

Contents of Work Package 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08: Advanced Design Solutions for Future Automotive ICEs

Coordinator of the WP

České vysoké učení technické v Praze: Doc. Ing. O. Vítek, Ph.D.

Participants of the WP

Skoda Auto: Ing. V. Uzlík, TU Liberec: Ing. R. Voženílek, Ph.D, Vysoké učení technické v Brně: Ing. L. Drápal, Ph.D.

Main Goal of the WP

The WP is focused on design solutions of future hybridized powertrain (based on ICE) with the main goal to improve efficiency while also considering effects of NVH, port fuel injection, lubrication, etc. Selected parts and subassemblies will be analyzed, optimized and tested/verified.

Partial Goals for the Current Period

TUL + Skoda Auto: focus on port fuel injection + lubrication circuit performance.

BUT + Skoda Auto: analyze & design & optimize ICE parts for future applications focused on improved efficiency.

Contents of Work Package 4-WP08: Advanced Design Solutions for Future Automotive ICEs

Official 4-WP08 Deliverables:

- 4-WP08-001 | **Intake module with an innovative position for new-generation of fuel injectors**, G-funk, XII./2025, Skoda Auto 0.9; TUL 0.1
- 4-WP08-002 | **Lubrication channel of the experimental driving unit system**, G-funk, XII./2025, Skoda Auto 0.9; TUL 0.1
- 4-WP08-003 | **Key component parts and subassemblies for optimized engine of a hybrid power train**, G-funk, XII./2025, Skoda Auto 0.5; BUT 0.5
- 4-WP08-004 | **Advanced computational model of dynamics and tribology of the engine for a hybrid power train**, O-ostatní, XII./2025, Skoda Auto 0.5; TUL 0.5

Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

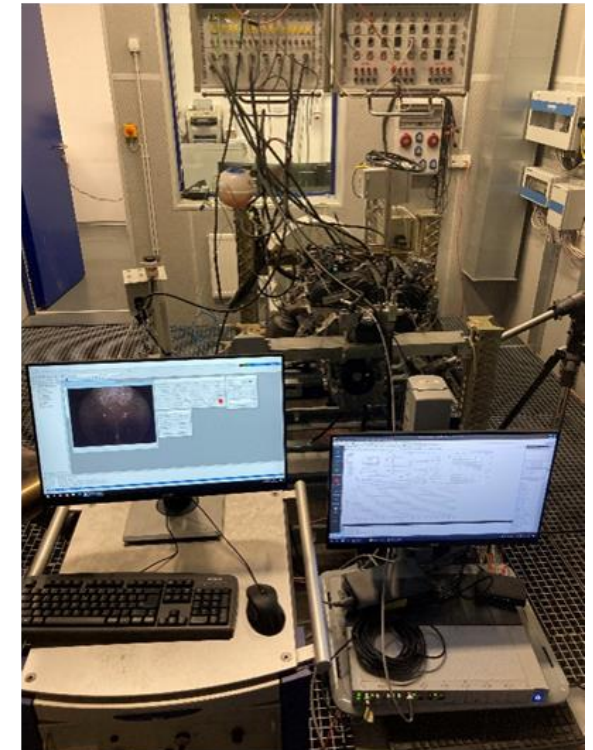
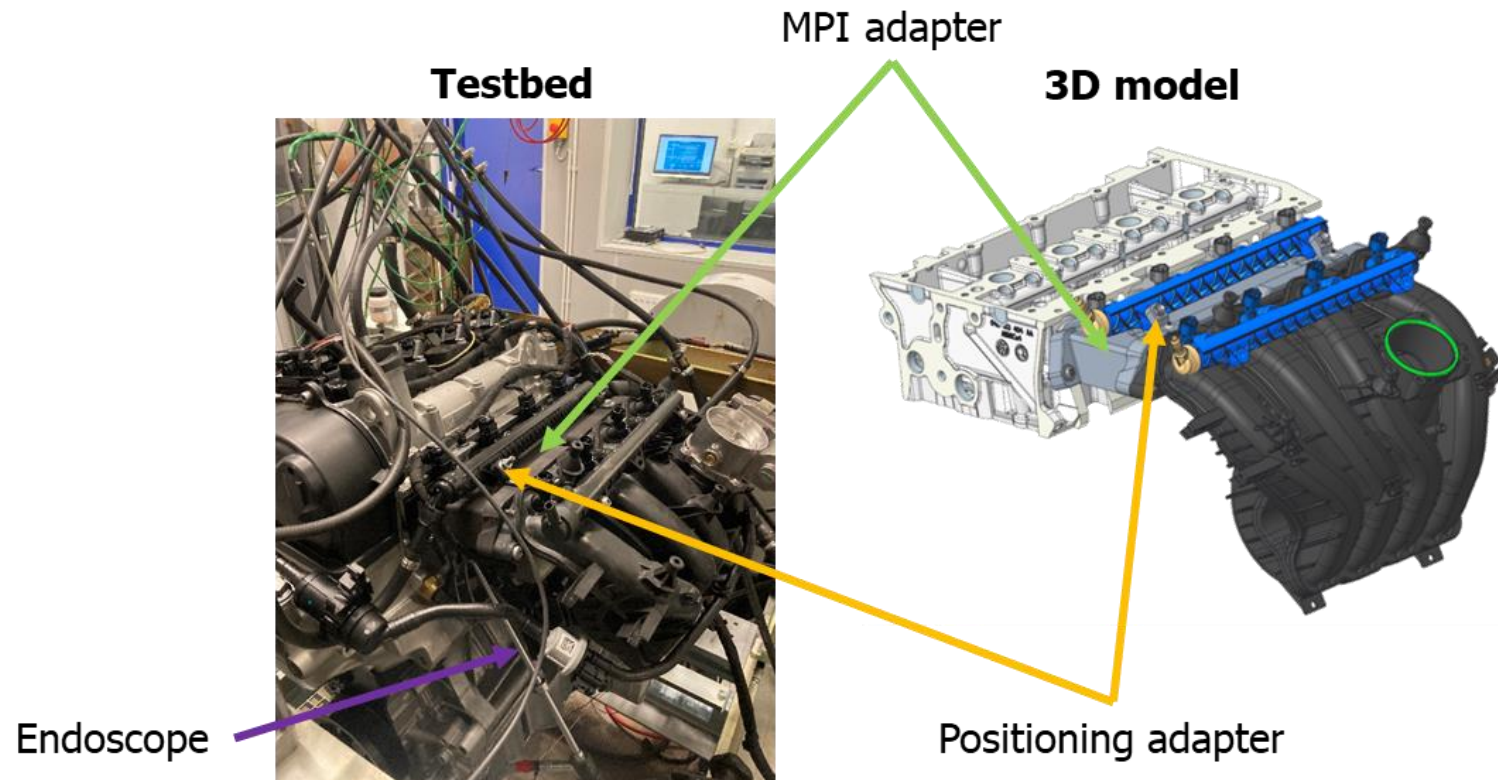
4-WP08-001: Intake module with an innovative position for new-generation of fuel injectors

- A new generation of intake manifold module (for a non-supercharged gasoline piston internal combustion engine) will be created, enabling innovative positioning of the (primarily liquid) fuel injectors, both currently used and injectors for synthetic and low-carbon fuels. The module will be prepared so that it is possible to install it on the currently used and developed power unit with the external formation of the fuel-air mixture. The indication and visualisation techniques available at the workplace at TUL will be used to identify and verify the correct position of the initial state designed by the 3D modelling method.
- Main topics (for the current time period):
 - Updated design of the experimental setup.
 - New/updated SW tools to process/analyze experimental data.
 - Automation of the whole procedure.

Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-001: Intake module with an innovative position for new-generation of fuel injectors

- Experiments:

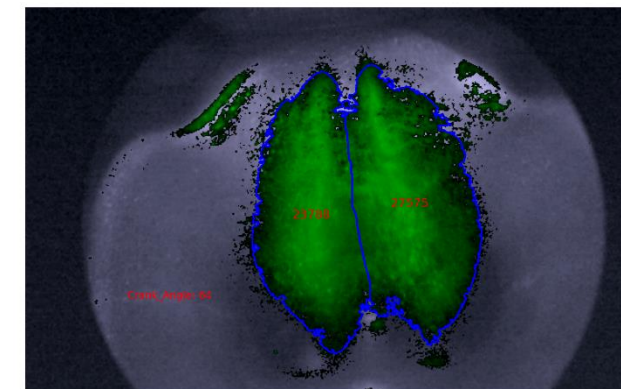
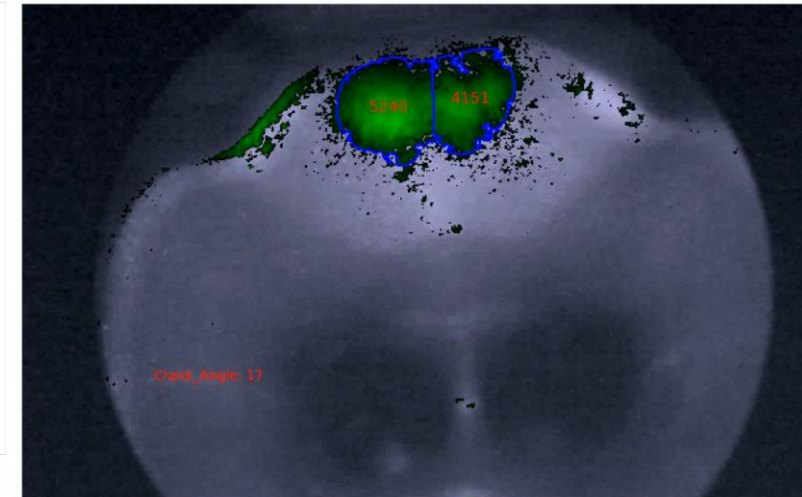
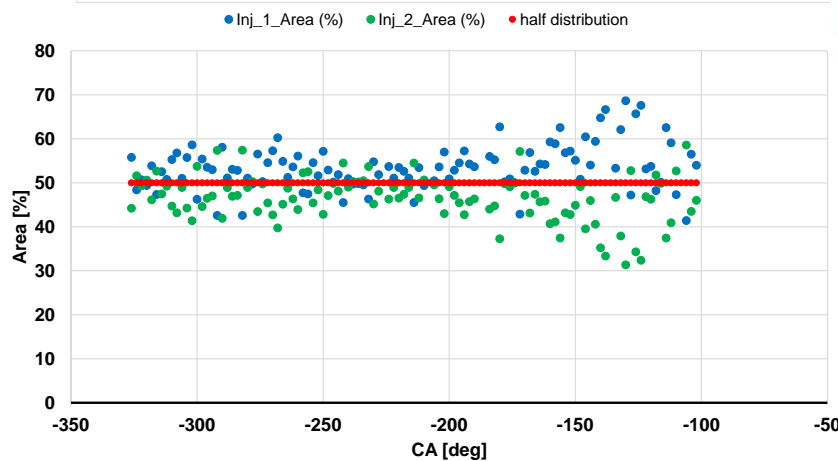
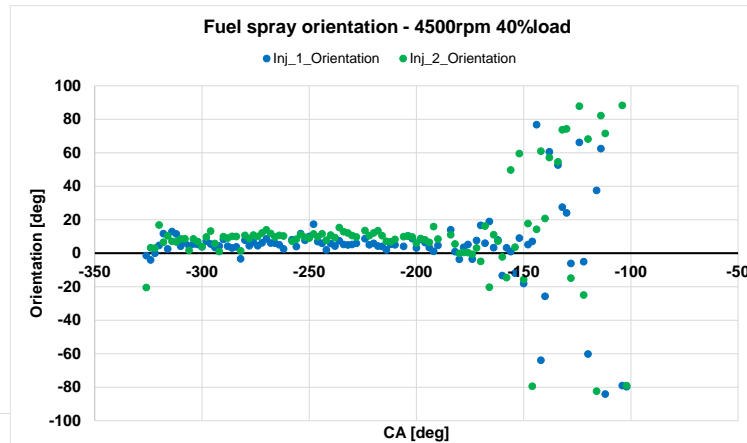


Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-001: Intake module with an innovative position for new-generation of fuel injectors

- Data analysis:

- New/updated design.
- Modified/updated SW to analyze & visualize the data => integral/global data are derived from that.
- Automated procedure.



Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

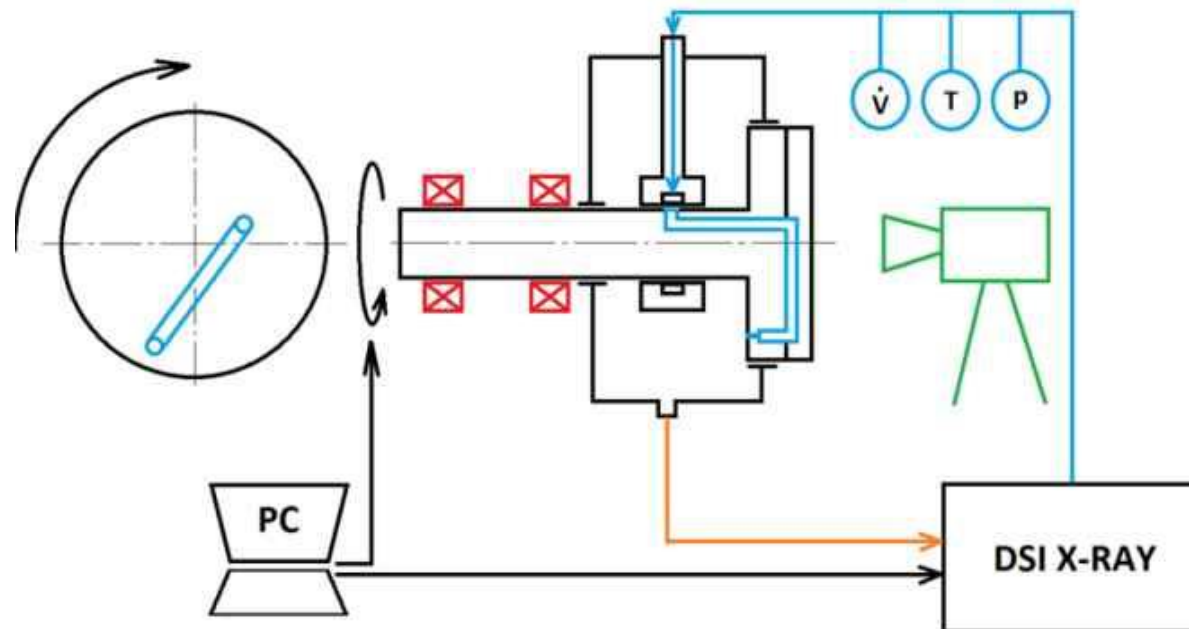
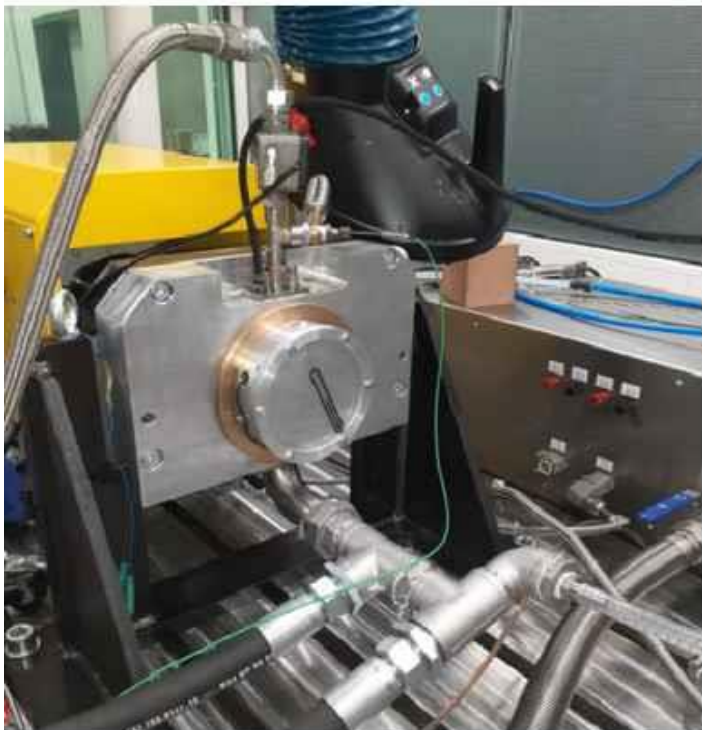
4-WP08-002: Lubrication channel of the experimental driving unit system

- A part for modelling and simulating oil flow through the lubrication channel of the rotating crankshaft will be created. The part will be created in several design variants, and the operating conditions of the drive unit will be simulated on it. The channel will be optimized based on computer simulations, and the results will be compared with real measurement results on an experimental test site. The goal is to create experimental support for the structural arrangement of the crankshaft lubrication system of the drive unit, which will ensure a reliable lubrication function with low energy requirements in the entire range of operating conditions of the drive unit.
- Main topics (for the current time period):
 - Design modifications of the whole experimental setup to improve ability to monitor important parameters & properties.
 - To test different designs of lubrication channel/circuit while focusing on wide range of operating conditions.
 - To create computer models to improve understanding of important phenomena and to support analysis of the experimental data.
 - Main goal is to focus on reliable lubrication function/operation under entire range of operating conditions while lowering energy consumption/requirements of the whole lubrication circuit.

Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-002: Lubrication channel of the experimental driving unit system

- Oil flow trough the rotating channel + control of camshaft adjusters:



Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-002: Lubrication channel of the experimental driving unit system

- Analysis of events in the hydraulic system - model of the part with the lubrication channel:
 - Some parts of the simulation/experimental model (carrier and rotor of the telemetry system, special stator with distribution channels, auxiliary carrier of the scanning camera).



Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

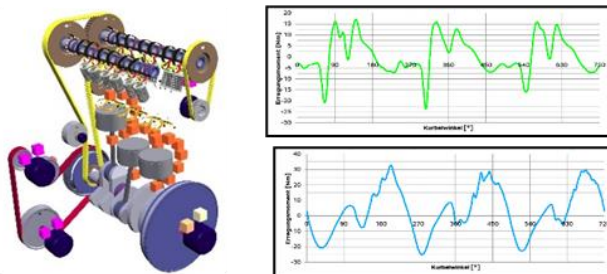
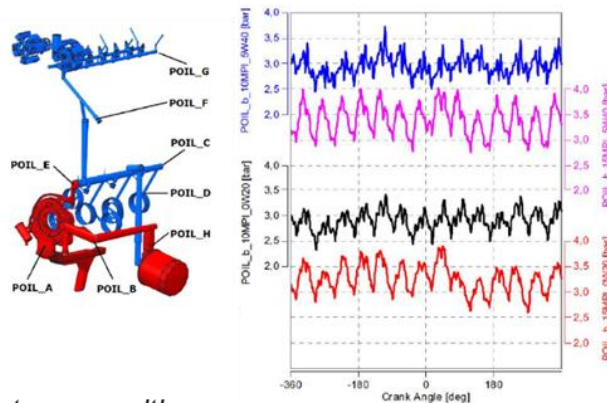
4-WP08-002: Lubrication channel of the experimental driving unit system

• Engine Oil System Neural Network:

Inputs

Courses of pressures
in the oil system

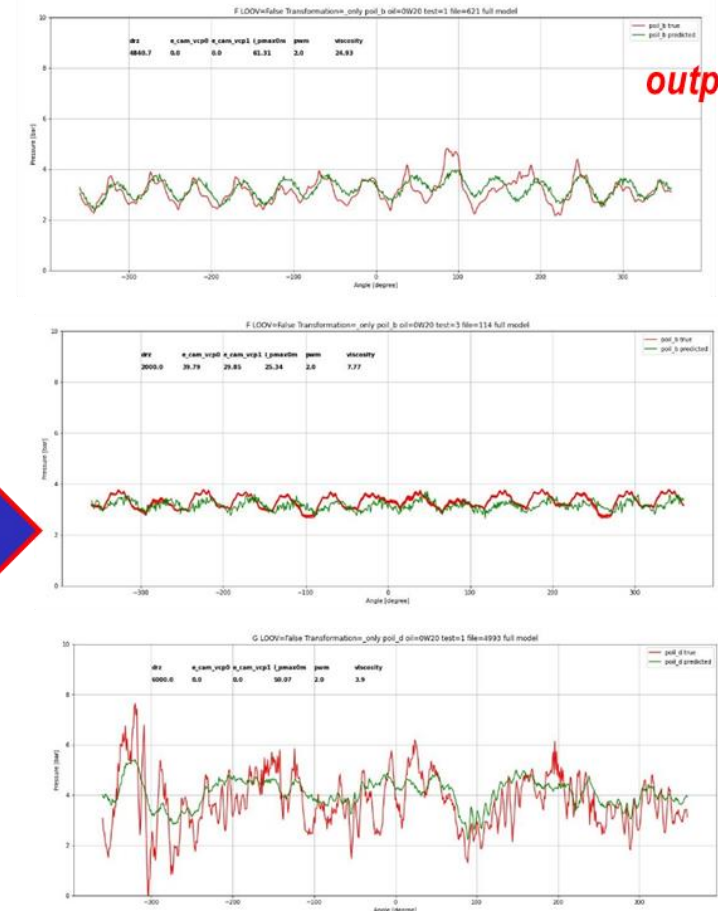
- Engine speed
- Oil temperature
- Oil viscosity
- Intake and exhaust cam position
- 3-cylinder and 4-cylinder layouts
- Oil pressure in the system
- Engine load Course of moments on camshafts



