Efficiency Increase of a High Performance Gas Engine for Distributed Power Generation

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Imagination at work

Agenda

- Introduction
- GE's Jenbacher Type 6 gas engine
- Gas exchange
- Combustion
- Summary

Introduction

GE's Jenbacher gas engines for distributed power generation…

…provide electrical and thermal energy in a flexible, efficient & reliable manner – onsite and with short lead time

…operate with various types of fuel gas and low pollutant emissions

…serve 50 and 60 Hz grids, operate in grid-parallel and island mode

…cover an electrical power range from 250 to 9 500 kW

…offer electrical efficiencies up to 49.0 % and CHP efficiencies >90 %

…take the lead in special gas applications

Type 2
250 - 330 kW

Type 3
500 kW – 1 MW

Type 4
800 kW - 1.6 MW

Type 6
2.0 - 4.4 MW

J920 FleXtra
9.5 MW

Introduction

Future Requirements

Customer

- Investment costs
- Operation costs
- Availability
- Operation flexibility (gas comp. & ambient conditions)
- Lead time from stopped engine to full power to the grid
- Compliance to grid-code requirements (voltage drop)
- Compliance to emission limits

Thermodynamic development

⇒ Specific power output

⇒ **High electrical efficiency…**

⇒ Distance to knock and misfire borders

⇒ Methane number requirement

⇒ Power de-rating due to ambient conditions

⇒ Transient behavior

⇒ **…especially at low NO_X emissions**

Introduction

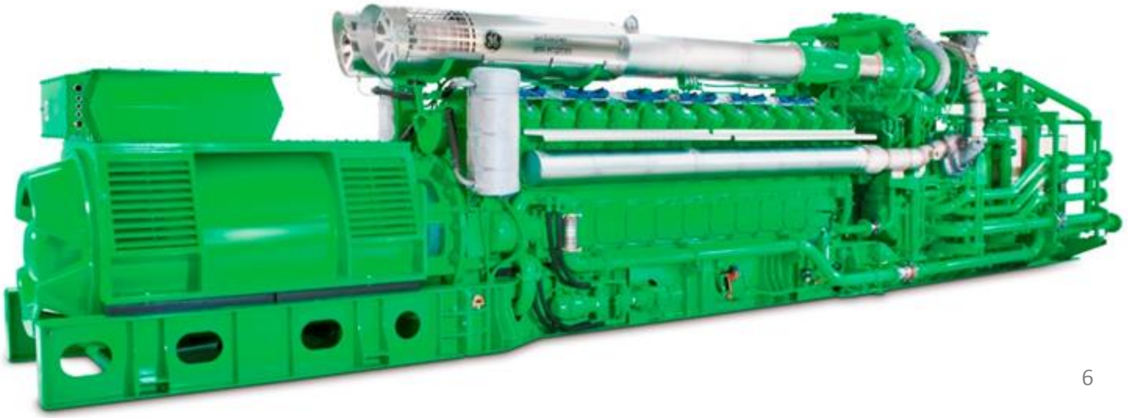
GE's Jenbacher Type 6 gas engine

Engine version	J624 H	J620, 616 and 612 F
Engine process	4-stroke spark ignition engine with lean A/F mixture	
Mixture preparation	Gas-mixer upstream of turbocharger	
Turbocharging	2-stage (2-stage mixture coolers)	1-stage (2-stage mixture cooler)
Gas exchange	Single cylinder heads with 4 valves per cylinder	
	Advanced early miller timing	Moderate early miller timing
Combustion concept	Scavenged prechamber with passive prechamber gas valve	
Ignition	MORIS high energy ignition system, spark plug	
Power control	CBP and throttle valve	

Introduction

GE's Jenbacher Type 6 gas engine

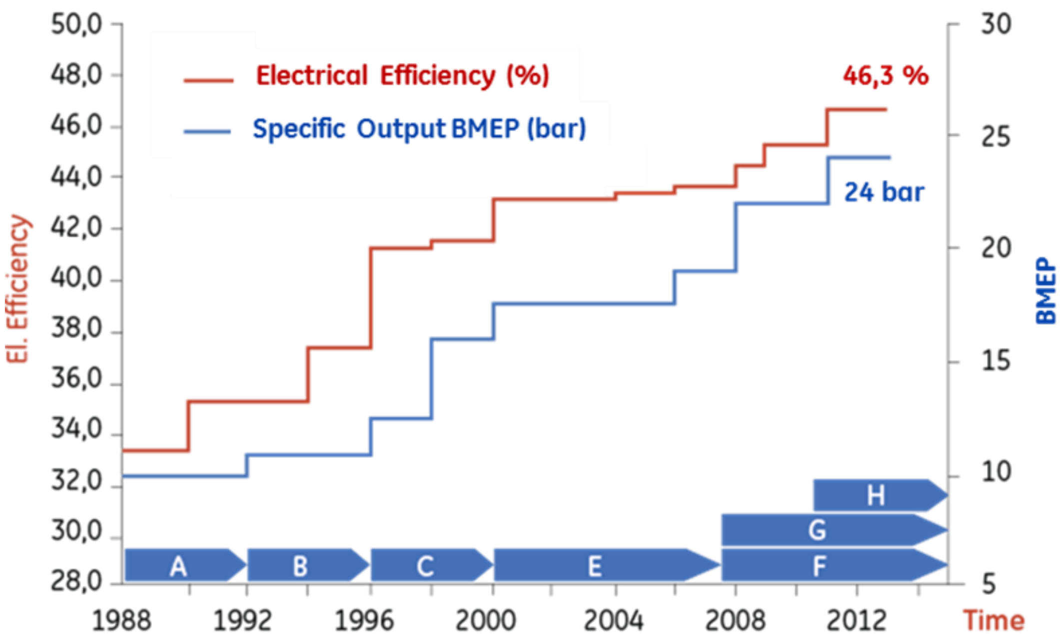
Engine version	J624 H	J620, 616 and 612 F
Bore / Stroke [mm]	190 / 220	
Displacement [dm^3]	6.24 per cylinder	
BMEP [bar]	24	22
Rated speed [1/min]	1500 (50 Hz), 1500 with gearbox (60 Hz)	
Engine power [kW_{el}]	4400	3350, 2680 and 2010
Electrical efficiency [%]	46.3 @ MN >83	45.6 @ MN >84
Total efficiency [%]	90.3	89.1



