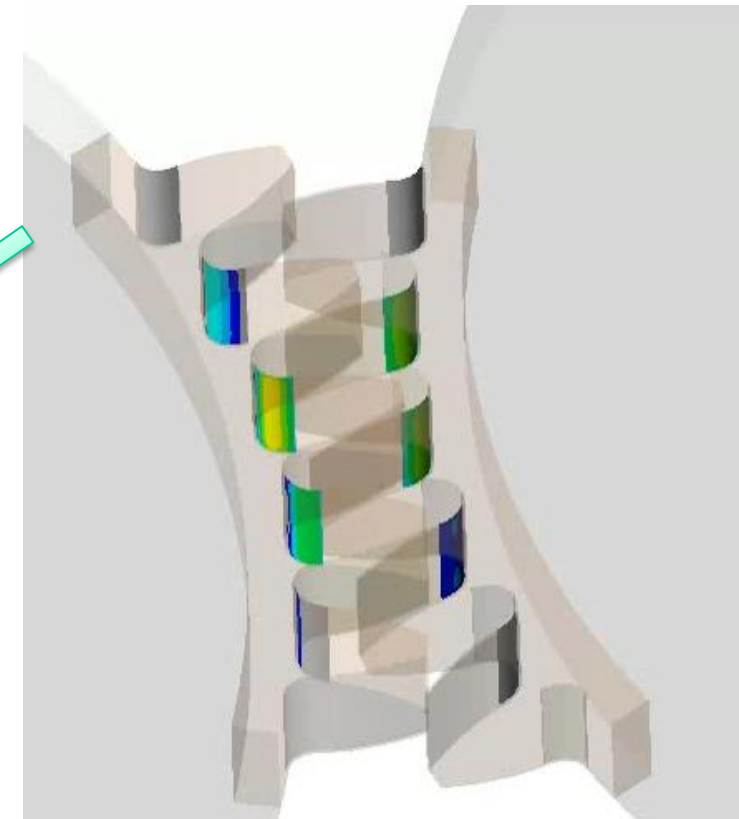
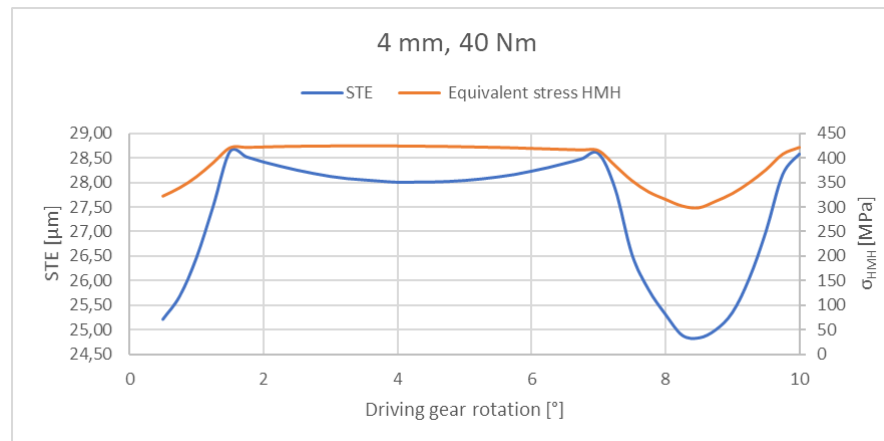
### **Official 3-WP09 Deliverables**

- 3-WP09-001 | **Gear with low transmission error**, G-funk, VI./2026, BUT 0.3; TUO 0.3; SA 0.4
- 3-WP09-002 | **Digital twin of the test bench for monitoring gear mesh**, O, VI./2026, BUT 0.3; TUO 0.3; SA 0.4
- 3-WP09-003 | **Composite Joint Shaft**, G-funk, XII./2025, CTU FME 0.4; SA 0.1, Compotech 0.5
- 3-WP09-004 | **Composite Joint Shaft dedicated and optimised for usage in passenger car's powertrains**, O, VI./2026, CTU FME 0.4; SA 0.1, Compotech 0.5
- 3-WP09-005 | **Powder Metal assymetric gearwheels**, G-funk, XII/2025, CTU FME 0.6; SA 0.4
- 3-WP09-006 | **Gearboxes for electric vehicles**, O, VI/2026, CTU FME 0.9; SA 0.1

## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-001: Gears with low Transmission Error.

