Contents of Work Package **3-WP02**: Digital twin of advanced valve-train system(s)

Coordinator of the WP

České vysoké učení technické v Praze, Ing. Radek Tichánek, Ph.D.

Participants of the WP

Eaton Elektrotechnika s.r.o. - Ing. Ondřej Bolehovský

Main Goal of the WP

Development of a digital twin (i.e., a multipurpose simulation model) of advanced valve train systems that captures manufacturing tolerances and wear over the engine lifecycle. Predict performance and other critical engine characteristics to avoid/limit degradation.

The software for DCDA simulations that enables detailed thermodynamic analysis of a general DCDA system applied to any type of ICE. Large-scale optimizations will be carried out to find theoretical limits/benefits.

Partial Goals for the Current Period

- DT: Gathering and prioritizing partner requirements
- DT: Development of the base model
- DCDA: Development of energy balance analysis tool
- DCDA: Performed test of modularity and capability

of the software tool

Contents of Work Package **3-WP02**: Digital twin of advanced valve-train system(s)

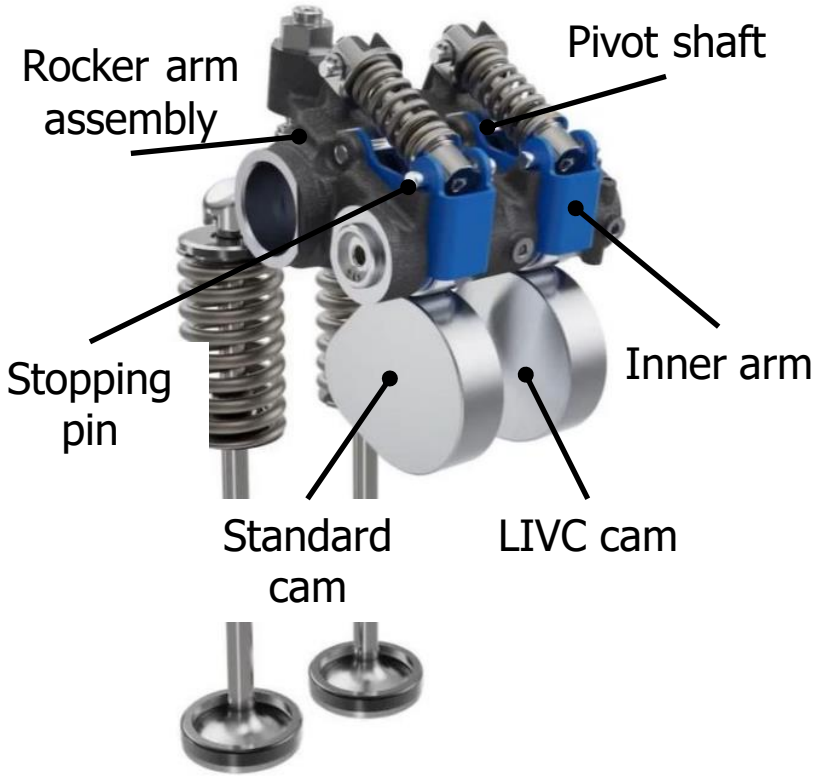
3-WP02: Digital twin of advanced valve-train system(s)

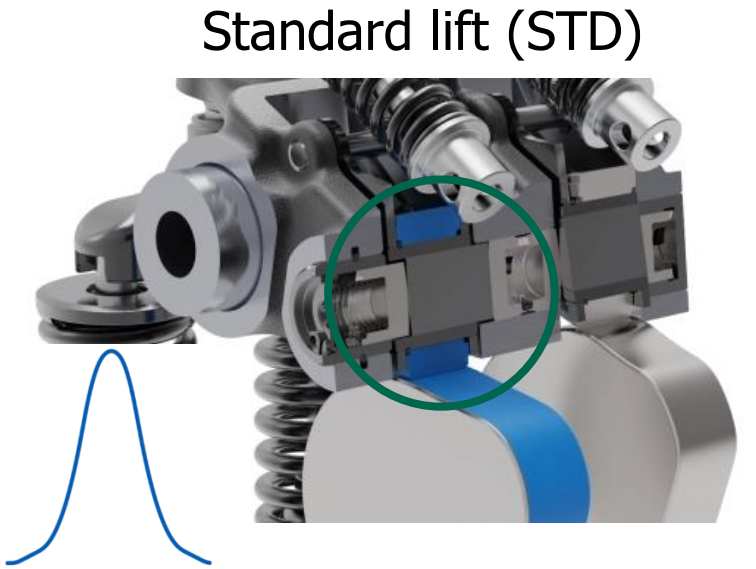
Official 3-WP02 Deliverables:

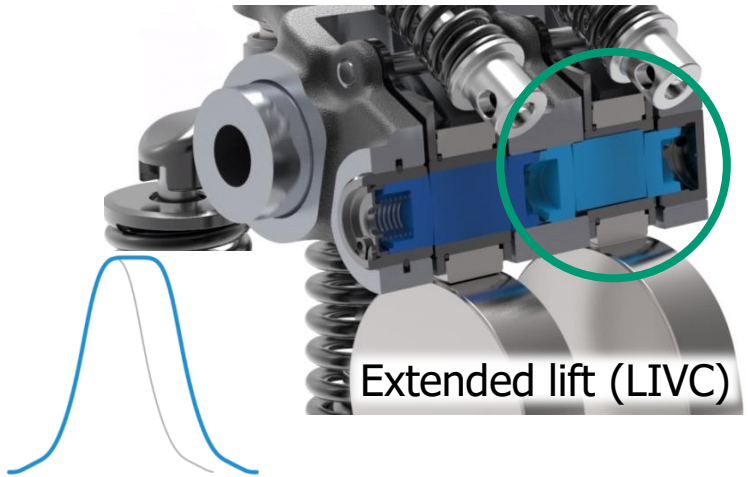
- 3-WP02-001 | **Digital twin of advanced valve-train system(s)**, R-software, VI./2026, EATON 0.6; CTU 0.4;
- 3-WP02-002 | **Report on Milestones - Valve train**, O-other, VI./2026, CTU 0.9; EATON 0.1 – Ing. Ondřej Bolehovský