Introduction

GE's Jenbacher Type 6 gas engine

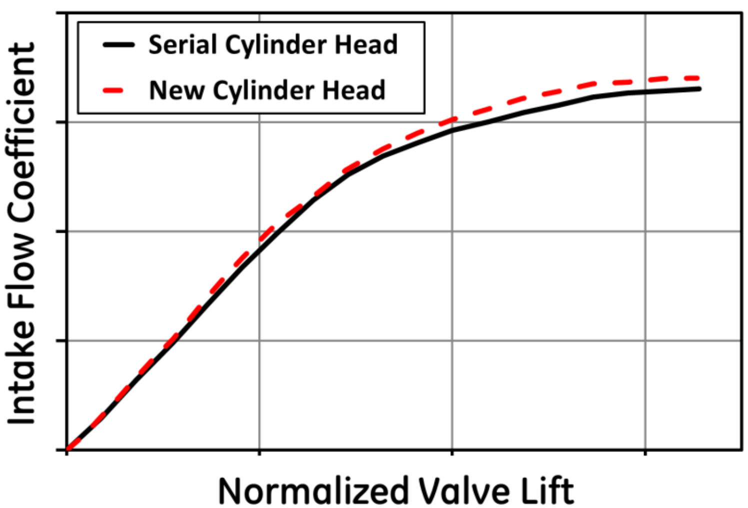
- More than 25 years of proven service
- More than 3 500 engines across the globe
- Average availability of 98 %

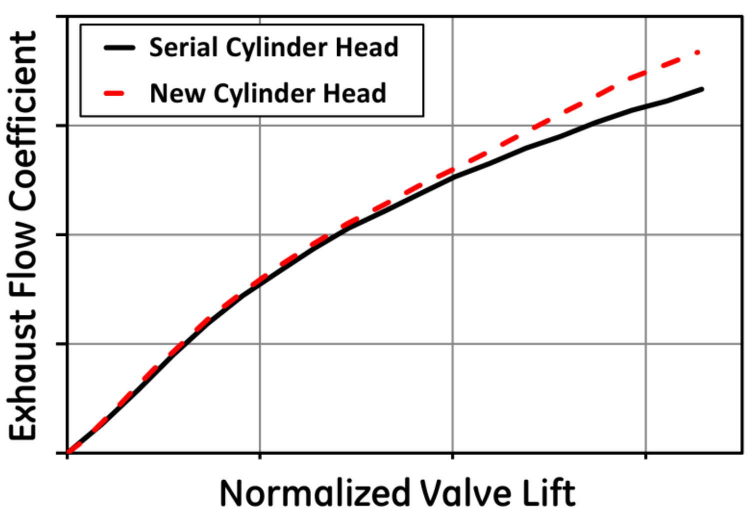


Gas Exchange.
Efficiency Potentials

Gas Exchange

Cylinder head





- New version for future BMEP increase
- Opportunity used to improve flow characteristics of IN and EX ports
- Smart cooling gallery to reduce IN port surface temperatures
- Increased volumetric efficiency and reduced gas exchange losses