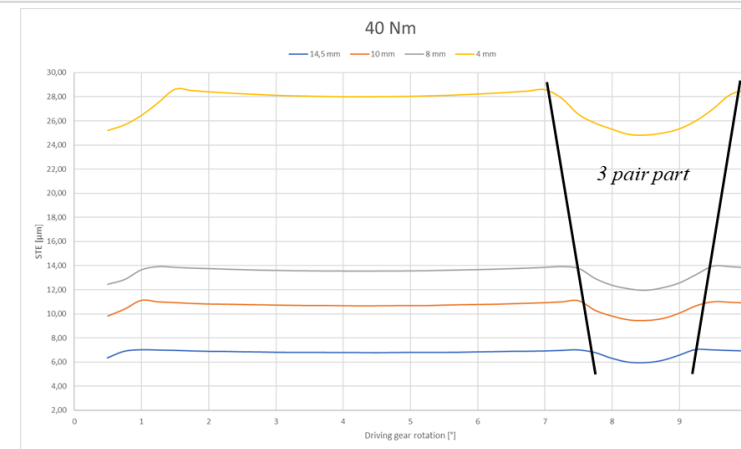
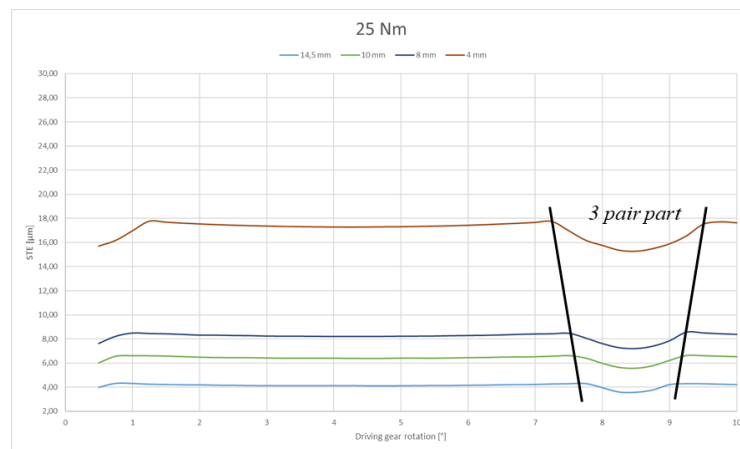
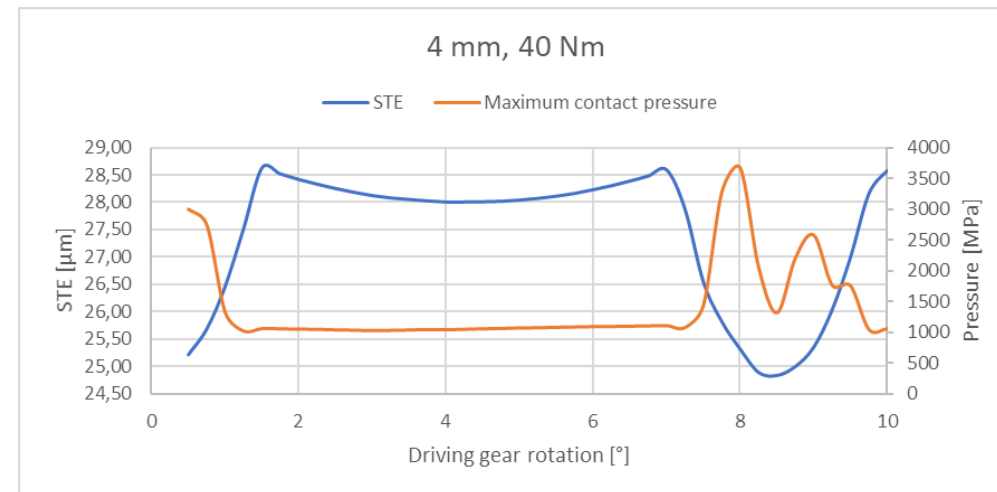
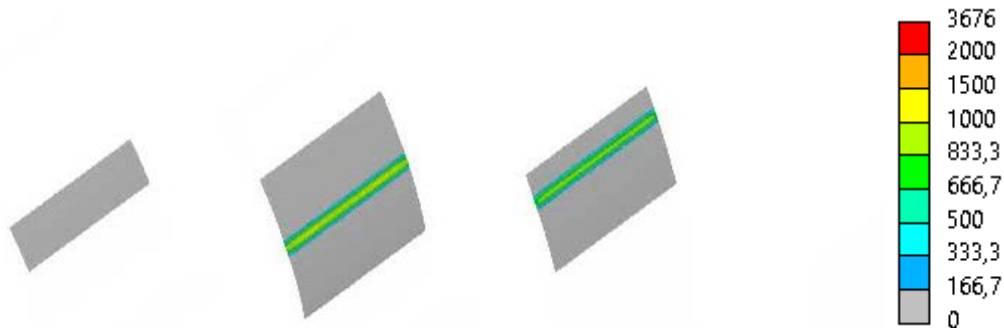
- Determination of gears for sensitivity study
  - Different width of gear
  - Determination of stress distribution
  - Different loading with respect of test rig for evaluation



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-001: Gears with low Transmission Error.

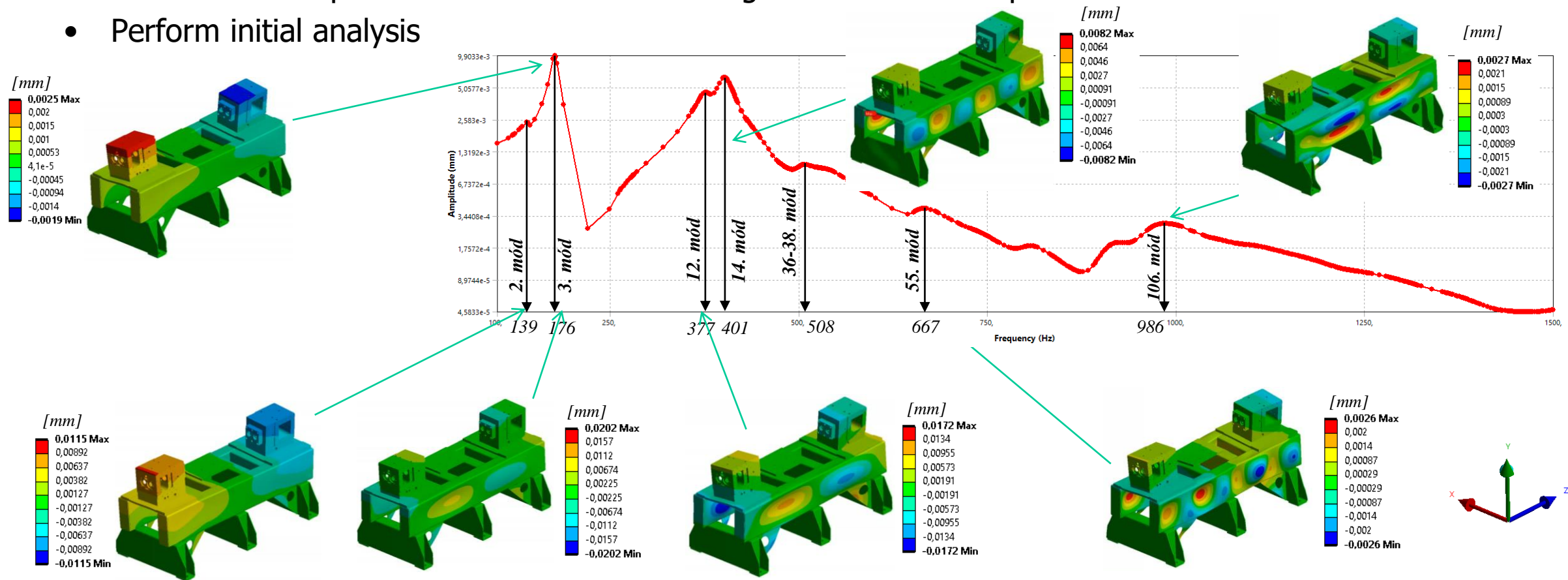
- Sensitivity study
  - Different thickness of geometry



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-002: Digital twin of the test bench for monitoring gear mesh stiffness.