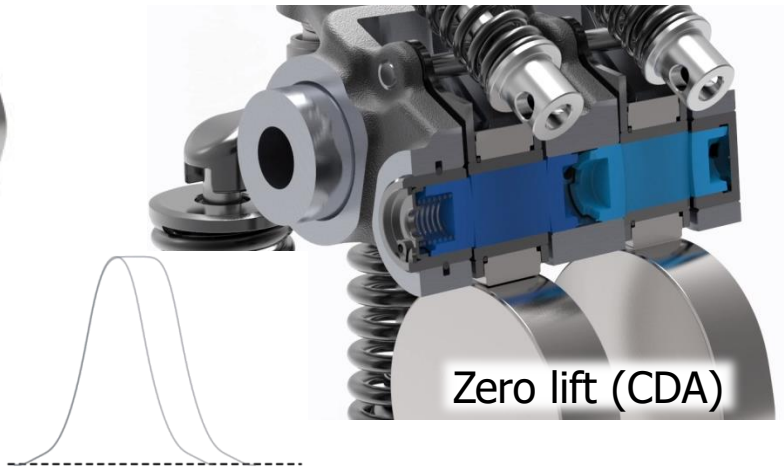
Activities in **3-WP02**: Digital twin of advanced valve-train system(s)

3-WP02-001 | **Digital twin of advanced valve-train system(s)**





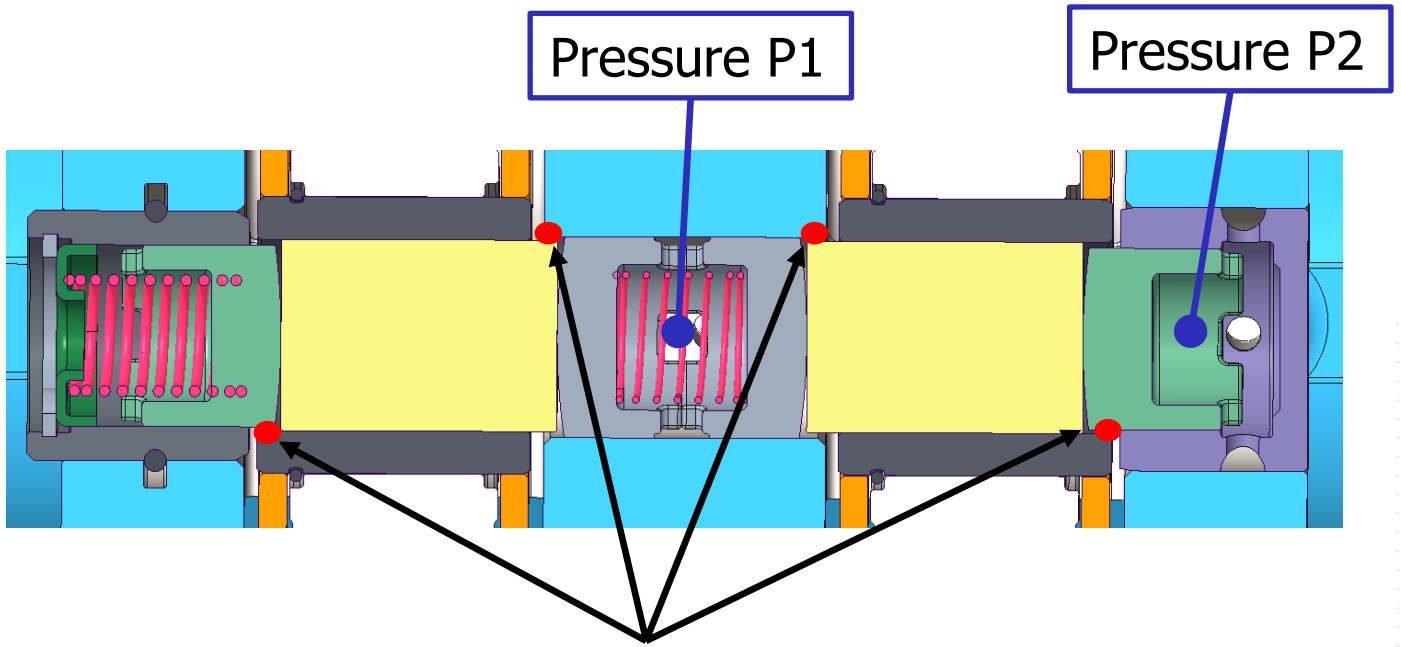




Eaton Dual Deactivating Roller Rocker (2DR Rocker)

