



Large marine lean-burn natural gas engine development

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Contents

- Background
- Introduction of M23G gas engine
- Development Approach
- Design Phase
- Development Test
- Summary





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SMDERI

- Shanghai Marine Diesel Engine Research Institute (SMDERI), founded in 1963, is attached to China Shipbuilding Industry Corporation (CSIC.)

Main strategic business:

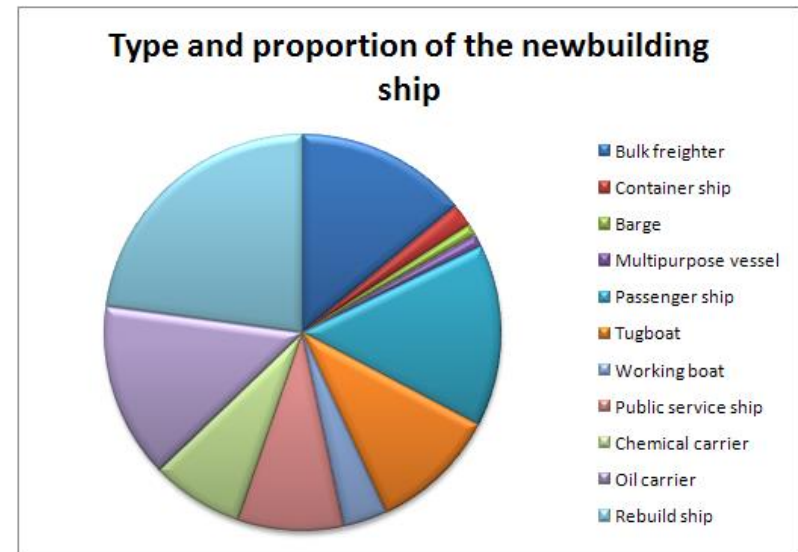
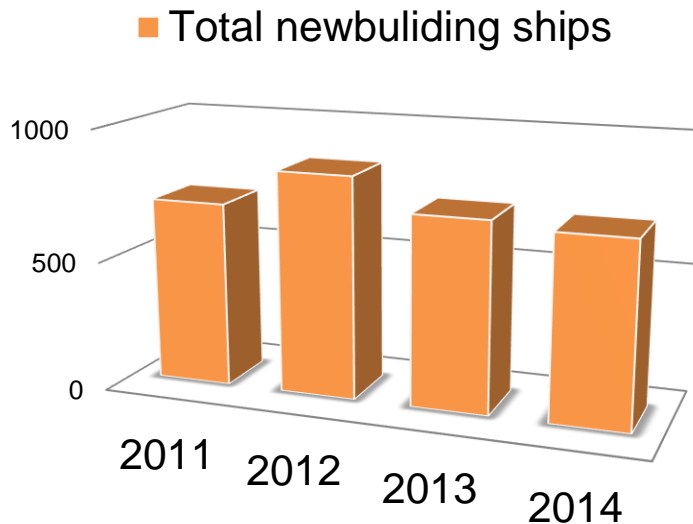
- ☐ Diesel and gas engine
- ☐ Stirling engine
- ☐ Power system integration
- ☐ Ship automation system
- ☐ Energy-saving and environment protection equipment
- ☐ Energy service





Background

- There are quite large marine engine market in China.



• *Detail date quoted from CCS

- The total inland and coastal newbuilding ships in China, during 2011 to 2014.
- The proportion of each type for inland and coastal newbuilding ships in China, during 2011 to 2014.



Background



NOx and PM emission from the ship must be reduced to a lower level in the near future.

There are methane slip limits for DF and gas engine also.

“Limits and measurement methods for exhaust pollutants from marine compression ignition engines (CHINA I, II)”



Background



Complete, being build, and plan to build LNG receiving station, along the river and coast in China.

West-to-East Natural Gas Transmission Project



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Introduction of M23G gas engine

■ Prototype engine is a 210mm bore size diesel engine-CS21 diesel engine



- 6,8,9 cylinders, 900~1000rpm
- Power range: 1320~1980kW
- Conventional fuel system/Common rail
- IMO Tier II/ IMO Tier III with SCR
- With independent intellectual property rights
- The operating time is already over several hundreds hours on *Haigang 711*.

Haigang 711 tug boat



Introduction of M23G gas engine



M23G gas engine on the bench

- M23G gas engine specification
- Bore: 230mm, Stroke: 320mm
- 1600kW@1000rpm with 8 cylinders
- Marine and power generation application
- Inherently safe design
- IMO Tier III without aftertreatment



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Development Approach

- Design Phase
 - Concept design, technical solution and main target and specification
 - Detail design, CAE and CAD work
- Produce Phase
 - Component produce
 - Assembling
- Engine Test Phase
 - Performance test
 - Type approval test
 - Endurance test



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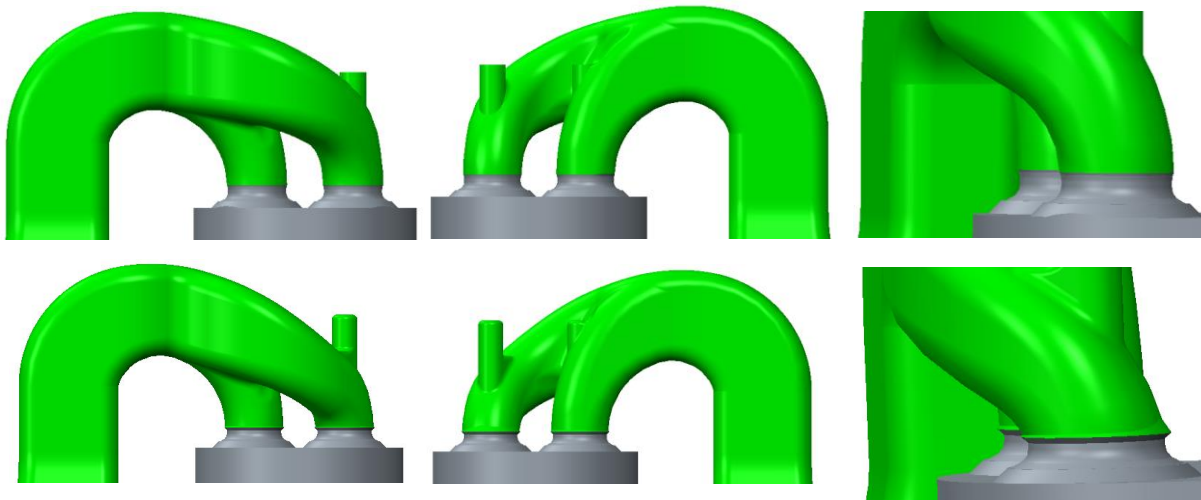
Technical concept

- Pre-chamber spark ignition, with individual gas supply to pre-chamber
- Gas port admission
- A/F ratio control with throttle and waste gate
- Lean burn concept for fulfill with IMO Tier III limits and requirements and Ministry of Environmental Protection in China, without any after-treatment
- Inherently safe design for marine application, such as double wall gas piping



Simulation investigation of combustion

• Intake port



Lower swirl

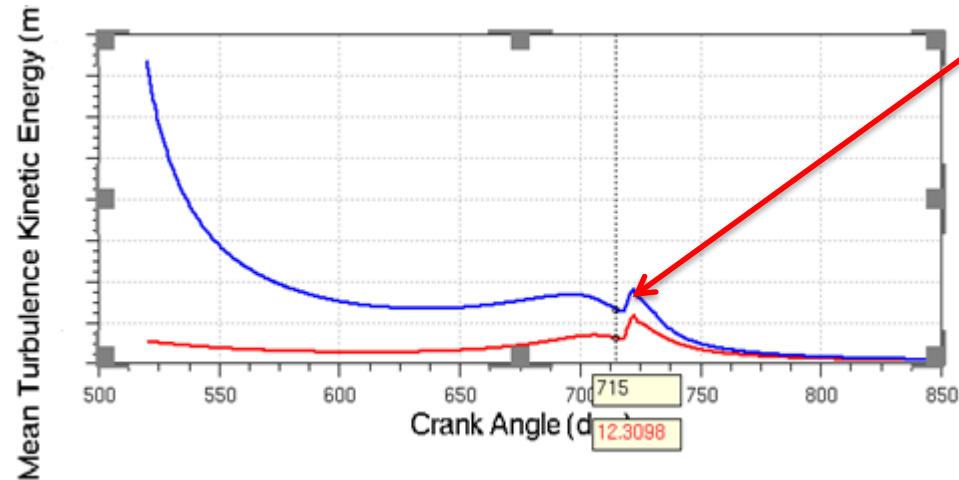
Higher swirl

The lower swirl intake port is modelling from the diesel engine.

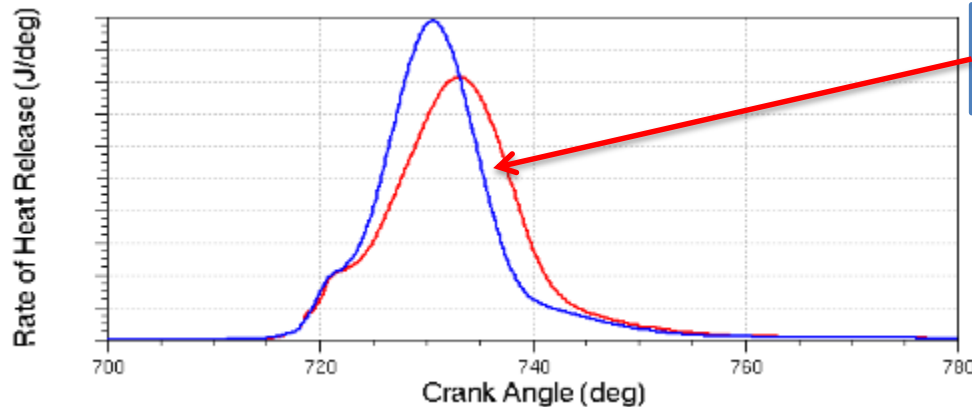


Simulation investigation of combustion

• Intake port



■ High swirl number intake port has higher Turbulence kinetic energy (TKE) at the start of combustion (SOC)



■ Higher TKE makes faster combustion

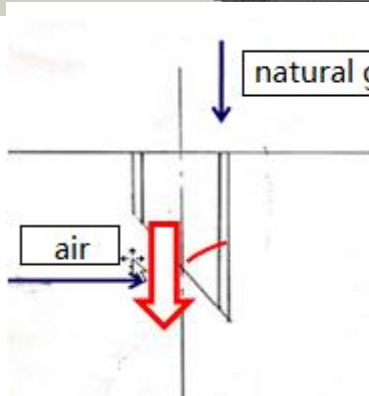
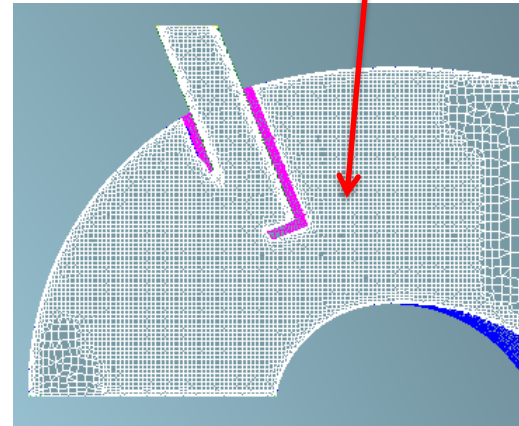
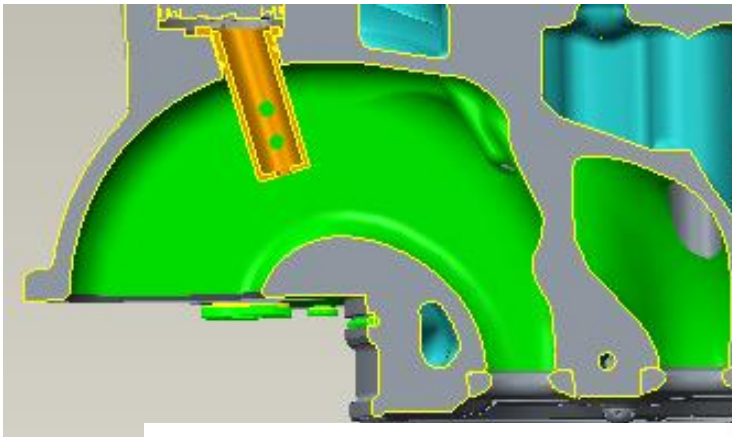
— Higher swirl
— Lower swirl



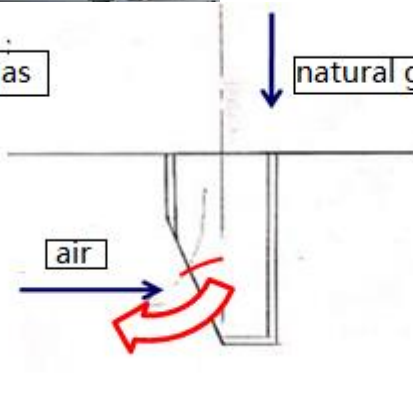
Simulation investigation of combustion

• Gas inlet nozzle

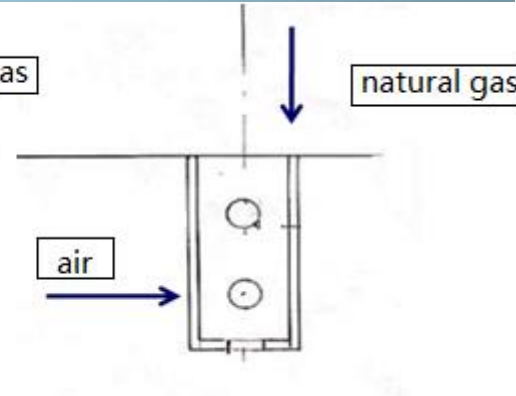
■ Cells concentration near by the nozzle



Bevel angle cut



Half bevel angle cut



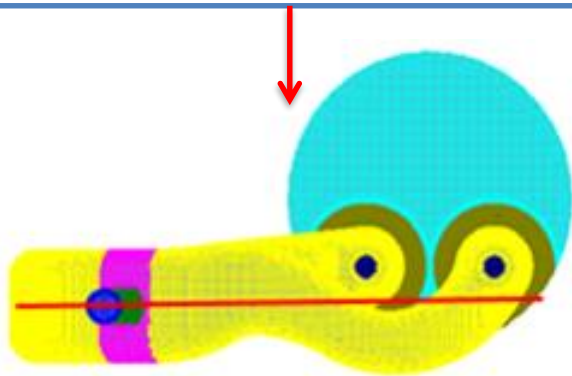
Multiholes



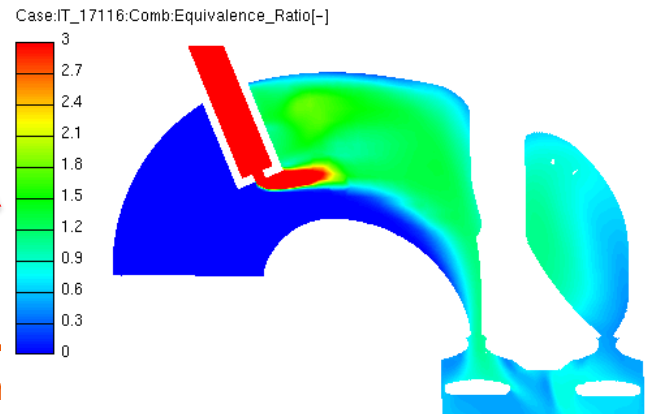
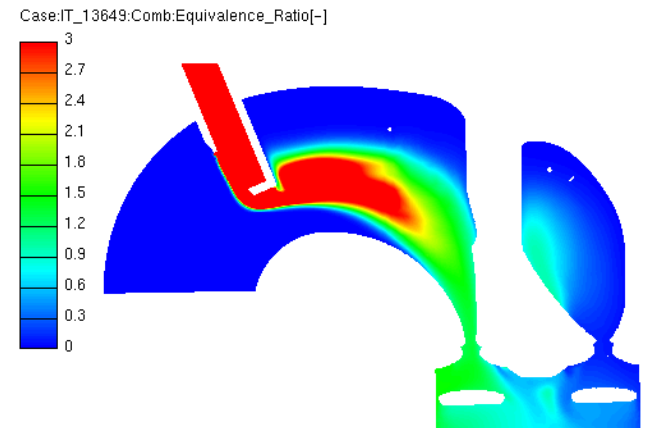
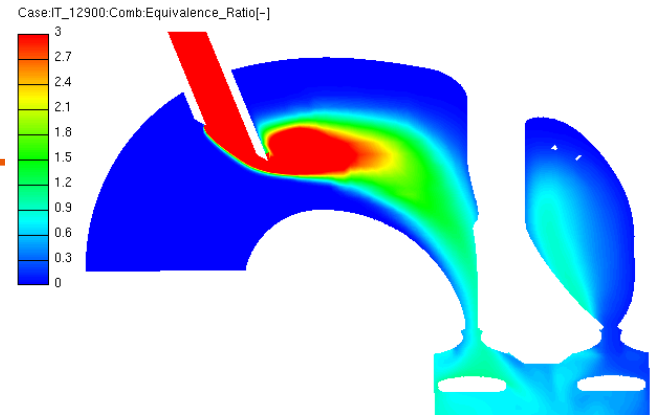
Simulation investigation of combustion

• Gas inlet nozzle

■ Equivalence ratio distribution along the vertical section in the intake port



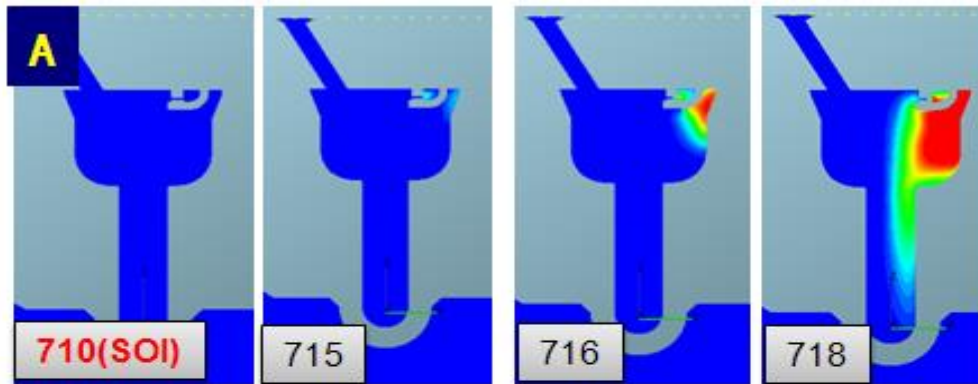
■ Multi-holes has the better mixture effect



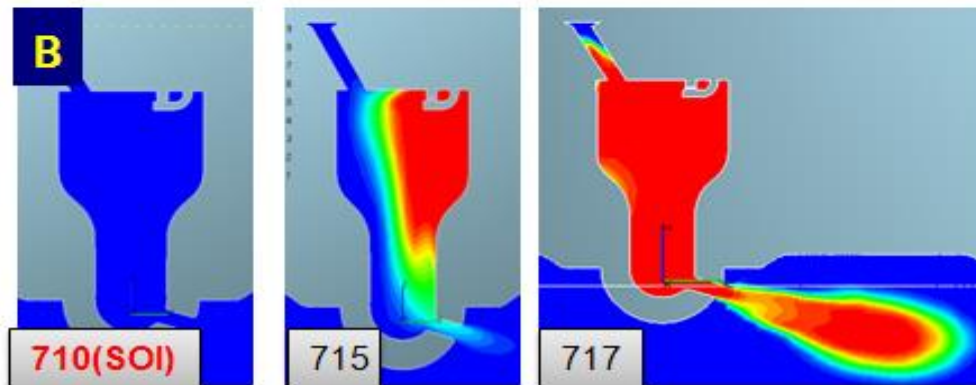


Simulation investigation of combustion

• *Pre-chamber* & *Piston top*



■ **Combustion reaction progress** in pre-chamber and main chamber can show the difference obviously

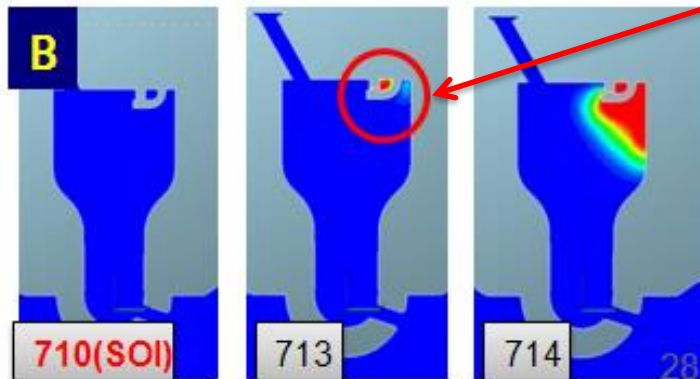
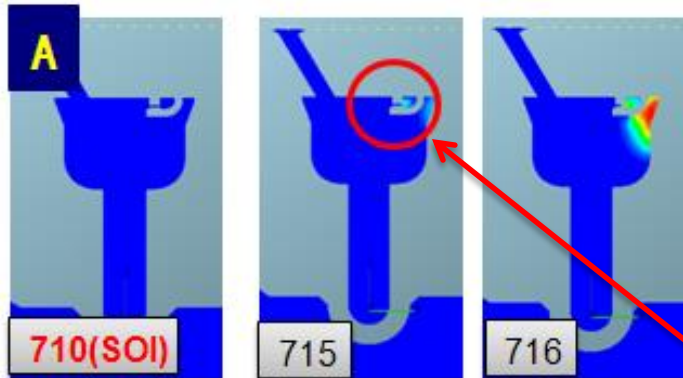


■ During the whole process, B has faster combustion reaction progress than A



Simulation investigation of combustion

•Pre-chamber&Piston top



■ Around the spark plug, B come out the earlier initial flame core than A



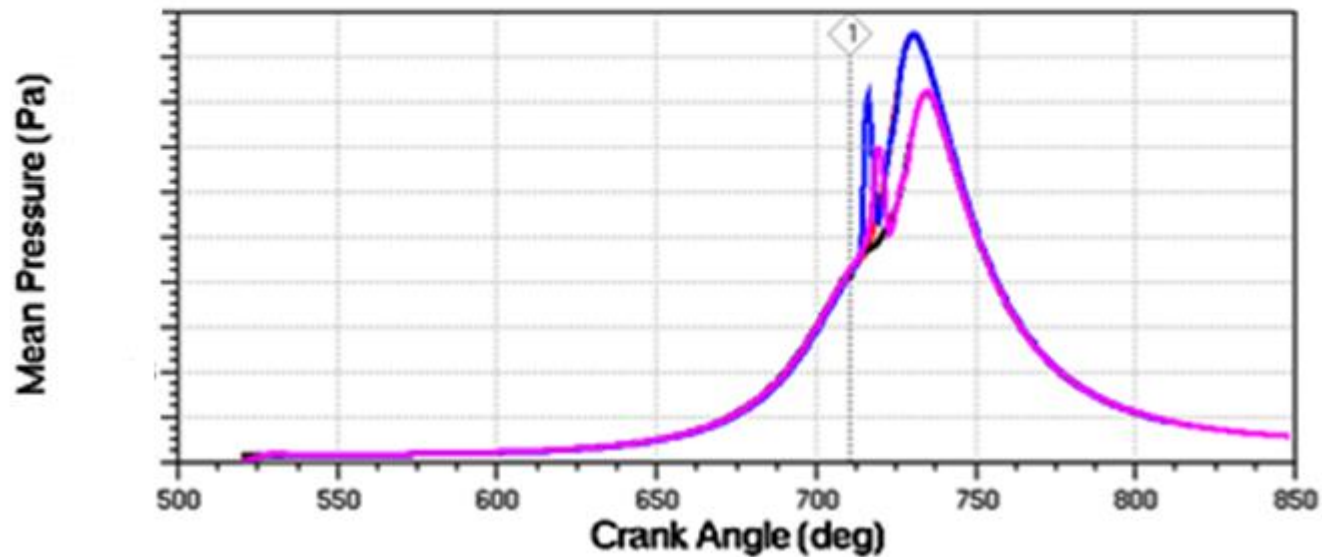
Simulation investigation of combustion

• *Pre-chamber* & *Piston top*

— A, pressure in pre-chamber and main chamber

— B, pressure in pre-chamber and main chamber

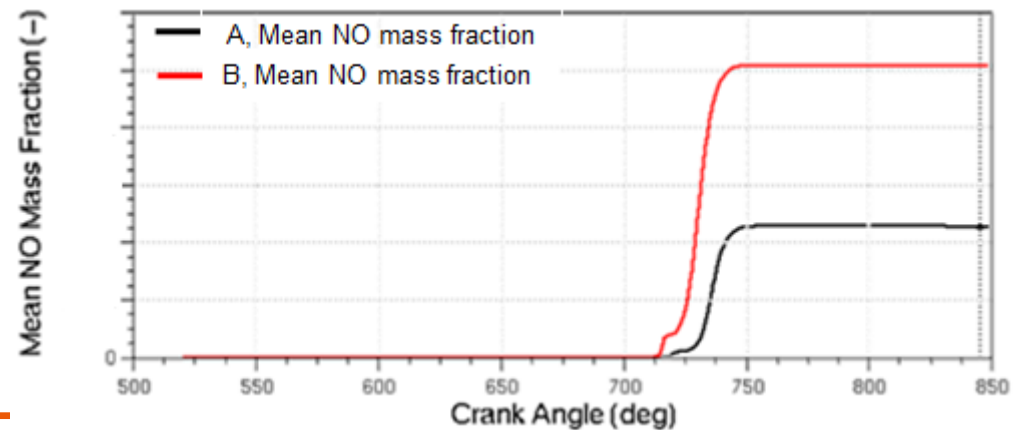
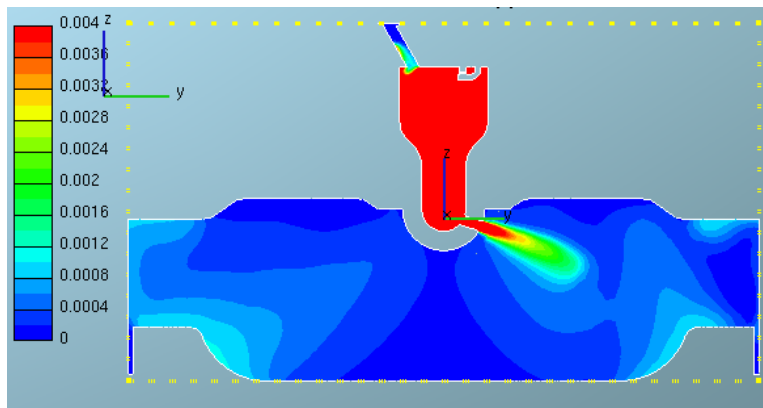
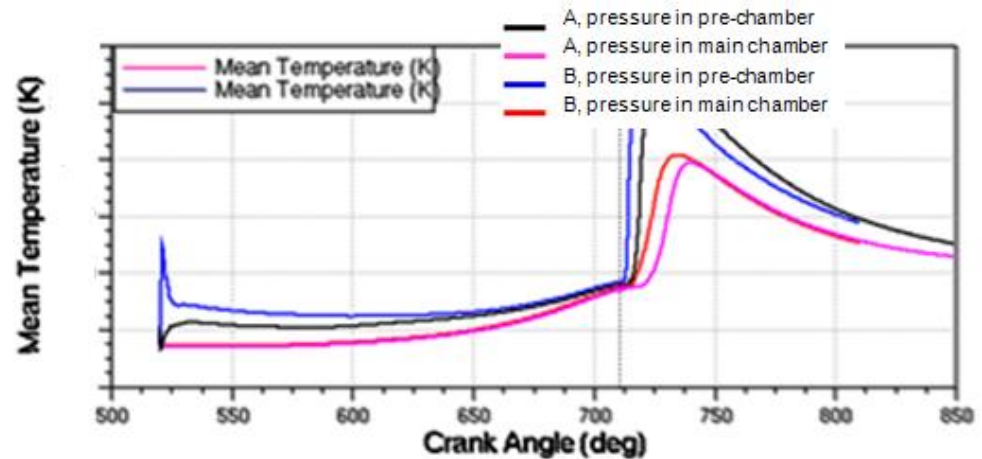
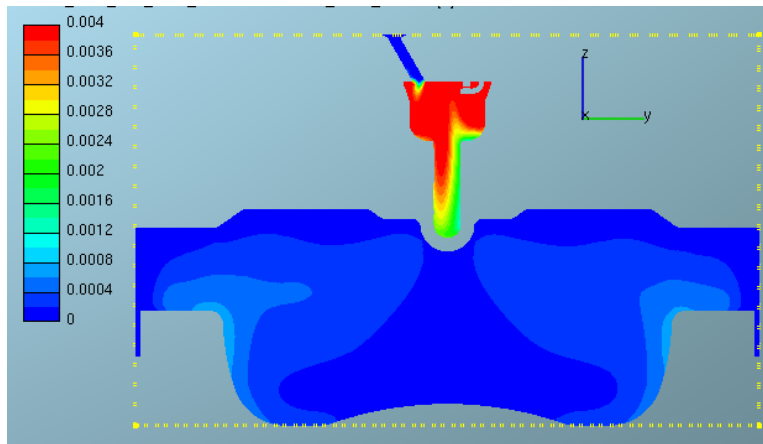
SOI: 710°CA





Simulation investigation of combustion

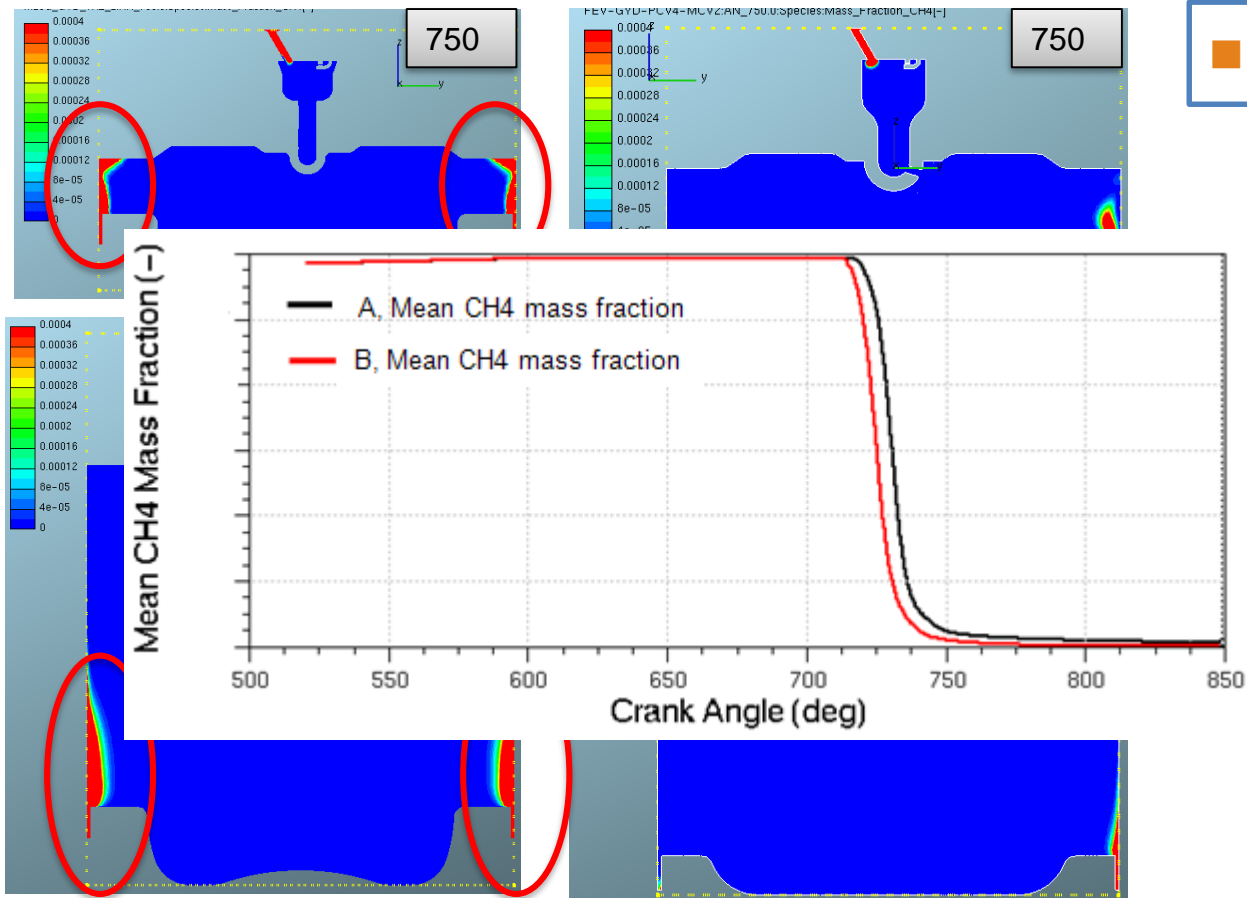
•Pre-chamber&Piston top





Simulation investigation of combustion

•Pre-chamber&Piston top





Intake and exhaust system

Exhaust piping

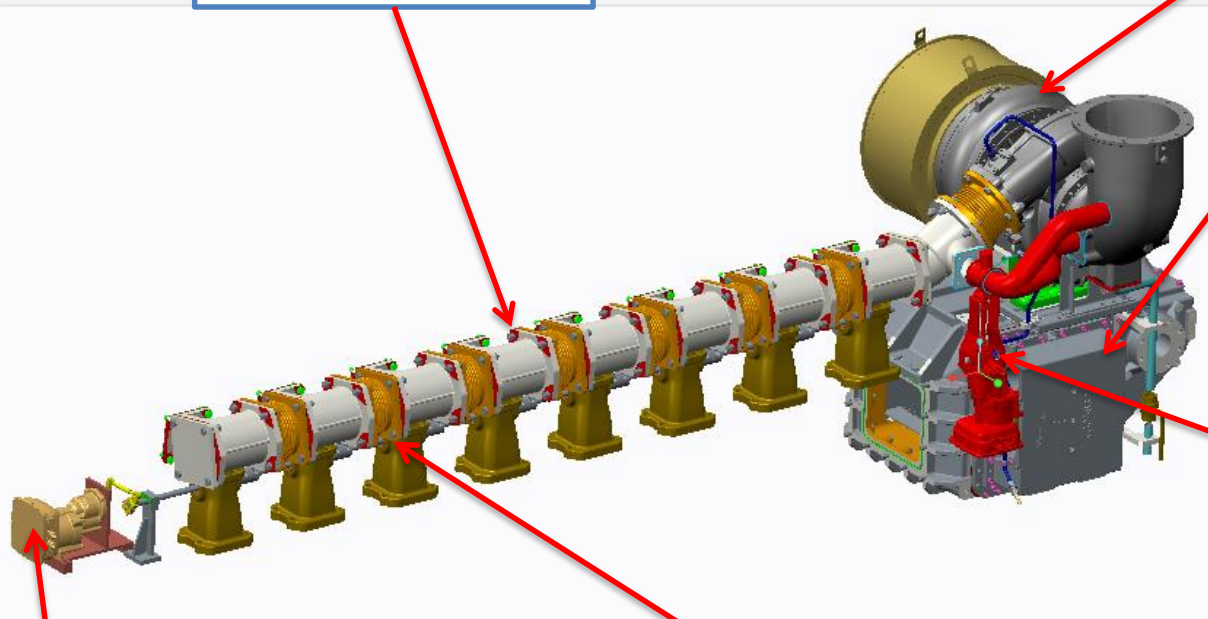
Turbocharger

Intercooler

Waste-gate valve

Motor for throttle

Throttle in the intake manifold



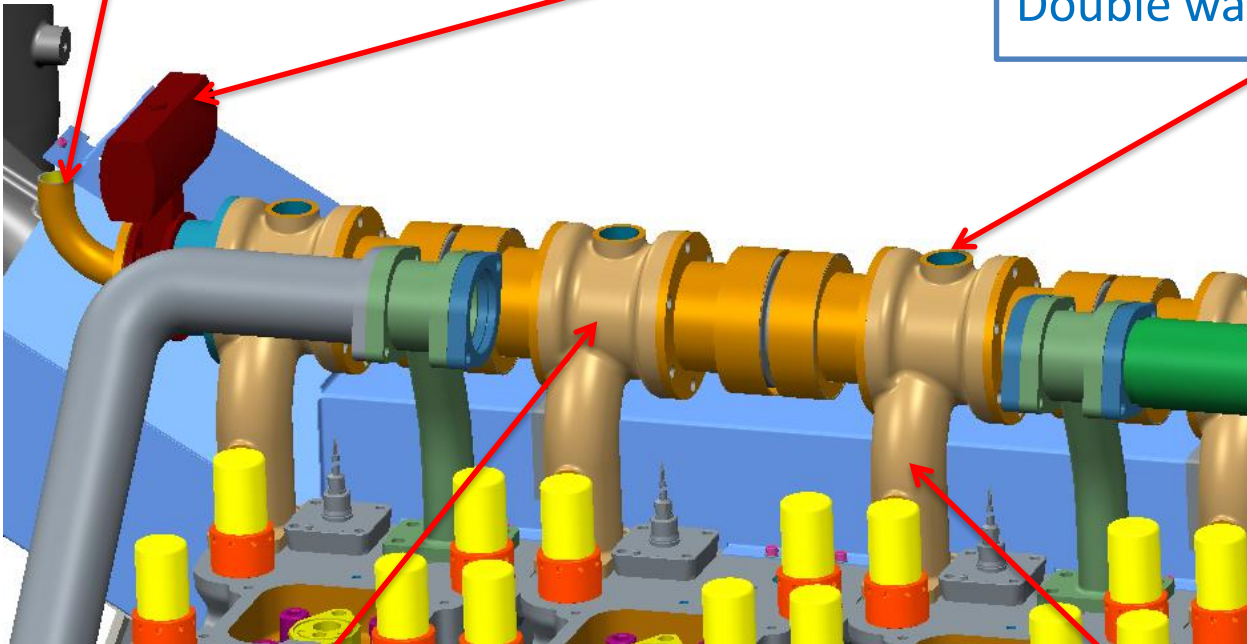


Double wall gas piping

Double wall venting outlet

Venting valve

Double wall venting inlet



Main gas pipe with double wall

Gas manifold with double wall



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Performance test

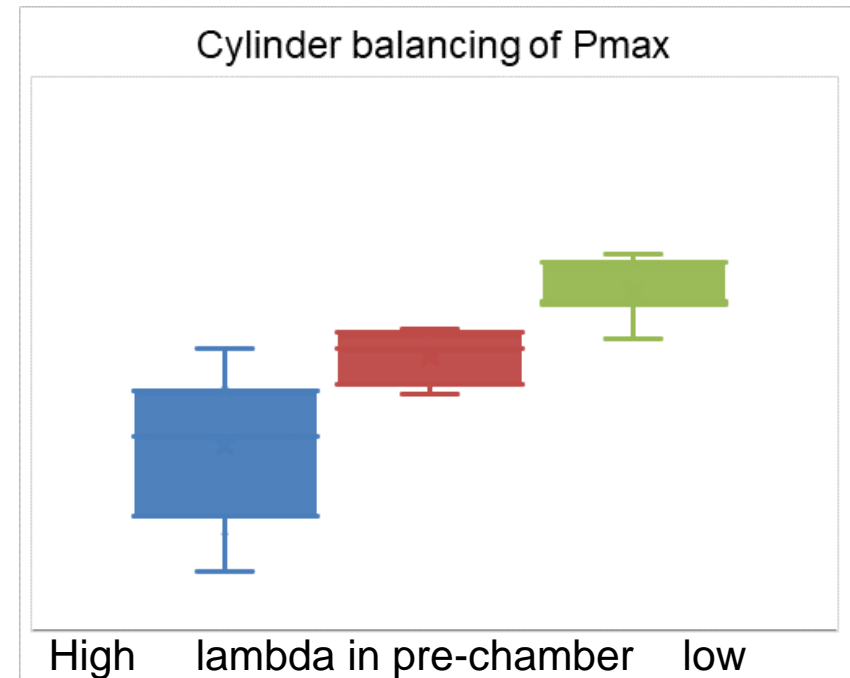
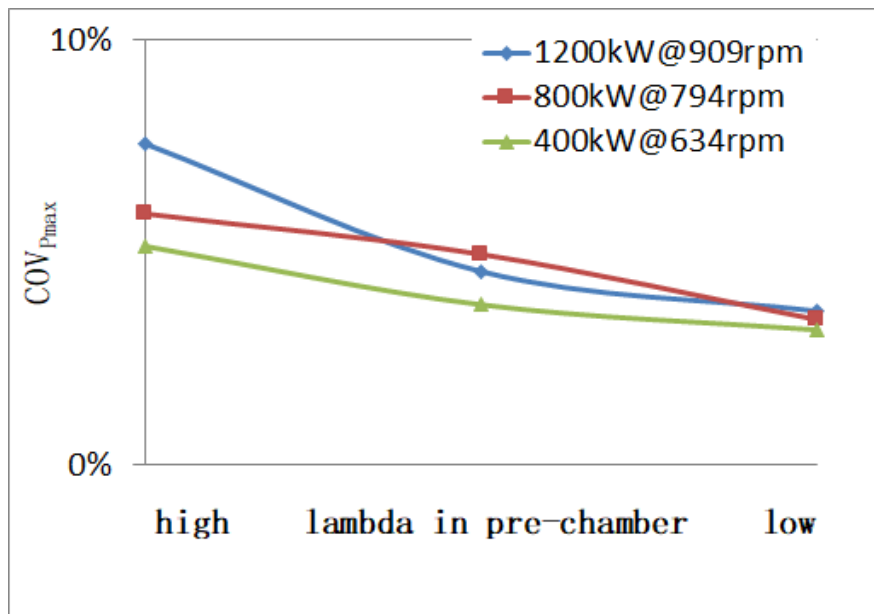
- Technical specification

Parameter	Value
Power	Rated load:1600kW @1000rpm 110% load:1780kW @1032rpm
NOx Emission	<1.6g/kWh (weighted average)
Thermal efficiency	42.5%
Peak firing pressure	135bar
Exhaust temperature(Turbine inlet)	<580°C
COV _{Pmax}	6%
COV _{IMEP}	3%



Performance test

- The cylinder balancing and COV



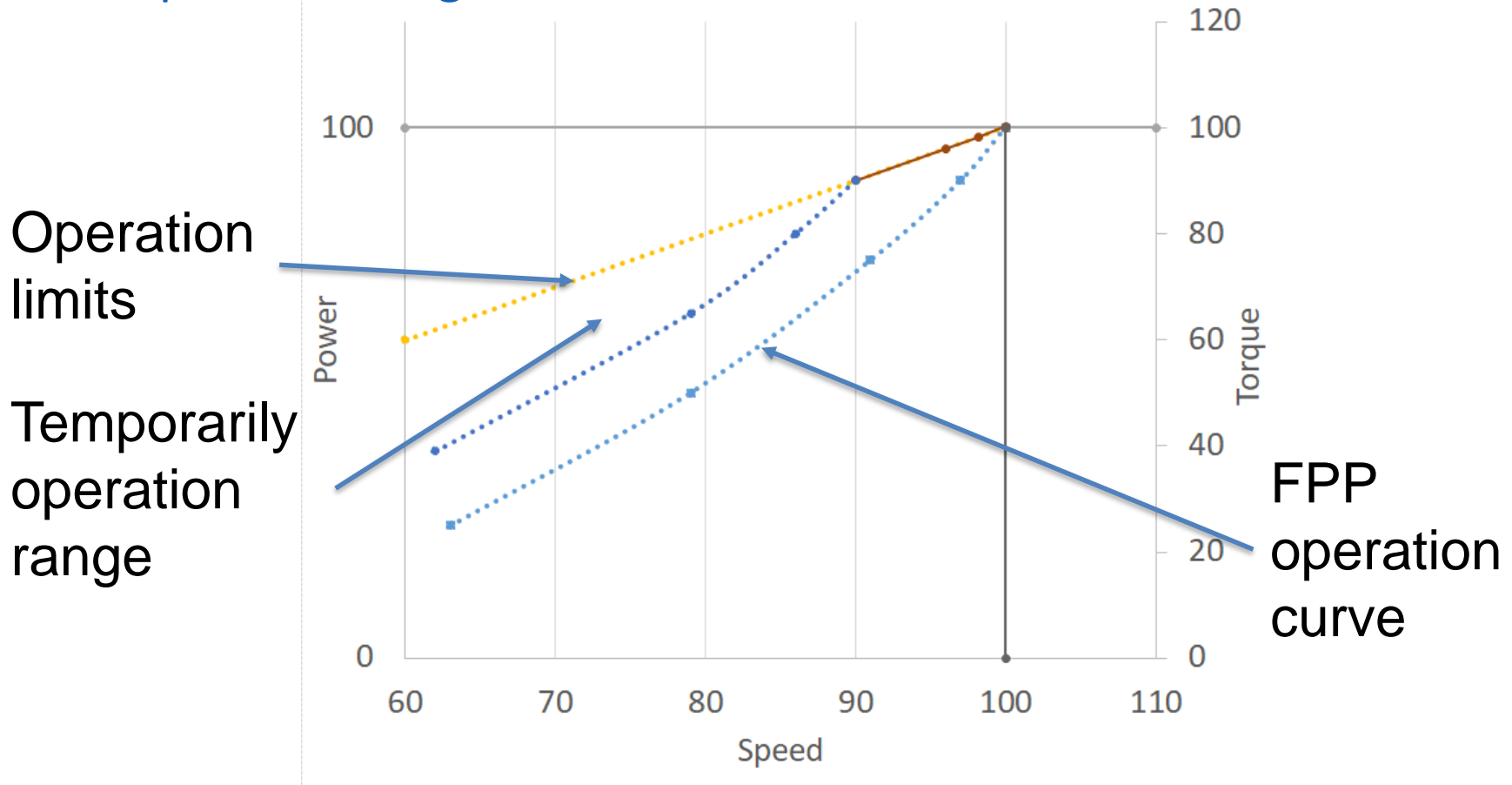
$COV_{P_{max}}$ (mean value of cylinders)

Cylinder deviation of P_{max}
(mean value of cylinders)



Performance test

- Operation range





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Type approval test



Certificate issue site



Certificate of type approval



EIAPP



Endurance test

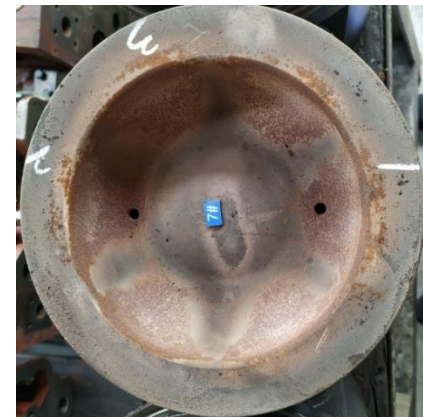
- After 600 hours endurance test, the check of key parts.



The bottom of the cylinder head



Piston

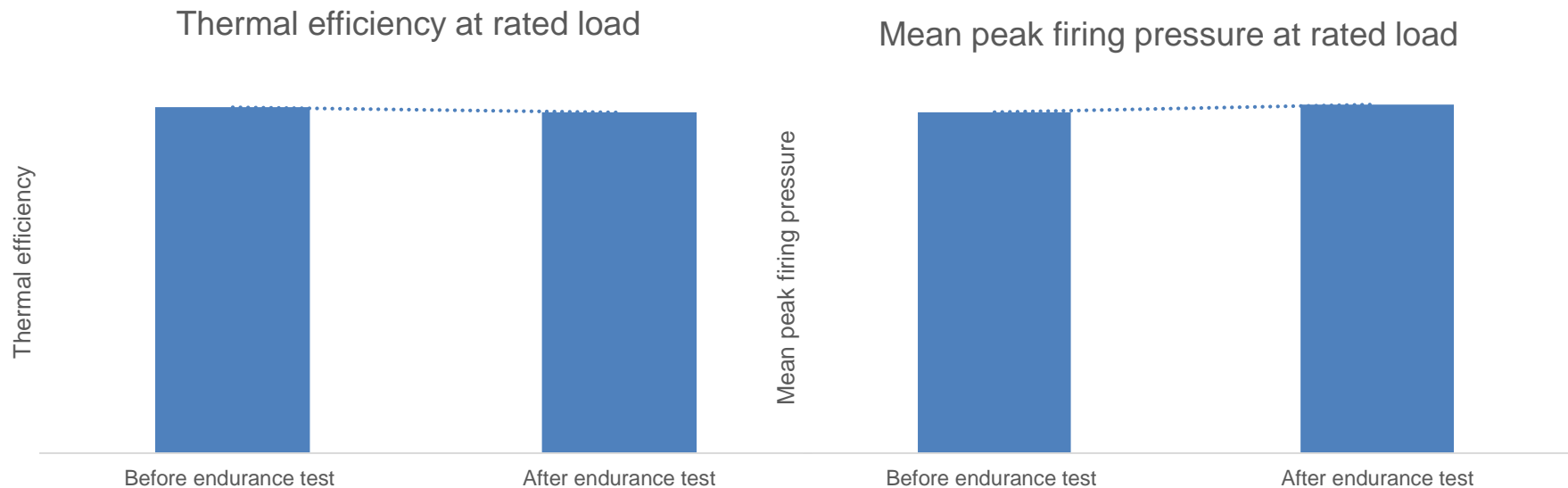


Piston top



Endurance test

- After 600 hours endurance test, the performance retest





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Summary

- M23G gas engine has finished the design, produce and test phase, and has already been well developed and get the CCS certification. M23G is fulfill the IMO Tier III level, has competitive economy performance, with Inherently safe design, take into account both marine and power generation application.
- During the development phase, CFD has been used much for evaluation and optimization, that was help to improve the efficiency and shorten the design phase. The cylinder balancing and COV issue also have been well optimized.
- M23G has passed the 600 hours endurance test, and proved its reliability and stability.
- Based on the success application of 6CS21 diesel engine, it's to believe that the M23G will be accept from the market in the near future.



Thanks for your attention!

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