H_2 ICE Competences

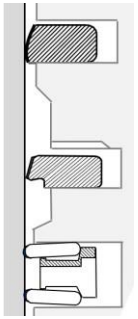
IAA Transportation 2022

MAHLE

H_2 ICE System Approach

Power Cell Unit & Valve Train Components

Piston



Valve set

Liner

Piston rings

Bearings

Crank Case Ventilation

High Pressure Impactor

Test Cell

- Test bench for Heavy Duty H2-ICE engines
- In-house testing to apply MAHLE expertise for optimization in system environment
- Possibility for joint development with industry partners

System Approach

- Holistic investigation of H_2 ICE with partners
- Rig tests
- Engine testing on bench
- Demonstrator vehicles

MAHLE provides Power Cell Unit, Valve Train and Crank Case ventilation components embedded in a strong system approach

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MAHLE components

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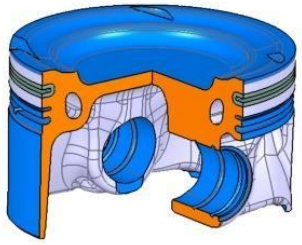
Light Duty Vehicle H_2 ICE activities

MAHLE competences

- MAHLE competences applied to dedicated PCU, valve train components and crank case ventilation for DI H_2-ICE
  - Engine demonstrator (I4, 2.0l)
  - Engine for a PHEV vehicle demonstrator (I3, 1.0l)
- 500 h endurance testing
- Piston / valve temperature measurement carried out
  - Piston temperatures slightly lower than in gasoline operation
  - Intake and exhaust valve below thermal limit



Measuring points (9 Templugs / piston)			Piston 1	Piston 2	Piston 3	Piston 4	Templug
Piston crown	Centre		1	10	19	28	M 3
Bowl rim	FS	0°	2	11	20	29	M 3
	RS	180°	3	12	21	30	M 3
1st Ring groove	FS	0°	4	13	22	31	M 3
	ATS	90°	5	14	23	32	M 3
	RS	180°	6	15	24	33	M 3
	TS	270°	7	16	25	34	M 3
Pin boss	FS	0°	8	17	26	35	M 3
	RS	180°	9	18	27	36	M 3

Benefits

- Material and coating solutions based on MAHLE's experience with gas engines (CNG and H_2 engine components)
- Realization of an "Zero CO_2 engine concept" by enabling conventional engine components for Hydrogen combustion
- Short lead time (approx. 2 years) until SOP

Outlook

- Project started to investigate material and tribology fundamentals

MAHLE H_2 ICE system knowhow will support to decarbonize cost sensitive (TCO approach), high range and high payload LDV applications

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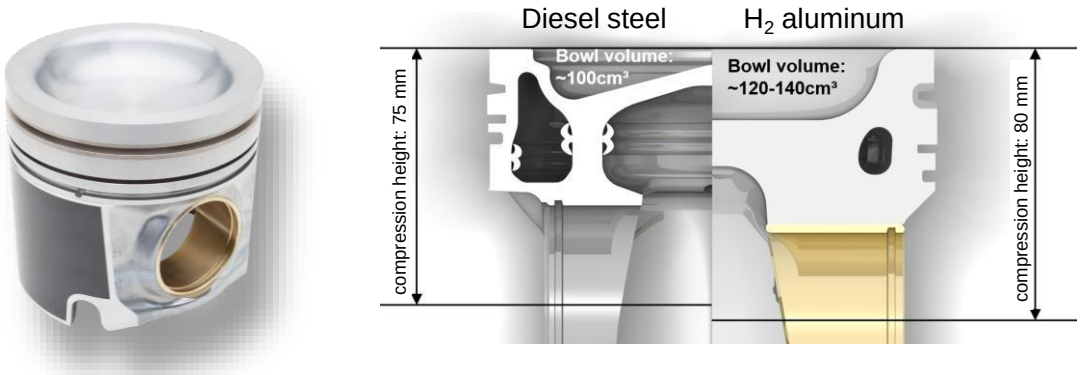
Heavy Duty Vehicle H_2 ICE activities

MAHLE competences

- MAHLE competences applied to dedicated PCU, valve train components and crank case ventilation for PFI / DI H_2-ICE
  - ~13l H_2-PCU developed
  - MAHLE internal combustion process investigations



MAHLE dedicated H_2 HD aluminum piston (l) & comparison to diesel steel baseline (r)

Benefits

- Material and coating solutions based on MAHLE's experience with gas engines (CNG and H_2 engine components)
- Realization of an "Zero CO_2 engine concept" by enabling conventional engine components for Hydrogen combustion
- Short lead time (approx. 3 years) until SOP

Outlook

- Further projects started / planned to
  - investigate material and tribology fundamentals
  - measure piston temperatures, oil and particle emissions
  - test PCU variants
  - investigate NVH and cavitation behaviour

MAHLE H_2 ICE system knowhow will support to decarbonize multiple high-load HD applications

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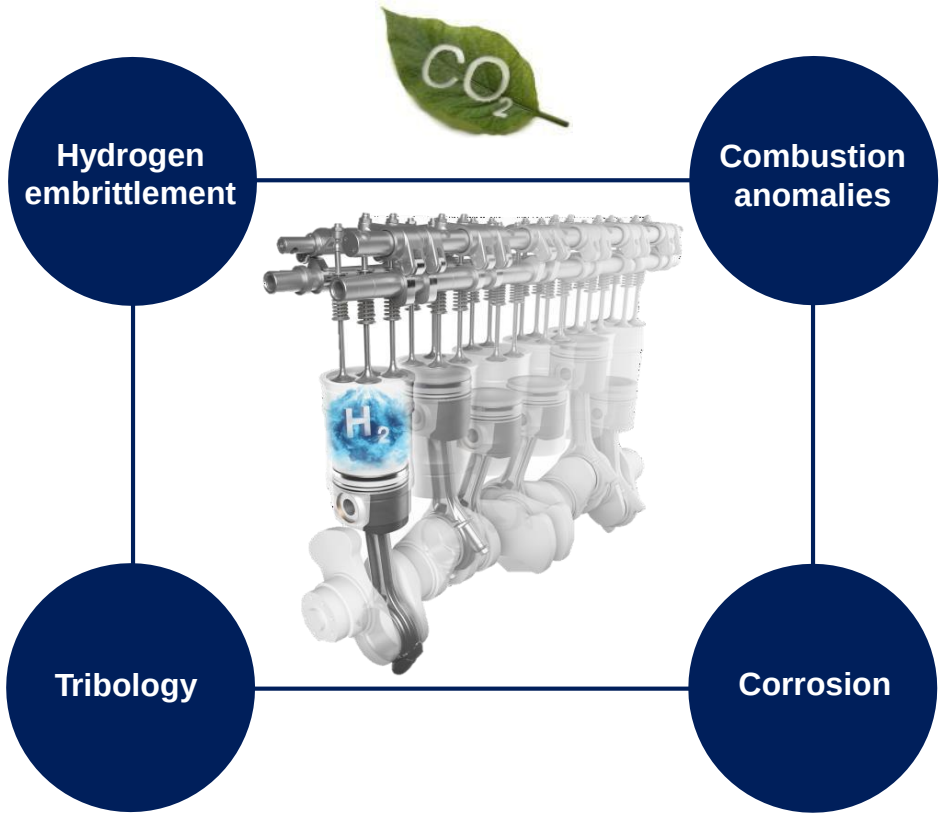
MAHLE solutions and competences for PCU & valve set



Ring package:

- Coating against wear caused by oil dilution
- Blow-by reduction
- Reduction of LOC[1] & related emissions

Valve set:

- H2 compatible materials
- Material combination for "dry" operation conditions
- Corrosion resistant materials against condensation

Liner:

- Optimized shape & honing
- No use of anti-polishing ring

Piston:

- Optimized ring belt area for reduced LOC[1] & Bby[2]
- Low piston temperature to reduce combustion anomalies (use of Al)
- Reduced CR[3] & adapted bowl geometry

[1] LOC: Lube Oil Consumption I [2] Bby: Blow-by I [3] CR: Compression Ratio

Evolutionary development: Optimized components for zero CO_2 combustion technology

– **Holistic optimization and robustness increase required**

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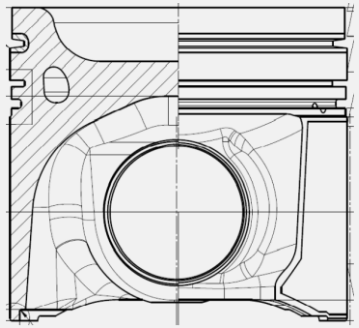
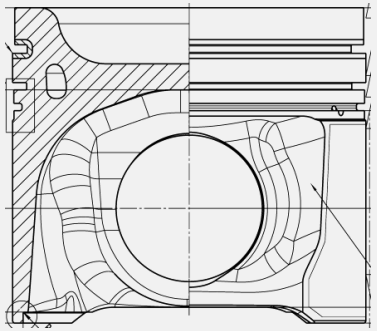
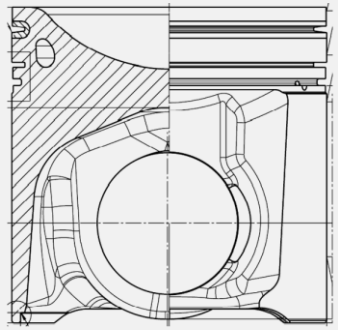
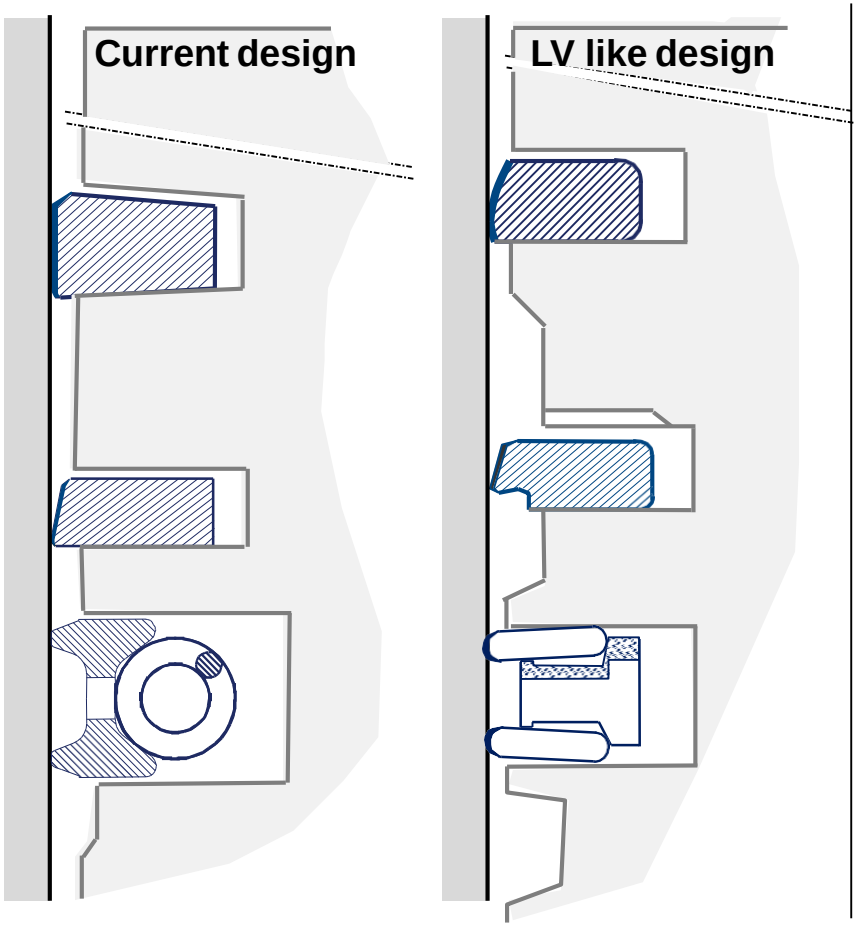
Piston for H_2 ICE

Current Activities

- Piston technology with aluminum base material due to lower temperature and PCP expected
- Engine testing to gather further experience and foster possible pre-development activities if needed

	~130 mm	~150 mm	~ 140mm
Aluminium Piston			
Status	Engine running inside MAHLE	Engine tests being carried out outside MAHLE	Engine test planned inside MAHLE

LV Experience in Throttled Condition
MHD Experience in Slobber Conditions



- Modify top ring from keystone to rectangular
  ↓ Temperature, CBU expected
- Adjust the second land volume for better pressure release
  - Guarantee top ring stability!
- Second ring with Napier design + drilled gas port
  - Better oil scraping + avoid pressure increase + avoid 2nd ring collapse
- Increase 3rd land height and volume
  - Better pressure release + minimize oil filling
- 3 piece OCR in case of PN/LOC issues with idle, motoring and lower loads
  - Better axial conformability/sealing

H_2-ICE: Valve set specification

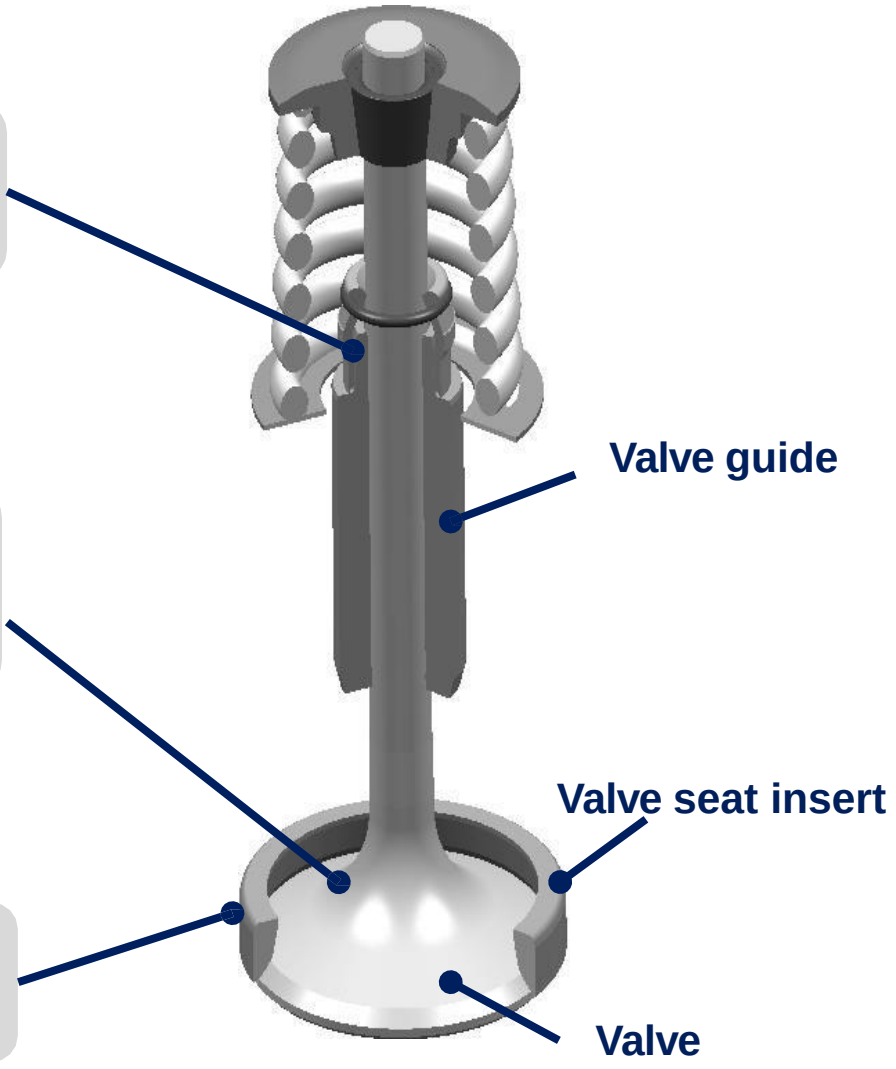
Valve stem sealing:
- **Gas lip design for high LOP according to high boost**
- **Minimum leakage rate for „zero emission“ approach**

- High boost levels combined with gaseous fuels impose tribological challenges in valve stem - valve guide system
- Strongly contradictory requirements regarding lube oil supply regarding tribology and emissions

Intake and exhaust valve:
- **Corrosion resistant materials**
- **Fully nitrided for improved wear resistance according to gaseous fuel requirements**

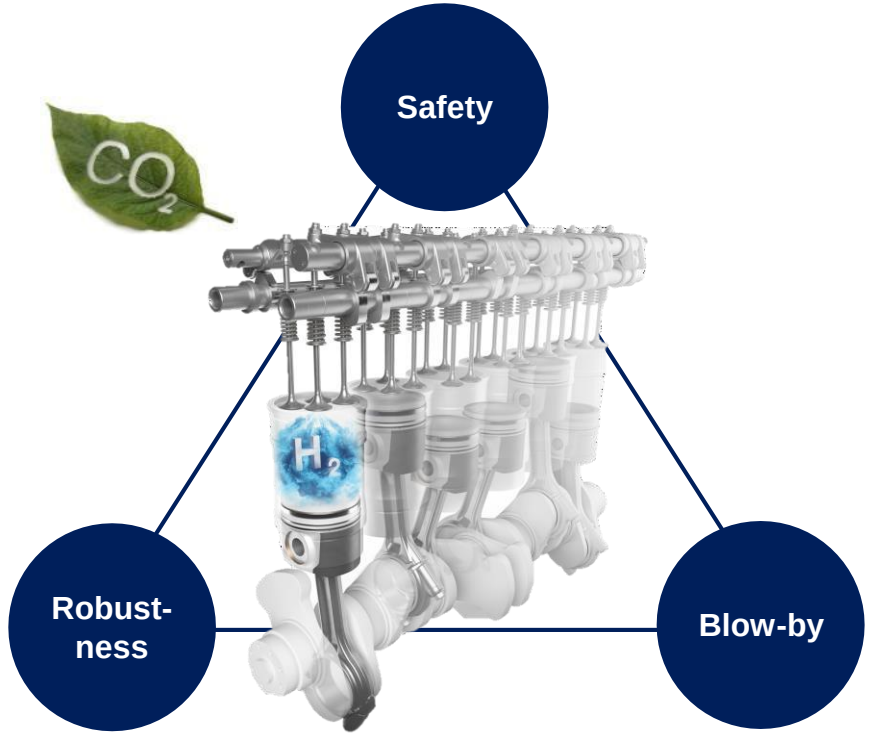
- No liquid fuel on intake side and no combustion residues on exhaust side aggravate tribological challenges significantly
- Strong condensate formation from EGR (exhaust gas recirculation) as exhaust gas is pure H_2O

Valve seat inserts:
- **Materials with high wear resistance and good corrosion resistance**



A new combination of requirements compared to established fuels regarding tribology & corrosion in front of moderate thermal loads

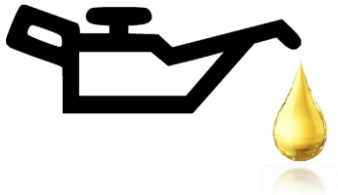
MAHLE solutions and competences for crank case ventilation system & oil



Crank case ventilation:

- Assure subcritical H_2 concentration in crank case by active purging
- Variable scavenging air flow @ constant crank case pressure
- Avoid accumulation and condensation of humidity to prevent oil dilution

MAHLE High-pressure impactor



Oil:

- Composition of dedicated H_2 oils can differ completely from diesel / gasoline oils (oil dilution, less soot formation, …)
- MAHLE plans to investigate H_2 specific oils in cooperation with oil suppliers

Evolutionary development: Optimized components for zero CO_2 combustion technology

– **System approach to meet safety and robustness requirements**

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Crankcase Ventilation for H_2 ICE

Challenges

- Unburned hydrogen within the crankcase ❼ risk of backfire
- High water content of blow-by-gases ❼ oil dilution
- Residual oil content ❼ balancing of oil separation efficiency and water accumulation

Technology

- Description
  - Electrically driven side channel blower with pressure regulated impactor
  - 24 V and 12 V application
  - Up to 120 W @ max flow capacity 400 l/min and 60 mbar pressure creation
  - Integrated electronics and pressure sensor (active OBD check)
  - Independent positioning of drive and oil mist separator
- Benefits
  - Scavenging flow independent from engine operating point
  - High separation efficiency
  - Reliable and robust design

MAHLE High-pressure impactor

High performance in combination of scavenging and cleaning crankcase gases