⇒ **+ 0.15 % points in engine efficiency**

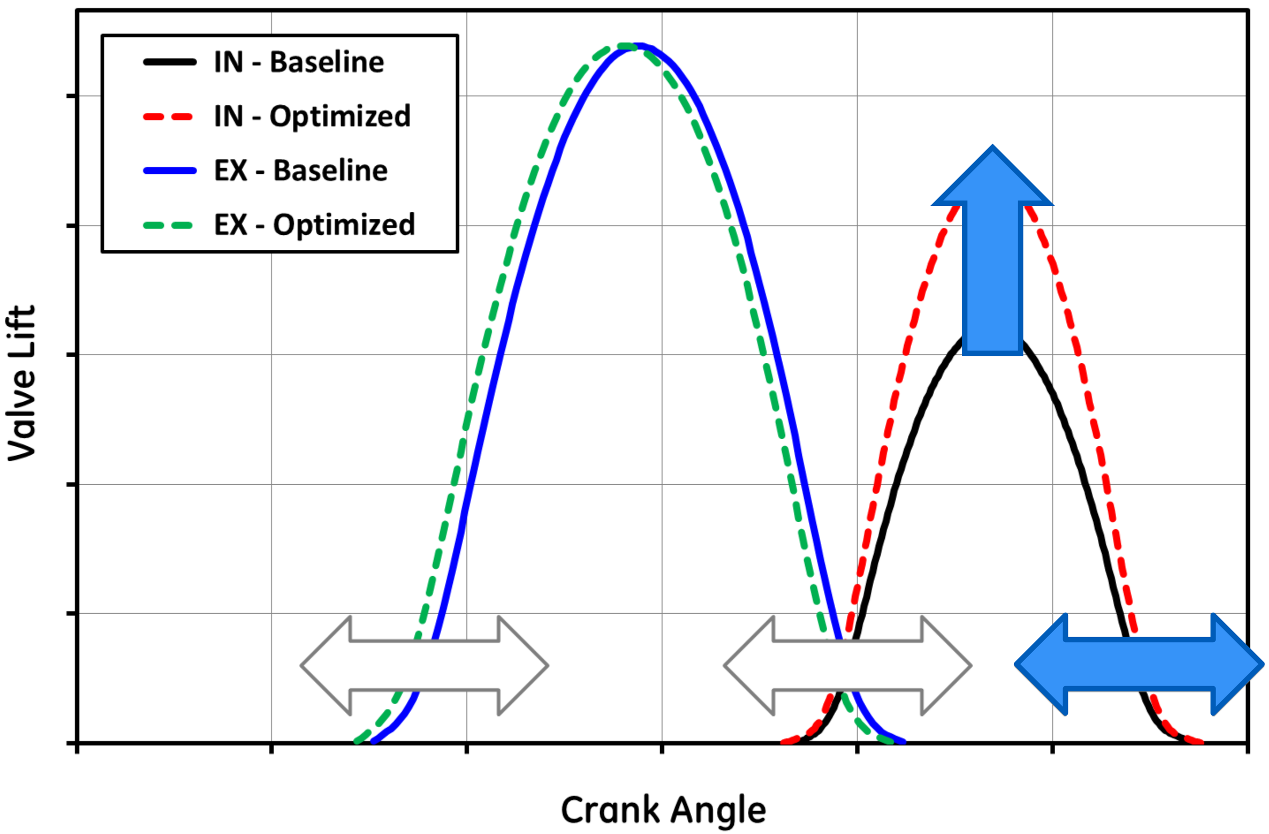
Gas Exchange

Cam shaft

⇒ **+ 0.15...0.5 % pts in engine efficiency**

⇒ **+ 5 K in intake manifold mixture temp.**

- Potential for higher valve accelerations on the intake side
- Layout of IN valve lift, Miller timing / CR, valve overlap & EX valve opening



J624 H

- advanced Miller timing
- very high potential boost pressure

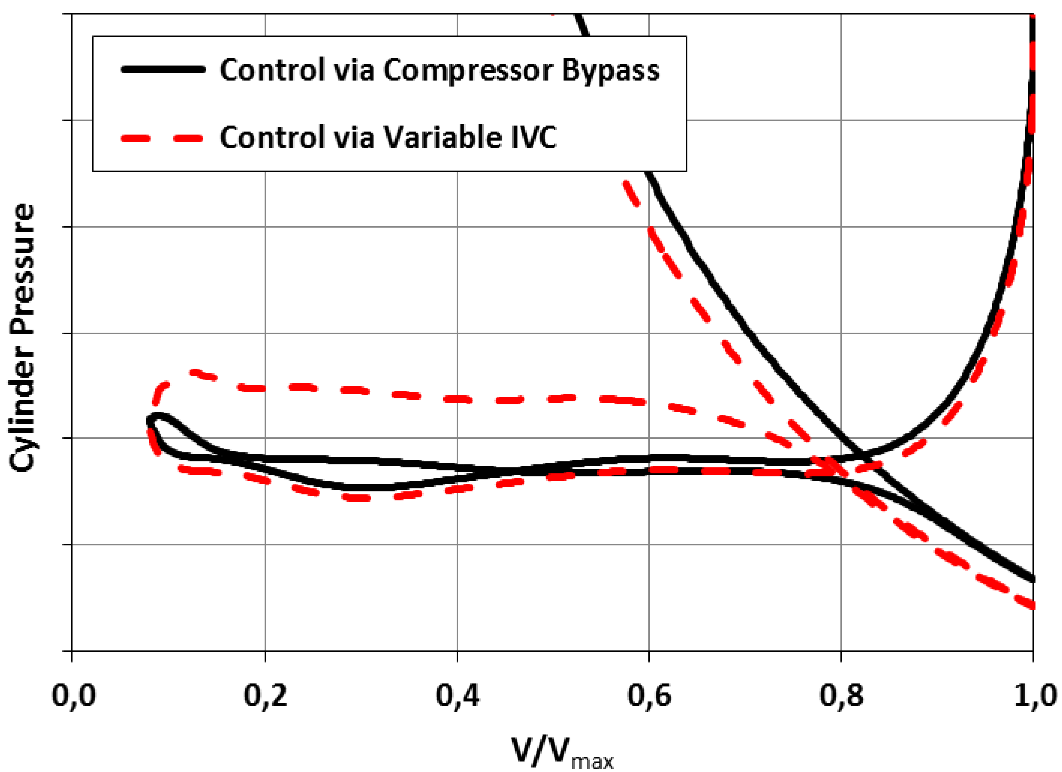
J6xx F

- moderate Miller timing
- limited boost pressure

Gas Exchange

Variable valve train

- Engine efficiency during <u>steady state</u> operation can be increased by using a continuously variable intake valve closing for power control
- <u>Transient</u> response during load acceptance can be improved as well



Efficiency benefit

- closing CBV, advancing Miller timing

⇒ higher boost pressure, improved gas exchange

Transient benefit

- Reducing Miller timing at part load (no knocking)

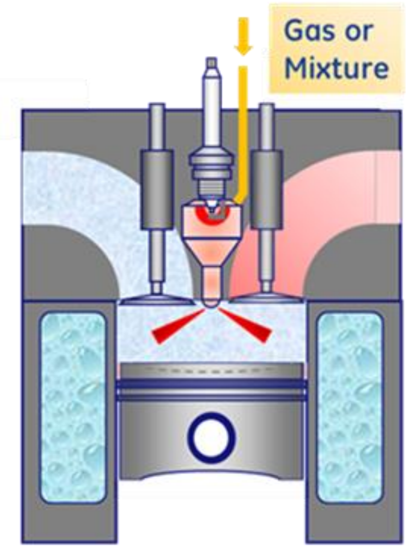
⇒ optimal cylinder filling, fast power pick-up

