Contents of Work Package 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12: WP12 Optimization of the Key Design Units of New Generation Vehicles

Coordinator of the WP

University of West Bohemia, responsible person: Ing. Pavel Žlábek, Ph.D.

Participants of the WP

ŠKODA TRANSPORTATION a.s._Ing. Petr Špalek

VZÚ _ Ing. Jan Chvojan, Ph.D

UWB – Regional Technological Institute _ Ing. Pavel Žlábek, Ph.D

Main Goal of the WP

2-WP12-001 Composite train drive shaft. This composite shaft should replace the currently used shaft made from steel, but due to composite it should have lower weight and better dynamic behaviour. There will be done special focus on connection between the flange and composite part of the shaft too.

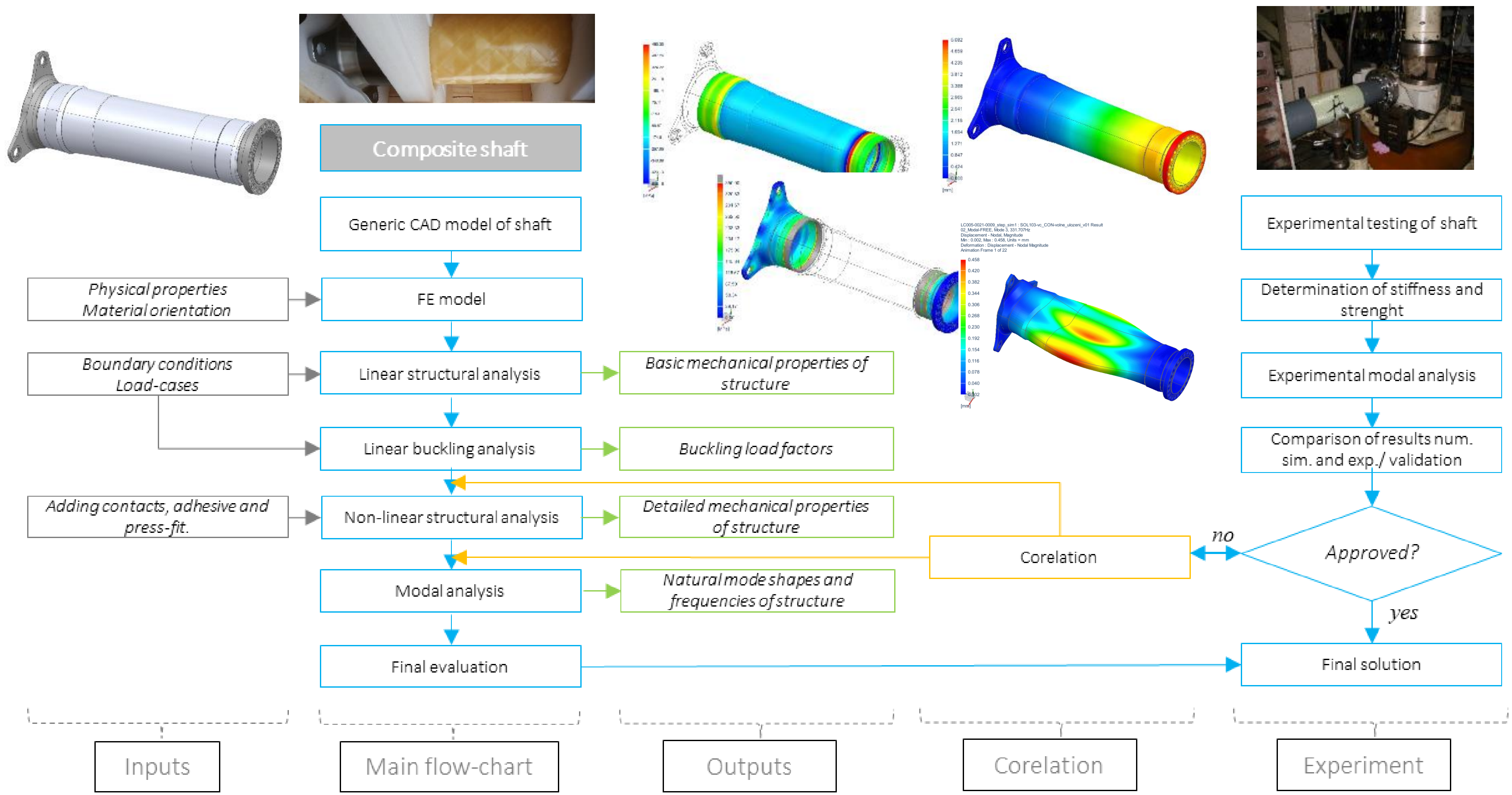
Partial Goals for the Current Period

2-WP12-002 Overview of the functional features of a composite shaft.

