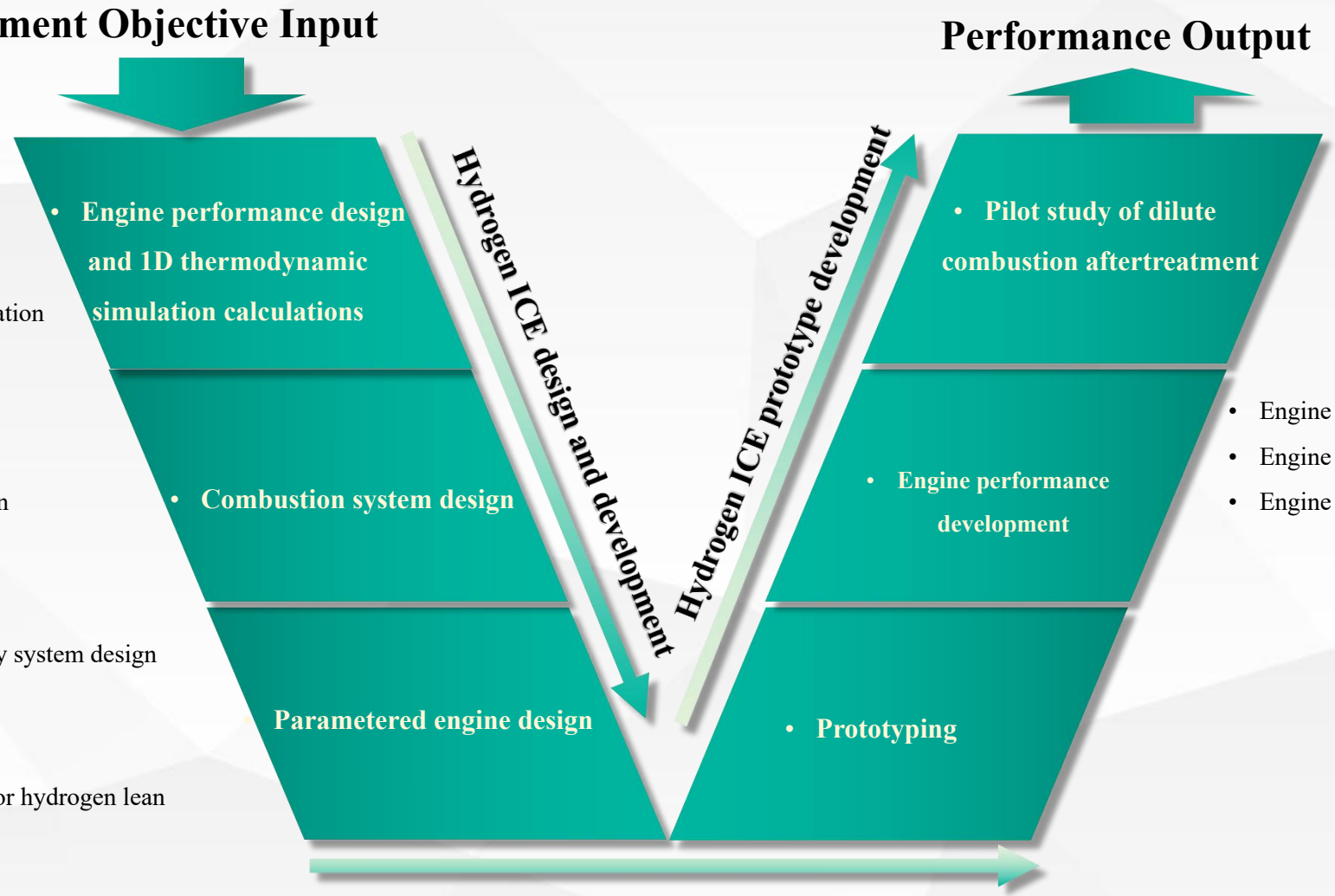
Hydrogen ICE Development Technology

Content

❑Development process



- Performance analysis of the whole machine
  - Air exchange system design
  - Supercharger matching calculation

- Hydrogen nozzle design
- High compression ratio combustion system design

- Cylinder hydrogen injection supply system design

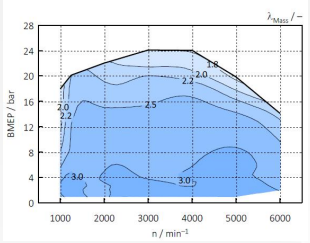
- H2 ICE EGR system design
- Design of aftertreatment scheme for hydrogen lean combustion