- Creation of computational model of the test rig to determine the position of sensors
- Perform initial analysis

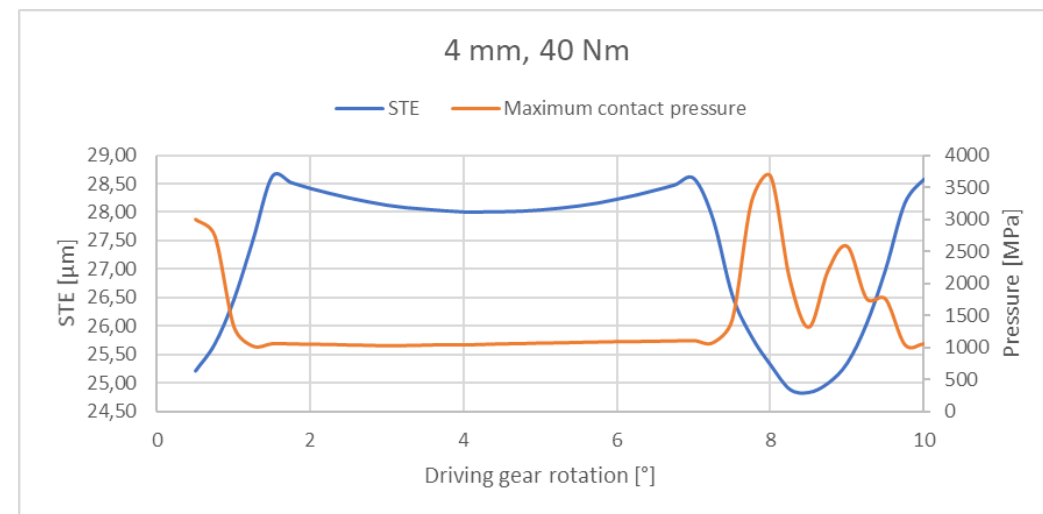
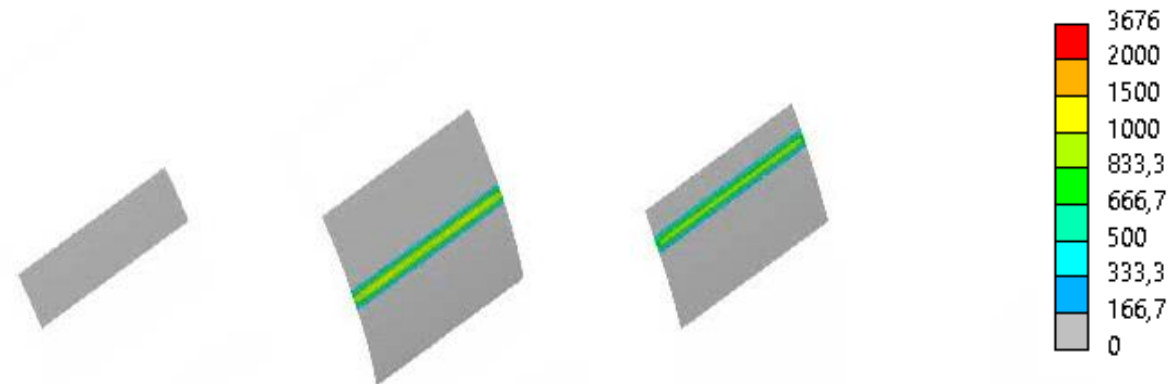




## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-002: Digital twin of the test bench for monitoring gear mesh stiffness.

- Perform initial measurement
  - Static transmission error – low RPM
  - Dynamic transmission error – up to 1000 RPM
  - Vibration measurement
  - Determination of TE – comparison to numerical simulation



## Activities in **3-WP09 New Solutions for Automotive Transmissions**

### **3-WP09-003: Composite joint shaft**

- Torque – 3200 Nm
- Max speed – 3100 rpm
- Weight reduction (currently 11 059 g)
- Maintain fatigue life, temperature and chemical resistance and price



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

- Critical speed
  - Higher diameters, higher stiffness → higher critical speed
  - Lower density, lower length → higher critical speed

$$n_{krit} = \frac{30\pi}{4} \cdot \sqrt{\frac{E}{\rho}} \cdot \frac{\sqrt{D^2 + d^2}}{L^2}$$