2-WP12-003 Composite shaft design and stress analysis.

Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12-001 Composite Train Drive Shaft - Process Flow-chart

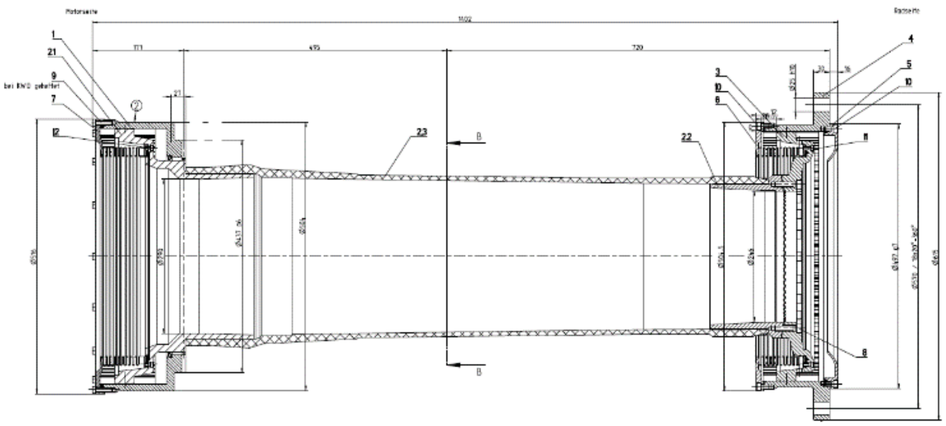


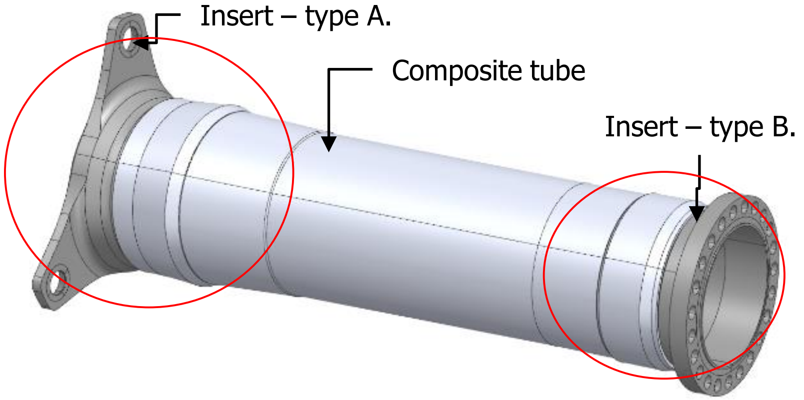
Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12-003 Composite Shaft Design and Stress Analysis.

CAD Model for FEM Analysis

The generic CAD model was created on the basis of data obtained from STRN. Simplification of non-essential details (in terms of stiffness and strength) was done to allow the discretization of the model into finite elements (FEM model).





Critical areas
connection of steel inserts-composite tube

Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12-003 Composite Shaft Design and Stress Analysis.

FEM Model of the Composite Shaft

- FEM model was created with using Siemens Simcenter 3D pre-processor. Second order brick elements (type CHEXA20) with relative size 6 mm were used for composite tube and steel insets of the shaft in combination with cohesive elements for glued joints (only for Non-linear analyses).

- Mesh parameters:
  - CHEXA = 80 989
  - CPENTA (cohesive) = 6 806
  - DOF = 1 592 300

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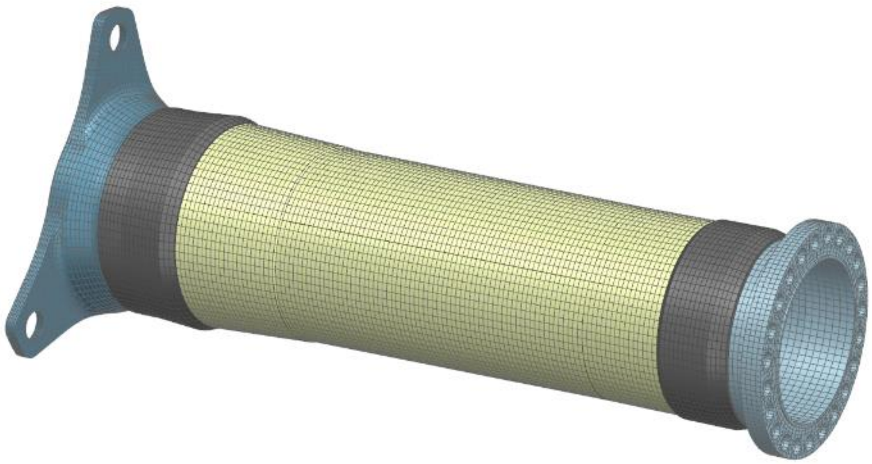
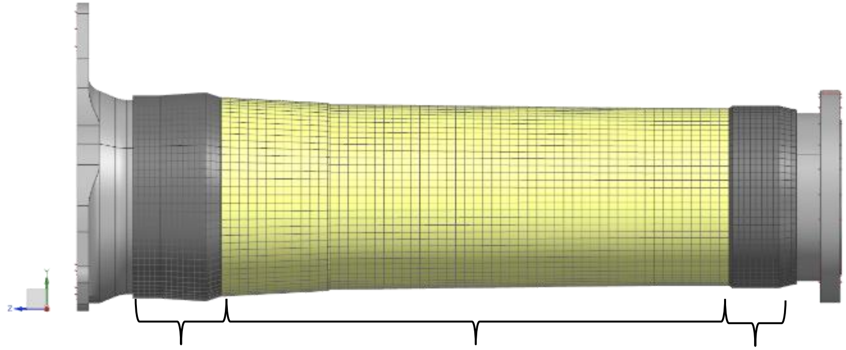
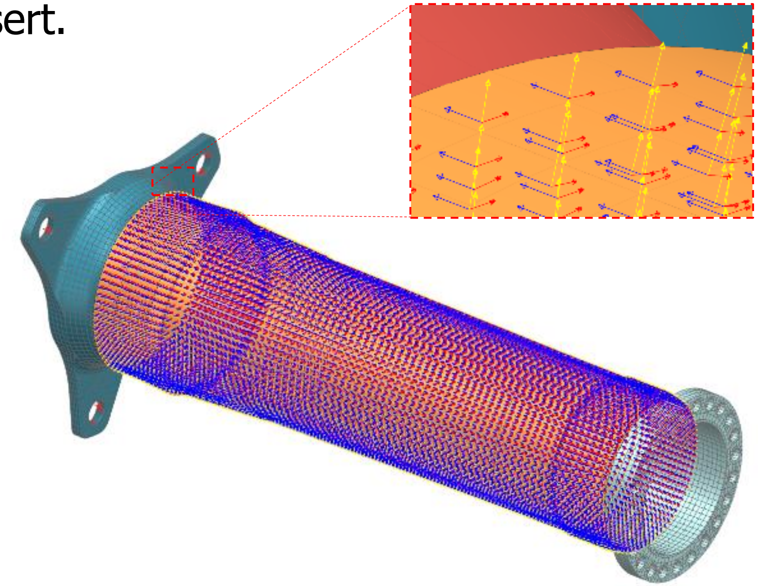


Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12-003 Composite Shaft Design and Stress Analysis.
Specification of the Physical Properties

- The basic mechanical properties of the composite part (tube) of the shaft were obtained from the manufacturer from the UK (Lentus composites). It is a combination of winding glass (GF) and carbon (CF) reinforcement and epoxy matrix. Carbon reinforcement provides increased stiffness/strenght in the radial direction of the tube at the area of the joint with a tube insert.
- The physical properties were applied by using NX Laminate Composite module.



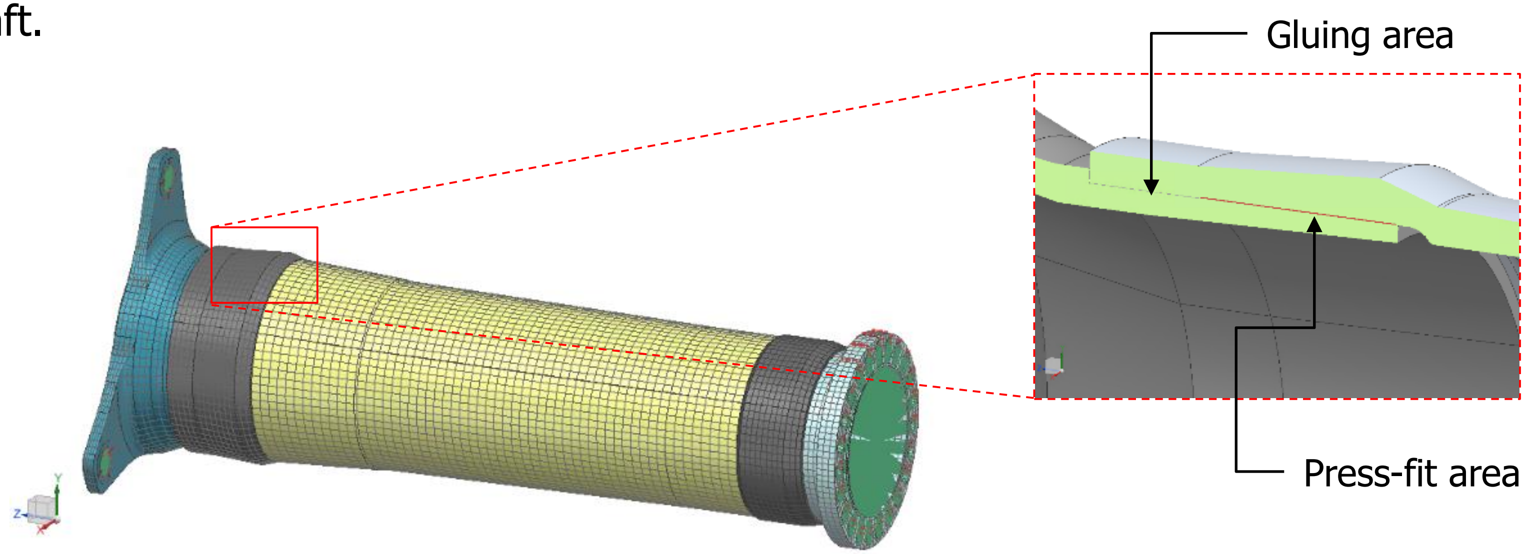


Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12-003 Composite Shaft Design and Stress Analysis.

Non-linear Structural Analysis of the Composite Shaft

- Non-linear static structural analysis was done by using NX Nastran (SOL401) Multi-step/Non-linear analysis for determination of detailed mechanical properties of the shaft.

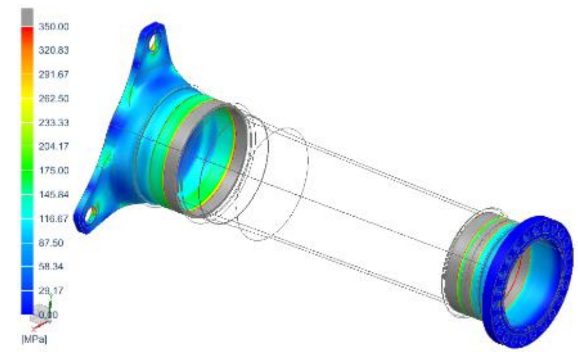


Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

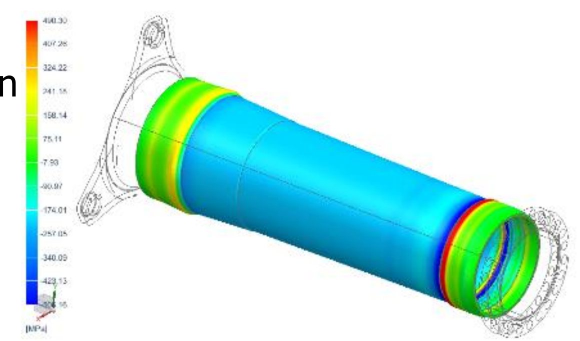
2-WP12-003 Composite Shaft Design and Stress Analysis.

Non-linear Structural Analysis of the Composite Shaft

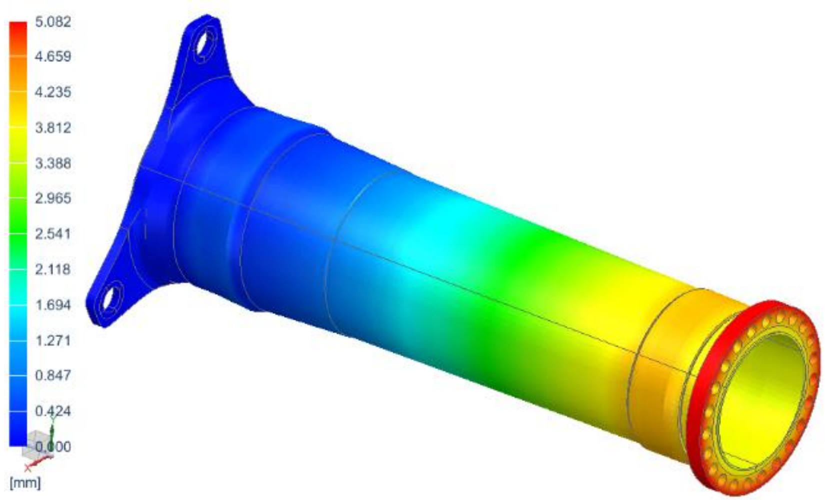
- **Results:**
  - Torsional stiffness = 48.19 kN/m/°
  - Max. tangencial displacement = 5.1 mm
  - Axial displacement = 0.1 mm



Inserts: Stress – Von Mises [MPa]



Shaft: Stress – critical direction 22 [MPa]



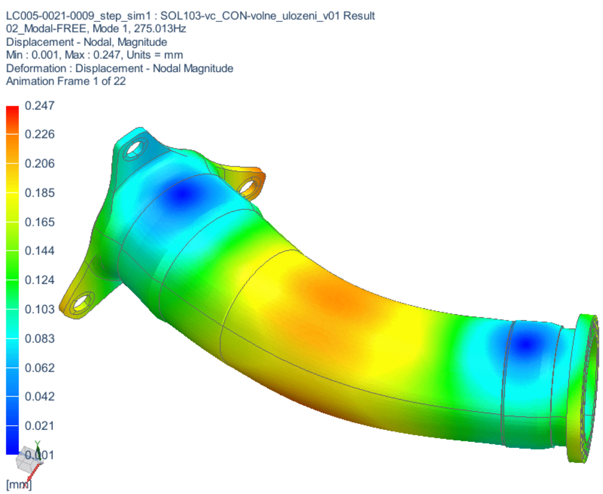
Displacement – magnitude [mm]

Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

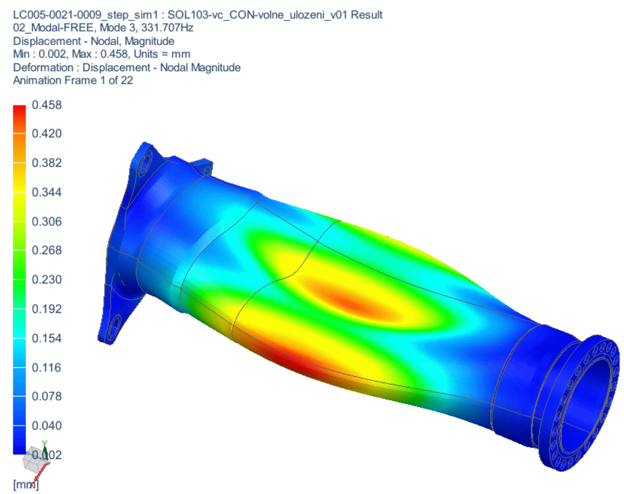
2-WP12-003 Composite Shaft Design and Stress Analysis.

Modal Analysis of the Composite Shaft

- Modal analysis was done by using NX Nastran (SOL103) Real Eigenvalues analysis to determine of basic dynamical properties (the natural mode shapes and frequencies of a structure during free vibration) of the shaft.



Mode 1, 275Hz



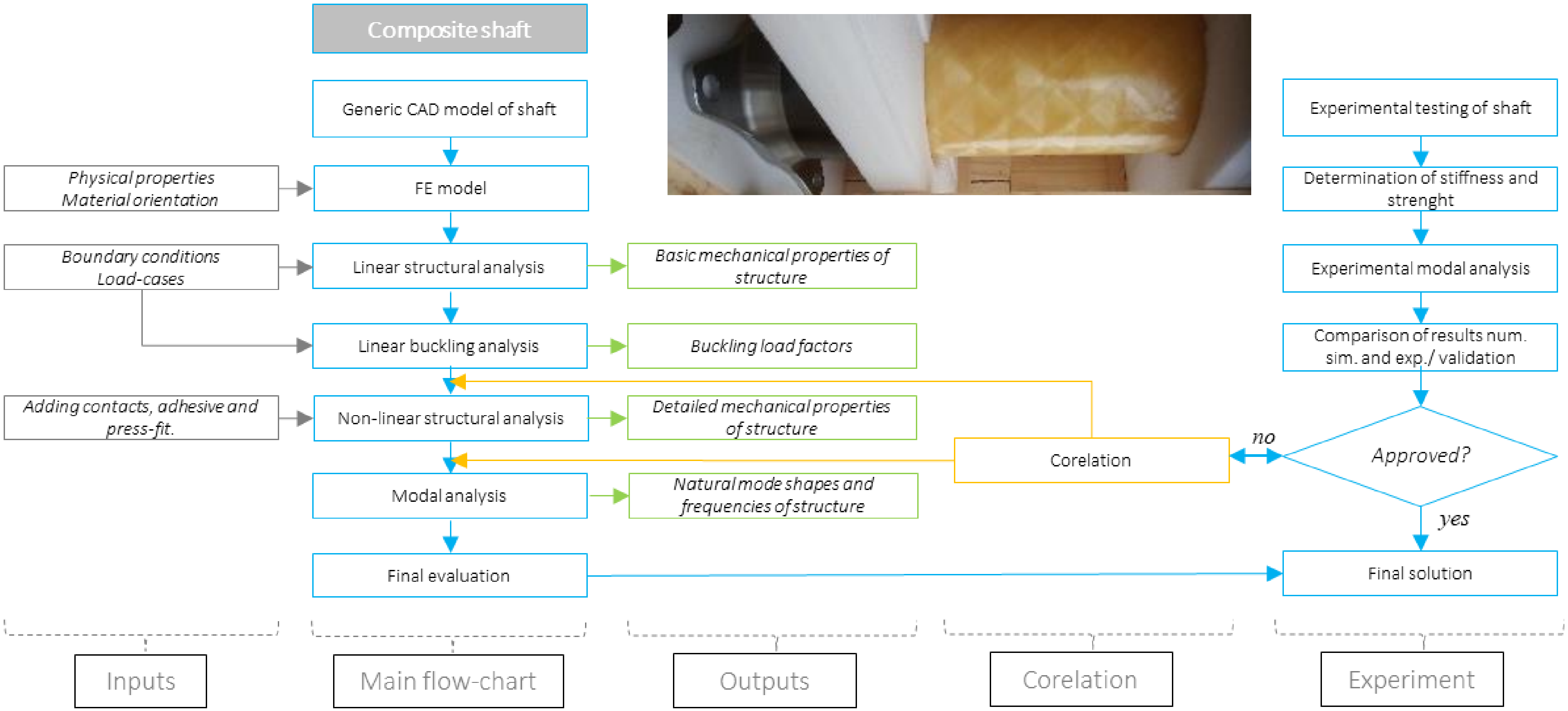
Mode 3, 331Hz

Mode 1, 275.013Hz
Mode 2, 275.034Hz
Mode 3, 331.707Hz
Mode 4, 331.813Hz
Mode 5, 444.851Hz
Mode 6, 470.98Hz
Mode 7, 538.755Hz
Mode 8, 538.876Hz
Mode 9, 607.489Hz
Mode 10, 607.629Hz
Mode 11, 723.045Hz
Mode 12, 723.167Hz
Mode 13, 731.82Hz
Mode 14, 731.932Hz
Mode 15, 934.44Hz
Mode 16, 934.442Hz
Mode 17, 986.869Hz
Mode 18, 991.563Hz
Mode 19, 1005.78Hz
Mode 20, 1006.28Hz

Activities in 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

2-WP12-003 Composite Shaft Design and Stress Analysis.

Process Flow-chart

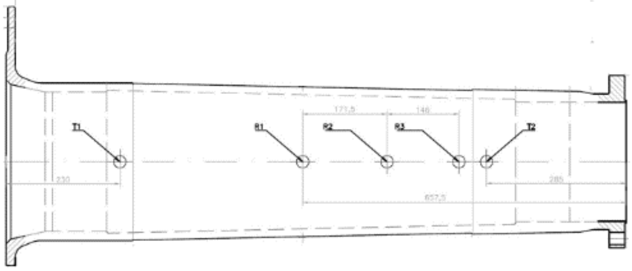


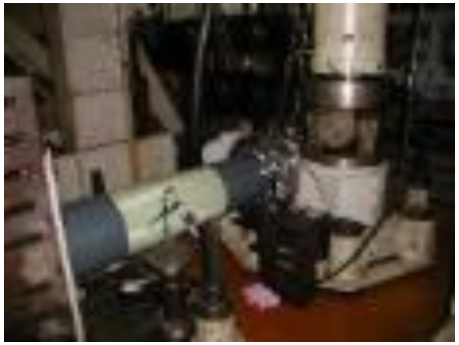
2-WP12-002 Overview of the Functional Features of a Composite Shaft

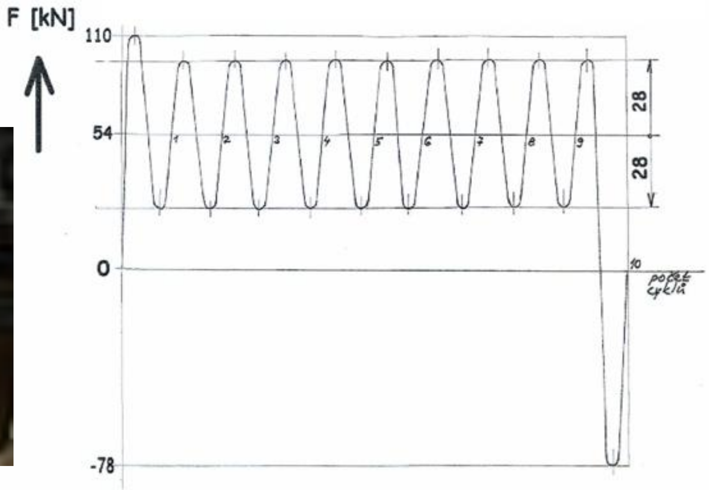
Experimental Testing of Shaft

- The designed loading block for dynamic testing is controlled by force The block consists of 10 cycles from which cycles number 2 to number 9 have the same amplitude equal to 28 kN and mean value equal to 54 kN and the first and last cycles of the block are the overloading cycle with higher amplitudes.
- On the shaft are equipped with 3 strain gauge rosettes (on the shaft axis). Strain gauge rosettes are used for evaluation of stiffness and stress at the control points.
- The testing parameters are following:

  R = 0,3
  Fmax = 110 kN
  Fmin = -78 kN







Fulfillment of goals and deliverables of 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

Current State of Deliverables, Milestones and Fulfillment of Goals

The partial phases leading to the fulfilment of the project objectives in 2020 were elaborated. The developing of the design phases of the component made from composite were performed and validated. The composite shaft was designed and produced, will be tested and the results obtained from the test will be compared with the calculation, it will leads to the ability to produce part which can replace the part from conventional (steel) material.

List of Due Deliverables and Their Added Value

2-WP12-001 Composite train drive shaft. The composite shaft will have lower weight but better dynamical behaviour due to lower damping coefficient.

2-WP12-002 Overview of the functional features of a composite shaft. It will be finished after testing of composite shaft and will describe the test procedure and results of test to help comparison with FEA.

2-WP12-003 Composite shaft design and stress analysis. Is finished with the process flow-chart. This flow chart will increase the knowledge how to make design, analyses and validation not only such kind of composite part.

Current contribution of 2-WP12 Optimization of the Key Design Units of New Generation Vehicles

Assessment of the Contribution of Deliverables

The models of calculation composite parts could be use in wide range of applications. Advantages of using composite materials in design of railway can improve the dynamic behaviour of not only the driveline. The research activities carried out should contribute to increase usage the parts from composite material in wide ranges of industry areas. Škoda Transportation company and R&D companies acquired knowledge contributes to increasing competitiveness and the possibilities of further development.

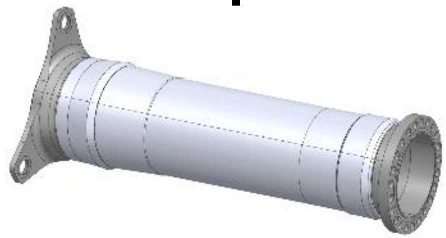
Acknowledgement

This research has been realized using the support of Technological Agency, Czech Republic, programme National Competence Centres, project #TN01000026 Josef Bozek National Center of Competence for Surface Transport Vehicles.

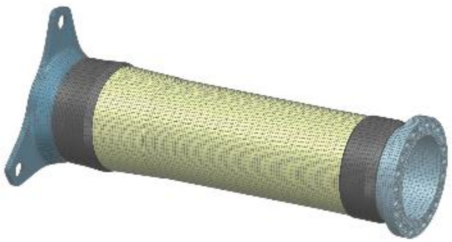
This support is gratefully acknowledged.

Výtah z prací 2019-2020 na 2-WP12 Optimalizace klíčových konstrukčních uzlů vozidel nové generace - ZČU – RTI_ Ing. Pavel Žlábek, Ph.D