- Engine Operating Characteristics Study
- Engine Control Strategy Study
- Engine Emission Characteristics Study

❑ Technical route

Efficient combustion system

- High compression ratio combustion system
- Efficient boosting system



Hydrogen ultra-lean combustion mode

- Significantly reduce original engine emissions
- Improve thermal efficiency of the engine

Aftertreatment technology

- Solve the problem of lean combustion post-treatment
- Near-zero emissions with NOx post-processors

Step1：Efficient and zero-CO2 combustion

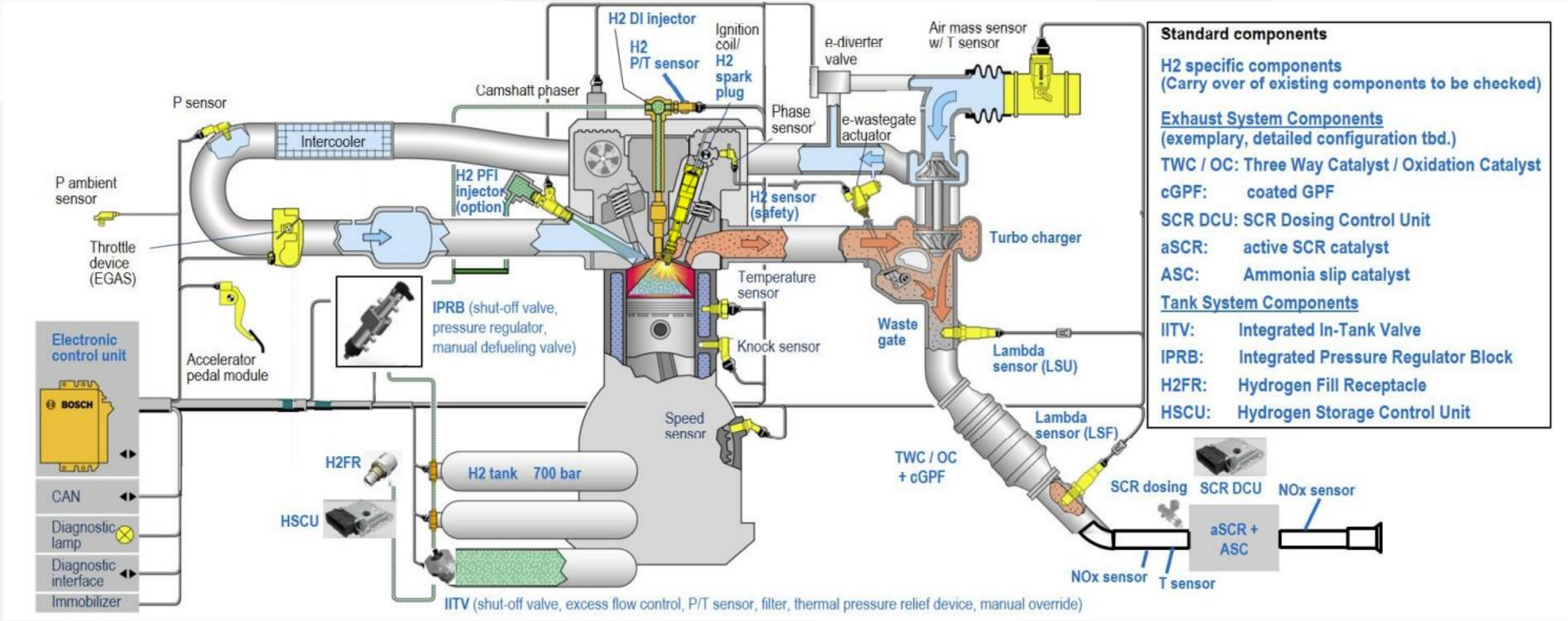
- ✓ Zero CO2 emissions
- ✓ High engine thermal efficiency
- ✓ Lower original engine emissions

Step2：Near-zero exhaust gas emission

- ➢ The efficient combustion system is combined with the lean combustion control strategy to achieve high starting heat efficiency and low original emissions.
- ➢ Nearly zero pollutant emissions are achieved from the aspects of original machine emission control and external purification technology.