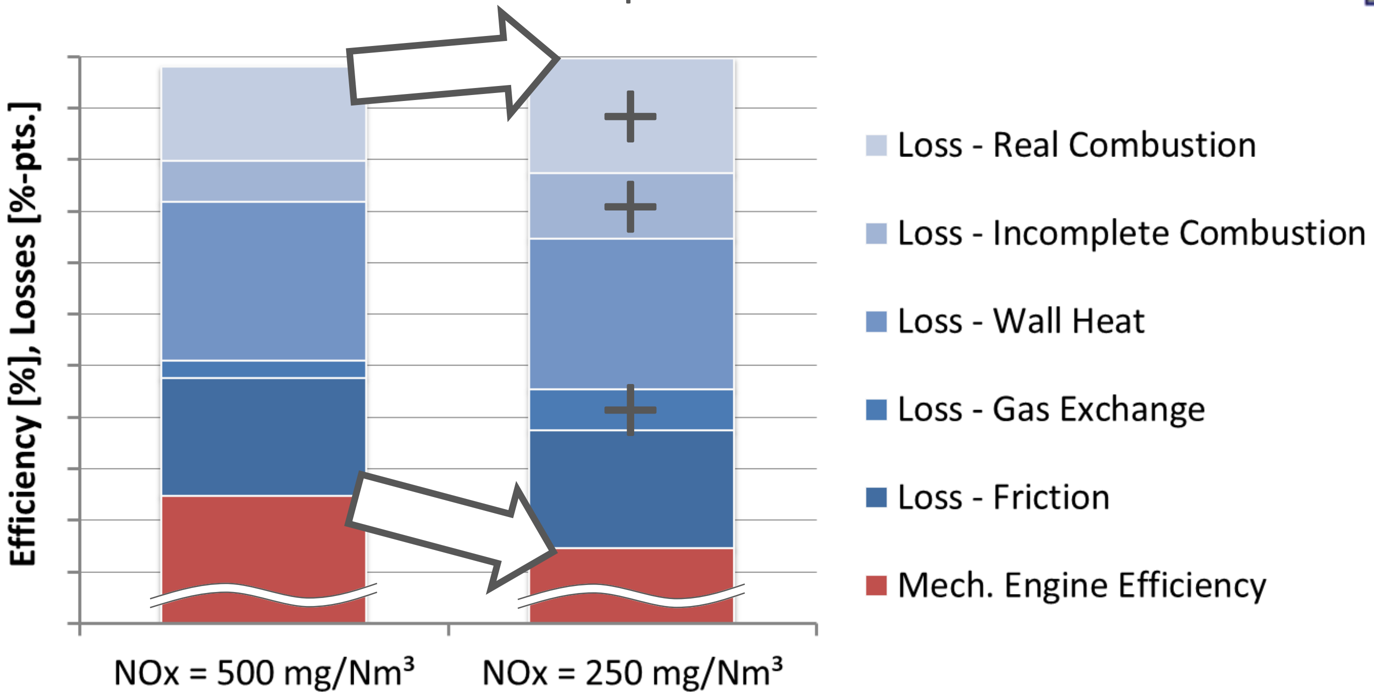
Combustion.
Efficiency Potentials

Combustion

The low NO_X challenge

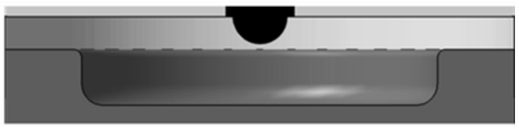
- Lower NO_X settings ⇒ leaner mixture in main chamber
  ⇒ higher losses in combustion (…misfiring)
  ⇒ higher losses in gas exchange
- Future emission trends ⇒ combined optimization of main combustion chamber and prechamber



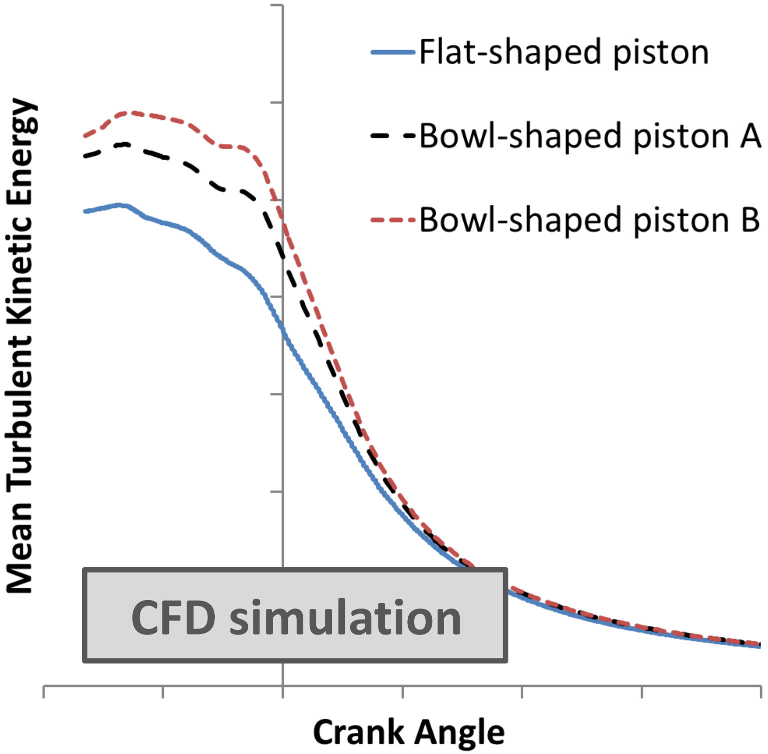


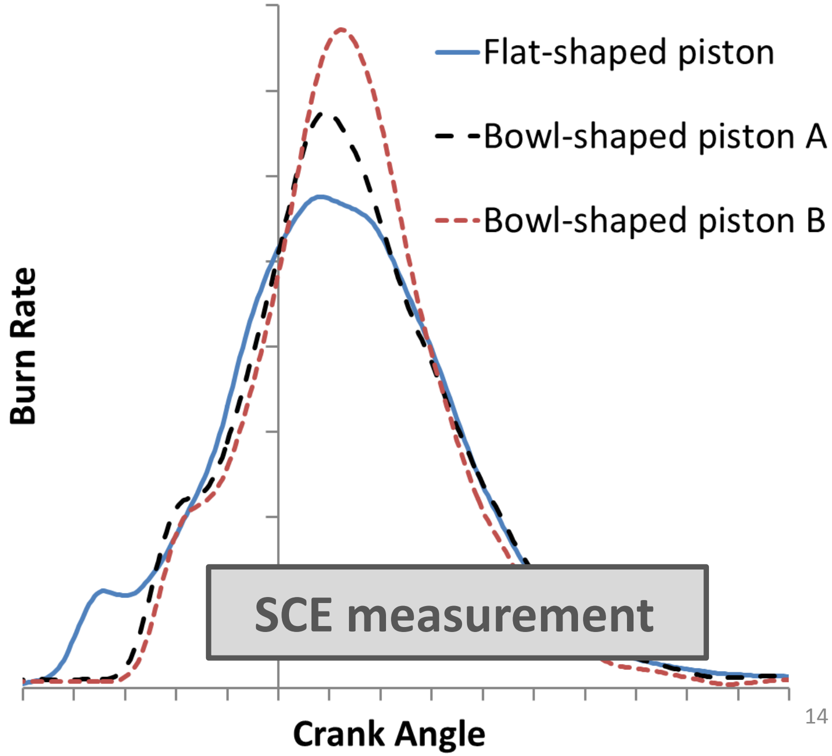
Combustion

Main combustion chamber



- Various shapes have been investigated by CFD simulation and SCE testing
- Compact main combustion chamber increases average flow turbulence ⇒ increased combustion speed and stability, reduced knocking