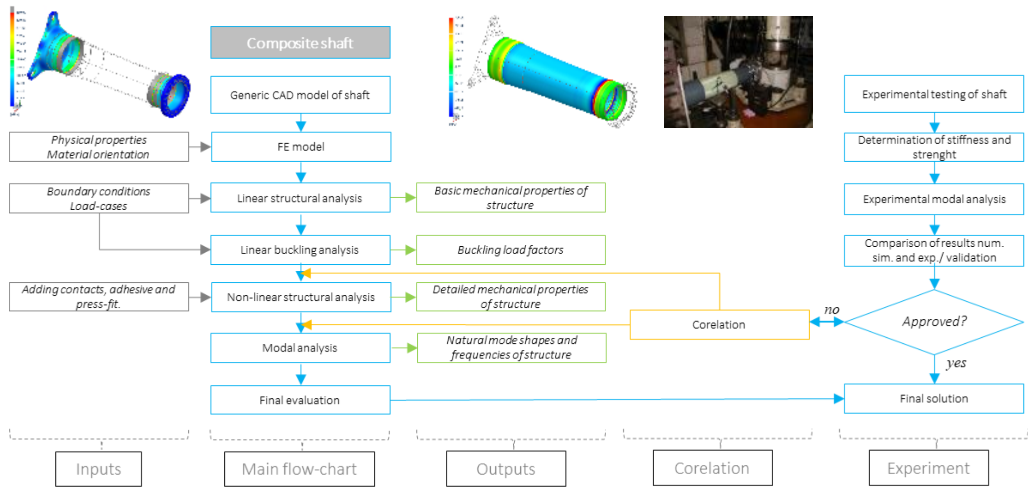
CAD model kompozitního hřídele



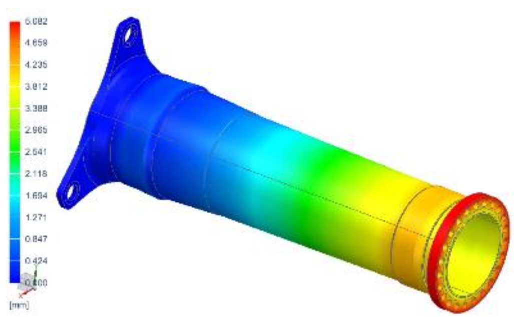
FEM kompozitního hřídele



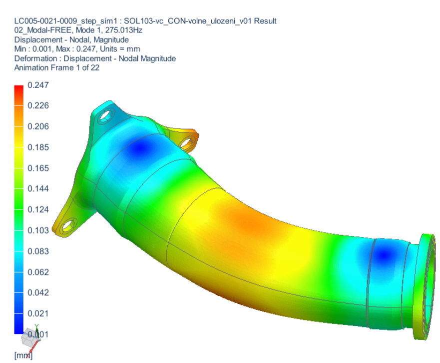
Procesní vývojový diagram

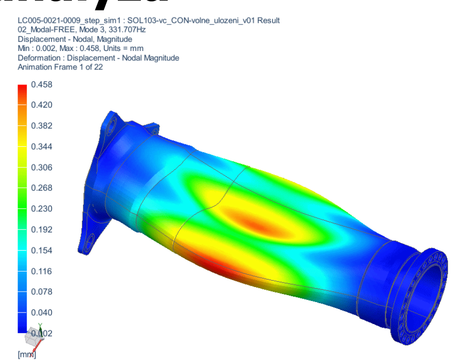


Výpočet deformace



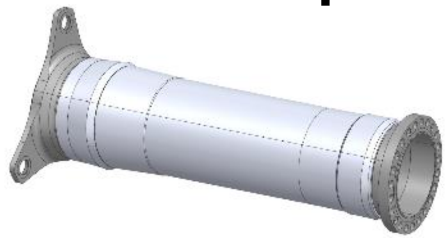
Modální analýza



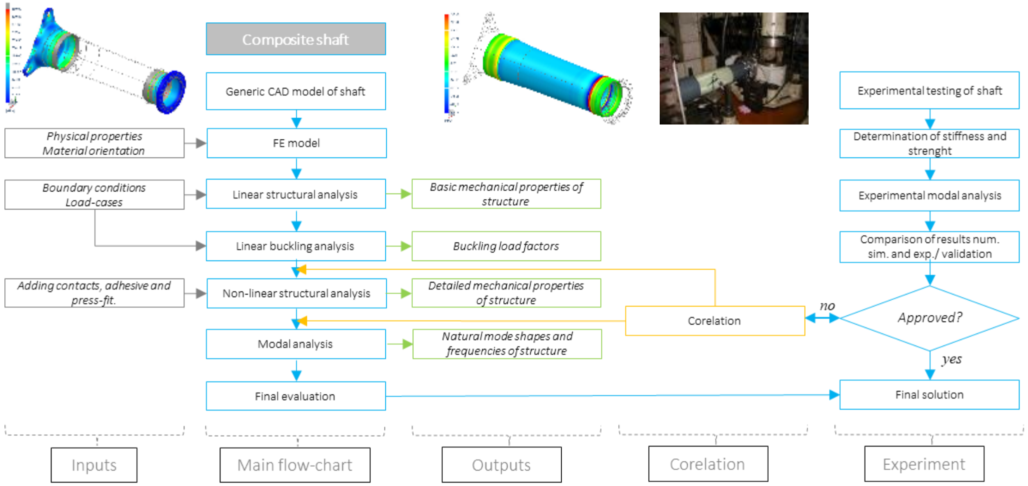


Results of 2-WP12 Optimization of the Key Design Units of New Generation Vehicles - Achieved 2019-2020 - UWB – RTI_ Ing. Pavel Žlábek, Ph.D

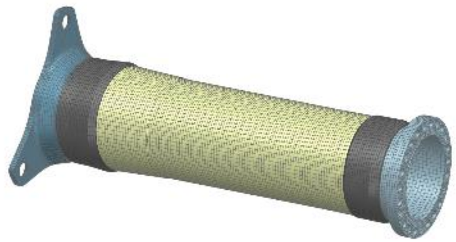
CAD Model of Composite Shaft



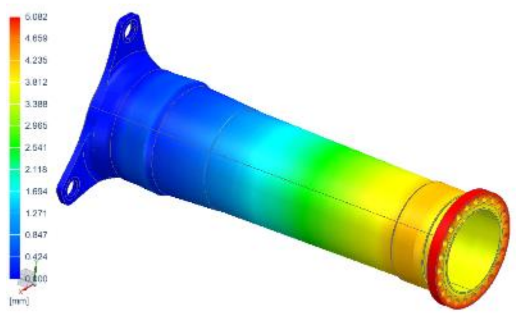
Process Flow-chart



FE Model of Composite Shaft



Displacement Calculation



Modal Analysis of the Composite Shaft