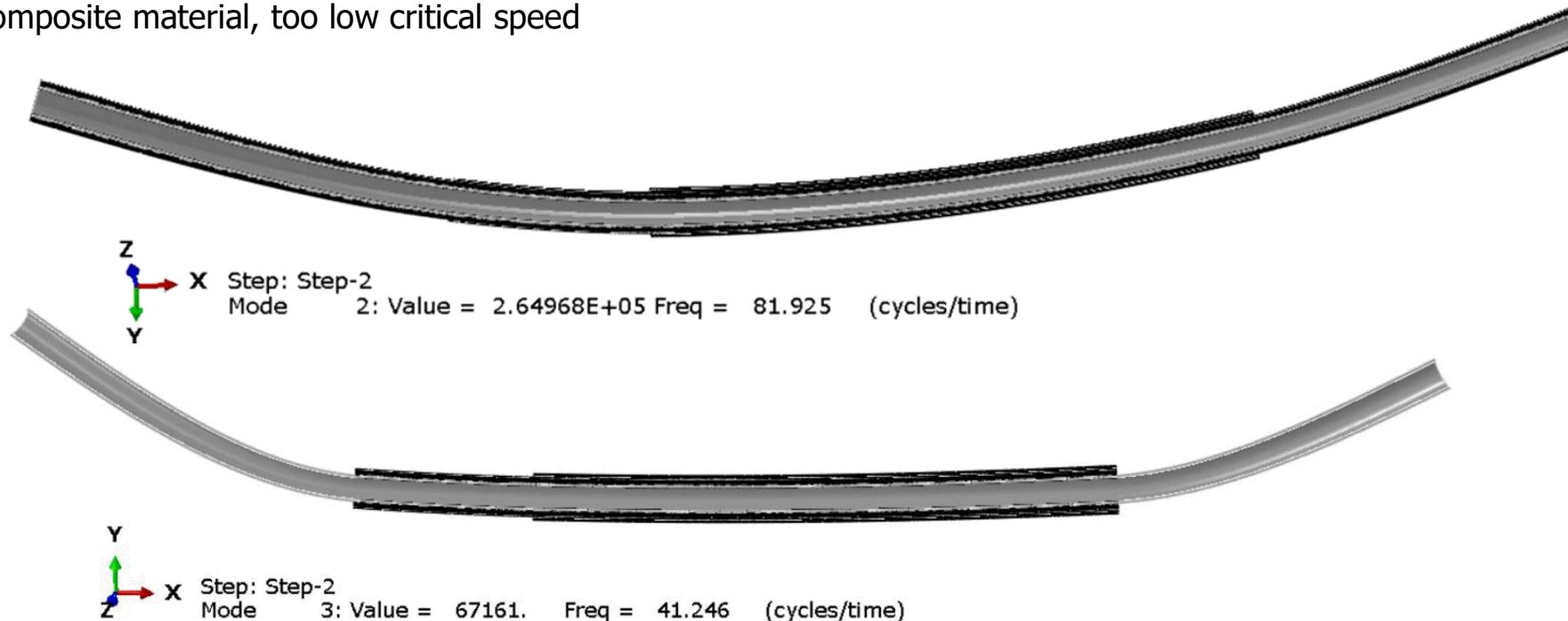




## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

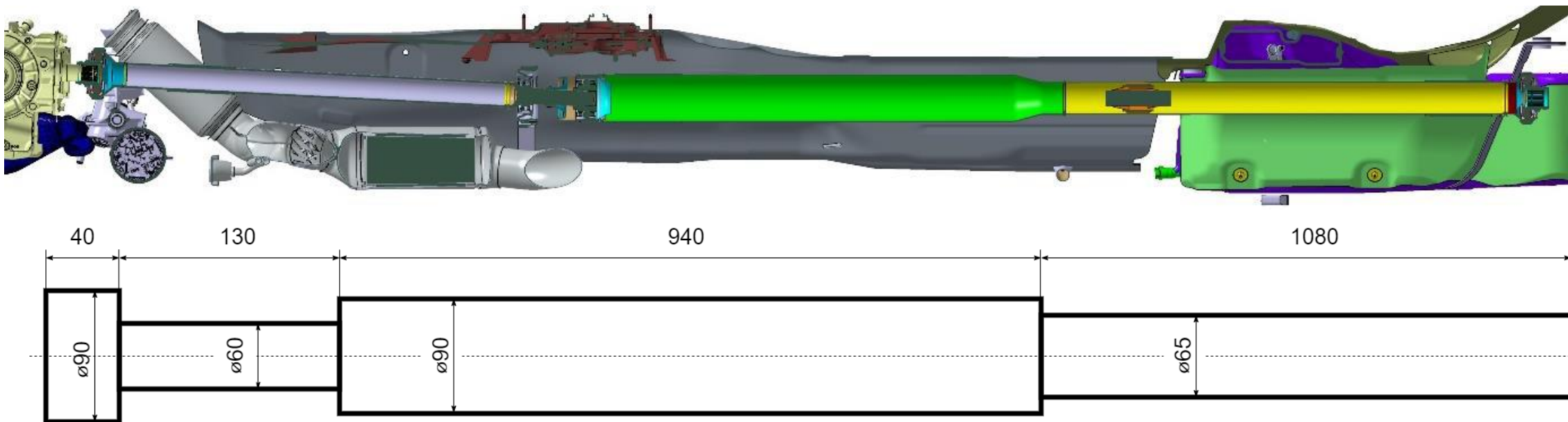
- Initial proposals
  - Combination of steel and UHM as reinforcement
  - Using just composite – not enough strength
  - Upper picture – critical speed ok, expensive (too much composite)
  - Lower picture – less composite material, too low critical speed



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

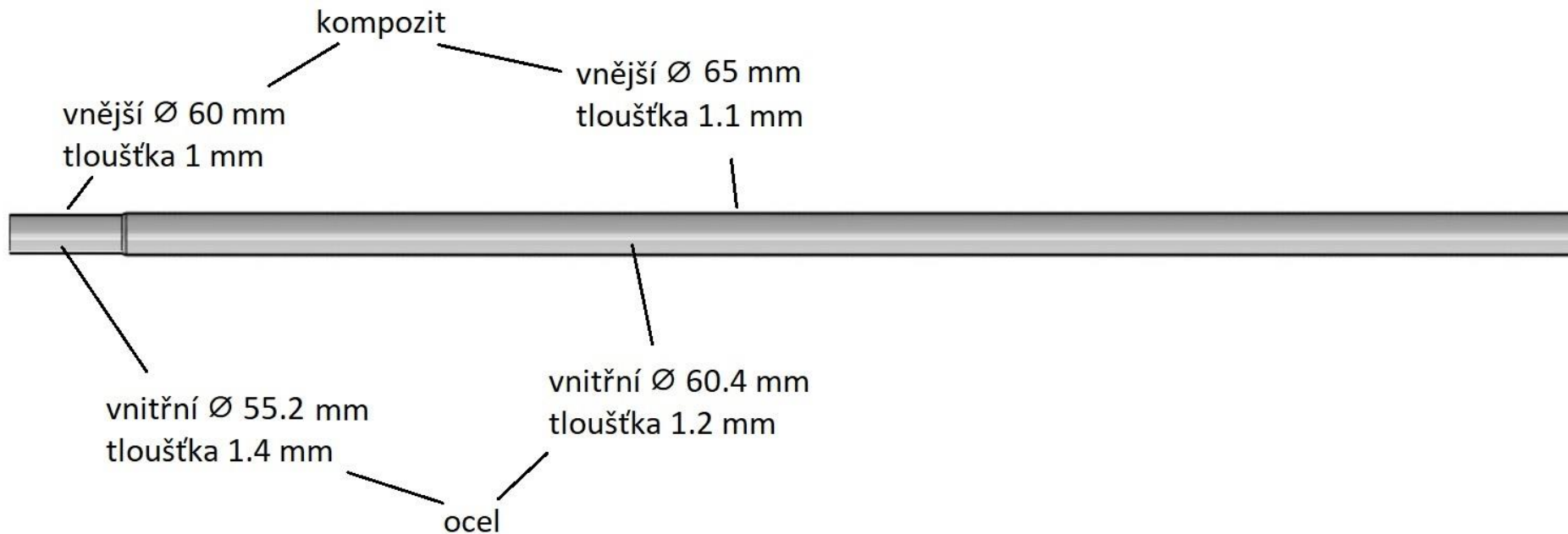
- Compromise solution
  - Leaving out parts to increase space for the shaft
  - New space for the shaft:



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

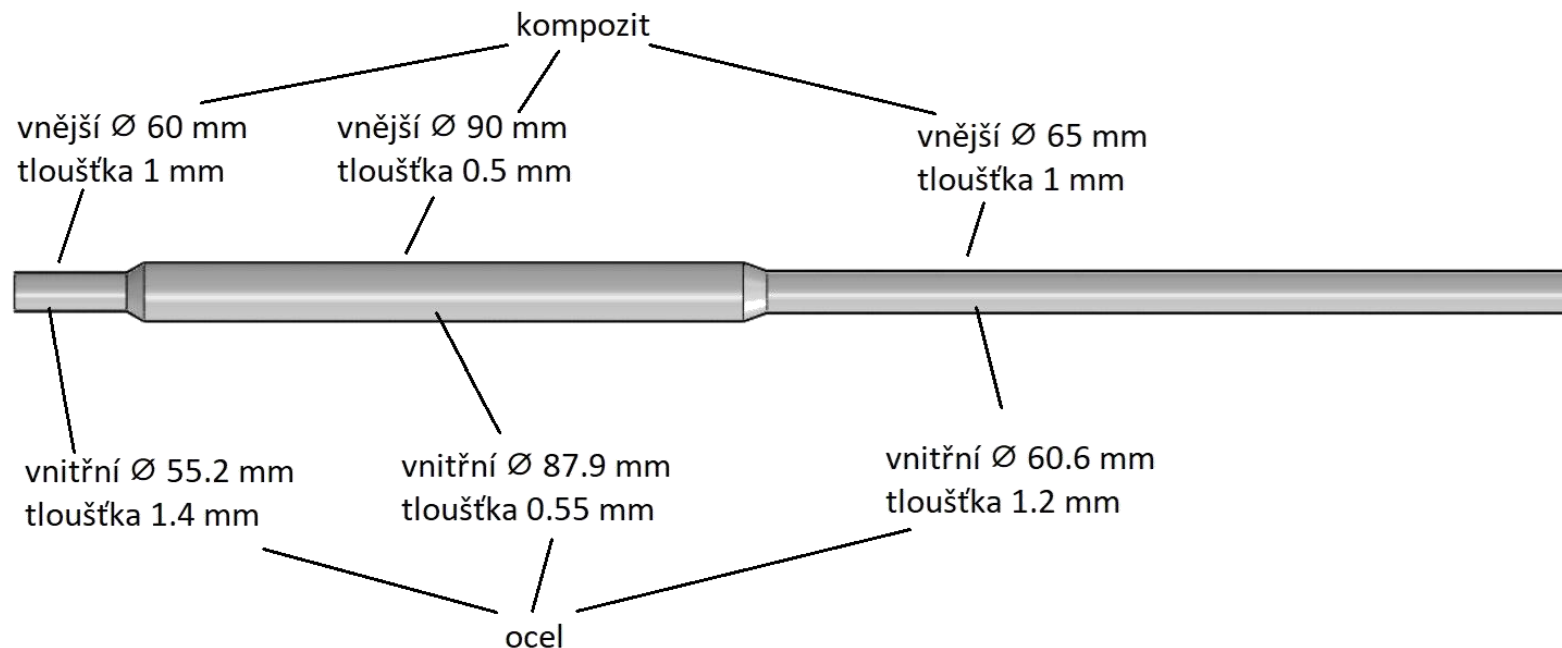
- Steel shaft – torque transmission, composite reinforcement – bending stiffness
- Critical speed 3210 rpm
- Price of composite 66 € (rough estimate 80 €/kg)



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

- Steel shaft – torque transmission, composite reinforcement – bending stiffness
- Critical speed 3350 rpm
- Price of composite 50 € (rough estimate 80 €/kg)
- Unfavorable – varying diameter of the steel shaft