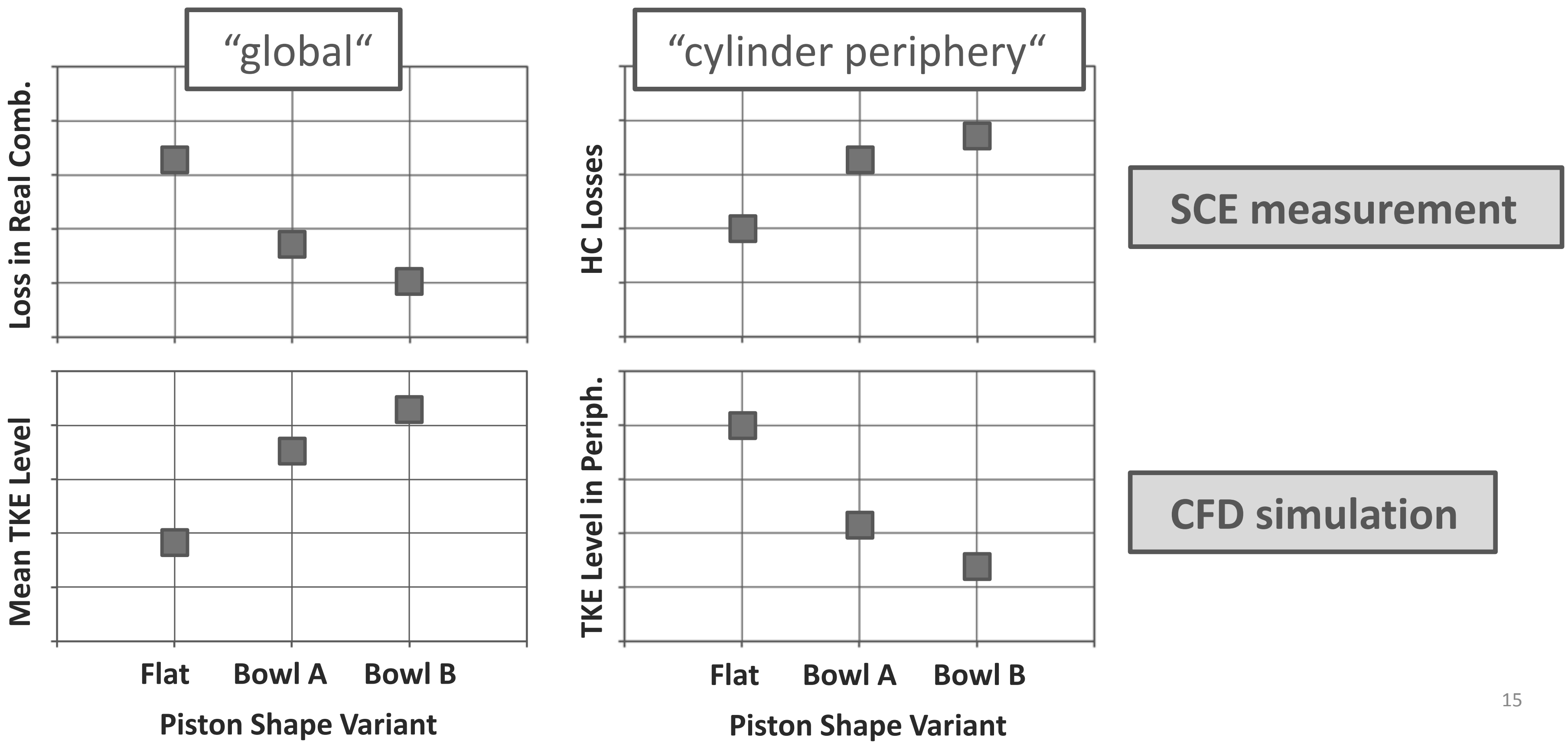




Combustion

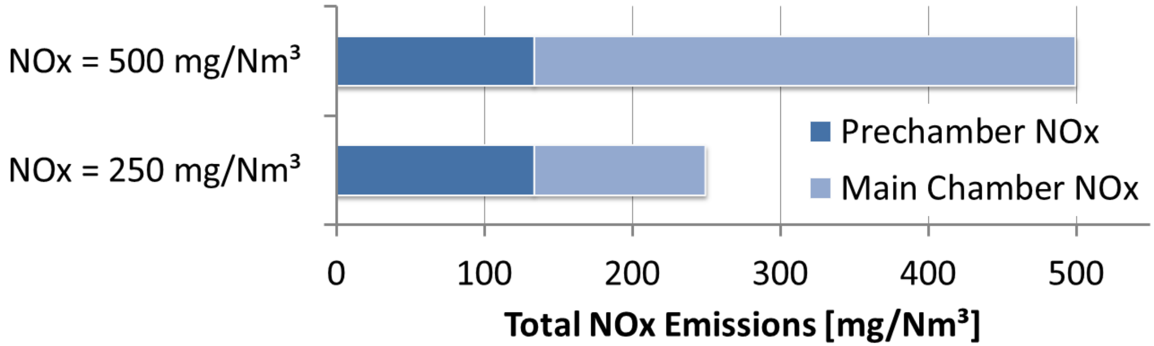
Main combustion chamber

- Piston bowl reduces local TKE ⇒ incomplete combustion and knocking
- Trade-off: Global TKE level ⇔ flame propagation at cylinder periphery



