Contents of Work Package 1-WP03 VaV Gas Engines for Vehicles and Distributed Heat and Power Production

1-WP03 VaV Gas Engines for Vehicles and Distributed Heat and Power Production

Coordinator of the WP

České vysoké učení technické v Praze, zodpov. osoba Ing. Jiří Vávra, Ph.D.

Participants of the WP

ŠKODA AUTO a. s., M. Hrdlička

VarioTec s.r.o., P. Králík

Main Goal of the WP

New concepts of gas engines for standard and hybrid vehicles.

Low cost, high durability gas engines for distributed heat/power cogeneration in smart grids.

Partial Goals for the Current Period

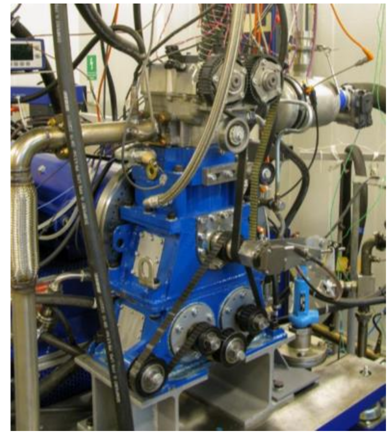
Experimental single cylinder engine (**Š**KODA **A**UTO 74.5mm bore) commissioning - active **P**re-**C**hamber implementation and basic functionality tests

Experiments and simulations of a multicylinder experimental engine (102 mm bore) with an actively scavenged pre-chamber by **VaT**

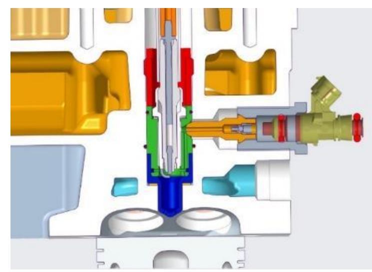
Activities in Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

1-WP03-001 - ŠKODA - ČVUT **S**ingle **C**ylinder **R**esearch **E**ngine commissioning

- **Passive P-C** designed by ČVUT, manufactured, installed in an unmodified cylinder head
- **Active P-C** design & manufacturing by ŠKODA & ČVUT
- **Initial experiments in progress**
  - 3 combustion system configurations with 2 P-C material variants, 3 different fuels
  - ECU calibration - optimization of spark, valve timing & knock
  - Automation of experiments in preparation using AVL CAMEO



Material	λ [$Wm^{-1}K^{-1}$]
17 248 X8CrNiTi18-10	15
CuCr1Zr	320



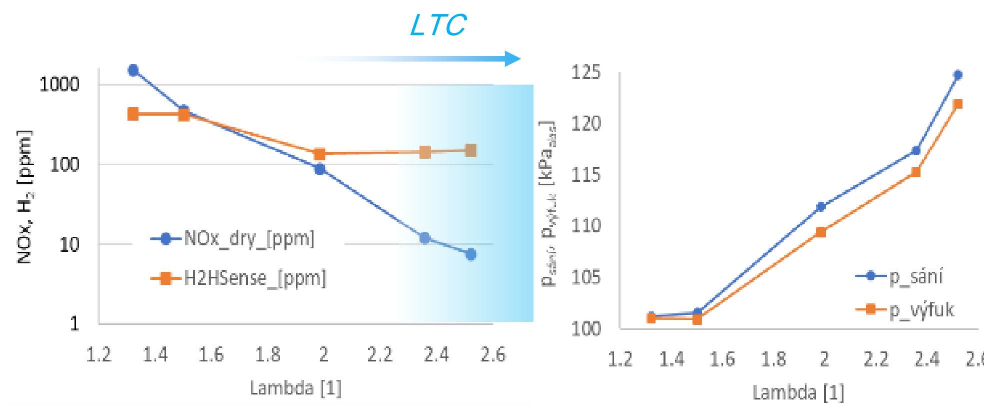
Configuration	Spark plug	Passive P-C		Active P-C	
		P-C Steel	P-C Cu	P-C Steel	P-C Cu
Gasoline BA95	✓	✓	✓	planned	planned
CNG	✓	✓	✓	planned	planned
Hydrogen	✓	?	?	planned	planned

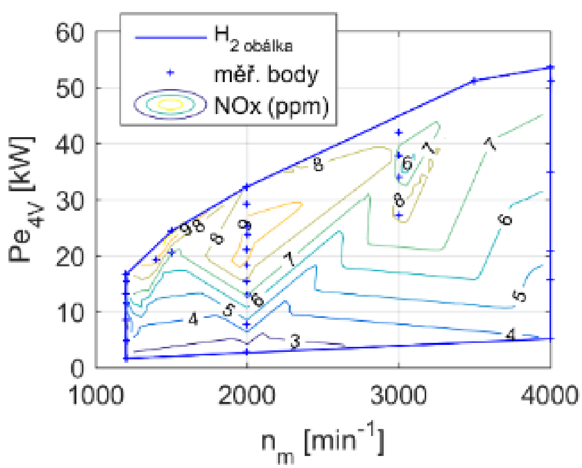
Activities in Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

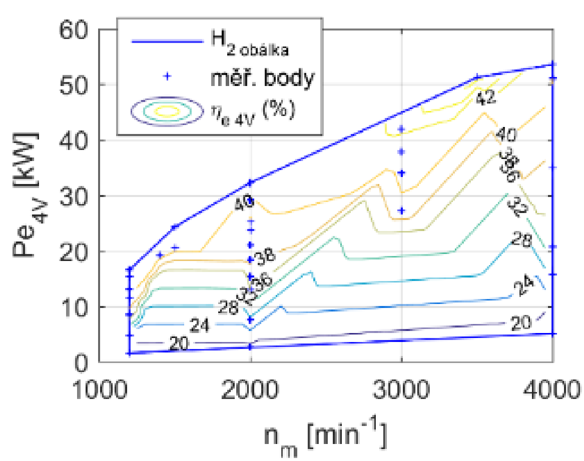
1-WP03-004 Low **T**emperature **C**ombustion in hydrogen fueled SI engine

- **NOx** in raw exhaust under **10ppm** in the entire engine map. Good prospects to comply with the NOx emission limit without exhaust A/T.
- Peak **brake efficiency of 43%**
- More than **97,6 % reduction** of tailpipe **CO_2** emissions compared to contemporary engines.

Lambda sweep at 2000 rpm and 6 bar of IMEP, CA_{50} = 10 CA° after TDC







09/2020

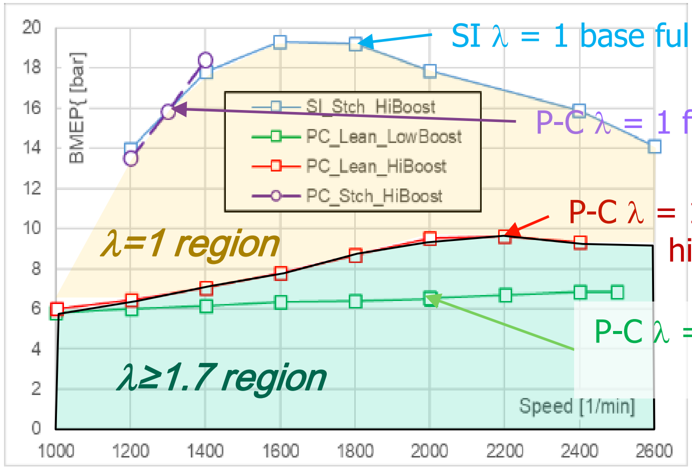
06/2020

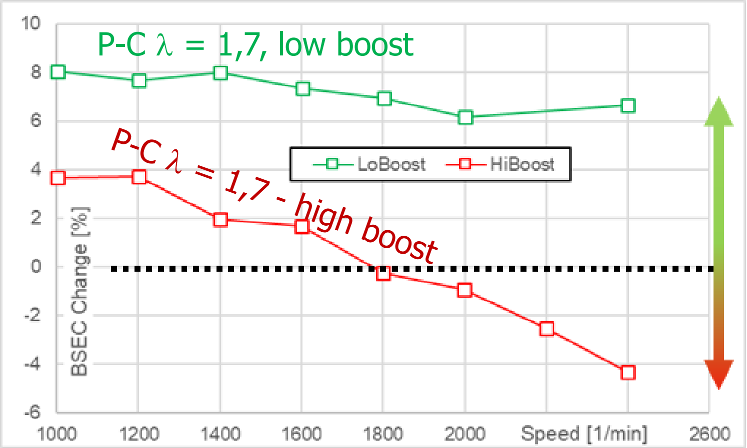
Activities in Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

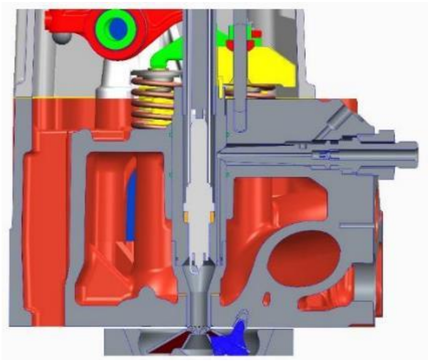
1-WP03-003 Active P-C allows lean burn operation *(λ≥1.7)* at part load

- Full load at λ = 1 (**t**hree **w**ay **c**atalyst compatible mode)
- Seeking for optimum for switching between λ=1 and lean burn mode at part load.
- Measured 8% improvement in BSEC over the SI at λ=1.

Measured on G432 engine (4 cylinders, ϕ102/120mm, VTG)





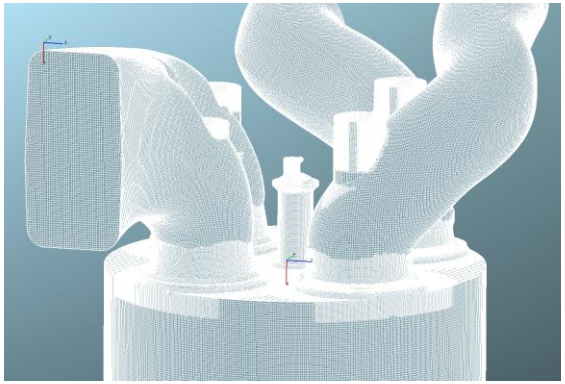


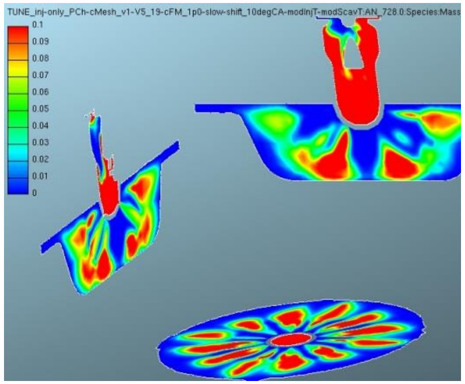
G432 engine (4 cylinders, ϕ102/120mm, VTG) in CTU lab

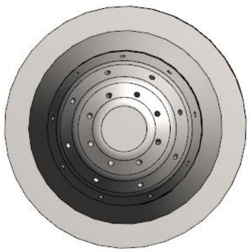
Activities in Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

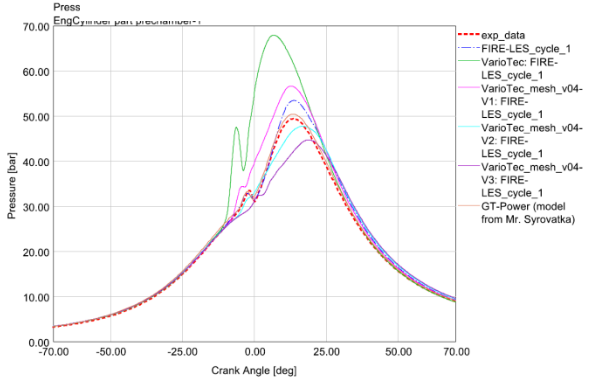
1-WP03-003

- pre-chamber design optimized while using 3-D CFD (complete engine cycle)
- active control of scavenging air and late injection of additional gaseous fuel
- pre-chamber sub-assembly was manufactured
- testing on ICE is being prepared

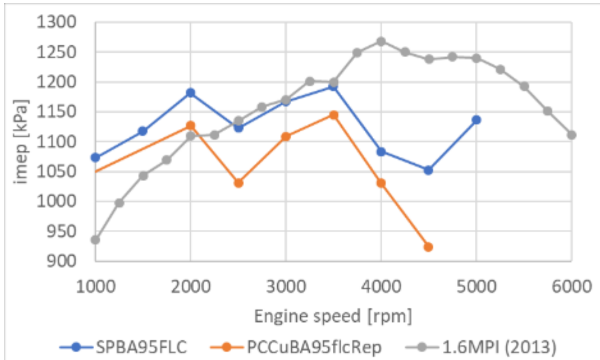


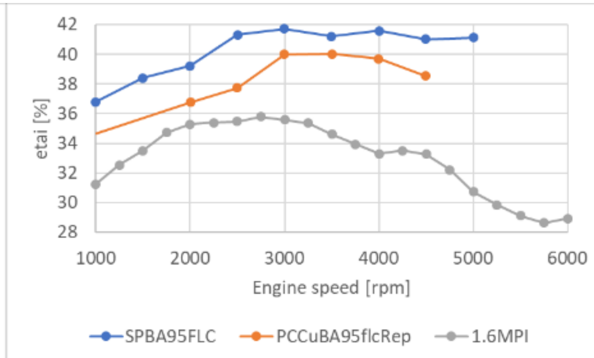


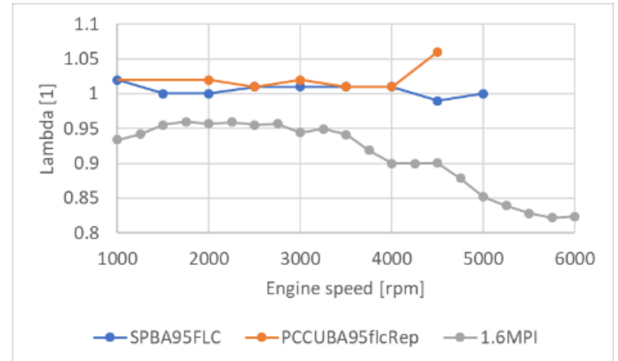




SCE – Results at full load curve, gasoline (BA95), lambda = 1
Comparison with 1.6MPI (2013), spark plug vs. passive P-C (Cu)

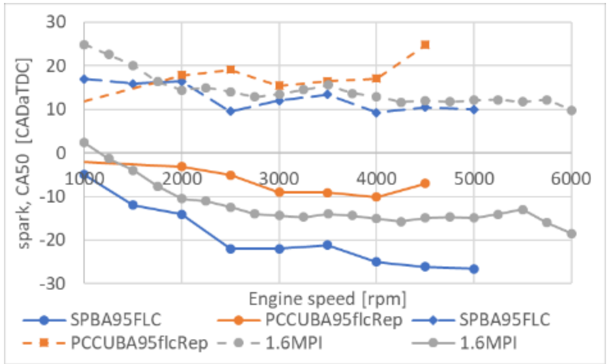


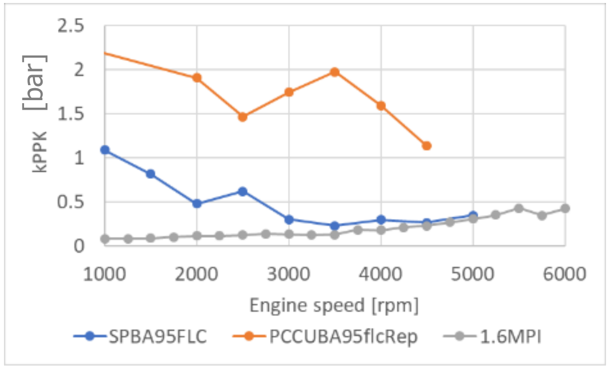




LHV_{2020} (41.5 MJ/kg) < LHV_{2013} (43.5 MJ/kg)
Passive P-C shows slightly lower power output and indicated efficiency than SI

$lambda_{2020} = 1$
$lambda_{2013} < 1$

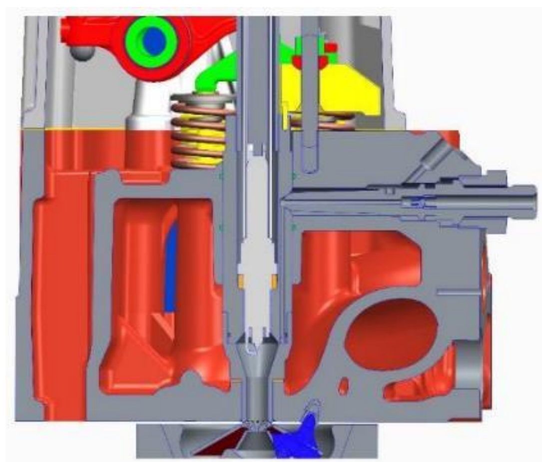




P-C shows faster heat release rate and a higher knock tendency than SI

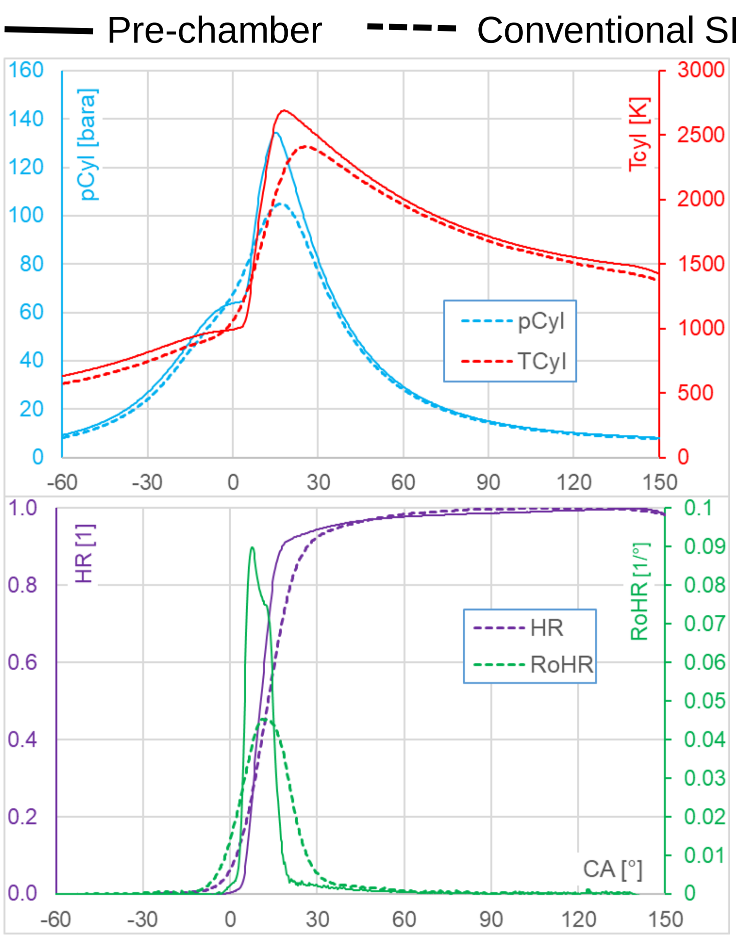
ČVUT active P-C, CNG fueled turbocharged 4 cyl, engine, ϕ102/120 mm

- ČVUT Pre-chamber design modification
  - Spark plug M8 -> M12 cooperation with Brisk Tábor, specifications for spark plug modifications for extended electrodes
  - Improved high voltage insulation
  - Tests in progress


Pre-chamber Ignition for Gas Engine with Advanced Combustion System

Investigation of full load operation



OPERATIONAL POINT

Speed 1400 /min (18 bar of BMEP)
Fully open throttle, VGT control adjusted for maximum boost pressure

STATEMENT

Due to high burning velocity with pre-chamber ignition the peak cycle pressure reach the assumed limit value at relatively low speed.

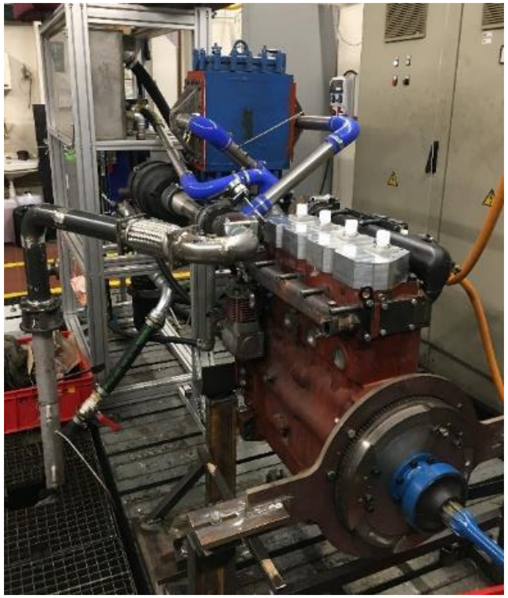
It is necessary to proceed with full load testing extremely carefully in order to protect testing engine against damage.

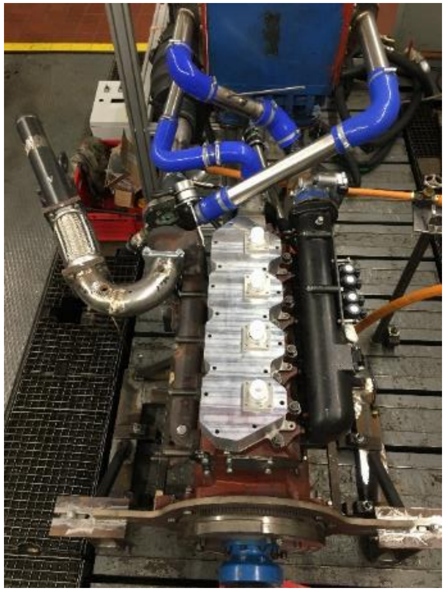
Original AVIA D432 diesel engine designed for EU3 with retarded combustion

Simultaneously test bench with ZETOR engine is under preparation

Zetor engine preparation

- Complete conversion of the CI diesel engine to an SI gas engine
- New pistons – machining, combustion chamber optimization, CR reduction from 17:1 to 13:1
- Ignition, ECU, gaseous fuel injection, throttle valve
- Cylinder head modifications - M12 spark plugs (similar design as AVIA engine)
- New valve cover
- New lab cooling system





Fulfillment of goals and deliverables of Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

Current State of Deliverables, Milestones and Fulfillment of Goals

- 1-WP-03-001 (ZV) | Gas engine for decarbonization of emerging markets | • Gfunk - funkční vzorek | A functional specimen of gas engine for passenger car for decarbonization of emerging markets. CTU FME 0.1, SA 0.9 – **in progress & no major delays:**
  - A functional specimen was manufactured. Experimental verification is being prepared.

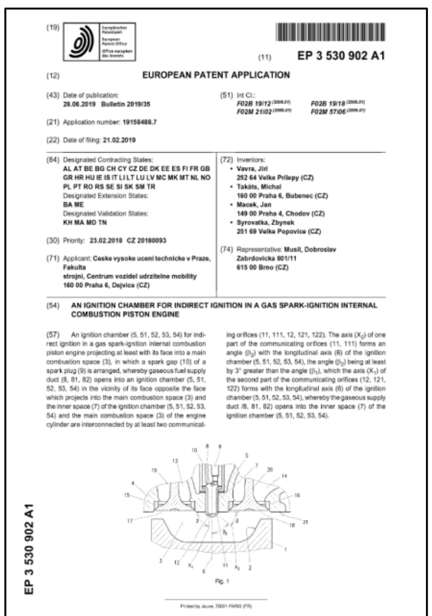
- 1-WP-03-003 (ZV) | Combustion system for a non-conventional piston engine | A functional specimen of a combustion system for a non-conventional combustion engine for non-road application (• Gfunk - funkční vzorek), CTU, VarioTec – **in progress & no major delays:**
  - Design, simulation and optimization phase was finished. A functional specimen was manufactured. Experimental verification is being prepared.

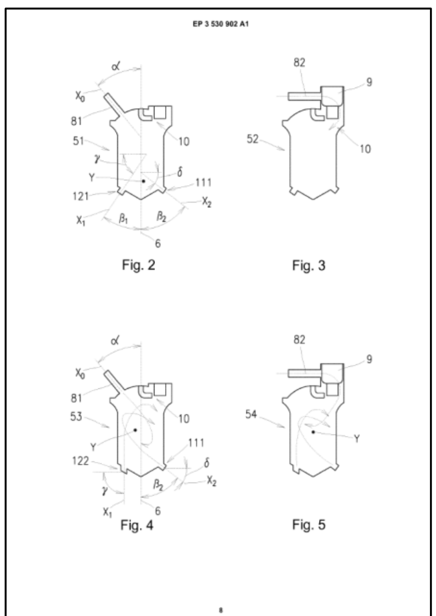
Fulfillment of goals and deliverables of Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

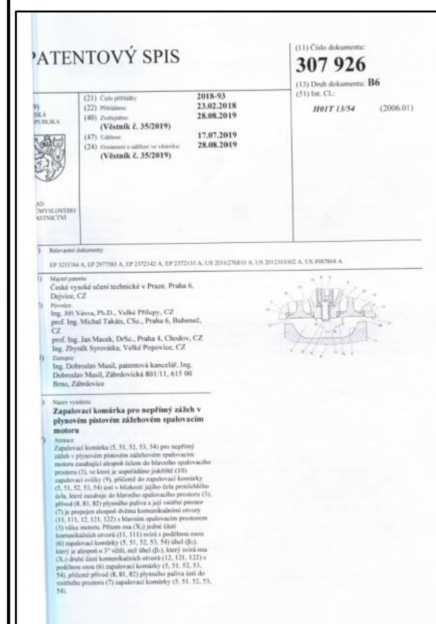
Current State of Deliverables, Milestones and Fulfillment of Goals

- 1-WP-03-002 | Ignition pre-chamber for indirect ignition in a gas fueled piston spark ignition engine | • O - ostatní výsledky | European patent application | 10. 12. 2020 | | CTU FME 0.9 | SA 0.1 |

Based on CZ Patent Application No 2018-93 a European Patent Aplication No. EP3530902A1 was prepared and filed on 21.2.2019







Fulfillment of goals and deliverables of Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

List of Due Deliverables and Their Added Value

1-WP-03-001 Actively scavenged pre-chamber can reduce the engine energy consumption at low and medium load conditions by 8(+) percent. Low content of nitrogen oxides in raw exhaust gas eliminates intentional or unintentional manipulation with results of emission measurements according to the legislative base.

1-WP-03-002 A patented arrangement of connection orifices induced a controlled movement of the pre-chamber charge, which further accents the positive influence of the pre-chamber on fast burning of extremely lean mixture.

1-WP-03-003 R&D started with design, simulation & optimization (using 3-D CFD) – this is expected to shorten the time necessary to achieve an optimal design; building a technology demonstrator.

1-WP-03-004 Hydrogen LTC ICE with and ultra-low tailpipe NOx emissions can be used as a means for hydrogen infrastructure development at significantly reduced costs compared to other H_2 energy transformers.

Peak brake efficiency of the small H_2 ICE reaches 43%. H_2 ICE can reduce tailpipe CO_2 emissions by more than 98%.

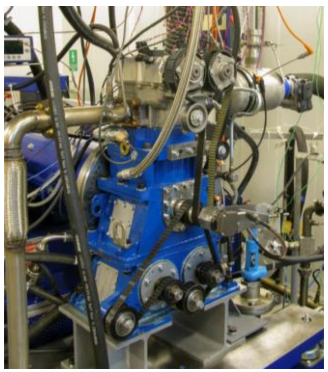
Fulfillment of goals and deliverables of Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production

Assessment of the Contribution of Deliverables

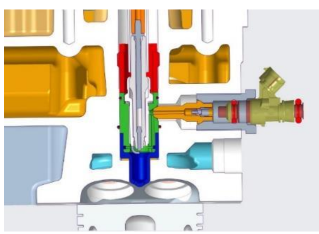
- ŠKODA - ČVUT SCRE in operation at the test bed at the ČVUT laboratory
- SI and passive P-C tests in progress for various fuels
- Highly promising hydrogen SI ICE results with LTC
- Lean burn operation at (lambda = 1.7) with active P-C for G432 engine shows 8+ percent benefit in fuel consumption proven by experiments.
- Low NOx raw emissions at low load.
- Thermodynamics of lean mixture combustion while using scavenged pre-chamber –1-WP06.
- Commercial activities with ŠKODA AUTO a.s. and VarioTec.

Results of Contents of Work Package WP03: Gas Engines for Vehicles and Distributed Heat and Power Production – Achieved 2019-2020

ŠKODA AUTO + CTU: combustion R&D



Material	λ [Wm^{-1}K^{-1}]
17 248 X8CrNiTi18-10	15
CuCr1Zr	320



Configuration	Spark plug	Passive P-C		Active P-C	
		P-C Steel	P-C Cu	P-C Steel	P-C Cu
Gasoline BA95	✓	✓	✓	planned	planned
CNG	✓	✓	✓	planned	planned
Hydrogen	✓	?	?	planned	planned

VarioTec + CTU: combustion R&D