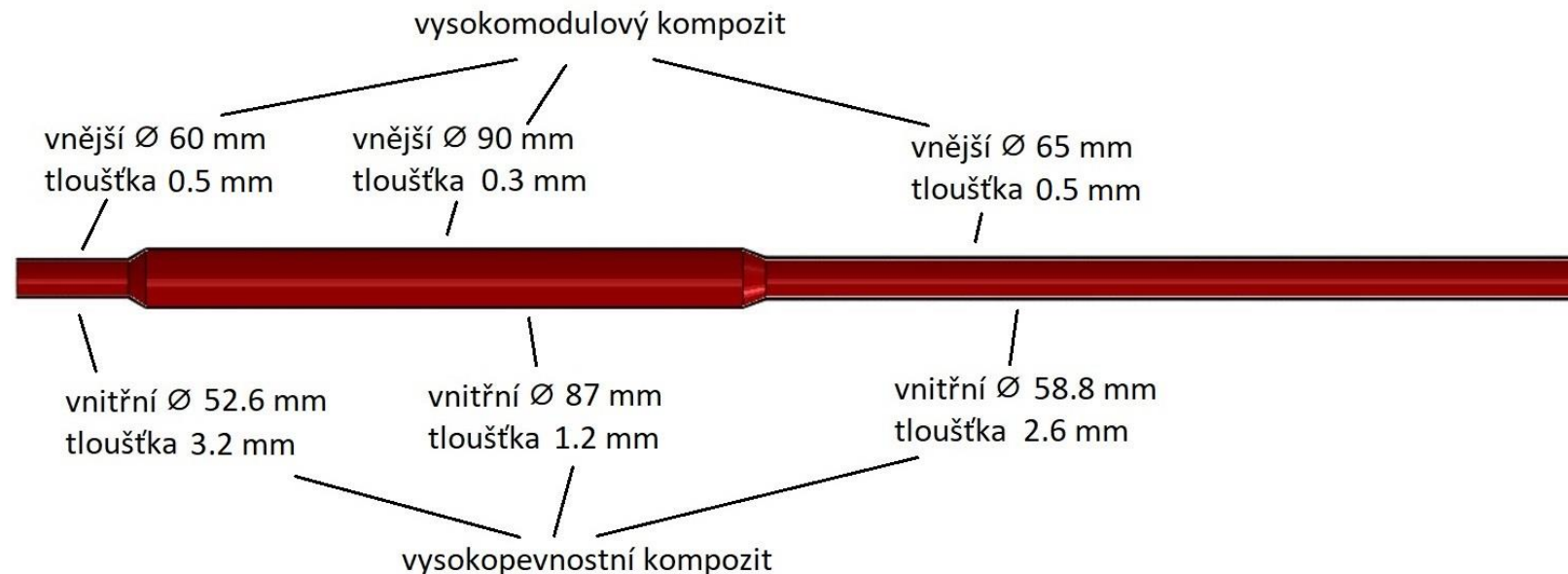




## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

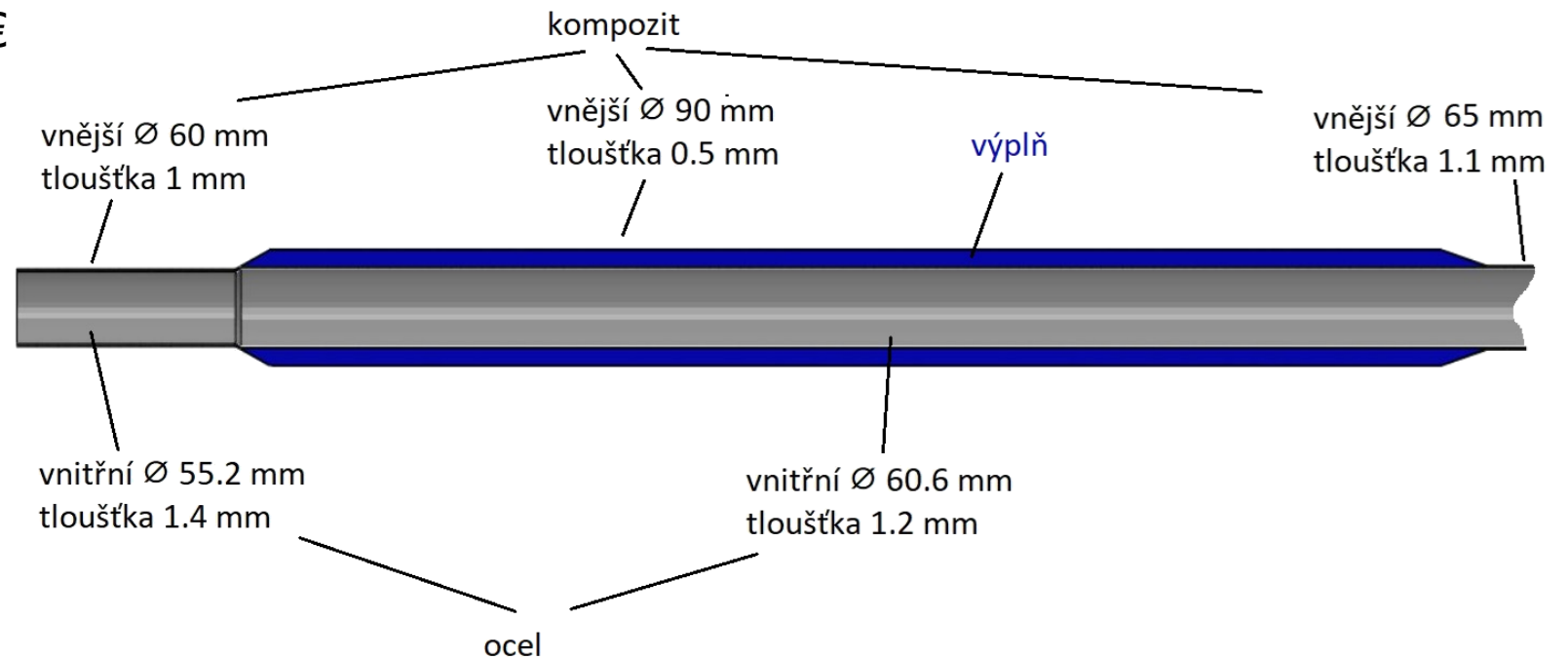
- Only composite
- HS  $\pm 45^\circ$  orientation – torque transmission, UHM  $0^\circ$  orientation – bending stiffness
- Critical speed 3310 rpm
- Price of composite 75 € (rough estimate HS 30 €/kg, UHM 80 €/kg)
- **Unable to withstand the load – low strength**



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

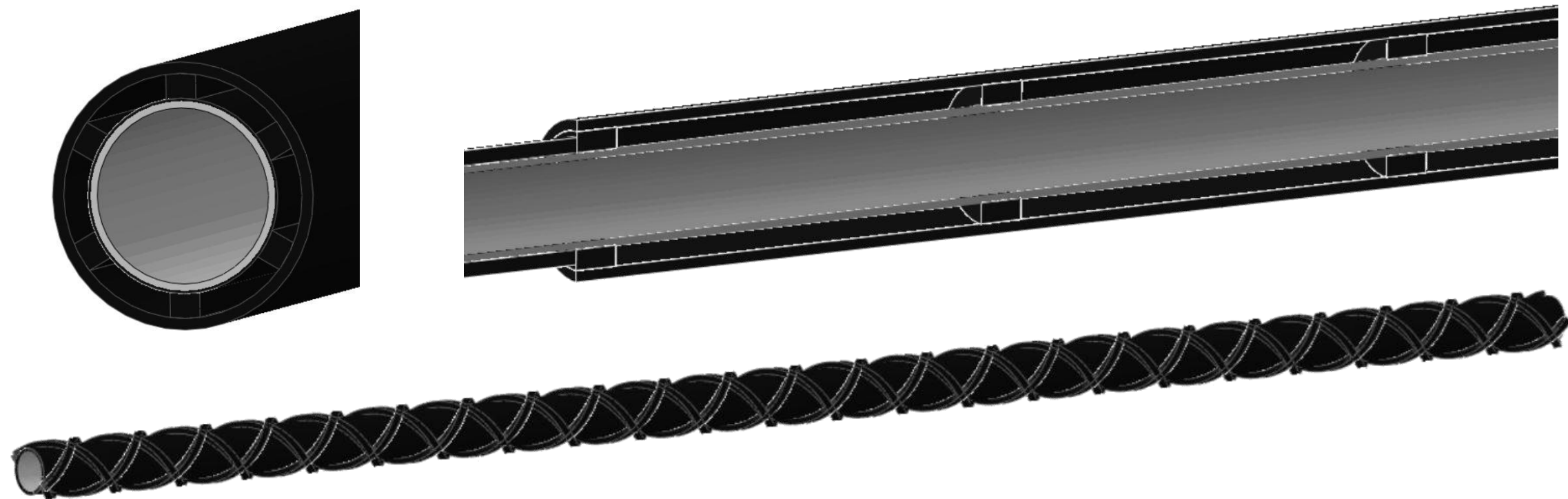
- Steel shaft – torque transmission
- Composite reinforcement – bending stiffness
- Filling – allowing the composite to be on high diameter (hard foam for example)
- Critical speed in the same range as before but depends on material of the filling
- Price of composite 50-60 €



Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-003: Composite joint shaft

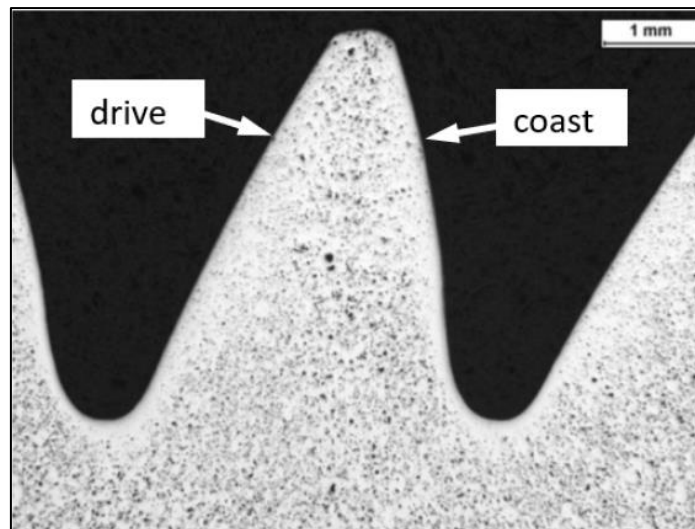
- Other concepts



## Activities in 3-WP09 New Solutions for Automotive Transmissions

### 3-WP09-005: Powder metal Asymmetric gearwheels

- In cooperation with our partner SKODA AUTO and other partners were in frame of PhD thesis fabricated asymmetric powder metal gearwheels with the rolling technology
- The structure of produced gearwheels was analysed with help of Light Optical Microscopes



Large gear (z=48) - overview



Large gear (z=48) - root

Source: Miláček O. *New Possibilities for Gearwheels in Automotive Gearboxes. CTU PhD Thesis. 2023*



## Activities in **3-WP09 New Solutions for Automotive Transmissions**

### **3-WP09-005: Powder metal Asymmetric gearwheels**

- The first proposal for microgeometry was defined.
- The companies capable to ensure such specific operation were contacted. The selection of the company is currently underway
- The closed-loop test stand will be used for first set of tested gearpairs.
- The main outcomes of this workpackage will be explored during next year

## Activities in **3-WP09 New Solutions for Automotive Transmissions**

### **3-WP09-006: Gearboxes for electric vehicles**

- Definition of requirements for search of new designs for gearboxes of electric vehicles:
  - Usage of new materials (e.g. Composite, powder metal)
  - New materials = new technology of fabrication => nontraditional approach
  - Combination of several tasks (e.g. Differential and ratio reduction)
  - Low amount of gears
  - High reduction ratio
  - Dog clutch shift (optional)
  - Possibility of hybrid usage (several sources)
- Chosen category of the vehicle
  - Small vehicle (Gross weight 1500 kg)

## Activities in **3-WP09 New Solutions for Automotive Transmissions**

### **3-WP09-006: Gearboxes for electric vehicles**

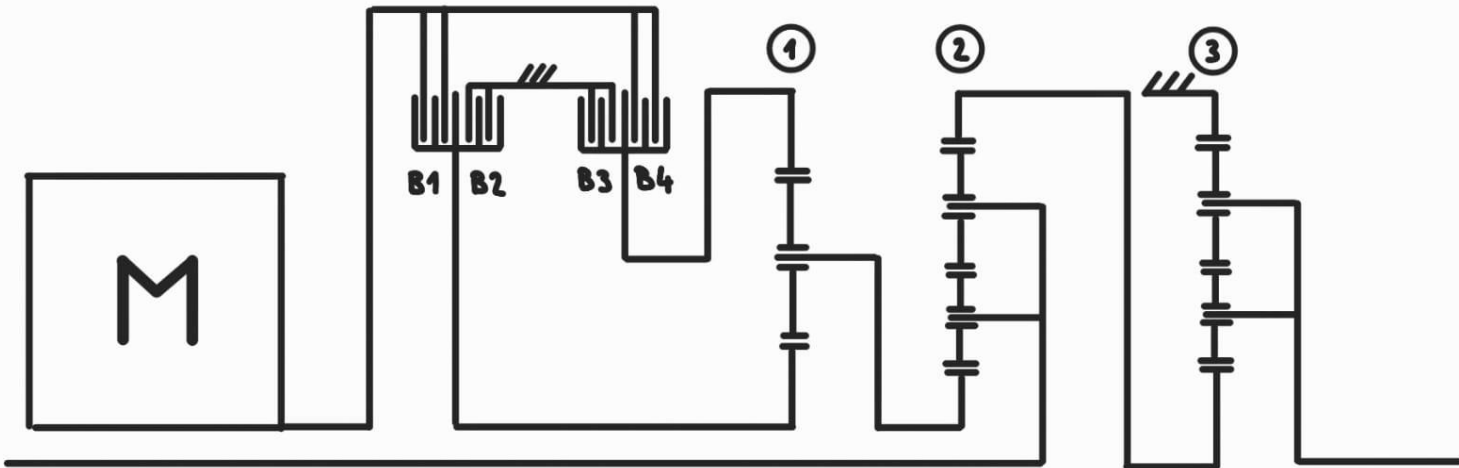
- First approach – design requirements:
  - Hollow electric motor
  - Minimal two speed gearbox, integrated function of differential and final drive
  - Usage of single planetary sets (optional; preferable)
  - Preferred solution without internal gearmesh
  - One shift element opens, one shift element is engaging
  - Low amount of opened clutches/brakes
  - Base ratios in limits of manufacturability, good efficiency
  - Fullfilled conditions of assembly

	<b>Ratio</b>
<b>1<sup>st</sup> speed</b>	<b>+/- 15</b>
<b>2<sup>nd</sup> speed</b>	<b>+/- 7,5</b>

Activities in 3-WP09 New Solutions for Automotive Transmissions

3-WP09-006: Gearboxes for electric vehicles

Variant 1



	B1	B2	B3	B4
$i_{p1}$	X		X	
$i_{pn}$		X		X

Set 1	Set 2	Set 3
$z_{p1} = 34$ [1]	$z_{p2} = 18$ [1]	$z_{p3} = 30$ [1]
$z_{k1} = 68$ [1]	$z_{k2} = 63$ [1]	$z_{k3} = 72$ [1]
$z_{s1} = 17$ [1]	$z_{s2max} = 22,5$ [1]	$z_{s3max} = 21$ [1]

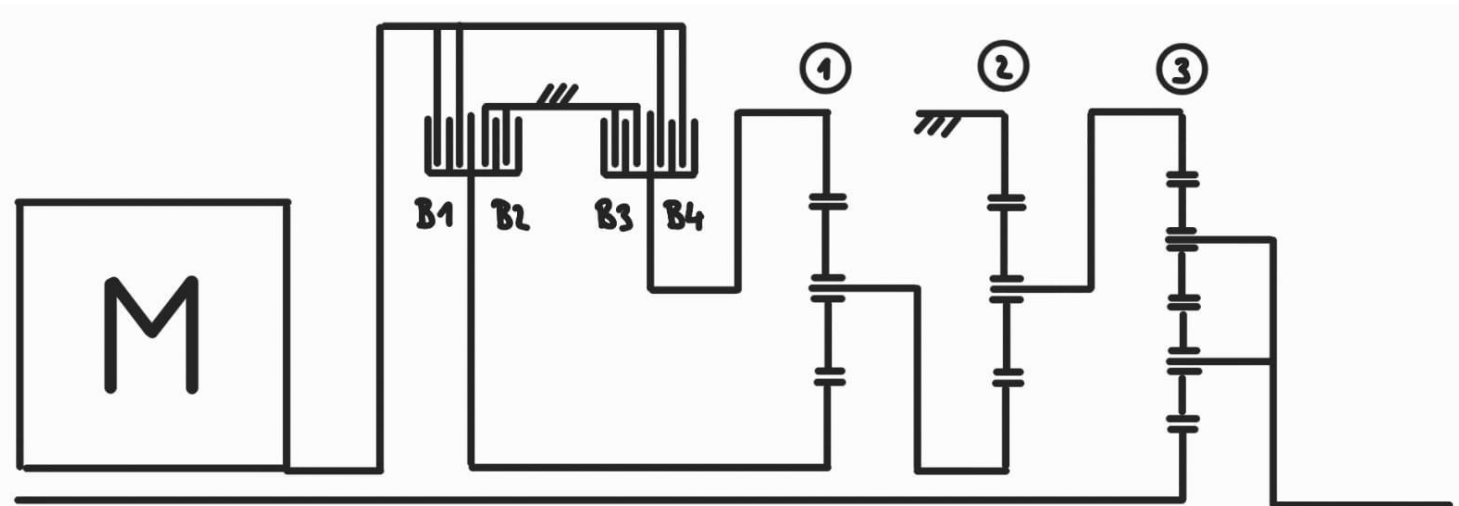
Source: Pelant Š. Diploma project, CTU in Prague, 2023



Activities in **3-WP09 New Solutions for Automotive Transmissions**

**3-WP09-006: Gearboxes for electric vehicles**

**Variant 2**



	B1	B2	B3	B4
$i_{p1}$	X		X	
$i_{pn}$		X		X

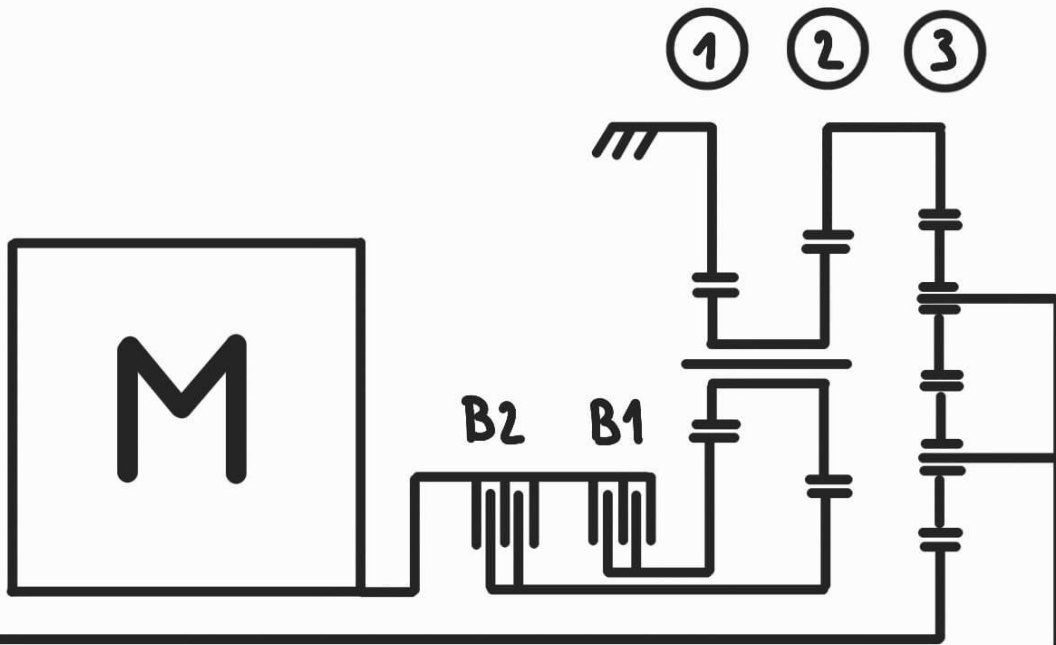
Set 1	Set 2	Set 3
$z_{p1} = 34 [1]$	$z_{p2} = 18 [1]$	$z_{p3} = 38 [1]$
$z_{k1} = 68 [1]$	$z_{k2} = 72 [1]$	$z_{k3} = 76 [1]$
$z_{s1} = 17 [1]$	$z_{s2} = 27 [1]$	$z_{s3max} = 19 [1]$

Source: Pelant Š. Diploma project, CTU in Prague, 2023

Activities in **3-WP09 New Solutions for Automotive Transmissions**

**3-WP09-006: Gearboxes for electric vehicles**

**Variant 3**



	B1	B2
$i_{p1}$		X
$i_{pn}$	X	

Set 1	Set 2	Set 3
$z_{p1} = 32$ [1]	$z_{p2} = 21$ [1]	$z_{p3} = 38$ [1]
$z_{k1} = 66$ [1]	$z_{k2} = 77$ [1]	$z_{k3} = 76$ [1]
$z_{s1} = 17$ [1]	$z_{s2} = 28$ [1]	$z_{s3max} = 19$ [1]

Source: Pelant Š. Diploma project, CTU in Prague, 2023

## Activities in **3-WP09 New Solutions for Automotive Transmissions**

### **3-WP09-006: Gearboxes for electric vehicles**

- Future work:
  - Detailed investigation of kinematics, torque and energetic parameters of proposed solution in order of defined best solution from the point of view of possibility of usage of dog clutches and best efficiency
  - Further investigation of single planetary sets with passive spider
  - Search of solution with external gearwheels
  - Dimensional and energetic parameter comparison with standard solutions (fixed shaft designs, design without integrated differential, design without hollow electric motor).