Combustion

Prechamber

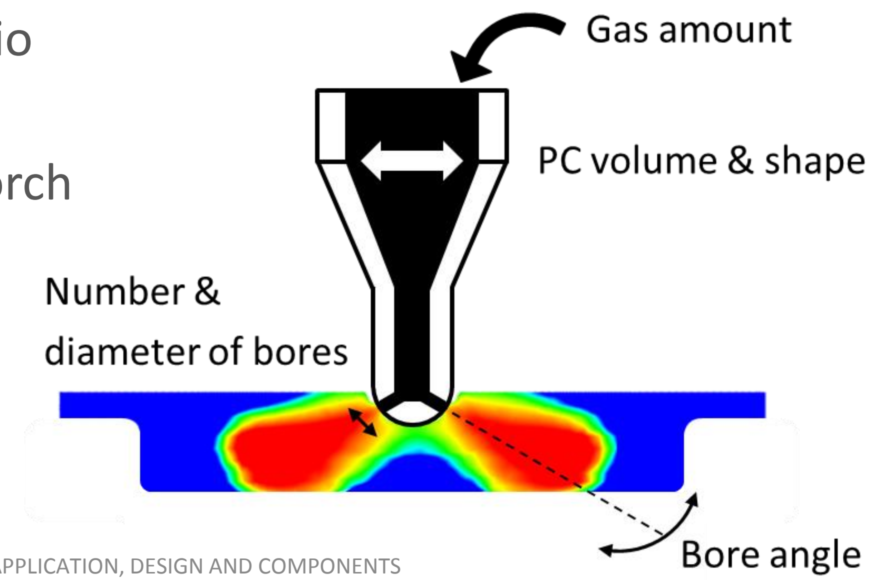


- Main challenge is to reduce prechamber NO_X w/o reducing flame torch impulse

- Sophisticated combination of A/F ratio and volume

⇒ best possible combination of flame torch impulse and NO_X formation

- Prechamber design and operation parameters have been optimized



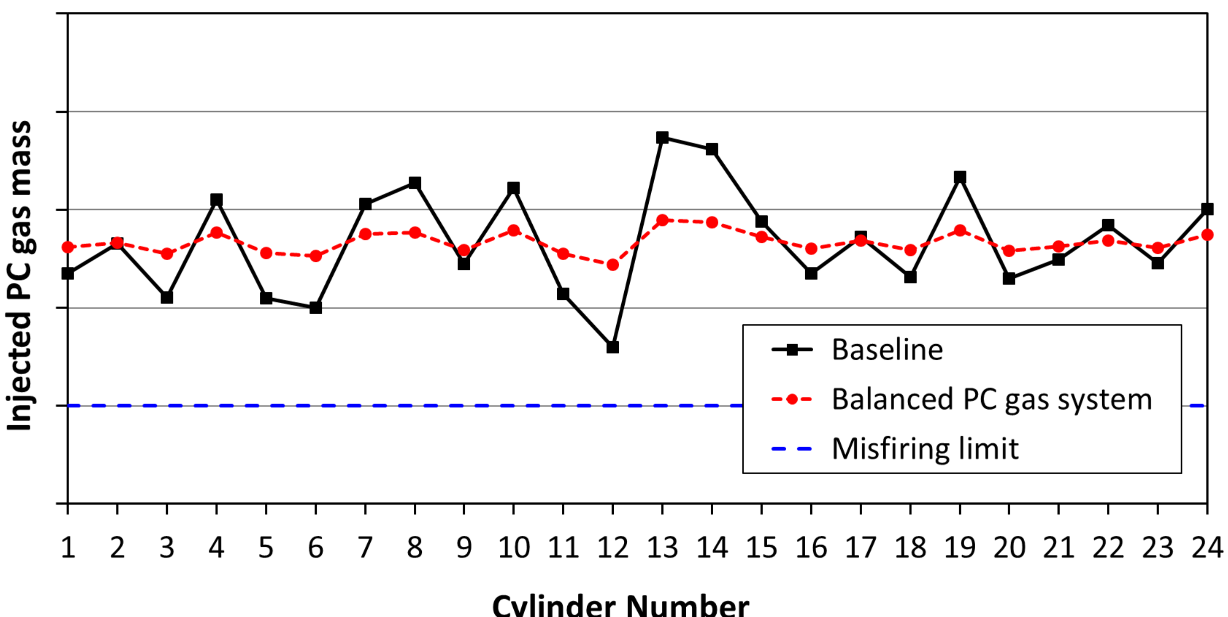
Combustion

Prechamber gas system

- Flame torch impulse depends strongly on prechamber A/F ratio

⇒ appropriate A/F ratio setting required for stable combustion @ low NO_X

- Detailed tuning of prechamber gas system results in very similar prechamber gas amounts for all cylinders



Balanced system

- 70 % reduction in min-max spread

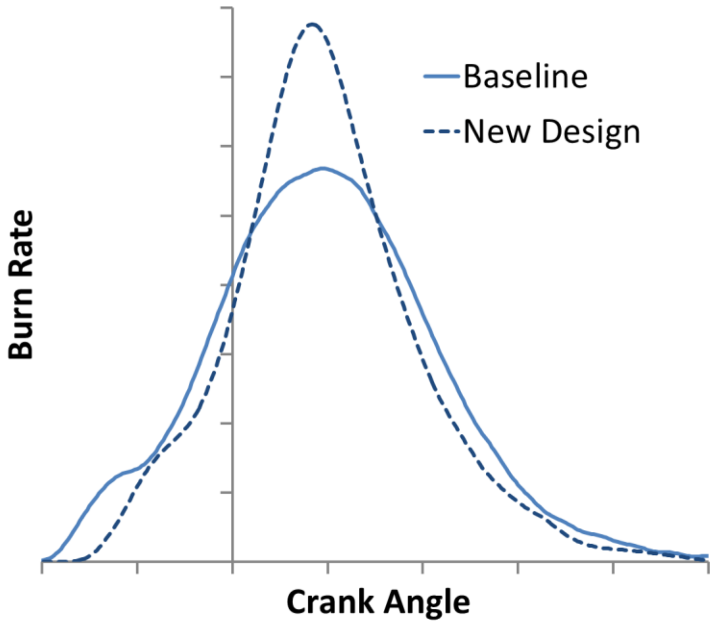
Positiv impact on

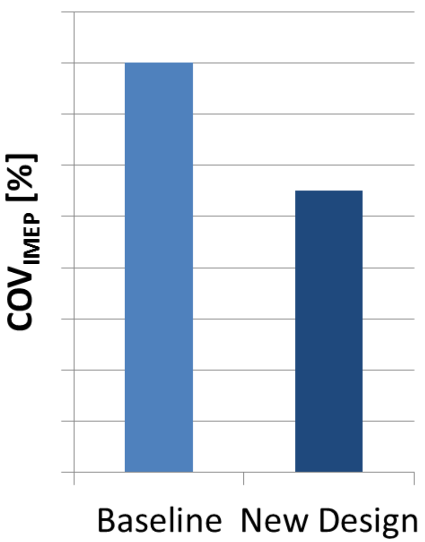
- Combustion stability
- Emission level
- Thermal/mechanical stress

Combustion

Final results of combustion development

- MCE results @ 24 bar BMEP, 250 mg/Nm³ NO_X, equal PFP and equal CR
- Combustion duration considerably shorter ⇒ higher engine efficiency
- COV_{IMEP} about 30 % lower ⇒ robust engine operation at very low NO_X





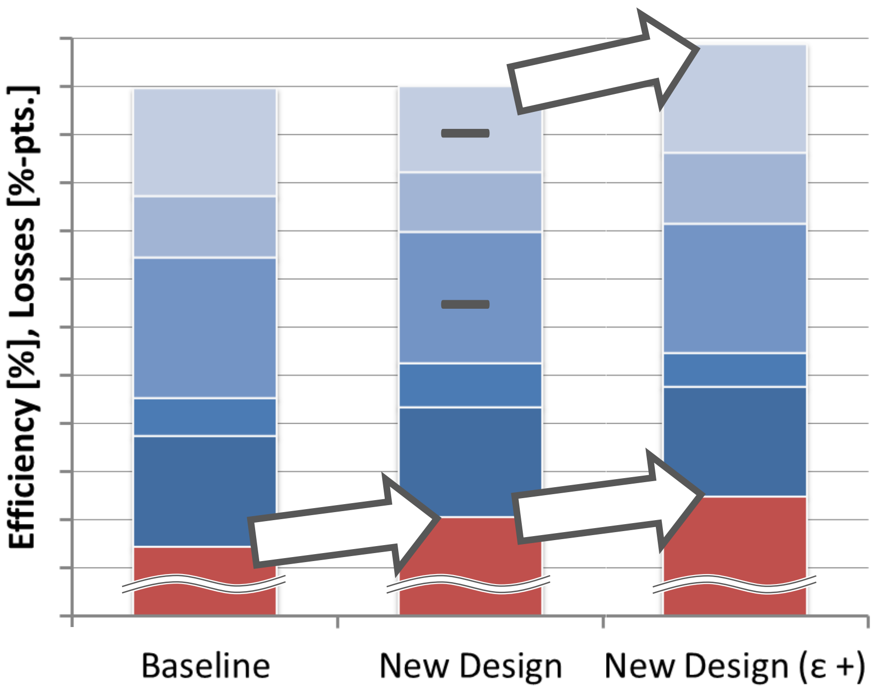
Combustion

Final results of combustion development

- Lower losses in real combustion and wall heat
- High A/F ratio and short combustion duration

  ⇒ reduced knocking tendency

  ⇒ higher CR ⇒ higher ideal engine efficiency



+ 0.3 % pts @ 500 mg/Nm³ NO_X

+ 0.6 % pts @ 250 mg/Nm³ NO_X

Summary

Potentials for further thermodynamic development

- The GE Jenbacher Type 6 gas engine family offers a very high electrical efficiency of up to 46.3 % at 24 bar BMEP already today
- Gas exchange and combustion can be improved, especially at low NO_X

  ⇒ electrical efficiency, thermal efficiency, robust operation at low NO_X, power de-rating due to ambient conditions and pollutant emissions
- Technical conditions for a future BMEP increase and for an improved transient performance are being created
- Apart from WG and VVT the stated measures will not increase engine costs

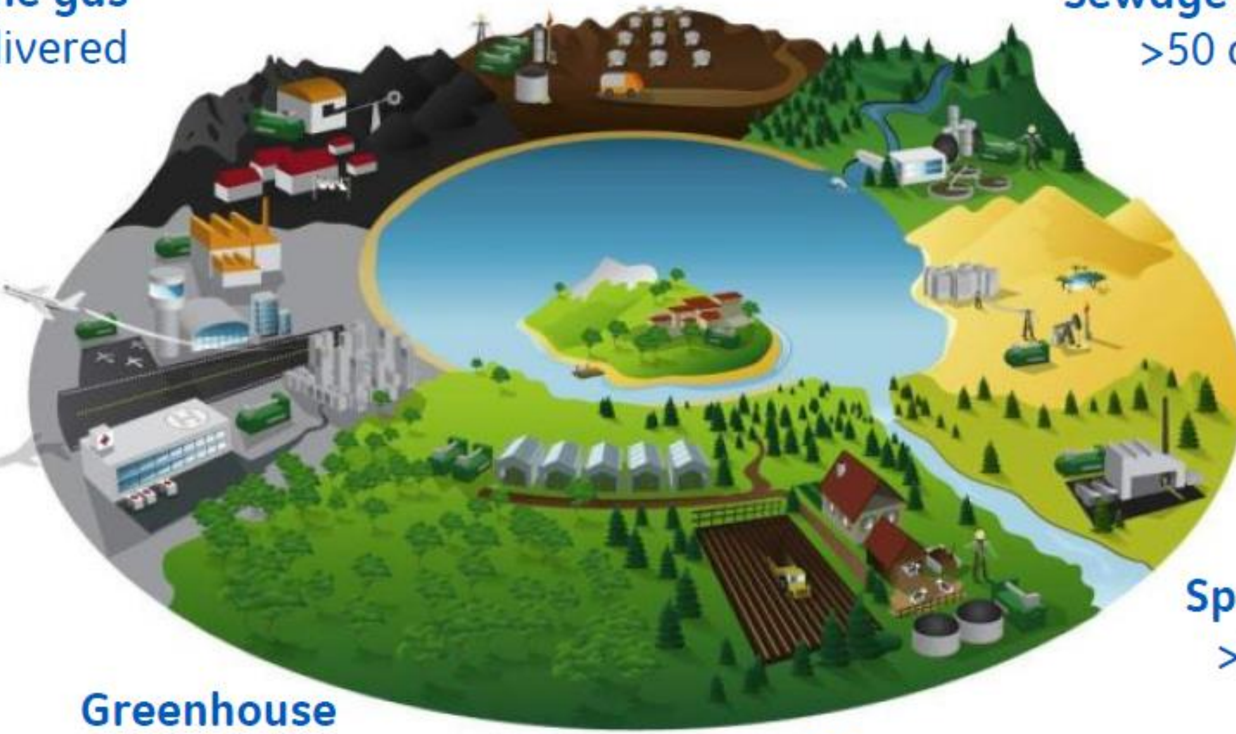
There are still considerable potentials for further thermodynamic improvements – also for a high performance gas engine like the J624 H

Thank you for your attention!

Questions?

Type 6 Gas Engine

Core applications



Landfill gas
>70 delivered

Coal mine gas
>150 delivered

Sewage gas
>50 delivered

CHP applications
>2,500 delivered

Flare gas
>70 delivered

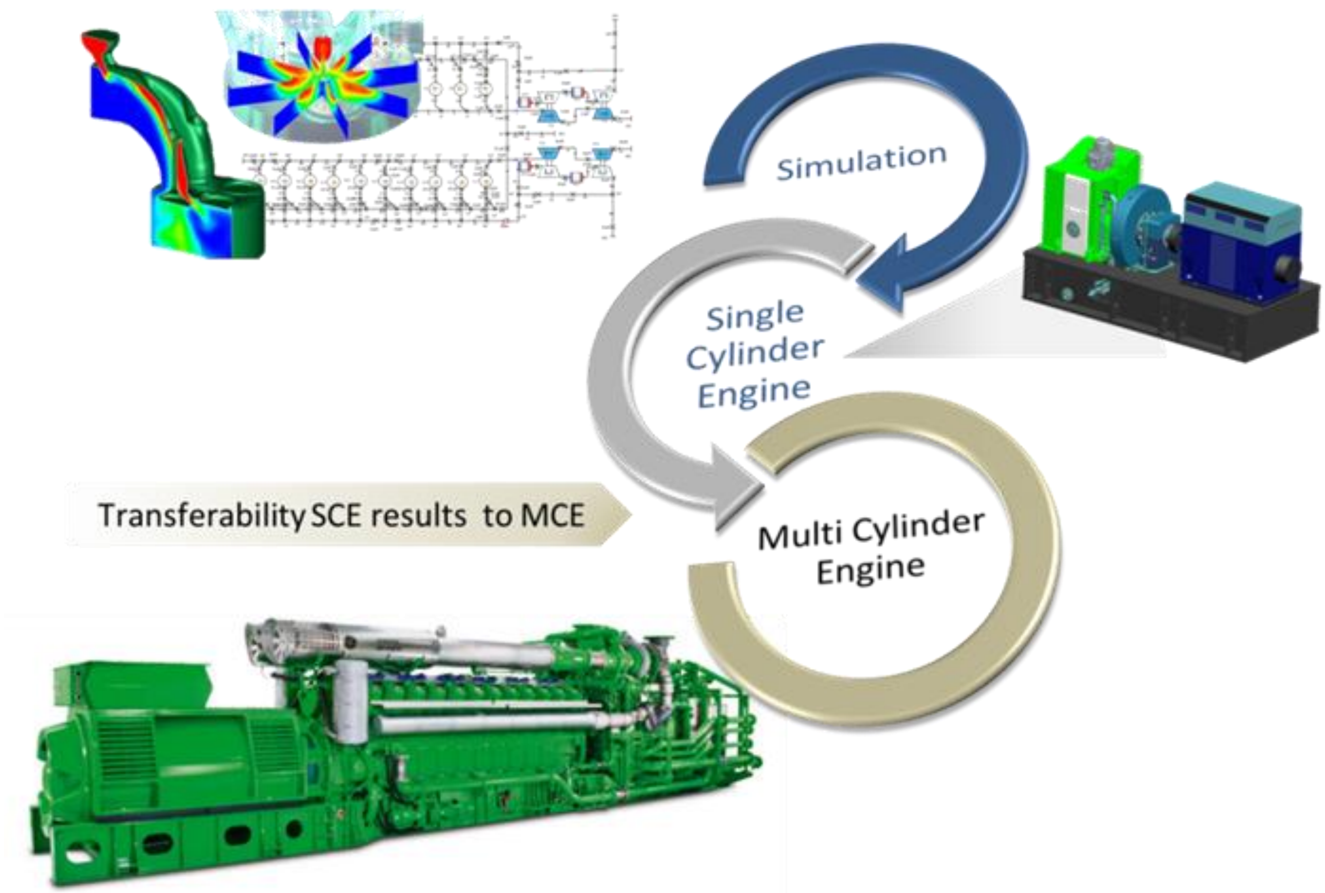
Special gas
>50 delivered

Greenhouse application
>700 delivered

Biogas
>40 delivered

Introduction

Development Methodology



Type 6 Gas Engine

Be global… act local

- More than 3,500 GE's Type 6 Jenbacher engines delivered
- Generating a total of ~9 GW of power
- Powering an equivalent of over 15 Million EU homes

Type 6 Gas Engine

Variants

Jenbacher Type 612

- 12 cylinder
- El. output: 2 MW (22bar)
- El. efficiency 45.0%
- Fleet > 530 engines delivered

Jenbacher Type 616

- 16 cylinder
- El. output: 2.7 MW (22bar)
- El. Efficiency 45.5%
- > 1,000 engines delivered

Jenbacher Type 620

- 20 cylinder
- El. output: 3.3 MW (22bar)
- El. efficiency 45.6%
- > 1,800 engines delivered

Jenbacher Type 624^{2}

- 24 cylinder
- El. output: 4.4 MW (24bar)
- El. efficiency 46.3%
- