



Contents of Work Package 1-WP08: Design Assistance Systems and Calibrated Simulation Processes

1-WP08: Design of Internal Combustion Engine with Design Assistance SYstem (DASY)

Coordinator of the WP

České vysoké učení technické v Praze, zodpov. osoba Ing. Jindřich Hořenín, Ing. Petr Hatschbach, CSc. Prof. Ing. Jan Macek, DrSc.

Main Goal of the WP

- SPEED IN ASSESSMENT, ENGINEERING, ANALYSIS
- Automate prediction of performance, computation of geometry, generation of solid models
- Integrate engineering and analysis phases into the design process for a robust design. Use knowledge-based design rules (including manufacturing)
- Provide consistent design process (product quality, reliability, ..)
- Provide rapid target assessment and tradeoffs of powertrains early in the vehicle program



Content

- Main goal of the WP
- Powertrain development procedure
- Parametric model definition
- Crankshaft mechanism design and optimization
- Camshaft mechanism design and optimization
- Gearbox design and optimization
- Powertrain design and optimization



Main goal of the WP

CREATION OF A QUICK TOOL FOR THE DESIGN OF A VEHICLE POWERTRAIN, WHICH ENABLES

- Quick creation of the basic geometry of the vehicle powertrains (powertrain study)
- Comparison of variant designs and selection of suitable geometry
- Quick definition of masses, moments of inertia and geometry dimensions for detailed calculations

DEVELOPMENT OF THE VEHICLE POWERTRAIN DESIGN METHODOLOGY (STANDARDS)

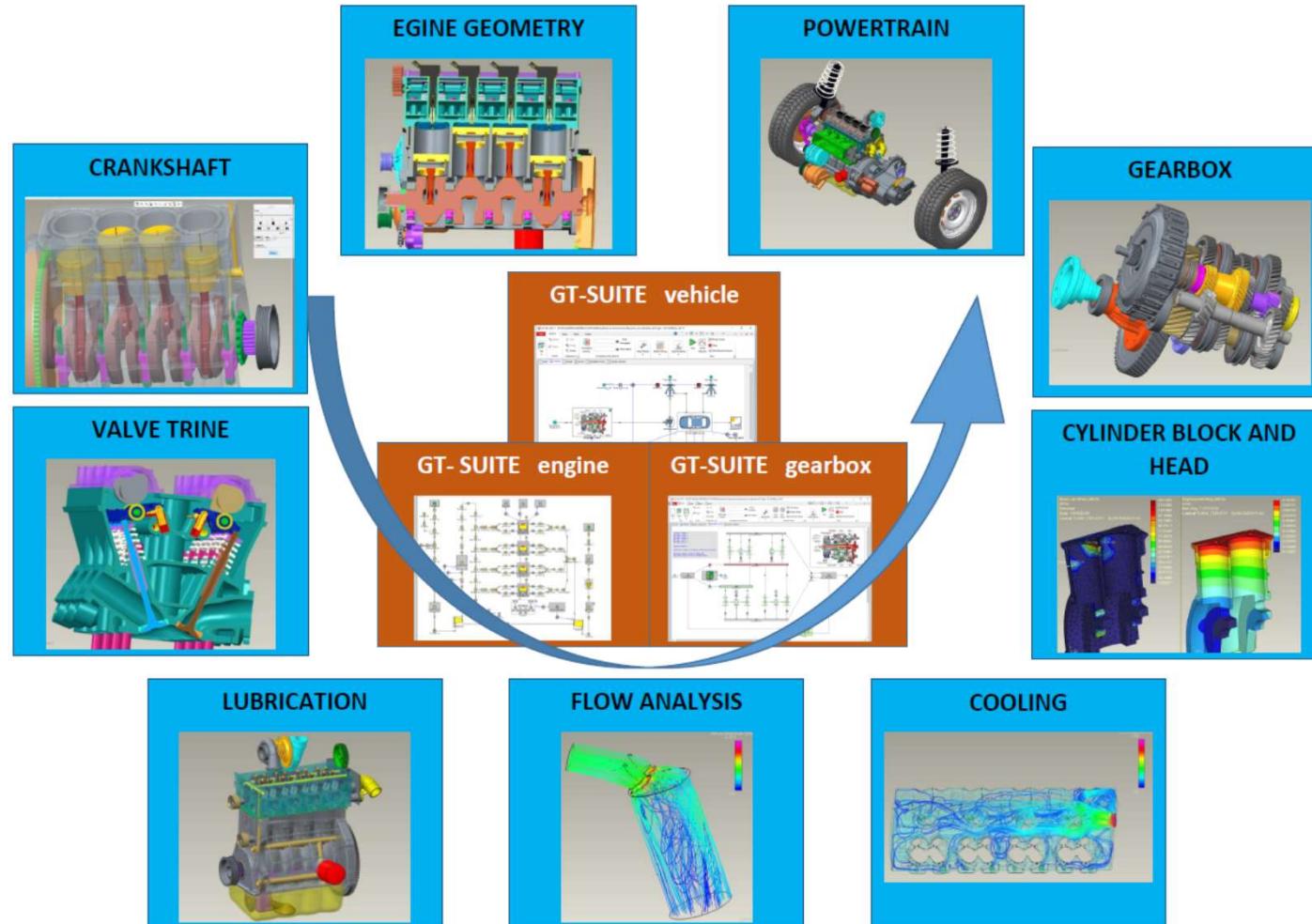
- Definition of aggregate subdivision
- Definition of the development process
- Consistent design process
- Automation of design steps
- Preservation of knowledge of experts in the methodology of the design process
- Bidirectional connection of 3D models with calculation programs

CREATION OF A PARAMETRIC 3D MODEL OF THE DRIVE UNIT

- ❖ Definition of parameters of parts and assemblies (dimensions, material, construction, ..) and their mutual relations
- ❖ Parameter database (performances, dimensions, materials, etc.)
- ❖ Database of design of key parts
- ❖ Implementation of design principles in 3D models
- ❖ Definition of boundary conditions and computational networks for strength analysis of parts



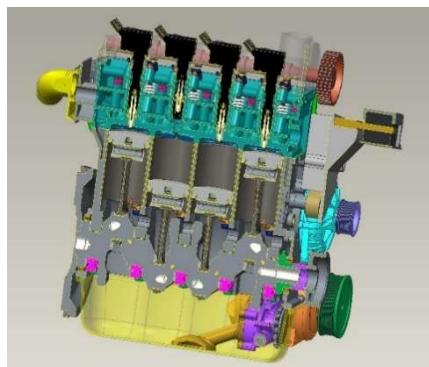
Powertrain development procedure





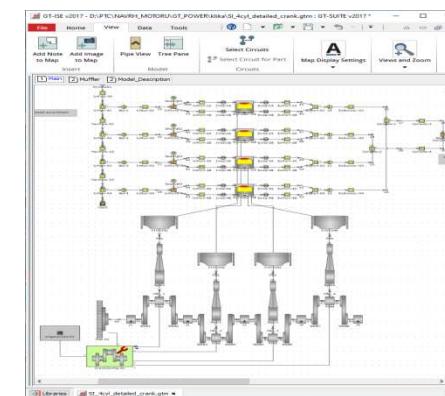
Interaction between DASY GT-SUITE

From DASY

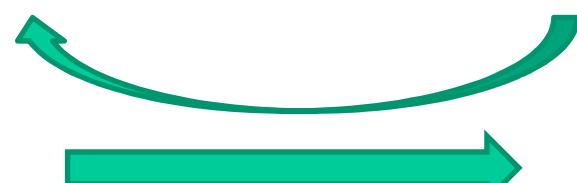
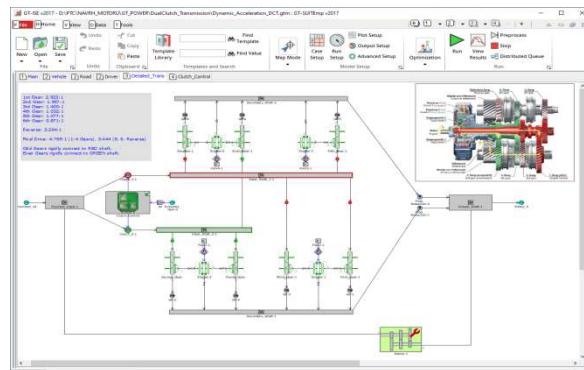


*connecting
text files*

into GT-SUITE

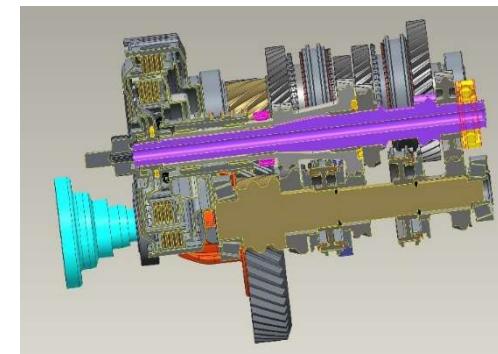


From GT-SUITE



*connecting
text files*

into DASY





Parameters calculation

Files generation

		4_SI_ENGINE-DETAIL - Vi.xlsx - Excel				4_SI_ENGINE-DETAIL - Vi.xlsx - Excel			
Soubor	Domů	Vložení	Rozložit	Vzorc.	Data	Reviz.	Zobrazení	Povolení	Daří se informace Hořenin, J...
INPUT	ENGINE TYPE	TYPE=	A	I	"TEST"	A	I		
	MAX POWER	P _e	A	I	118	kW	A	I	
	RPM	n _m	A	I	5000	1/min	A	I	
	COMPRESSION RATIO	ε	A	I	10,5		A	I	
	SPACE BETWEEN PISTONS	X _d	A	I	1	mm	A	I	
	PISTON Ø	BORE=	A	R	74,5	mm	A	R	
	STROKE	STROKE=	A	R	85,9	mm	A	R	
	CYLINDER NUMBER	i	A	I	4	mm	A	I	
MAIN JOURNAL	BORE SPACING	BS=	A	C	81,00	mm			
KRUKOVÝ PRÍDRŽ	JOURNAL Ø	MJ_DIA=	A	R	51,00	mm			
	JOURNAL LENGTH	MJ_LEN	A	R	24,00	mm			
	RADIUS	MJ_R	A	R	1,70	mm			
	LENGH	MB_LEN	A	R	19,00	mm			
	THICKNES	MB_THK=	A	C	2,15	mm			
CRANKPIN DOURA	JOURNAL Ø	CJ_DIA=	A	R	44,70	mm			
	JOURN...								
	RADIUS								
	BEARING								
	BEARING								
	CRANK:								
	ARM TH								
	FLYWHEEL ARM								
	PITCH C								
PISTON PIN	PISTON PIN LENGTH	PPIN_LEN=	A	C	52,00	mm			
	CONROD LENGTH	ROD_L=	A	C	152,00	mm			
	CRANK PIN WIDTH	ROD_WCR=	A	E	19,70	mm			
	BEARING	ROD_DCR=	A	E	47,81	mm			
	OUTER Ø-BEARING	ROD_DCR1=	A	C	63,00	mm			
	geometrie klik mech								
	geometrie klik mech								

I - Inserting input data
 T - Test parameters
 A - Possible Adjustments

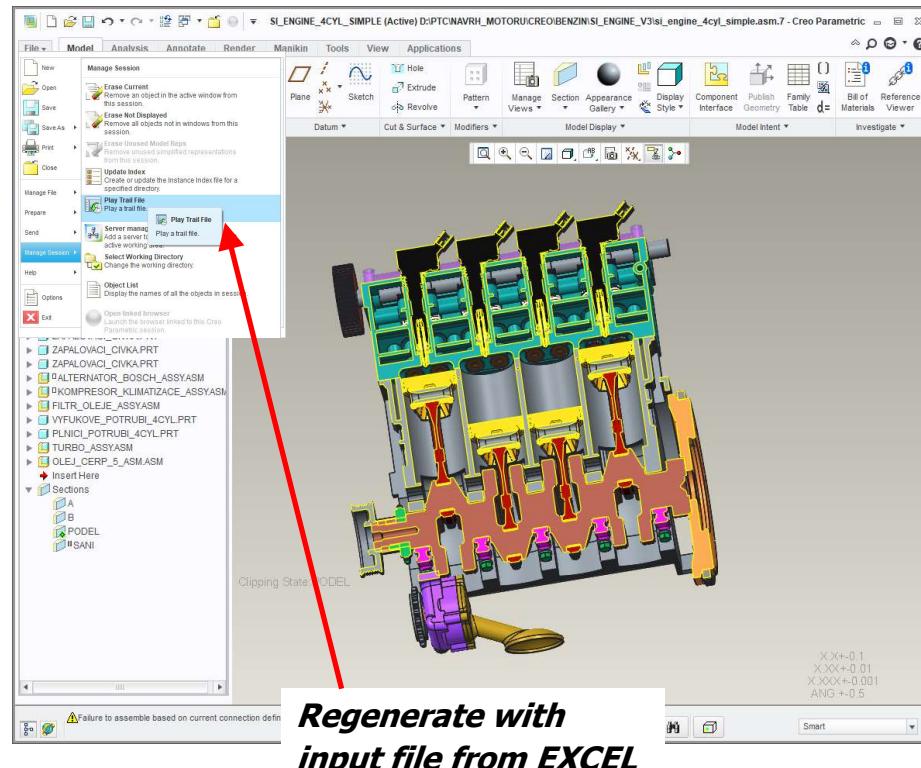
File for CREO
 180 parameters

File for GT-POWER
 30 parameters

head_deck_th=5
 max_dome=3
 piston_top_th=27
 piston_shirt_th=7
 ring_th=2,5
 cylinder_wall_th=5
 cylinder_l=210
 cylinder_water_top=15
 cylinder_water_bottom=195

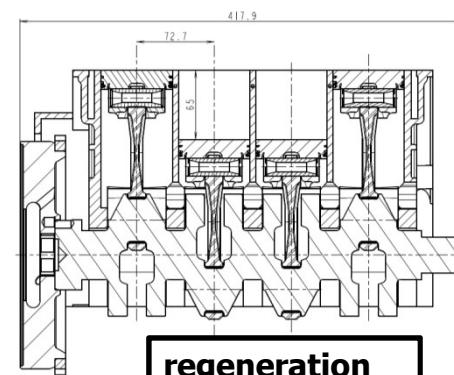
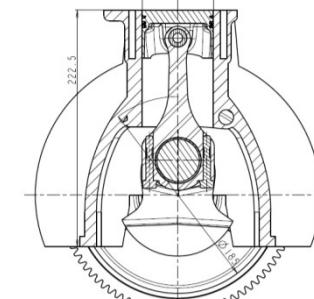


3D model in CREO generation

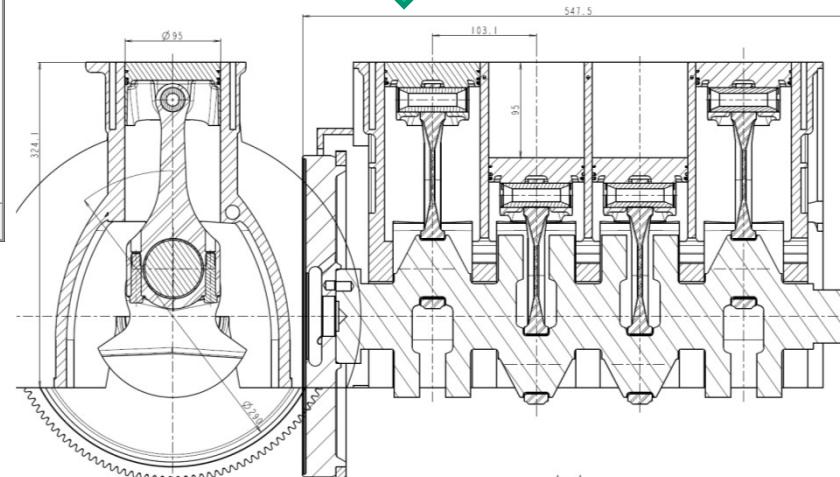


bore 67 mm

stroke 65 mm

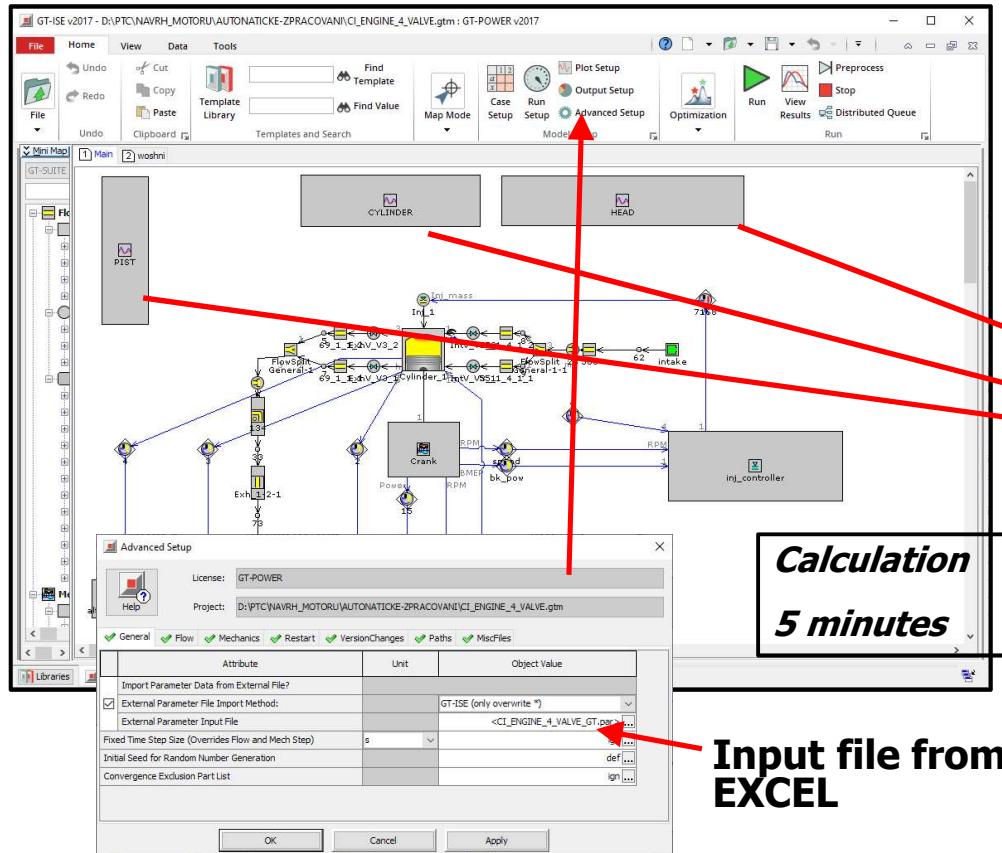


bore 95 mm
stroke 92 mm





GT-POWER calculation



Three separate windows show the results of different engine cases:

CASE # 1	Cyc.Angle	alfa_cyl	t_cyl	p_cyl
	deg	W/(m^2-K)	K	bar
1.0000000	2979.3664	1276.5715	69.181439	1.0000000
2.0000000	3097.7855	1308.6008	70.51362	2.0000000
3.0000000	3212.5145	1341.2629	71.786612	3.0000000
4.0000000	3322.6140	1374.3520	72.804064	4.0000000
5.0000000	3425.4399	1407.9569	73.623218	5.0000000
6.0000000	3519.5892	1445.8221	74.353126	6.0000000
7.0000000	3609.4281	1483.9102	74.846665	7.0000000
8.0000000	3684.9858	1521.8578	75.118845	8.0000000
9.0000000	3745.3594	1559.4343	75.164764	9.0000000
10.0000000	3789.6904	1596.4661	74.995849	10.0000000
11.0000000	3818.1149	1632.7654	74.621835	11.0000000
12.0000000	3829.2633	1668.0615	74.038427	12.0000000
13.0000000	3824.5329	1702.2062	73.273331	13.0000000
14.0000000			72.343655	14.0000000
15.0000000			71.267277	15.0000000
			70.059957	
			68.736681	
			67.312636	
			65.796163	
			64.211937	
			62.573649	
			60.894125	
			59.193694	
			57.466062	

Output files to CREO

- pressure
- temperature
- heat transfer coefficient, ...

Input file from EXCEL

A screenshot of a GT-ISE parameter block titled 'CI_ENGINE_4_VALVE_CYLINDER.trn – Poznámkový blok'. It shows input values for various cylinder parameters:

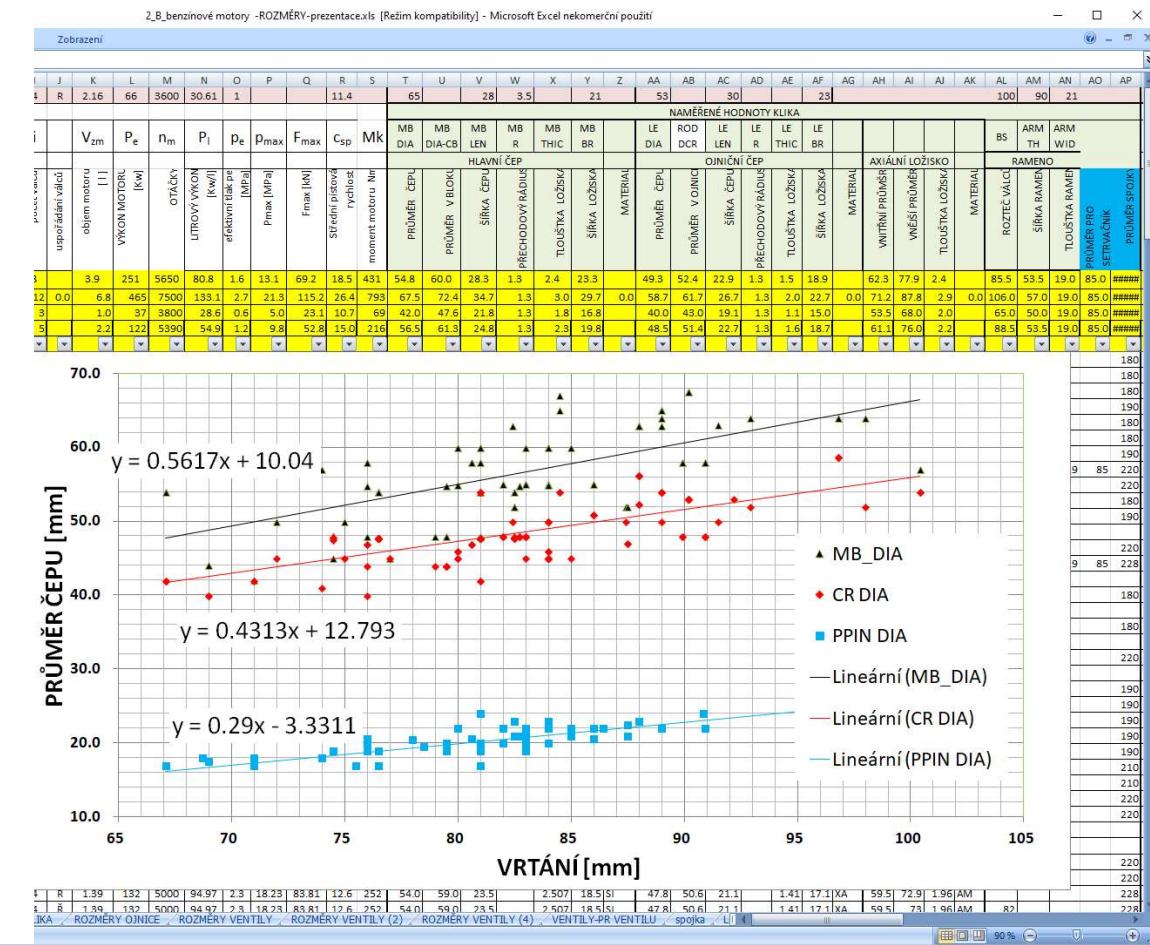
CASE # 1	cylinder1H	cylinder2H	cylinder3H	cylinder1TE	cylinder2TE	cylinder3TE	cylinder1T	cylinder2T	cylinder3T
	W/(m^2-K)	W/(m^2-K)	W/(m^2-K)	K	K	K	K	K	K
331.23126	165.87726	90.946085	1075.9009	861.69628	742.49188	490.58107	418.69273	399.33727	



Parameters definition

Creation of databases of performance parameters and dimensions of parts according to engine groups

- *Spark ignition engines bore from 67mm up to 102mm*
 - 400 engines
 - 180 engines with dimensions
- *Compression ignition engines passenger cars*
bore from 70mm up to 105 mm
 - 565 engines
 - 120 engines with dimensions
- *Compression ignition engines for commercial vehicles*
bore from 100mm up to 170mm
 - 110 engines
 - 10 engines with dimensions





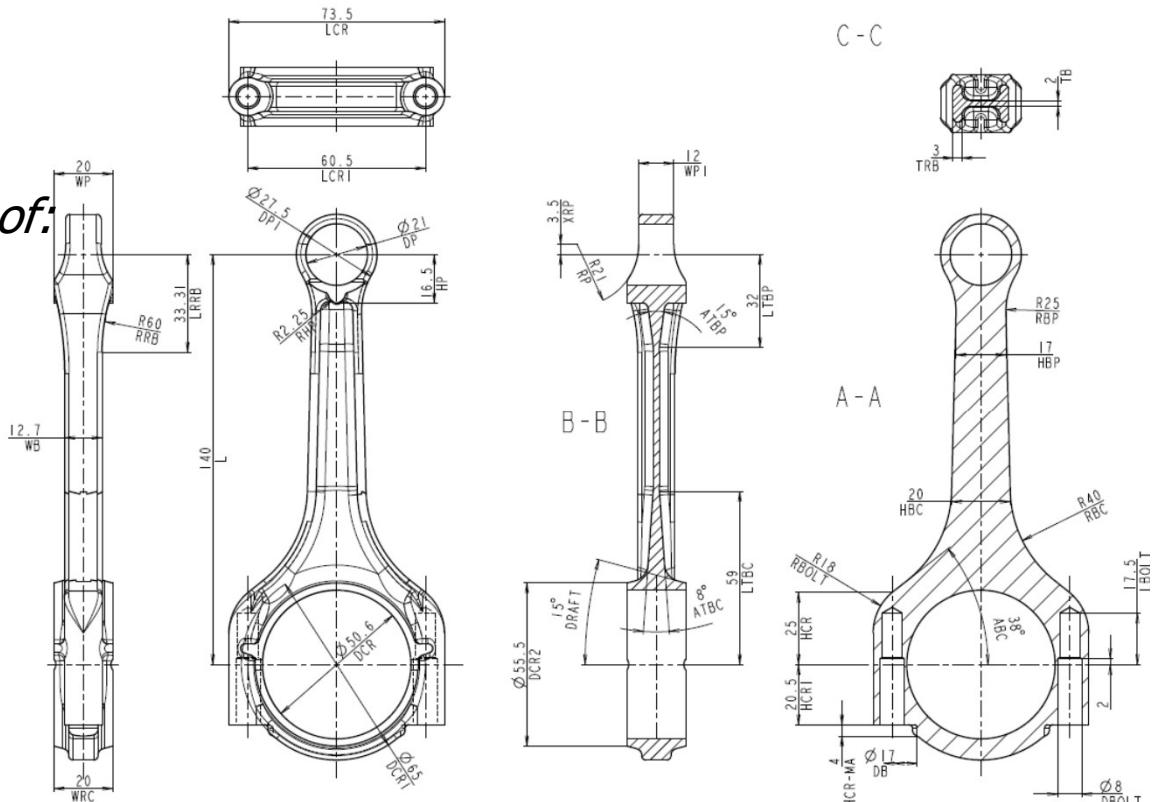
Parameters definition

Parameter types:

- Dimensions
- Material
- Design

Creating 3D models with definition of:

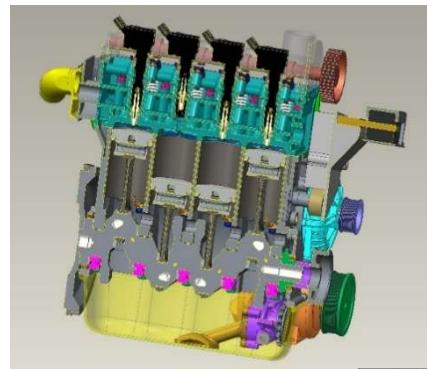
- parameter relationships
- reference dimensions
- control parameters
- geometry according to design principles
- material
- finite element mesh
- boundary conditions
- load
- calculation with evaluation





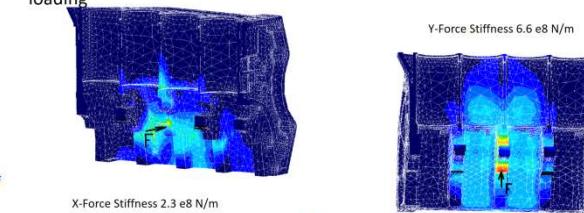
Crankshaft mechanism design and optimization

from 3D geometry



Crankshaft Bearing Stiffness

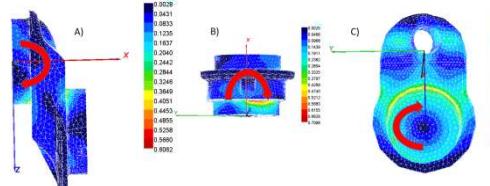
- Performed FEM rough analysis of the engine block under F_x , F_y loading



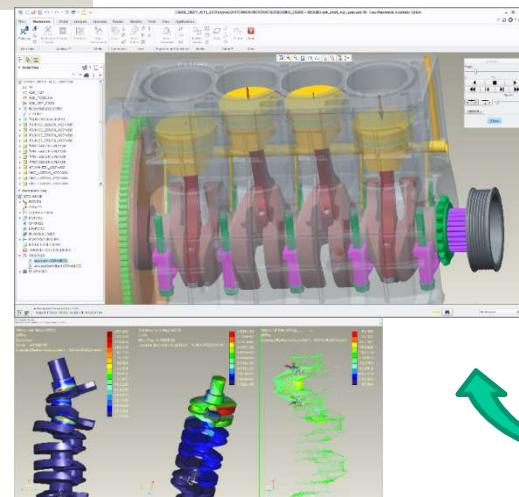
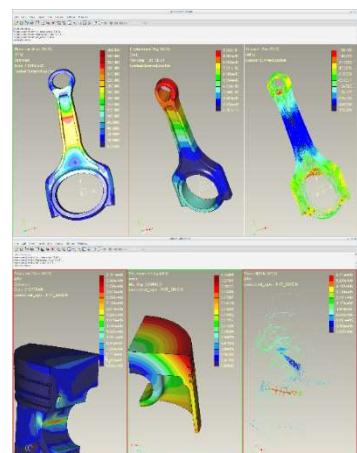
- **geometry**
- **weights**
- **Moments of inertia**
- **stiffness,**

Crankshaft Stiffness

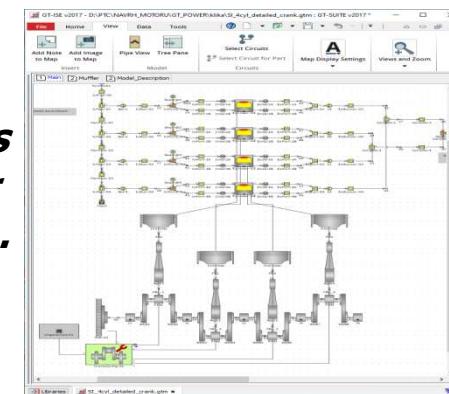
- Performed FEM analysis (GEM 3D) of the webs for different loading: in-plane (Moment/Angle) – A), out-of-plane (Moment/Angle) B), torsion (Moment/Angle) C), torsion (Moment/Displacement)



into GT-POWER



- **pressures**
- **temperatures**
- **heat transfer coefficient, ...**



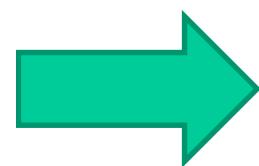


Camshaft mechanism design and optimization

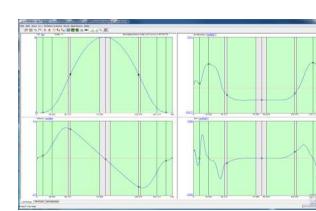
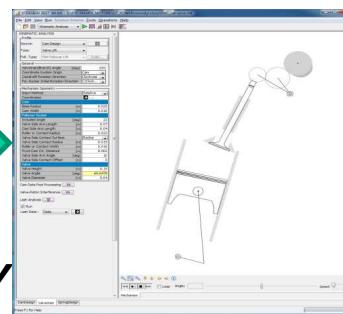
from 3D geometry



into VTDESIGN



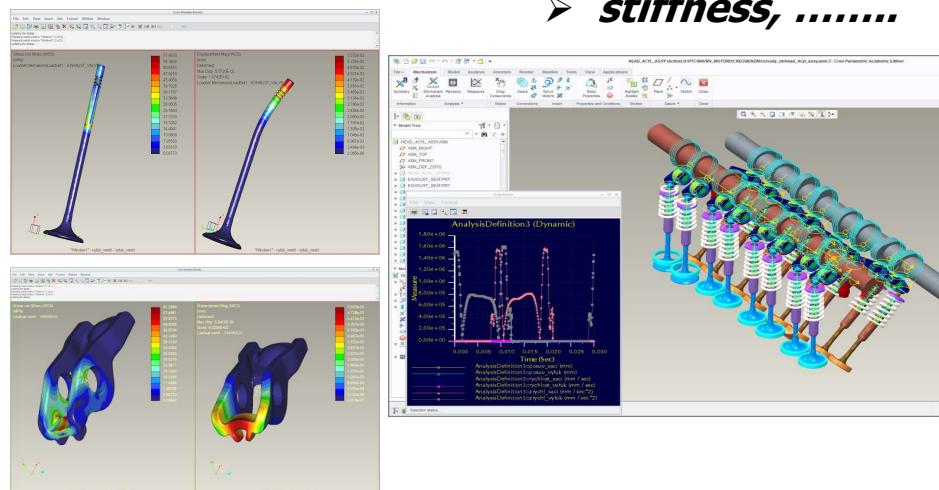
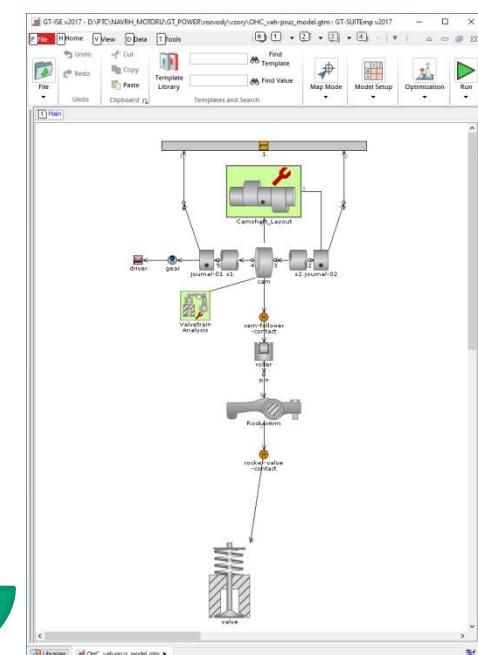
- *geometry*
- *weights*
- *moment of inertia*
- *stiffness,*



into GT-POWER



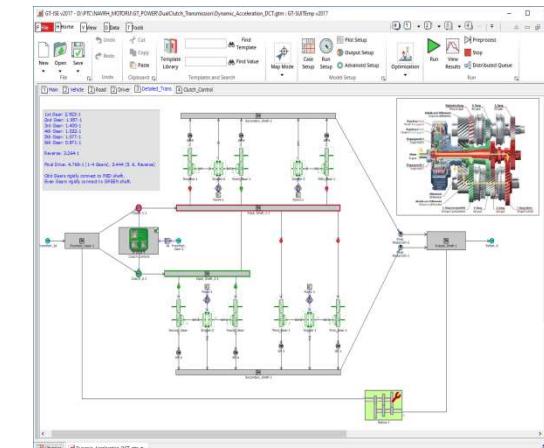
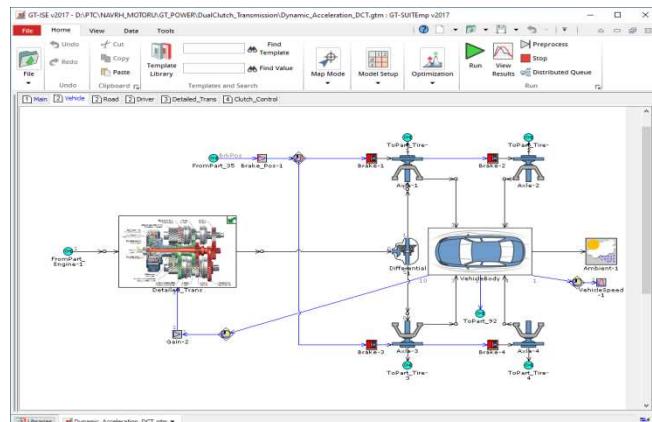
- *cam geometry*
- *springs, ...*



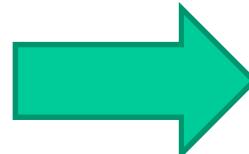


Gearbox design

from GT-SUITE

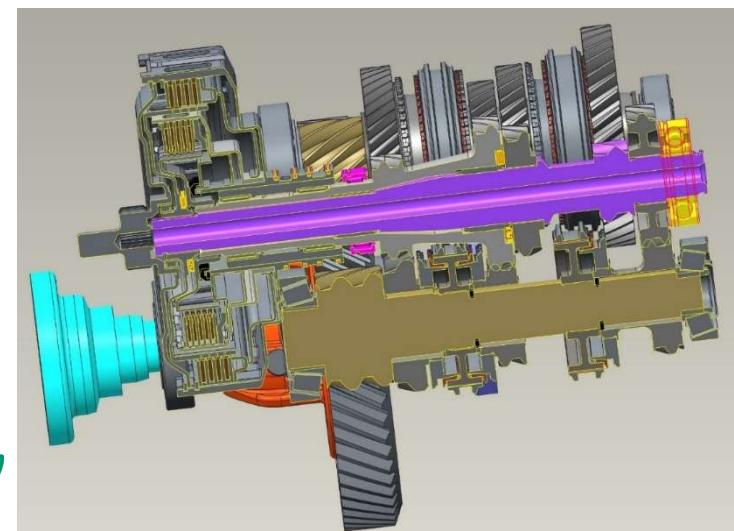


- **gears**
- **Number of teeth**
- **...**



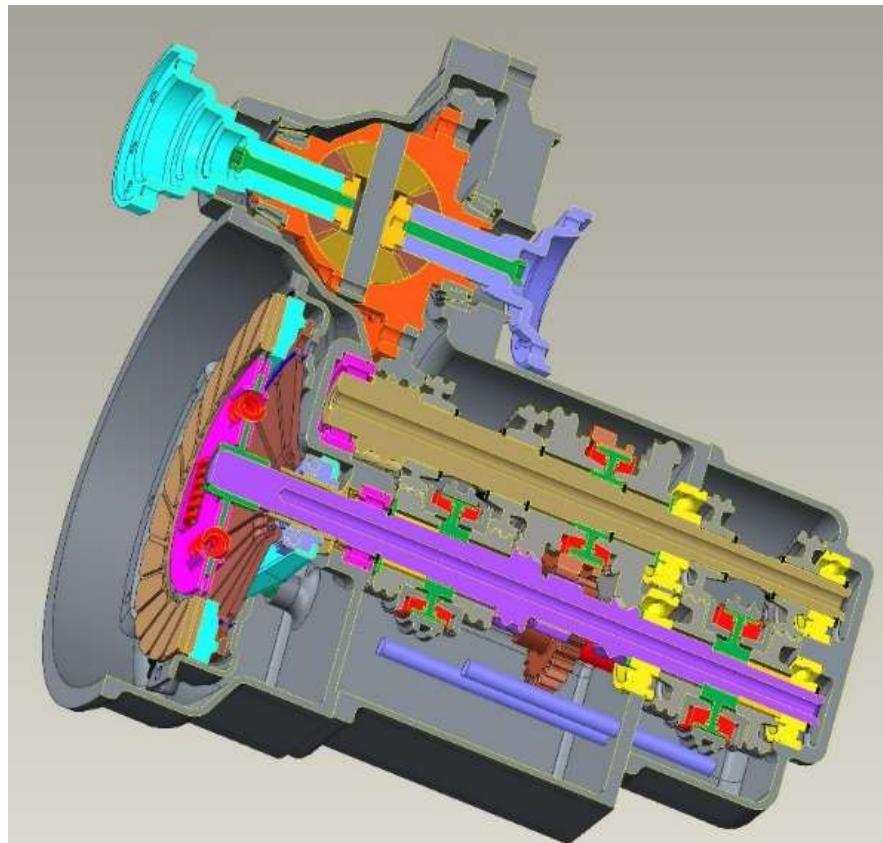
into 3D geometry

- **geometry**
- **weight**
- **moments of inertia**
- **stiffness,**

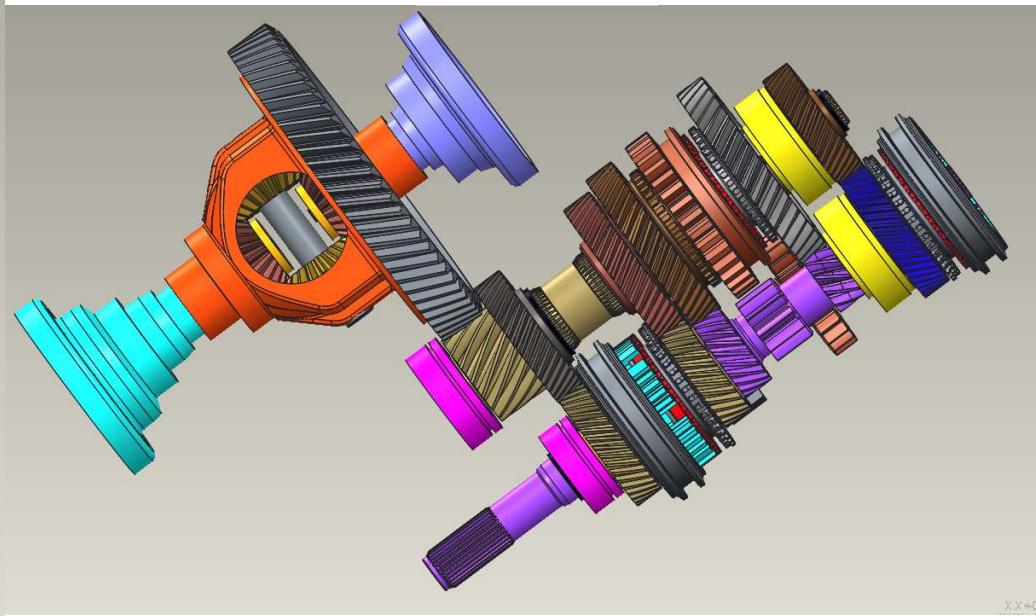




Manual gearbox 5/6 speeds



**3D gearbox model
controls
420 parametrs**

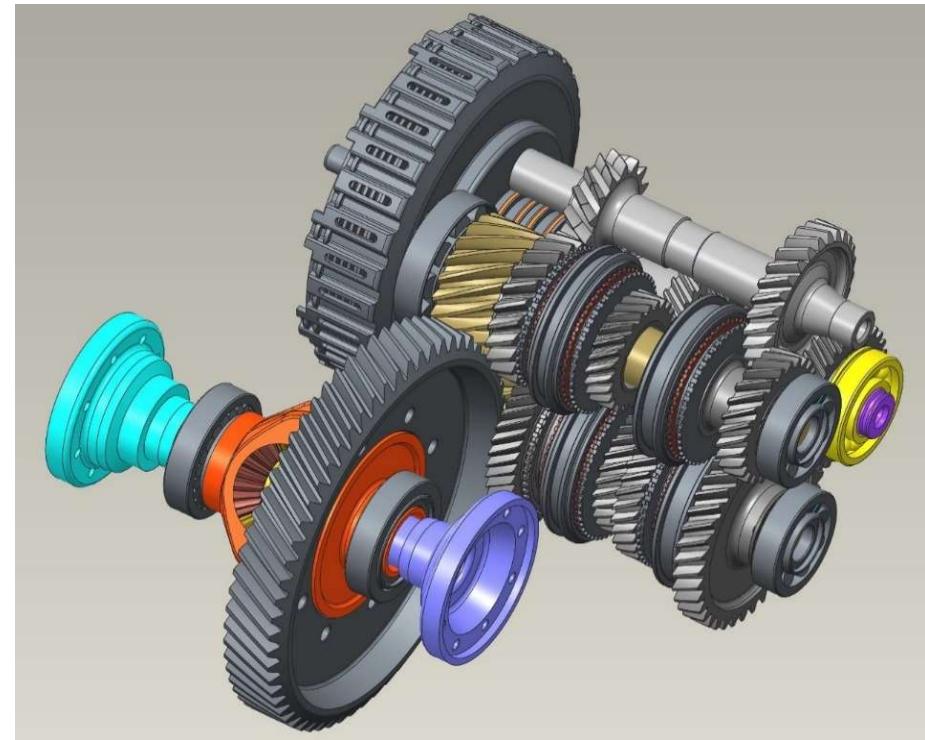
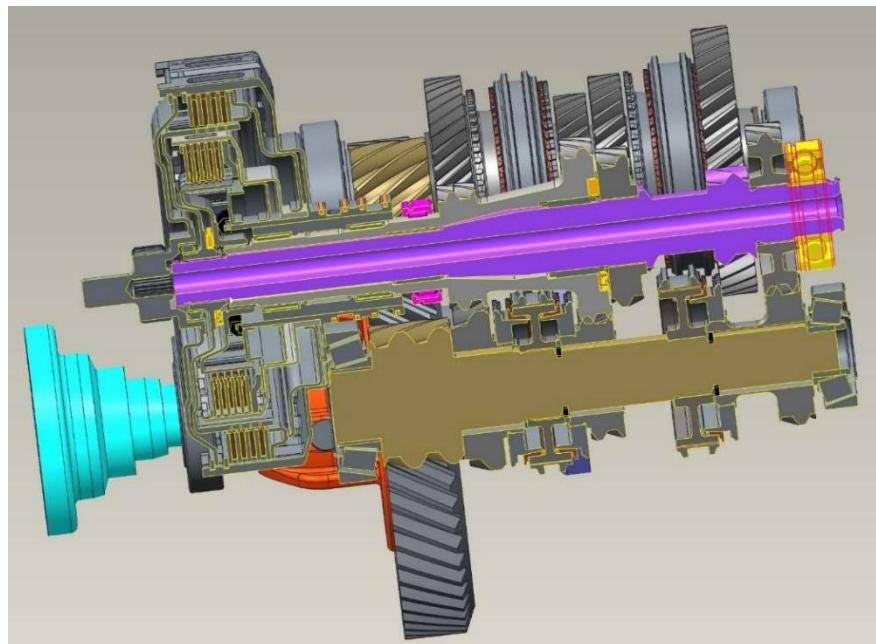




Direct Shift Gearbox DSG 6/7 speeds

**3D gearbox model
controls**

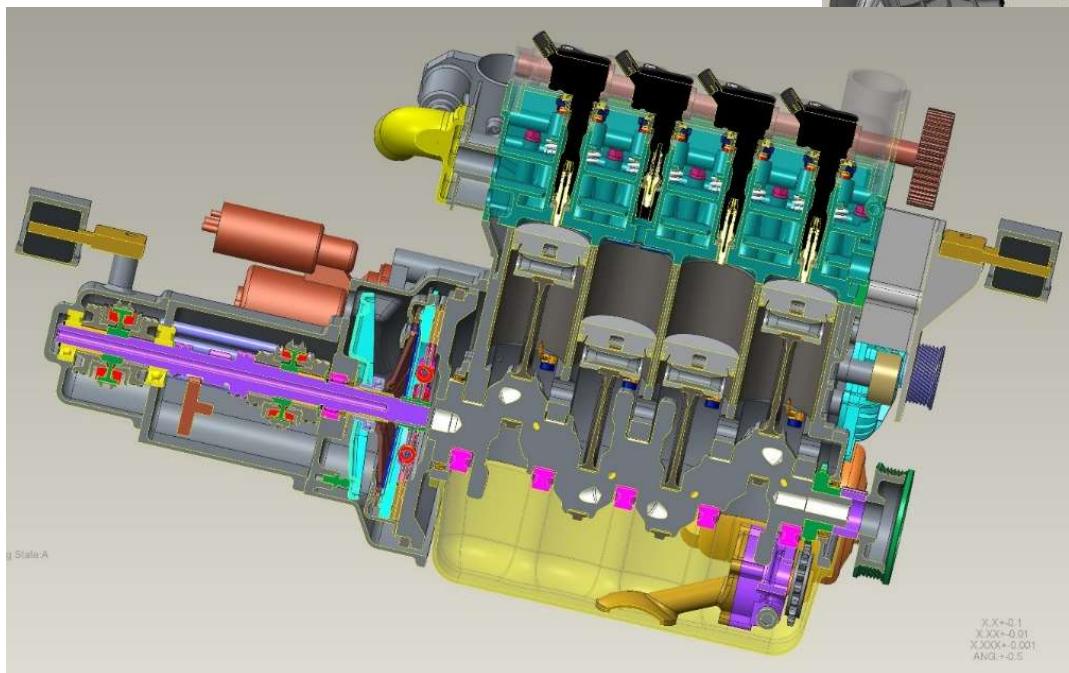
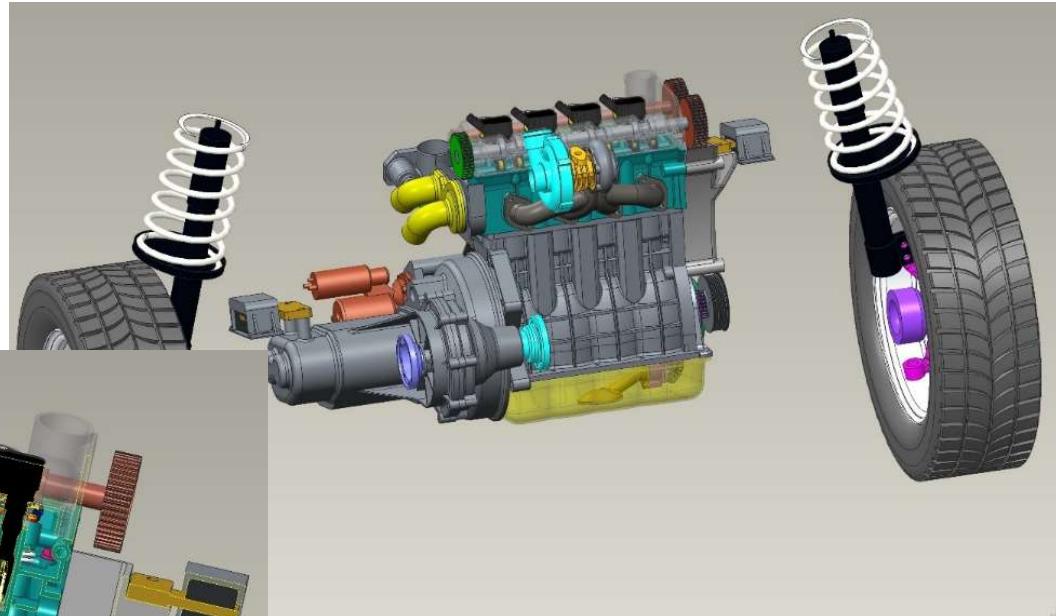
520 parametrs





Installation the powertrain to the vehicle

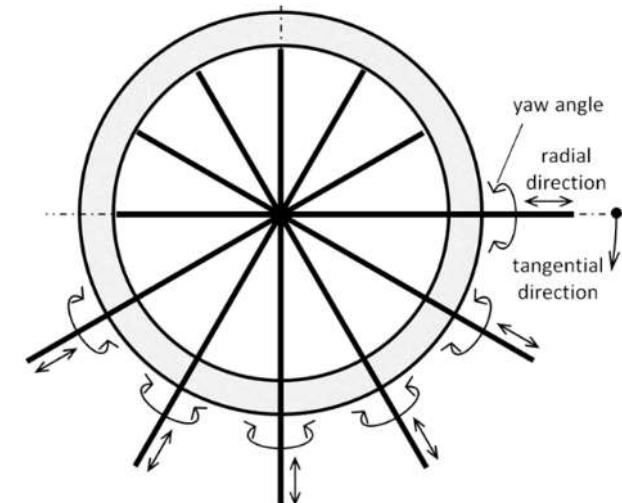
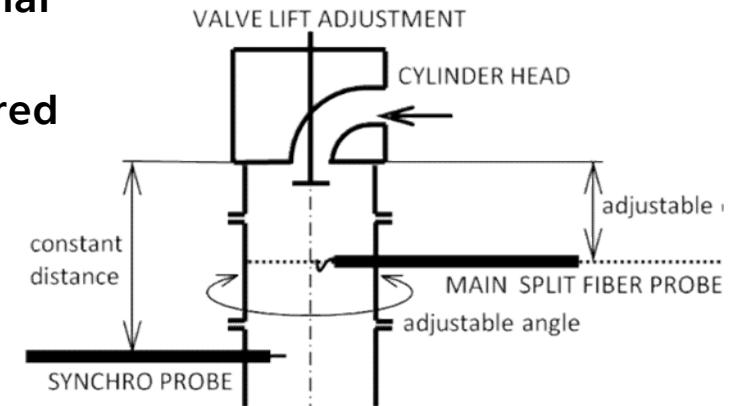
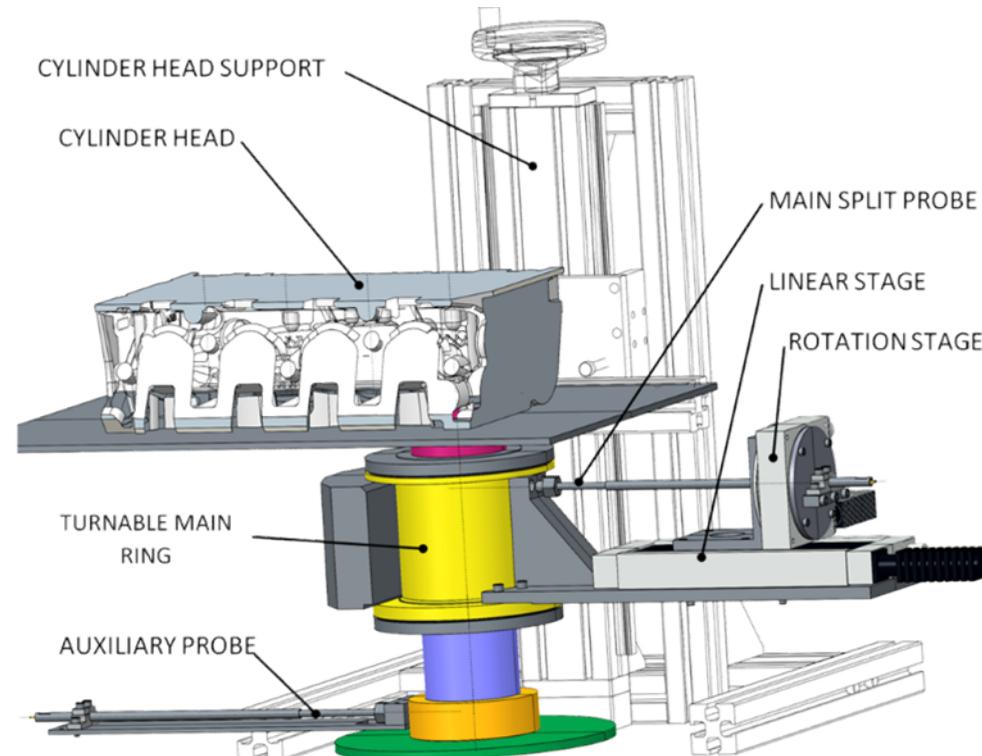
**3D parametric model of
Installation the
powertrain to the
vehicle
Collision control**





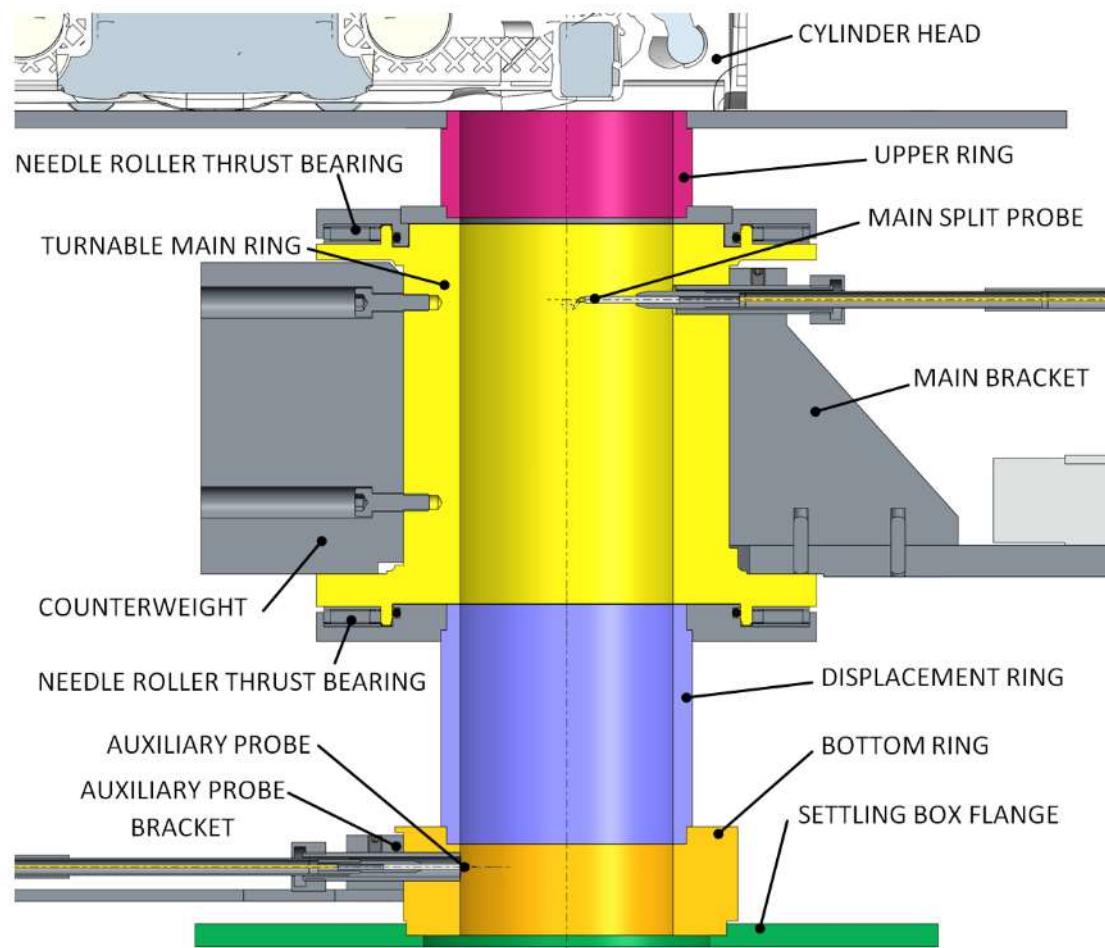
Steady flow rig for in-cylinder flow measurements using HWA

- thermo-anemometric probe can traverse in axial, radial and tangential direction
- axial and tangential velocity components are measured

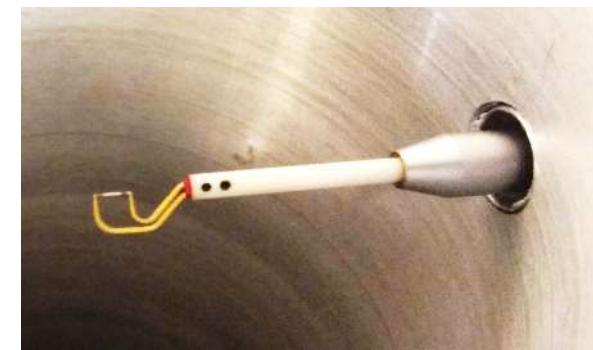




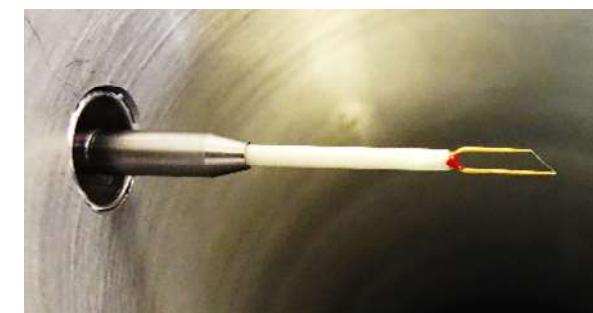
Steady flow rig for in-cylinder flow measurements using HWA



Main split-fiber thermo-anemometric probe Dantec 55R57



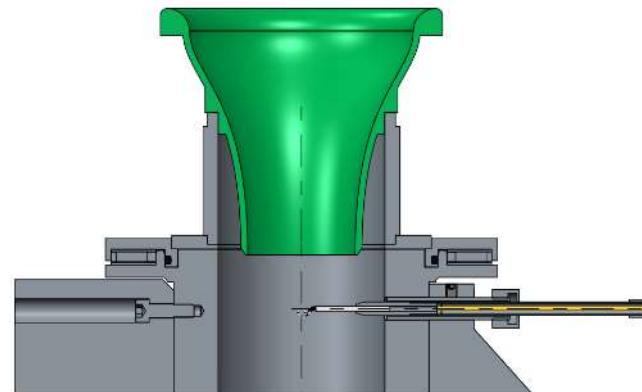
Auxiliary synchro and reference probe Dantec 55R02





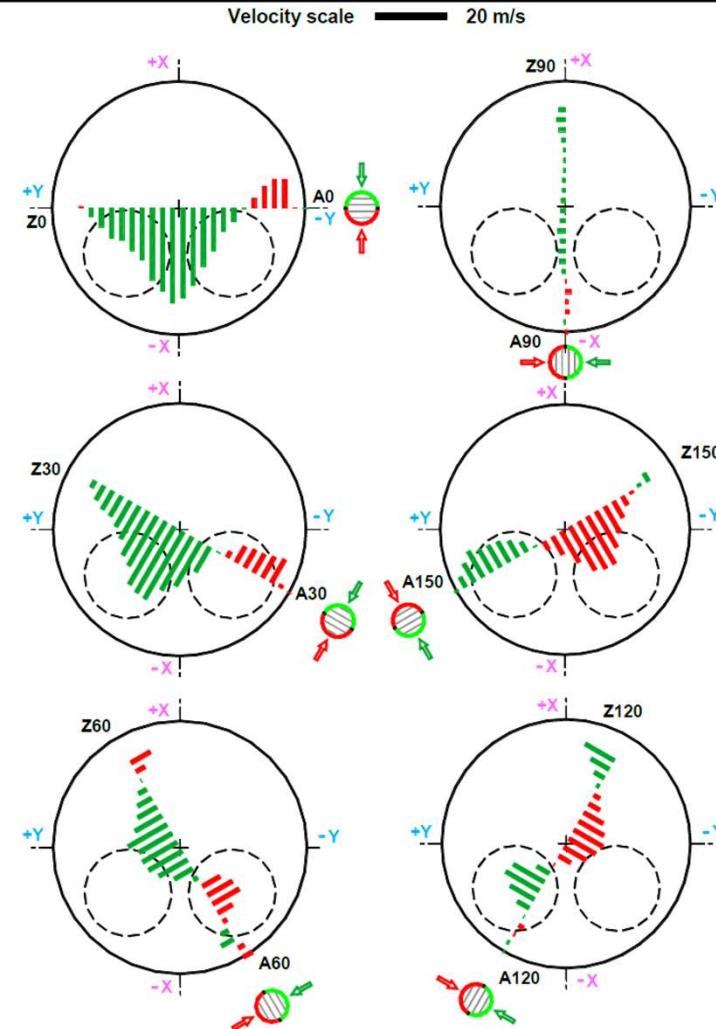
Steady flow rig for in-cylinder flow measurements using HWA

Probe calibration – in situ
velocity range 8 – 135 m/s



Set of experimental data has been acquired:
2 port variants, 2 valve lifts, 2 axial positions

Submitted article „Introductory
measurements of in-cylinder flow past
intake valve ports with a film split-fiber
probe“ to Flow Measurement and
Instrumentation Journal





Fulfillment of goals and deliverables of **1-WP08**: Design Assistance Systems and Calibrated Simulation Processes

Current State of Deliverables, Milestones and Fulfillment of Goals

1-WP08-001 (ZV) | Engine design parametric model | • R - software | Complete parameter model of ICE engine in CREO-Parametric. Parametric models of key engine parts in CREO Parametric, preliminary calculation of their dimensional parameters, collision control, subsequent strength control of key parts and creation of engine assembly. | 10. 12. 2020 | | CTU FME 1 |

1-WP08-002 | In-cylinder flow characteristic measurements | • Gfunk - funkční vzorek | A functional sample of steady flow rig for in-cylinder flow characteristic measurements using hot wire anemometry system. Measured velocity and turbulence can be used for calibration of CFD simulation | 10. 12. 2020 | | CTU FME 1 |

1-WP08-003 | Papers related to advanced design assistance system(s) and detailed port flow measurement. | • O - ostatní výsledky | CTU: 1x paper related to advanced design assistance system.

CTU: 1x paper related to detailed measurement of port flow. | 10. 12. 2020

List of Due Deliverables and Their Added Value



MobilitySympo a Kolokvium Božek JOBNAC 4. – 5. 11. 2020, CVUT Roztoky

Current contribution of 1-WP08: Design Assistance Systems and Calibrated Simulation Processes

Assessment of the Contribution of Deliverables

Parametric model of ICEs for DASY are generally applicable to design of powertrains. 3D models of ICEs are applicable in the design of hydride powertrains.

Steady flow rig for in-cylinder flow measurements is prepared and was tested on a specific measurement, including probe calibration. Submitted article to Flow Measurement and Instrumentation Journal.

Thank you for your attention

Acknowledgement

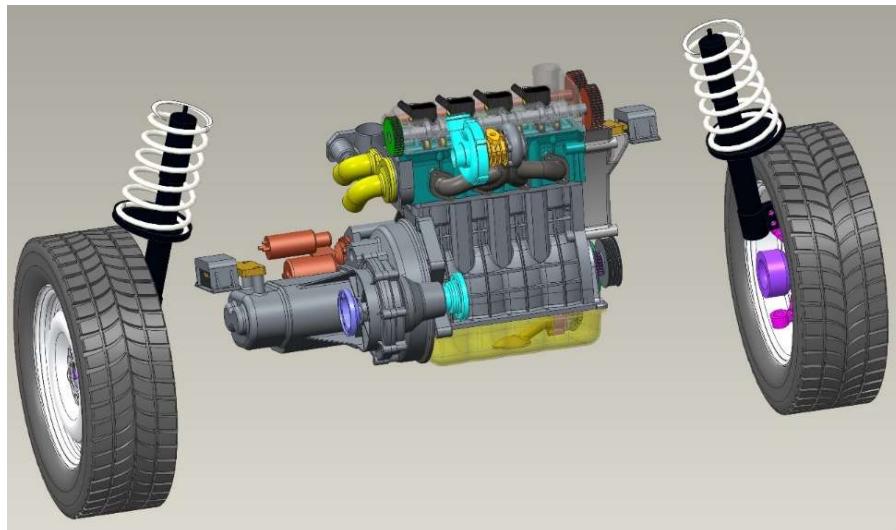
This research has been realized using the support of Technological Agency, Czech Republic, programme National Competence Centres, project # TN01000026 Josef Bozek National Center of Competence for Surface Vehicles.

This support is gratefully acknowledged.

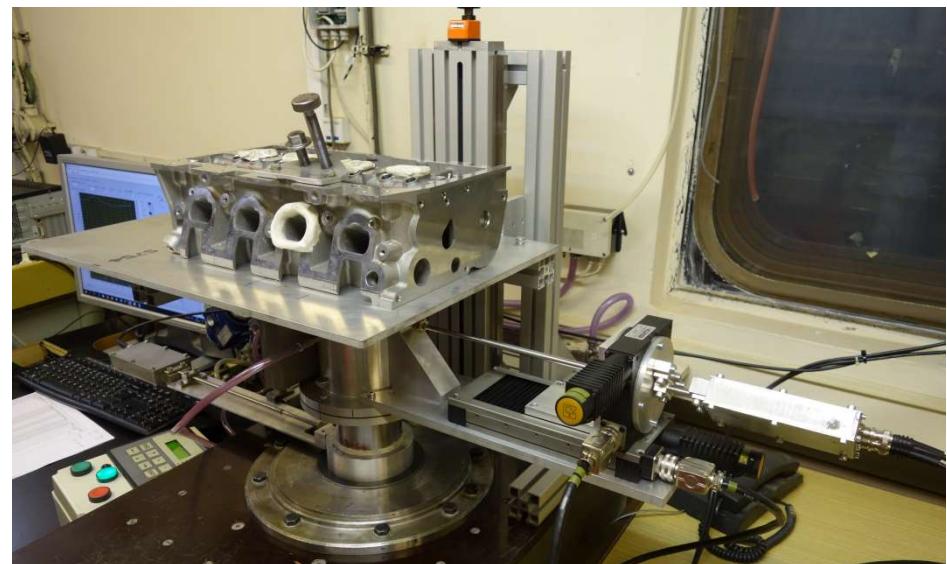


Výtah z prací 2019-2020 na 1-WP08: Asistenční vývojový systém a Kalibrované simulační procesy

3D parametrický model Instalace hnacího agregátu do vozidla



Zařízení pro měření proudového pole ve válci metodou žhaveného elementu

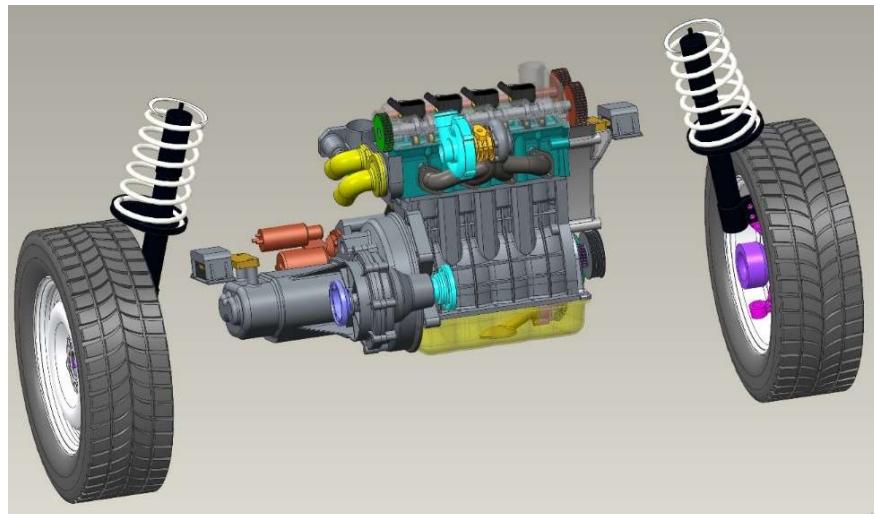




MobilitySympo a Kolokvium Božek JOBNAC 4. – 5. 11. 2020, CVUM Roztoky

Results of 1-WP08: Design Assistance Systems and Calibrated Simulation Processes –Achieved 2019-2020

3D parametric model of Installation the powertrain to the vehicle



In-Cylinder Unsteady Velocity Measurement Using Hot-Wire Anemometry