neural network

159 nodes
577
thousand
weight
coefficients

outputs



Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

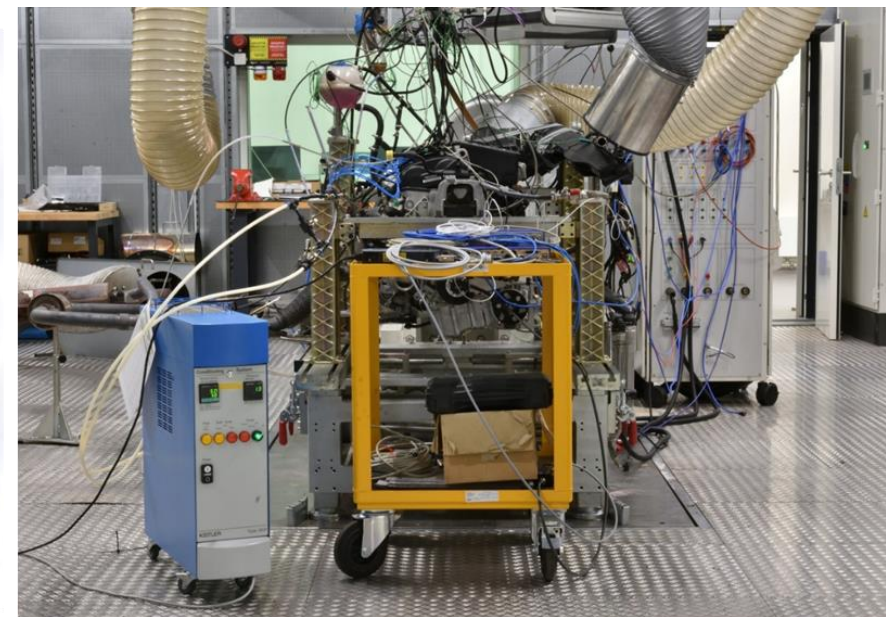
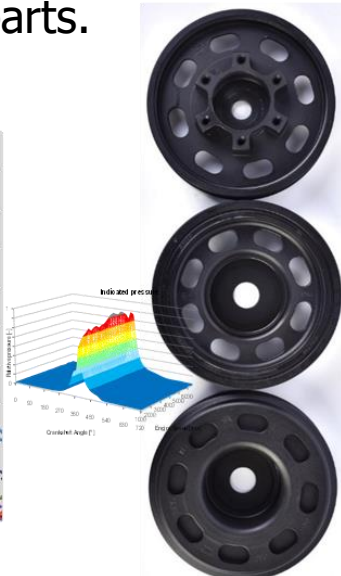
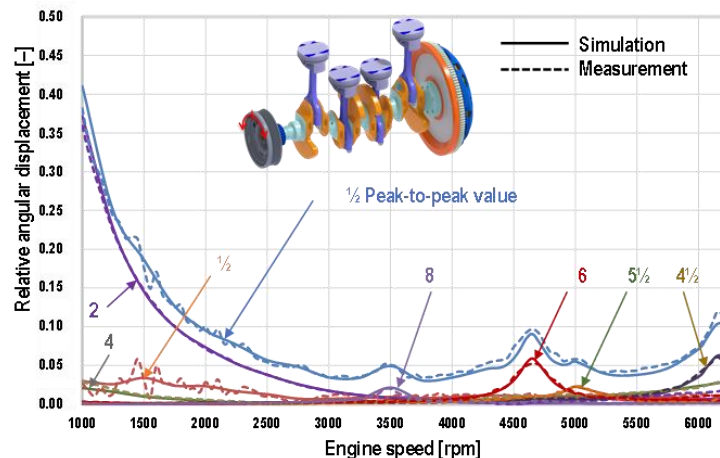
4-WP08-003: Key component parts and subassemblies for optimized engine of a hybrid power train

- A modern engine for a hybrid powertrain is a complex machine requiring considerable research and development effort. This result includes reaching the functional component parts and subassemblies of this engine, such as the crank train, engine block, etc. The following activities should lead to the achievement of the result: the choice of the basic layout regarding the existing manufacturing program of the ŠKODA AUTO company, conceptual engine design, advanced computational modeling of engine component parts and subassemblies, computational parametric studies and creation of CAD models of engine component parts, creation of drawing documentation, manufacturing of key component parts and subassemblies of the engine.
- Main topics (for the current time period):
 - Selection of target ICE and key components.
 - Dedicated experiments to calibrate computation models (relation to 4-WP08-004).
 - Initial analysis of possible deactivation modes.
 - Proposal of solution(s) to decrease torsional vibration(s) when cylinder deactivation is active.

Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-003: Key component parts and subassemblies for optimized engine of a hybrid power train

- Selectin of ICEs and dedicated experiments:
 - Choice of the default engine (spark-ignition naturally-aspirated four-cylinder engine Škoda Auto).
 - Functional tests of the default engine on a dynamometer under different conditions and with different component parts.
 - Statistical processing of engine test data.

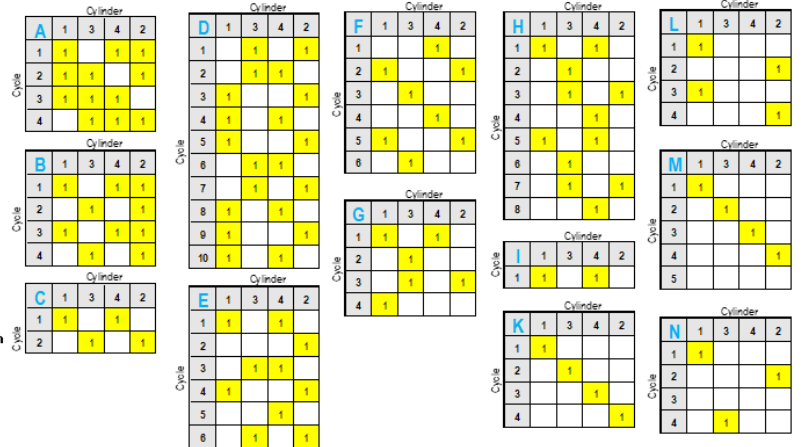
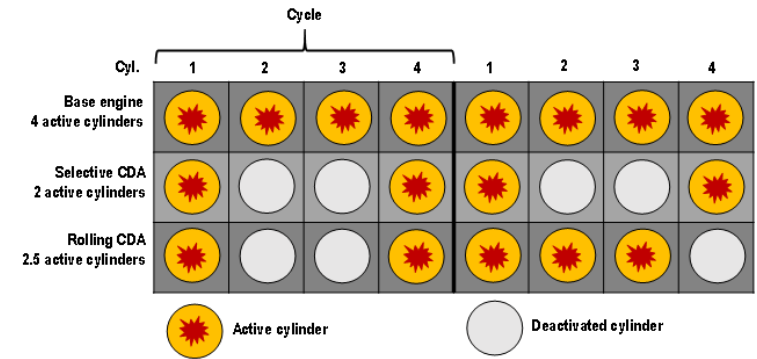
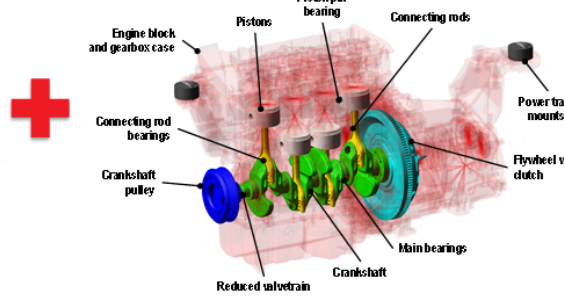
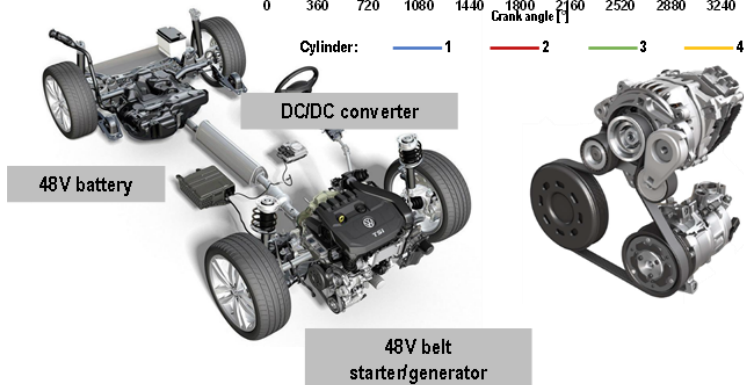
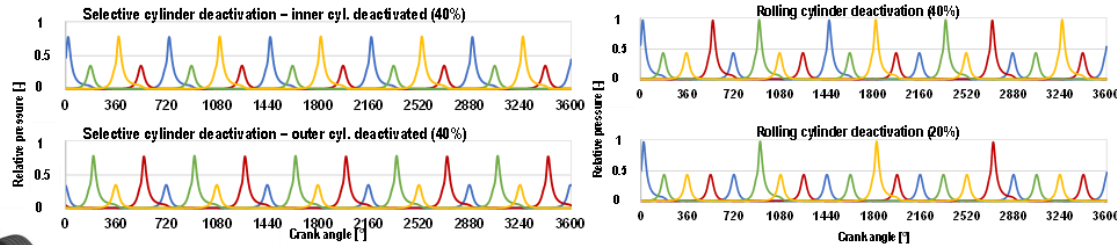


Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-003: Key component parts and subassemblies for optimized engine of a hybrid power train

- Cylinder deactivation:

- Design of strategies for cylinder deactivation (selective, rolling).
- Thermodynamic simulations of an engine with deactivated cylinders.
- Possible torque smoothing using P0 hybrid technique.



Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-004: Advanced computational model of dynamics and tribology of the engine for a hybrid power train

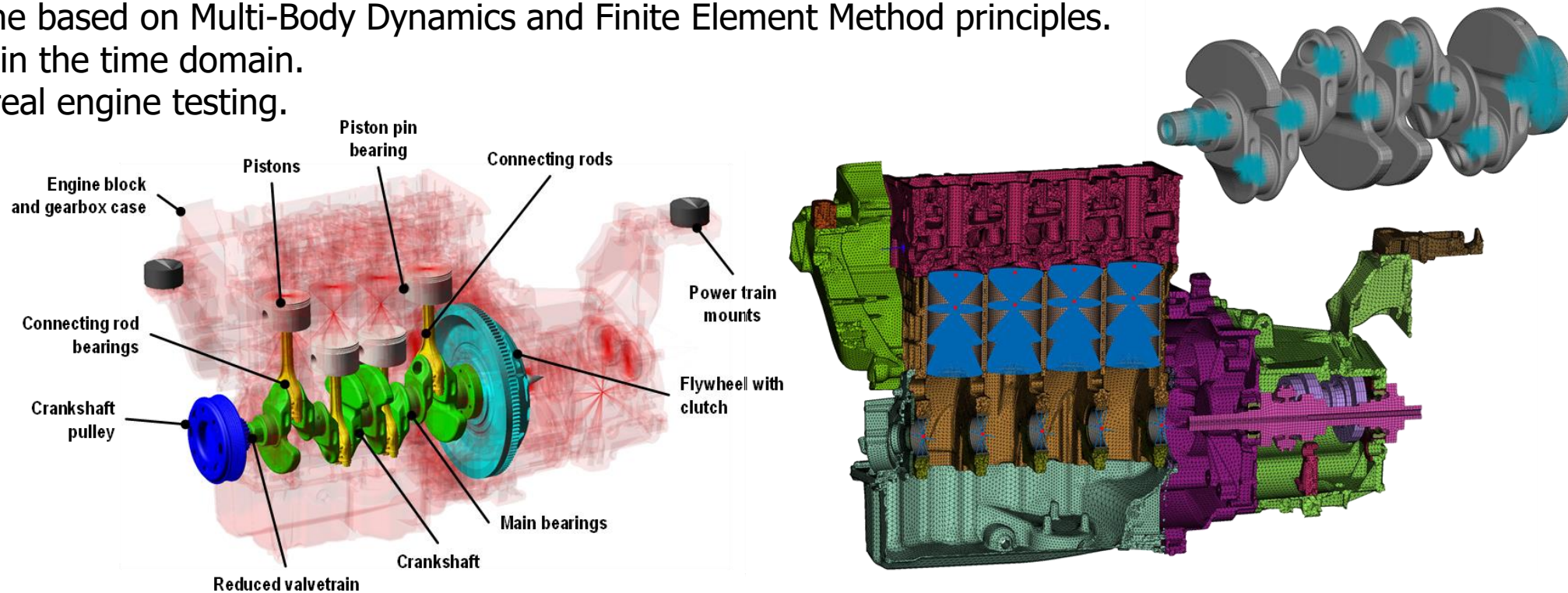
- This advanced computational model of the dynamics and tribology of the key component parts of the newly developed engine will enable parametric studies to be carried out and the engine subsequently optimized for high mechanical efficiency and low vibration with high robustness and low production costs. The model will be based on the principles of FEM, MBS and will allow to include many physical effects during simulations in the time domain. The following activities should lead to the achievement of the result: discretization of CAD models of engine component parts, simulation of the excitation effects of the computational model, building of an advanced computational model of dynamics and tribology of a modern engine for a hybrid power unit, building of own submodels, advanced computational model debugging, participation on domestic and international conferences, journal papers & student engagement.
- Main topics (for the current time period):
 - Calibration & verification of computation models.
 - Sensitivity studies and detailed analysis of consequences of cylinder deactivation application.

Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-004: Advanced computational model of dynamics and tribology of the engine for a hybrid power train

- Modeling of important parts/subassemblies:

- Virtual engine based on Multi-Body Dynamics and Finite Element Method principles.
- Simulations in the time domain.
- Verified by real engine testing.



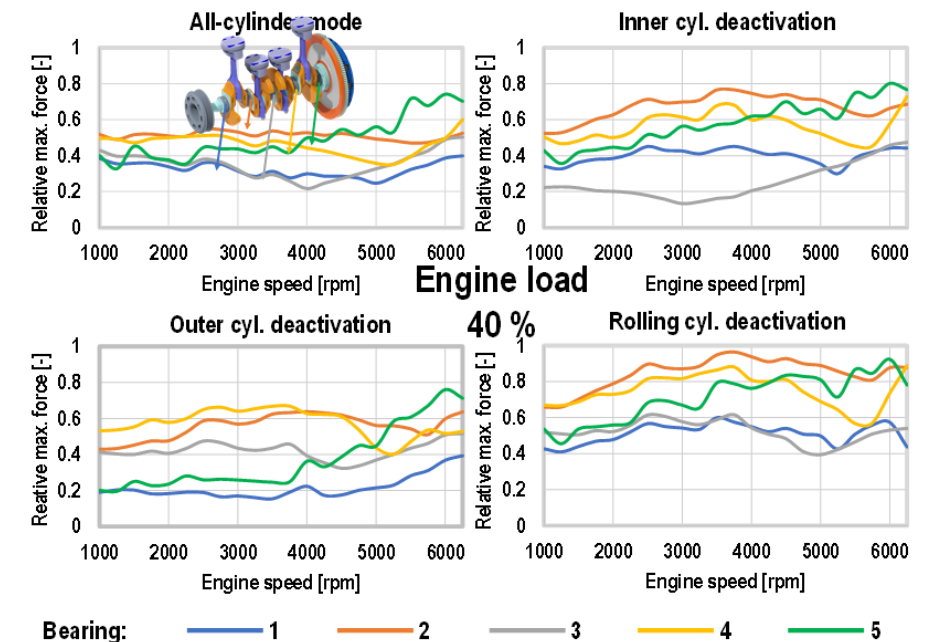
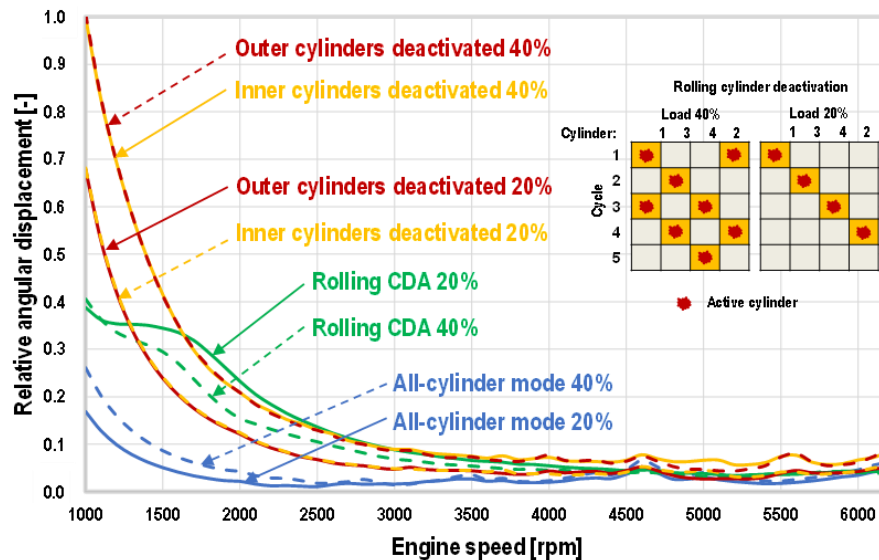
Activities in 4-WP08: Advanced Design Solutions for Future Automotive ICEs

4-WP08-004: Advanced computational model of dynamics and tribology of the engine for a hybrid power train

- Modeling of important parts/subassemblies:

- Evaluation of the effect of cylinder deactivation on engine dynamics without electric motor-generator:

- torsional vibration;
- bearing power losses;
- bearing load;



Fulfillment of goals and deliverables of 4-WP08: Advanced Design Solutions for Future Automotive ICEs

Current State of Deliverables and Fulfillment of Goals

- 4-WP08-001 | **Intake module with an innovative position for new-generation of fuel injectors**, G-funk, XII./2025, Skoda Auto 0.9; TUL 0.1 – **in progress & no major delays:**
 - Extensive measurements associated with fuel jet visualization were performed.
 - Supporting automated software for processing and quantifying events during the formation of a fuel-air mixture based on image recording is creating.
- 4-WP08-002 | **Lubrication channel of the experimental driving unit system**, G-funk, XII./2025, Skoda Auto 0.9; TUL 0.1 – **in progress & no major delays:**
 - Design and production work associated with the preparation of the experimental site is carried out.
 - Preparation of simulation models of oil flow through the lubrication channel is underway.
 - The preparation of a specialized software for the evaluation of events in the hydraulic system of the drive unit is in progress.

Fulfillment of goals and deliverables of 4-WP08: Advanced Design Solutions for Future Automotive ICEs

Current State of Deliverables and Fulfillment of Goals

- 4-WP08-003 | **Key component parts and subassemblies for optimized engine of a hybrid power train**, G-funk, XII./2025, Skoda Auto 0.5; BUT 0.5 – **in progress & no major delays:**
 - Performed functional tests of the default engine.
 - Processed measured quantities.
 - Proposed appropriate sequences for rolling cylinder deactivation.
 - Obtained (from CTU) simulated pressures in combustion chamber with cylinder deactivation.
- 4-WP08-004 | **Advanced computational model of dynamics and tribology of the engine for a hybrid power train**, O-ostatní, XII./2025, Skoda Auto 0.5; TUL 0.5 – **in progress & no major delays:**
 - Built a computational model of the default engine.
 - The computational model of the default engine is verified by measurement.
 - Studies of the effect on the dynamics and load on component parts of the default engine during cylinder deactivation are carried out.

Fulfillment of goals and deliverables of 4-WP08: Advanced Design Solutions for Future Automotive ICEs

List of Due Deliverables and Their Added Value

- **4-WP08-001** – deeper inside into fuel mixture preparation of future automotive applications, close cooperation with industrial partner (Skoda Auto) – both funded R&D projects and commercial ones.
- **4-WP08-002** – deeper inside into improvement of the lubrication system of future automotive applications, close cooperation with industrial partner (Skoda Auto) – both funded R&D projects and commercial ones.
- **4-WP08-003** – finding out whether it is possible to combine a naturally-aspirated engine, cylinder deactivation system and mild-hybrid technique to further increase the overall efficiency of the power unit (the mild-hybrid part is used to compensate for uneven engine running), project and commercial cooperation with industrial partner (Škoda Auto).
- **4-WP08-004** – a tool for predictive assessment of the dynamics of hybrid power units, assessment of appropriate sequences for cylinder deactivation, project and commercial cooperation with industrial partner (Škoda Auto).

Fulfillment of goals and deliverables of 4-WP08: Advanced Design Solutions for Future Automotive ICEs

Assessment of the Contribution of Deliverables

- New fuels for ICE – (3-WP07).
- Lubrication system for ICE - (4-WP08-004).
- Mechanical losses of ICE – (3-WP07-006).
- Cylinder deactivation – 3-WP02.

Current contribution of 4-WP08: Advanced Design Solutions for Future Automotive ICEs

Assessment of the Formal/Administrative Goals of the Work Package

All formal and administrative requirements are expected to be fulfilled.

	Skoda Auto	TUL	BUT
Finances (reporting/spending)	OK	OK	OK
Commercialization (the whole organization)	OK	OK	OK
Deliverables	OK	OK	OK



Current contribution of 4-WP08: Advanced Design Solutions for Future Automotive ICEs

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).



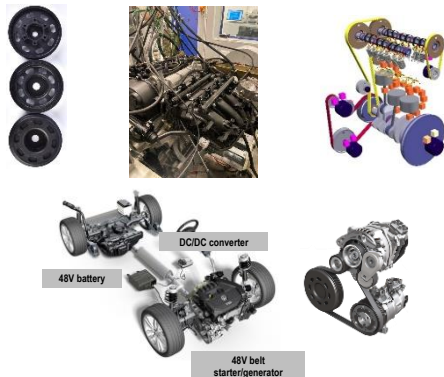
Výtah z prací 2023-2025 za 4-WP08: Advanced Design Solutions for Future Automotive ICEs

Skoda Auto: konstrukce

Experimenty na cílových motorech

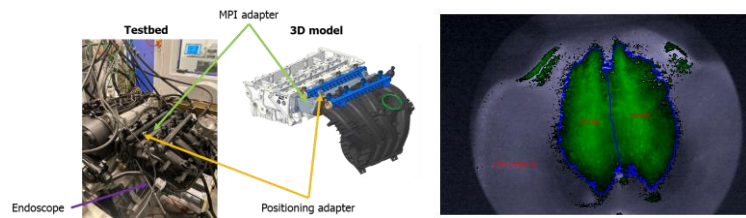


Podpora VO– motory pro testy, data, CAD/CAE modely, detailní výpočetní modely, testovací vybavení, atp.

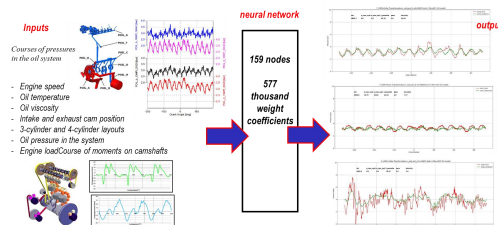


TUL: experimenty & hydraulika

Vizualizace paprsku paliva a automatizované zpracování dat

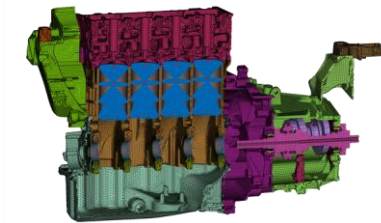


Analýza mazacího okruhu – simulace & experimenty

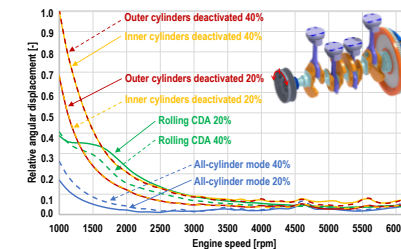


BUT: návrh & mechanika

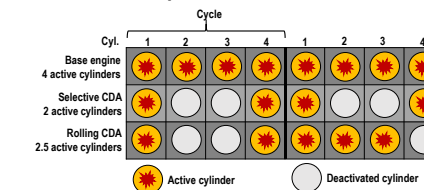
MKP model původního motoru i s převodovkou



Torzní kmity motoru s deaktivací válců



Různé módy deaktivace válců



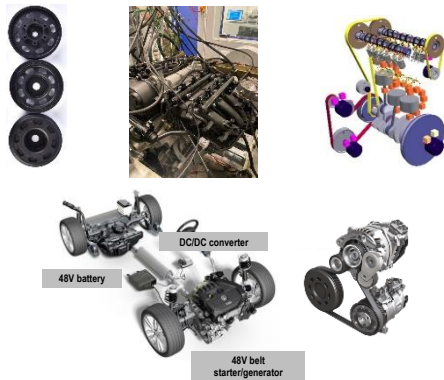
Results of 4-WP08: Pokročilé motory pro budoucí automobily – Achieved 2023-2025

Skoda Auto: ICE design

Measurement(s) on target ICE(s)

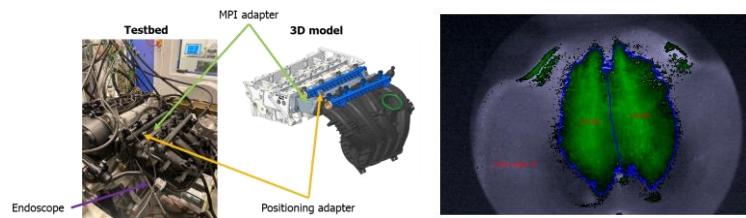


Provide a support to ROs – test engines, data, CAD/CAE models, detailed comp. models, test equipment, etc.

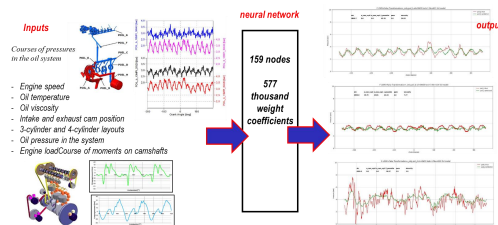


TUL: experiments & hydraulics

Fuel jet visualizations and automated data processing

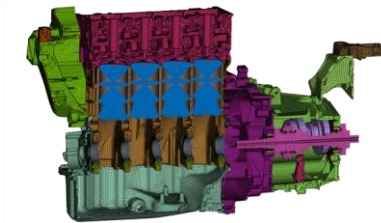


Analysis of lubrication circuit performance – experiments & simulations

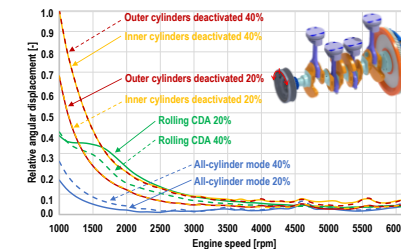


BUT: design & mechanics

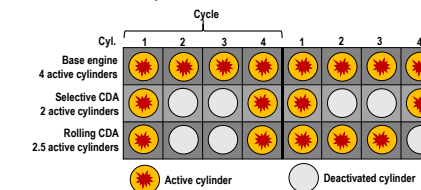
FEM model of the default engine and gearbox



Torsional vibration of ICE with cylinder deactivation



Different cylinder deactivation modes



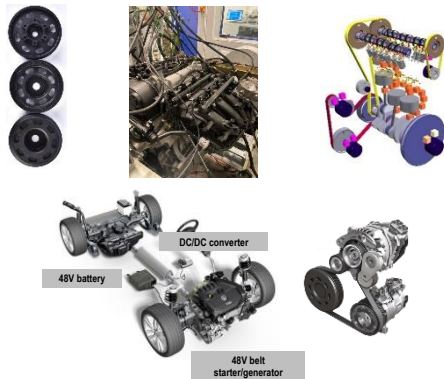
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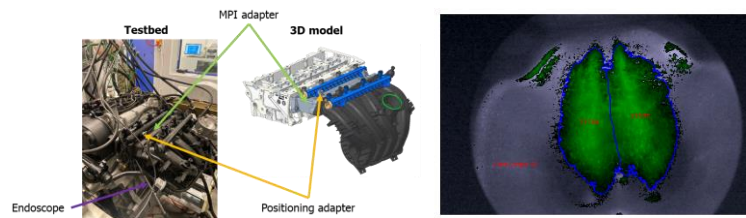


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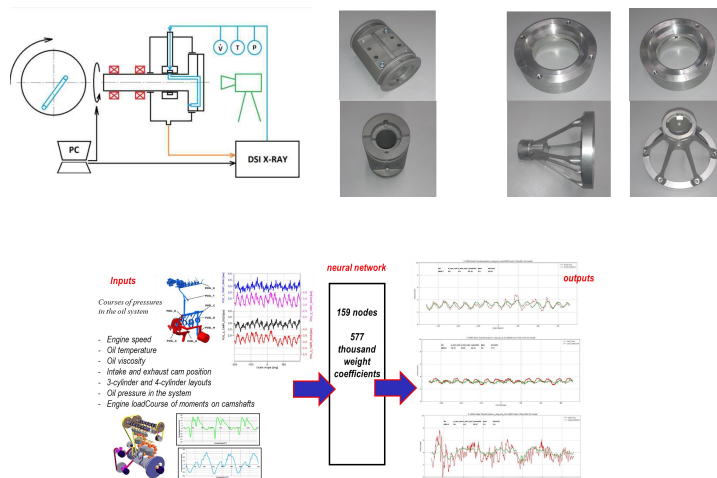


TUL: experimenty & hydraulika

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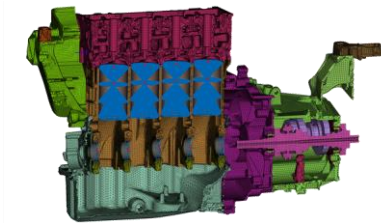


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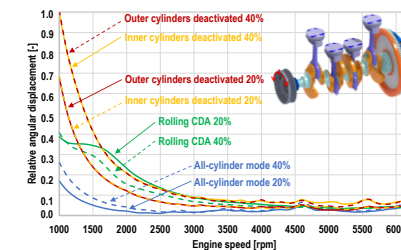


BUT: návrh & mechanika

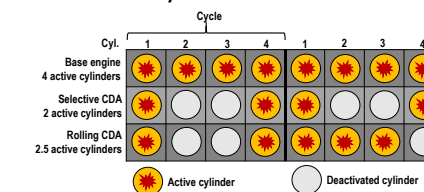
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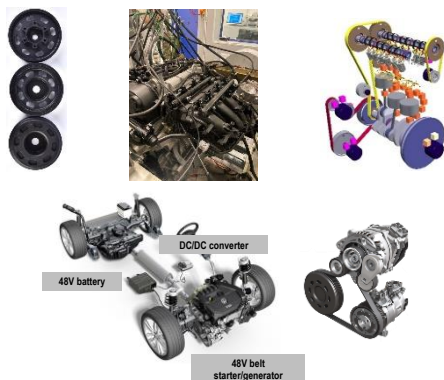
Results of 4-WP08: Advanced Design Solutions for Future Automotive ICEs – Achieved 2023

Skoda Auto: ICE design

Measurement(s) on target ICE(s)

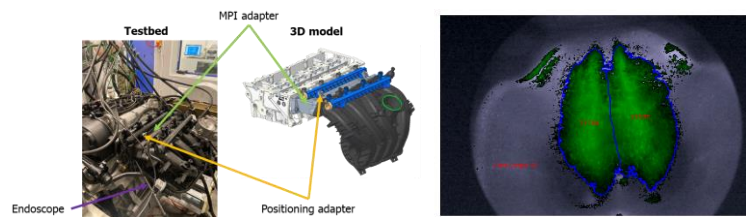


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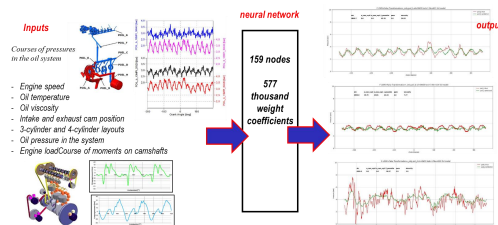
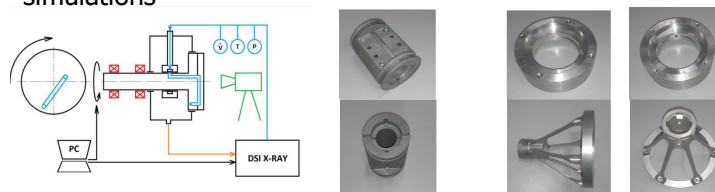


TUL: experiments & hydraulics

Fuel jet visualizations and automated data processing

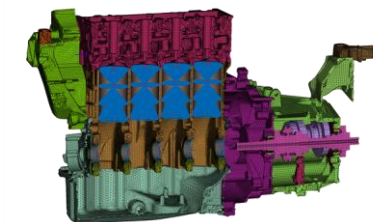


Analysis of lubrication circuit performance – experiments & simulations

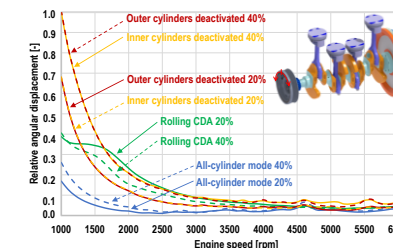


BUT: design & mechanics

FEM model of the default engine and gearbox



Torsional vibration of ICE with cylinder deactivation



Different cylinder deactivation modes