❑ Technical solution

■ Hydrogen internal combustion engine system composition



❑ Technical solution

Combustion System

- Homogeneous spark-ignited combustion
  - ✓ Flat-top diesel cylinder head with swirl intake ports
  - ✓ Pent roof, tumbling
- Dilute combustion
  - ✓ High thermal efficiency, reduced knock and Nox emissions
  - ✓ Compression ratio selected based on optimum performance in accordance with detonation boundaries

Hydrogen Injection System

- Direct Injection
  - ✓ Reduces boosting requirements
  - ✓ Reduces risk of backfire
  - ✓ Injector position is determined by the airflow in the cylinder
- Airway injection
  - ✓ Minimal structural changes
  - ✓ Risk of backfire

Air exchange system

- Matching injector selection to airflow status
- Optimization of the boost system
  - ✓ Single stage boost is expected to be 18 bar for BMEP
  - ✓ Two-stage boost will be higher
- High pressure EGR needs to be reduced

	Peak BMEP	Specific power	Peak BTE
Conventional single stage early-to-market	18 bar	25 kW/l	42%
Optimised two-stage future product	22 bar	29 kW/l	44%

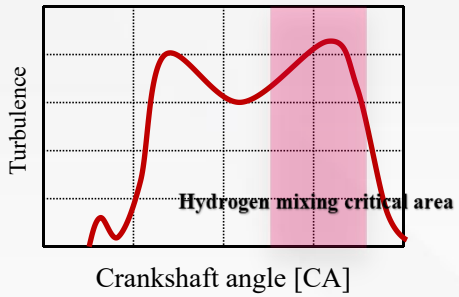
Mechanical / Friction

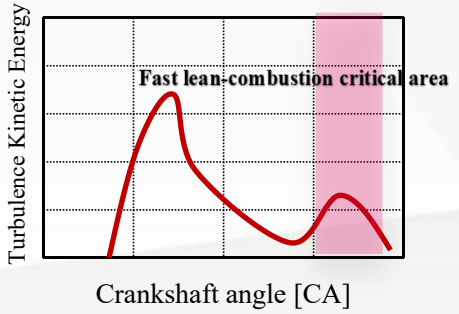
- ✓ Optimization of cooling systems for higher thermal efficiency
- ✓ Oil control - lubrication and particles
- ✓ Low fuel lubrication - valve train effects

❑Technical solution

• Combustion System Design

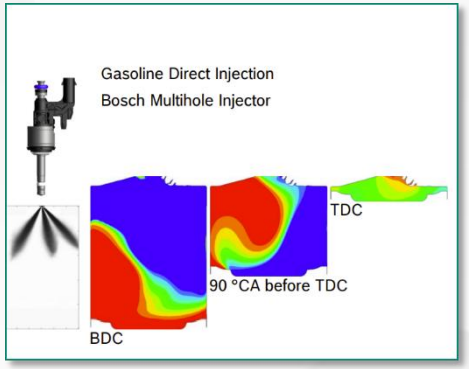
High-flow tumble gas paths and compact combustion chambers for improved tumble ratio and turbulence energy to increase initial combustion velocity.

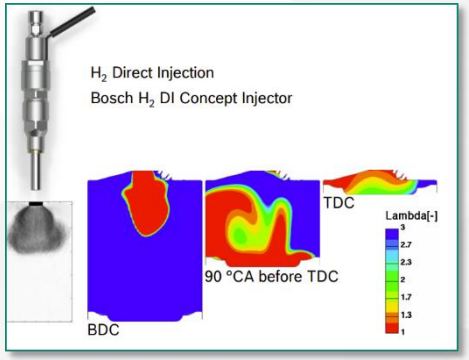




• Hydrogen Injection System

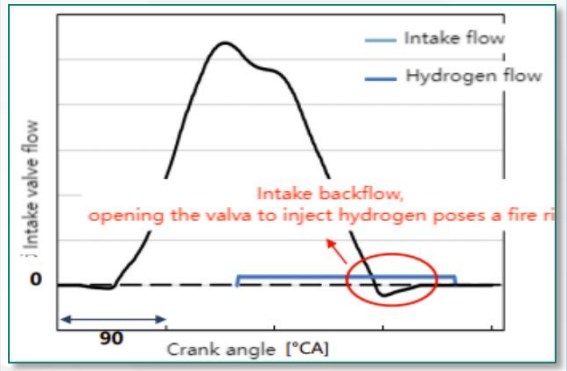
Hydrogen fuel nozzles for mixing uniformity and flashback control; optimized injection timing to shorten combustion time.