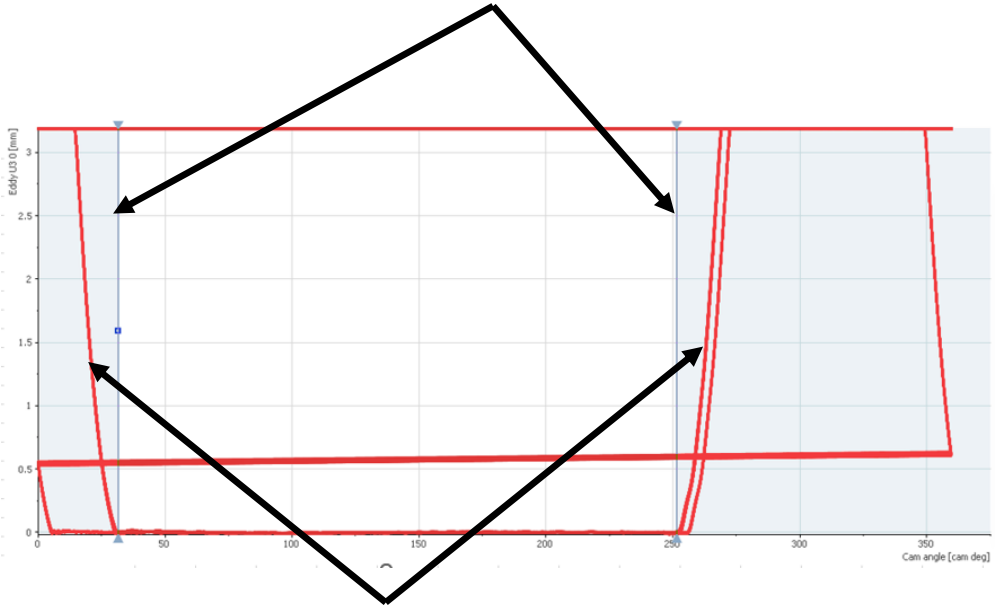
Activities in **3-WP02**: Digital twin of advanced valve-train system(s)

3-WP02-001 | **Digital twin of advanced valve-train system(s)**



Critical latch mechanism – critical possitions

Switching time = movement of the pins only on the base circle



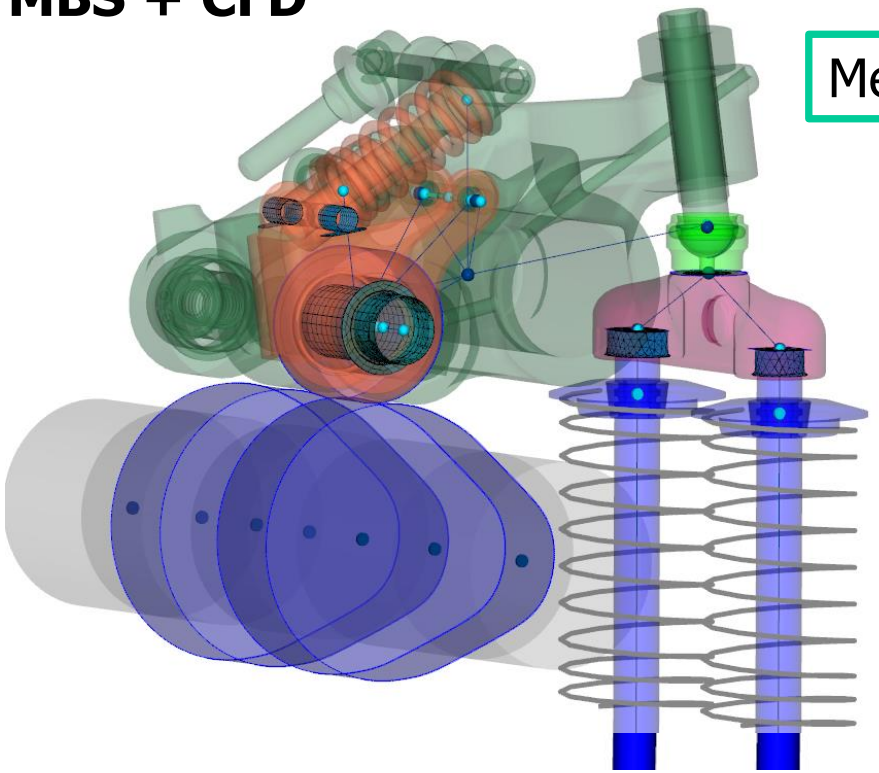
Valve lift

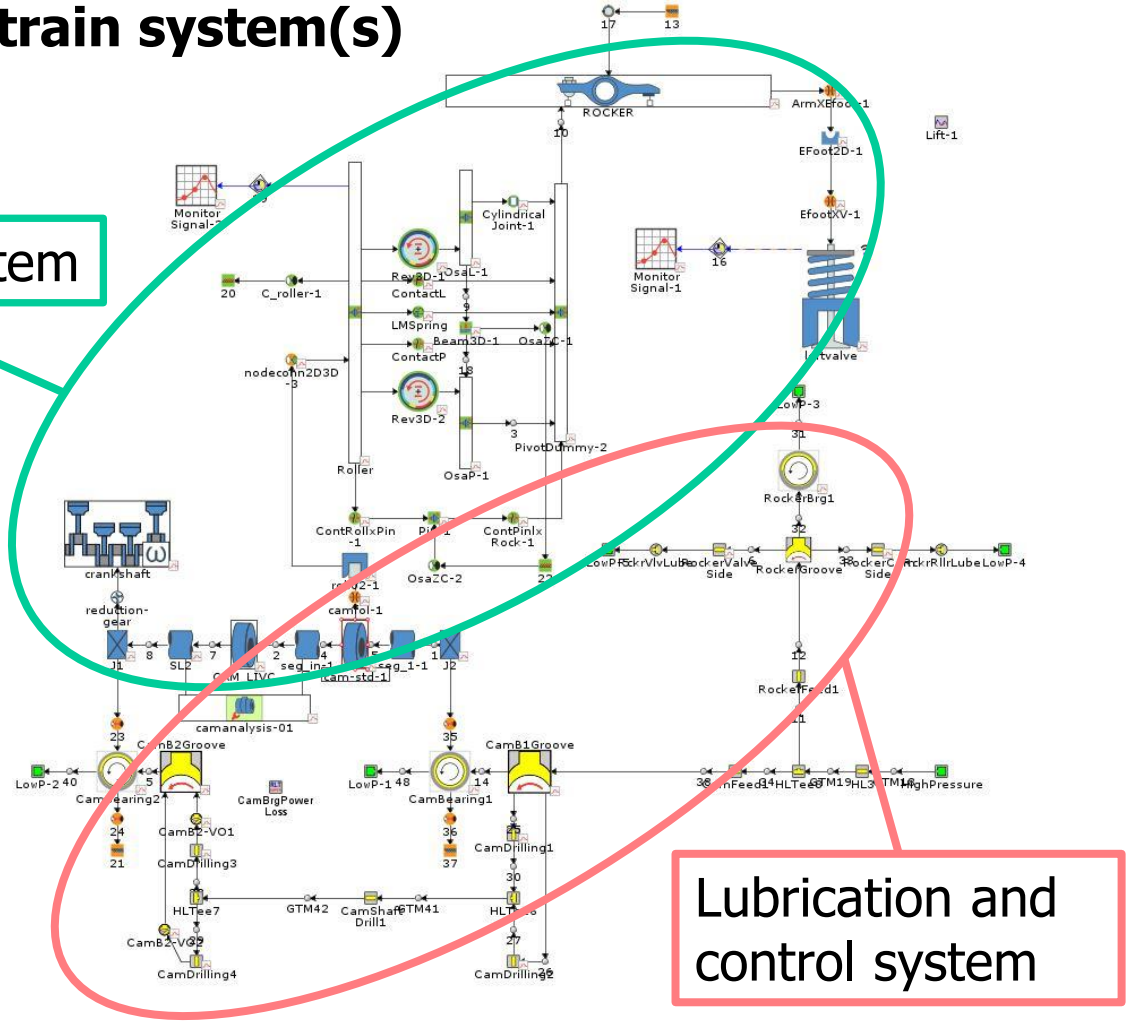
Activities in **3-WP02**: Digital twin of advanced valve-train system(s)

3-WP02-001 | **Digital twin of advanced valve-train system(s)**

Development of the base model

MBS + CFD

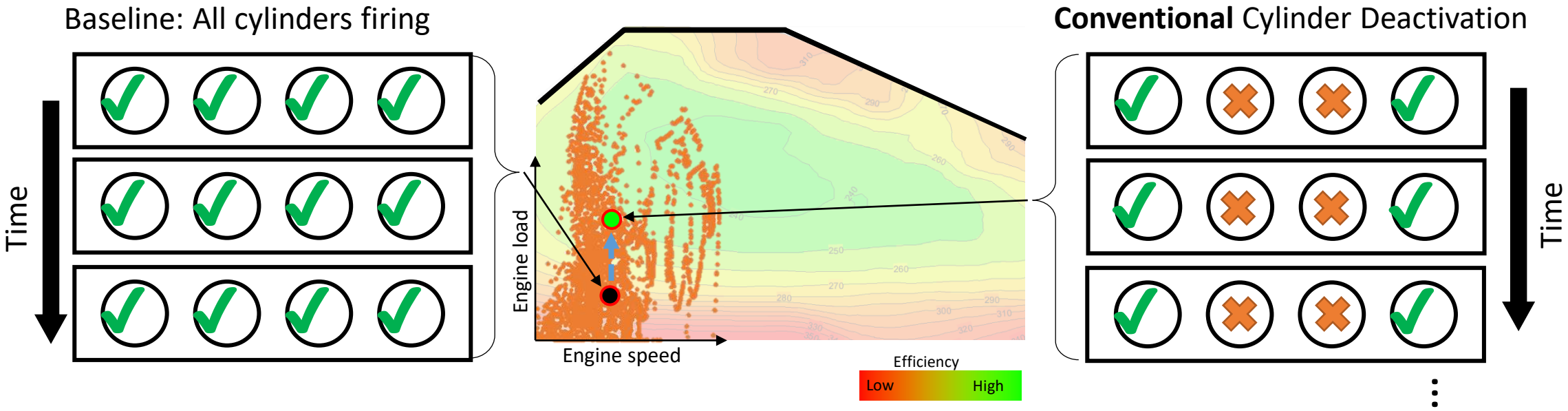




Activities in **3-WP02**: Report on Milestones - Valve train

3-WP02-002 | **Report on Milestones - Valve train**

Dynamic Cylinder DeActivation (**DCDA**) - Explanation



Activities in **3-WP02**: Report on Milestones - Valve train

3-WP02-002 | **Report on Milestones - Valve train**

Dynamic Cylinder DeActivation (**DCDA**) - Explanation

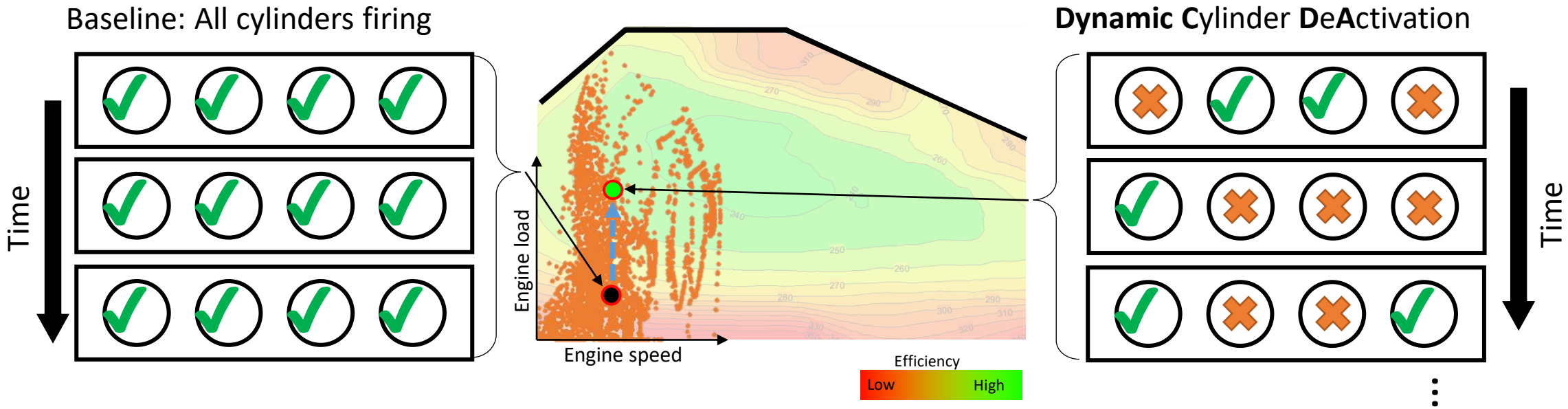


Table 6. Results of thermodynamic model optimization – BSFC percentage difference between the best CDA approaches and the baseline (average of 1500, 2000, and 3000 min^{-1}); three levels of engine displacement utilization: 25%[1], 50%[2], and 75%[3].

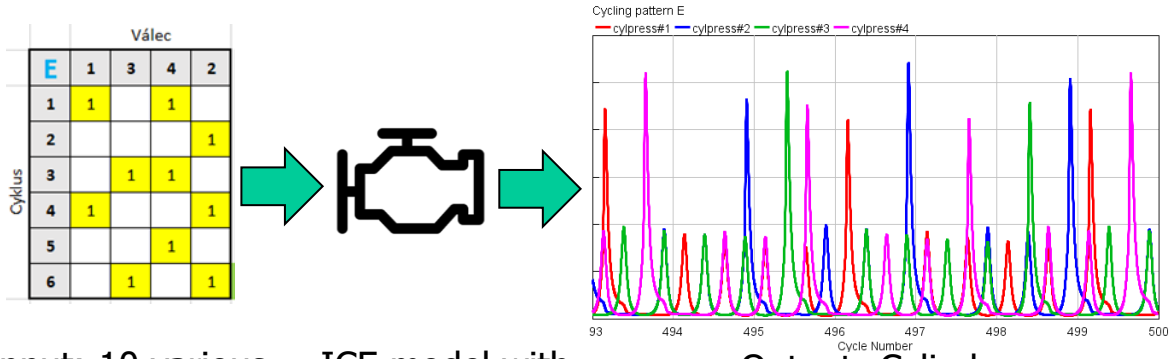
Torque [Nm]	20 [Nm]	30 [Nm]	40 [Nm]	50 [Nm]	60 [Nm]
DCDA vacuum	−18.3[1]	−9.2[2]	−6.3[2]	−4.2[2]	1.4[3]
DCDA air	−11.9[1]	−7.8[2]	−4.0[2]	−2.1[3]	2.3[3]
SCDA (air)	−17.1[1]	−10.8[2]	−6.6[2]	−3.9[3]	3.6[3]

Bolehovsky O, Vitek O, Mares B. Dynamic cylinder deactivation: Thermodynamic mapping for the case of stoichiometric SI ICE. International Journal of Engine Research. 2023;24(4):1724-1743.

Activities in **3-WP02**: Report on Milestones - Valve train

3-WP02-002 | **Report on Milestones - Valve train – Year 2023**

- Modularity and capability of the software tool was proved – applied on a different 4-cylinder engine model for utilization in another working package (4-WP08 of FEFEFOV):

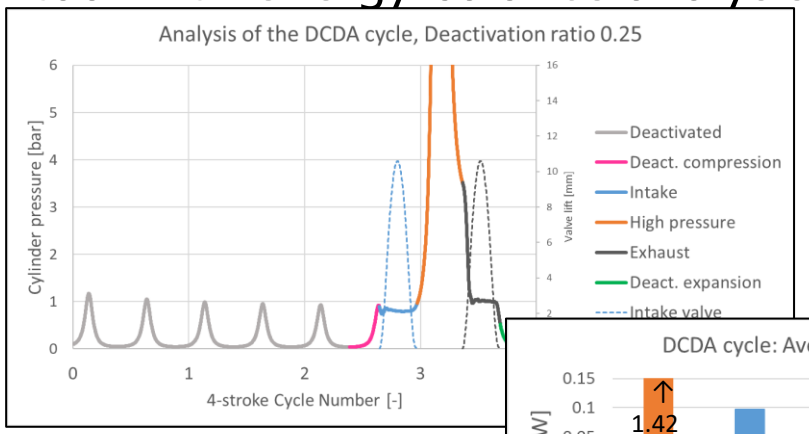


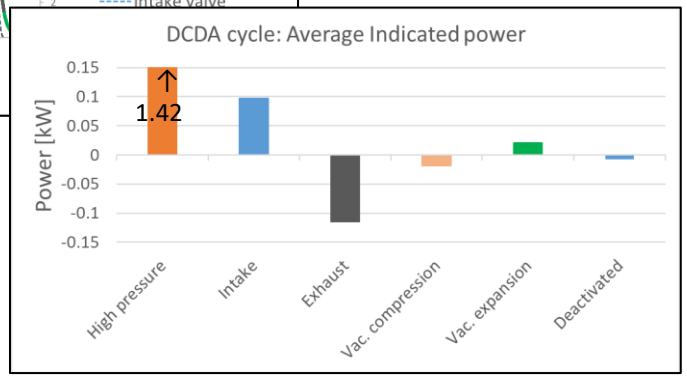
Input: 10 various cycling patterns

ICE model with DCDA tool

Output: Cylinder pressures

- After a broad optimization (2022), deeper understanding of energy balance of the DCDA cycle was needed → supplementing the DCDA tool with energy balance analysis capability:





Fulfillment of goals and deliverables of **3-WP02**: Digital twin of advanced valve-train system(s)

Current State of Deliverables and Fulfillment of Goals

- 3-WP02-001 | **Digital twin of advanced valve-train system(s)**, R-software, VI./2026, EATON 0.6; CTU 0.4 – in progress & no major delays:
  - Prioritized requirements based on partner data
  - Defined the scope of the project, including specifying the benefits of the model and defining its boundaries.
  - Selected the appropriate modeling approaches: 3D MBS + CFD for DT and CFD for DCDA
  - Collected measured data and progress in developing the base model

- 3-WP02-002 | **Report on Milestones - Valve train**, O-other, VI./2026, CTU 0.9; EATON 0.1 – in progress & no major delays:
  - The progress in developing the energy balance analysis tool
  - Proven application of modularity and capability of the software tool

Fulfillment of goals and deliverables of **3-WP02**: Digital twin of advanced valve-train system(s)

List of Due Deliverables and Their Added Value

- **3-WP02-001** – offer the Dual Deactivating Roller Rocker (2DR Rocker) for medium- and heavy-duty engines allows Eaton to keep its position on the market. Eaton expects 1-2% CO2 emission decrease, higher compression ratio and better aftertreatment thermal performance (LIVC)
- **3-WP02-002** – Eaton expects reduction NOx in low load cycle by around 40% while reducing CO2 by 5-8% (CDA) and NOx reduction up to 90% when combined with advanced aftertreatment.

Current contribution of **3-WP02**: Digital twin of advanced valve-train system(s)

Assessment of the Contribution of Deliverables

- modularity and capability of the software tool for DCDA was applied on a different 4-cylinder engine model for utilization in 4-WP08 of FEFEFOV project (VUT)

Current contribution of **3-WP02**: Digital twin of advanced valve-train system(s)

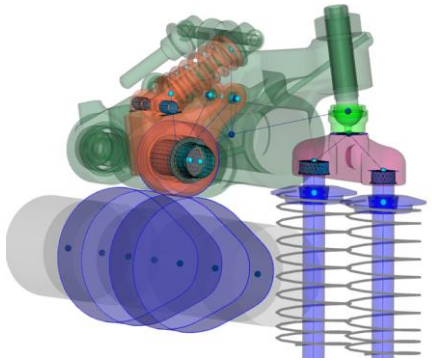
Assessment of the Formal/Administrative Goals of the Work Package

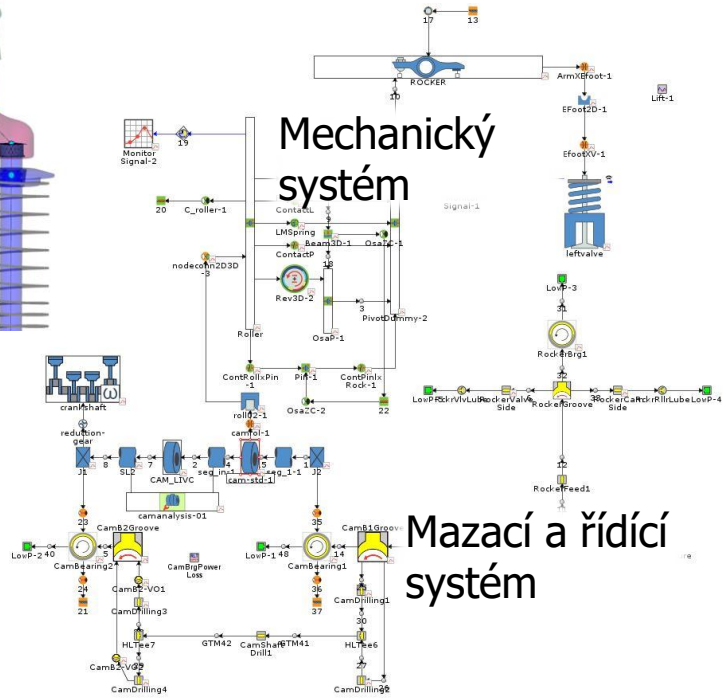
	CTU	Eaton
Finances (reporting/spending)	OK	OK
Commercialization (for whole organization)	OK	OK
Deliverables	OK	OK

Výtah z prací 2023-2025 na **3-WP02**: Digital twin of advanced valve-train system(s)

3-WP02-001

Byly vybrány přístupy k modelování: 3D MBS + CFD, shromážděna měřená data a bylo dosaženo pokroku ve vývoji základního modelu





Mechanický systém

Mazací a řídící systém

Ing. Radek Tichánek, Ph.D.
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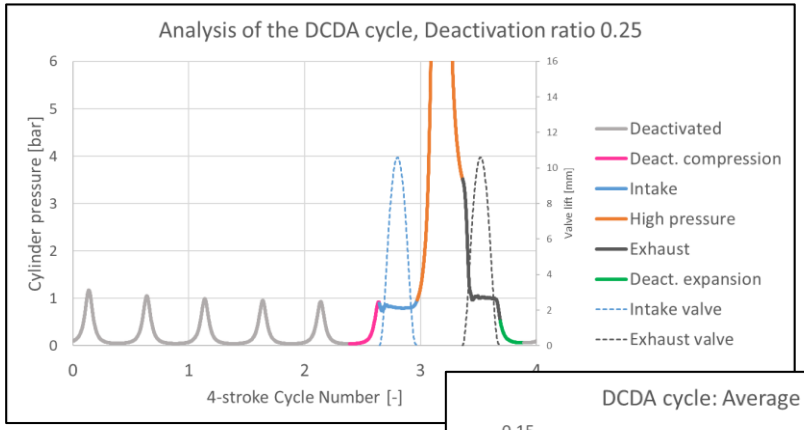
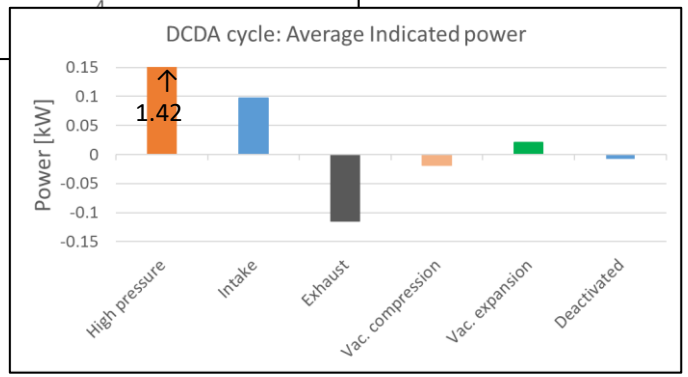
3-WP02-002

V roce 2022 proběhla rozsáhlá optimalizace motoru v DCDA módu, jejíž výsledky vytvořily požadavek na hlubší porozumění energetické bilance DCDA módu→ softwarový nástroj začal být proto rozšiřován:

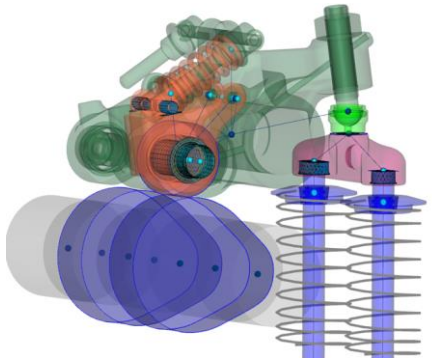


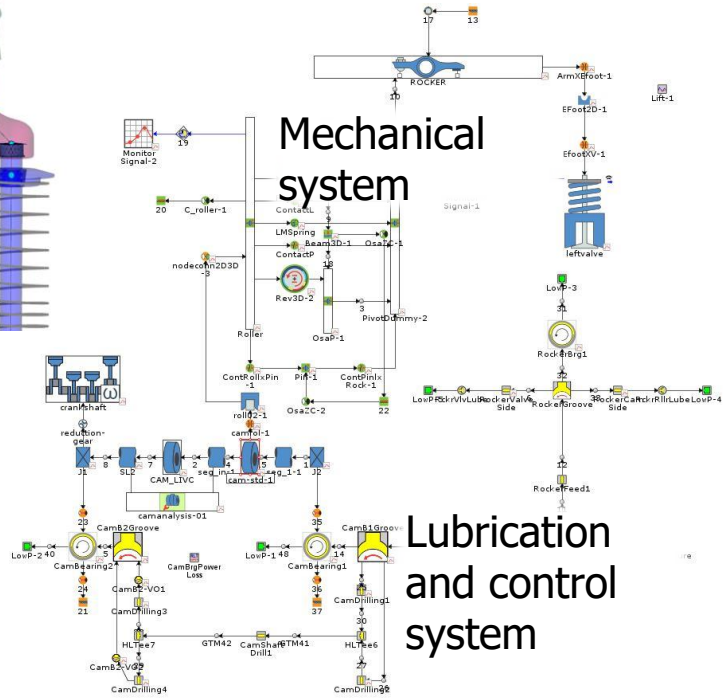


Results of **3-WP02**: Digital twin of advanced valve-train system(s) – Achieved 2023-2025

3-WP02-001

Selected the appropriate modeling approaches: 3D MBS + CFD, collected measured data and progress in developing the base model





Mechanical system

Lubrication and control system

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3-WP02-002

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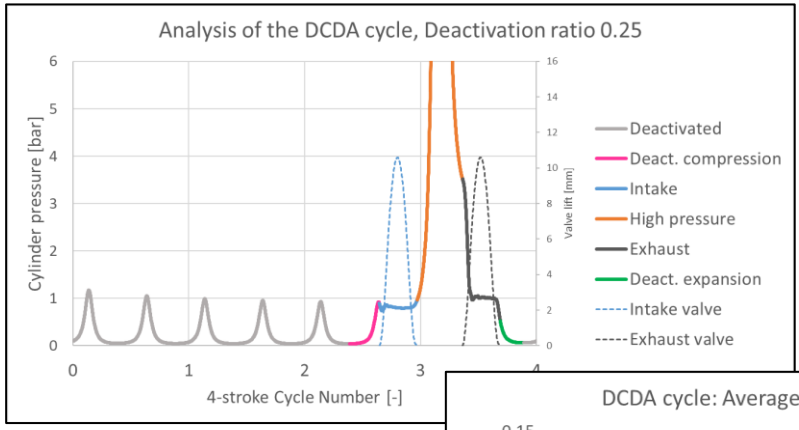

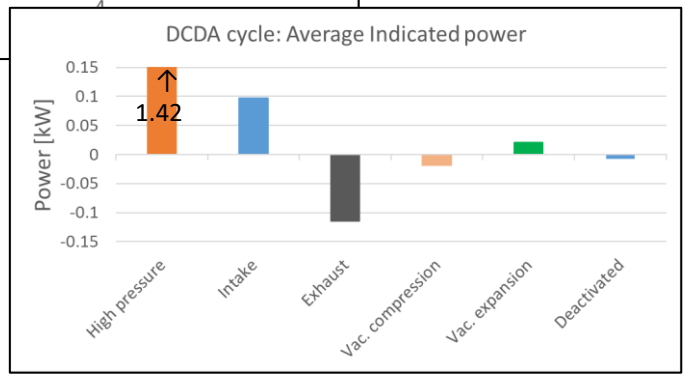

Výtah z prací 2023 na **3-WP02**: Digital twin of advanced valve-train system(s)

3-WP02-001

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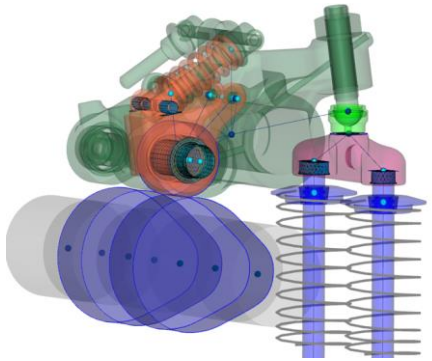

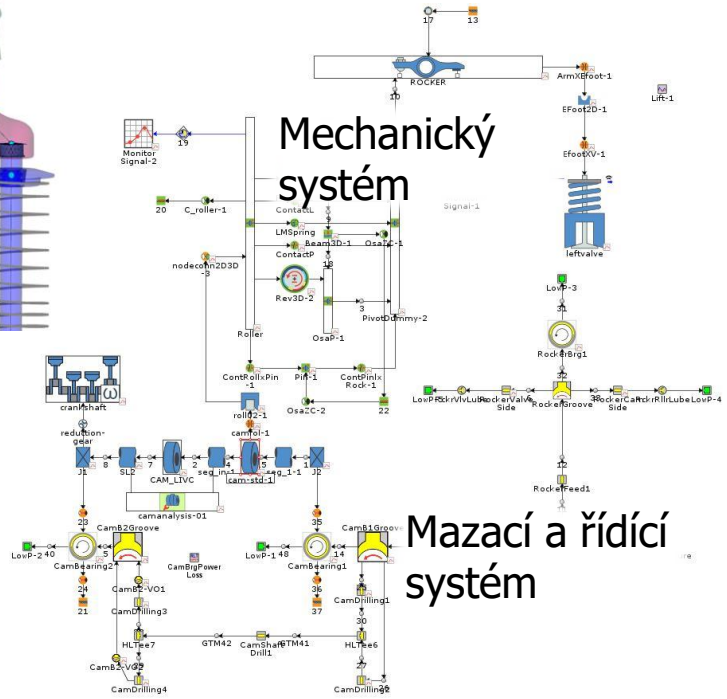

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3-WP02-002

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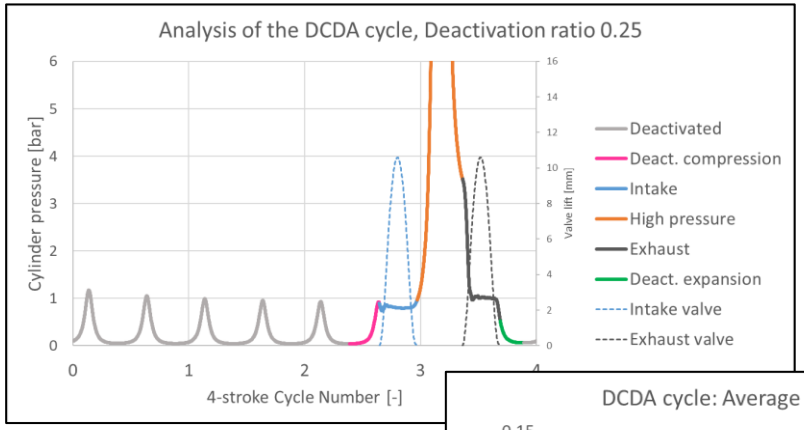

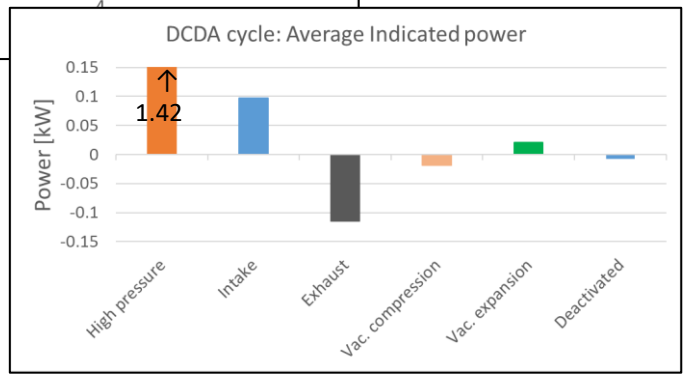

Results of **3-WP02**: Digital twin of advanced valve-train system(s) – Achieved 2023

3-WP02-001

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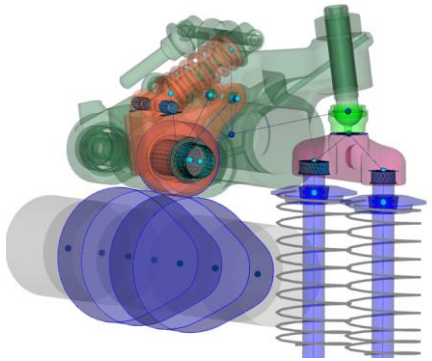

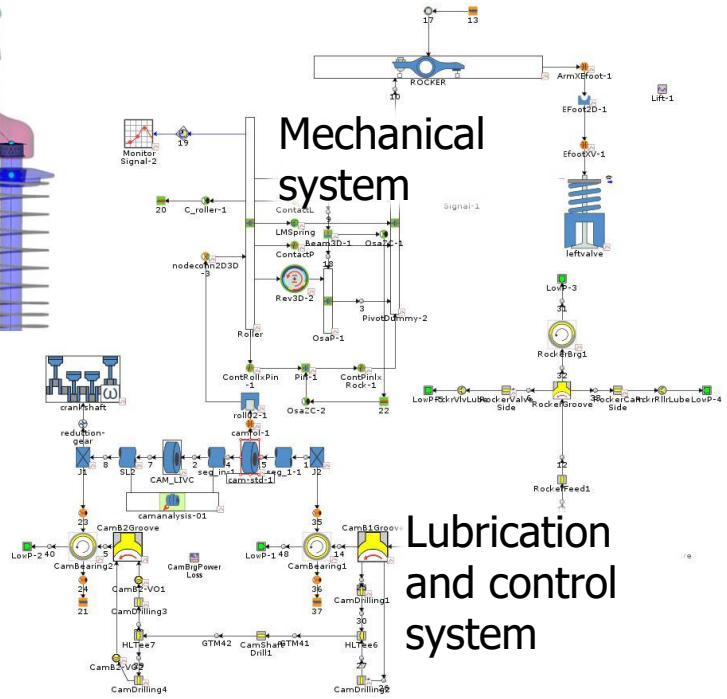

Mechanical system

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3-WP02-002

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