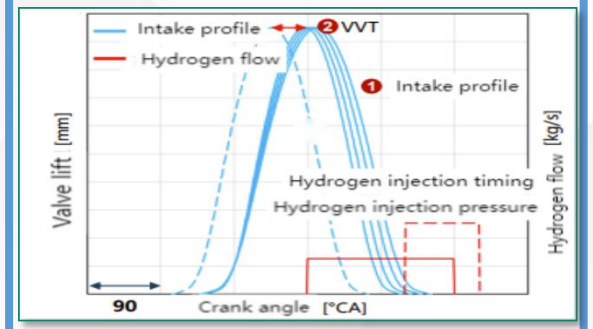




• Air exchange system

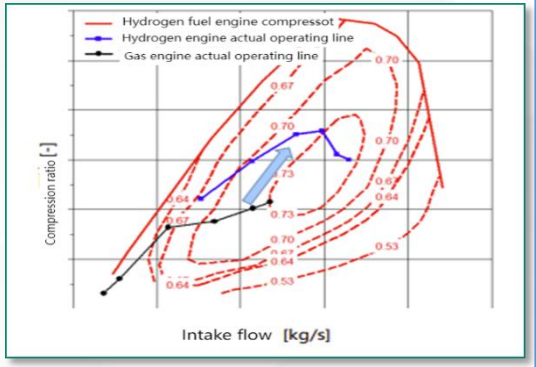
Adoption of Miller cycle gas distribution mechanism to optimize hydrogen injection strategy and avoid backfire risk.

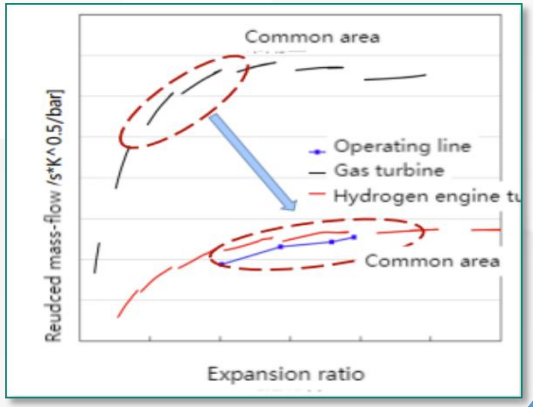




• Booster system

Specialized supercharger with high pressure ratio and high expansion ratio to balance thermal efficiency and power demand.

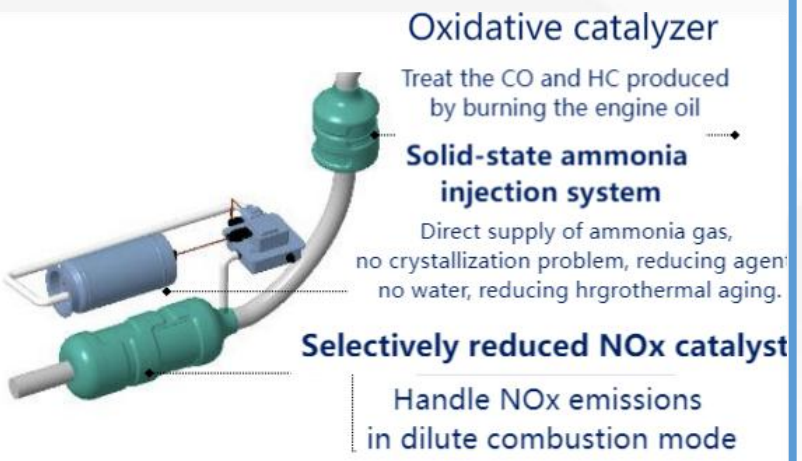




❑Technical solution

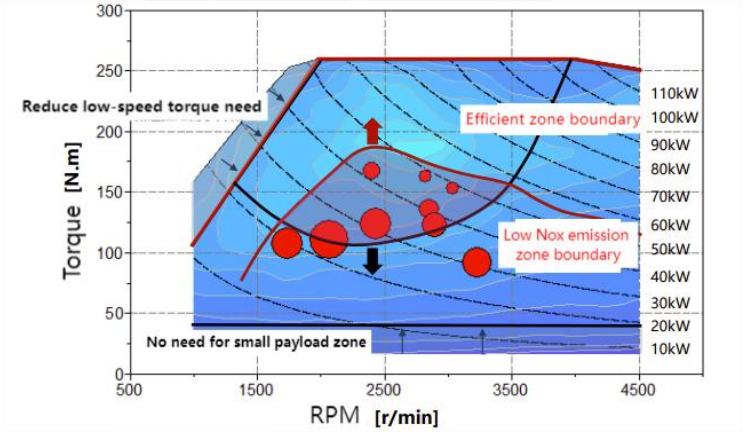
• Aftertreatment System

Liquid ammonia and DOC aftertreatment systems are used to achieve near-zero emissions.



• Prototype Development

Developed with test benches that meet environmental and safety standards, and select workload ranges based on dynamic, economical, and emission. targets



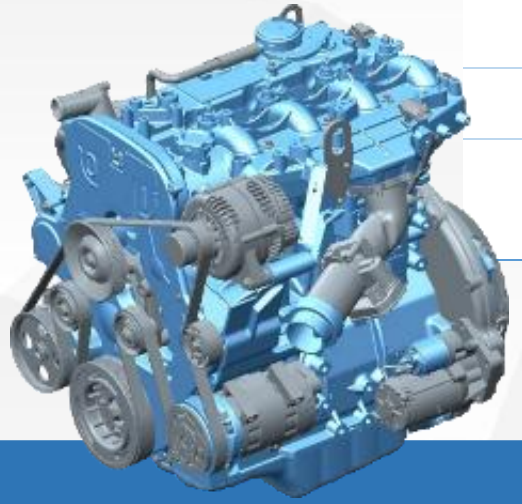
2.8L intercooled hydrogen ICE

- Project Name: **Hydrogen ICE Development**
- Cooperation period: 2022~2023
- Main work: Conversion of natural gas engine to hydrogen ICE
- Our work: structural design, CAE simulation analysis
- Current status:

✓ Structural design is completed.

✓ Prototype trial production is underway.

ITEM	Parameter
Model	**4E**
Type	**L4、TSI、DI**
Displacement（mL）	**2776**
Bore × stroke（mm）	**94×100**
Compression ratio	**12**
Power（kW/rpm）	**75/3200**
Torque（Nm/rpm）	**350/2000**
Thermal efficiency	**38%**

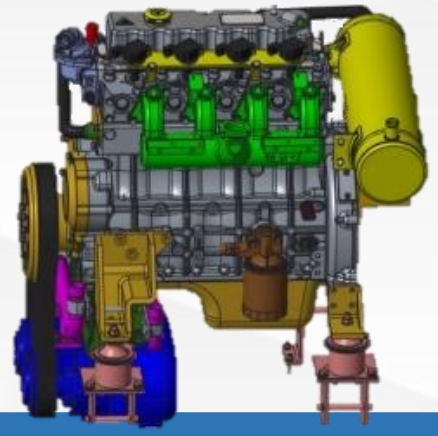


2.7L naturally aspirated hydrogen ICE

- Project Name: **2.7L Hydrogen ICE Development**
- Cooperation period: 2022~2023
- Main technology: Conversion of diesel engine to hydrogen ICE
- Our work: structural design, CAE simulation analysis
- Current status:

✓ Structural design is completed.

✓ Prototype trial production is underway.



ITEM	Parameter
Model	**4D**
Type	**L4、NA**
Displacement（mL）	**2850**
Bore × stroke（mm）	**93×·05**
Compression ratio	**10**
Power（kW/rpm）	**35/2500**
Torque（Nm/rpm）	**160/1800**
Thermal efficiency	**36%**

2.0L TSI DI hydrogen ICE

- Project Name: **Efficient Hydrogen ICE Development**
- Cooperation period: 2022~2024
- Main work: hydrogen energy dilute combustion special engine development
- Our work: structural design, CFD simulation analysis
- Current status:

✓ Structural design is completed.

✓ Water jacket simulation analysis is in progress.

ITEM	Parameter
Model	**4GC**
Type	**L4、TSI、DI**
Displacement（mL）	**1994**
Bore × stroke（mm）	**78.5×103**
Compression ratio	**14**
Power（kW/rpm）	**120/4500**
Torque（Nm/rpm）	**260/1700~3500**
Thermal efficiency	**43%**

THANKS !

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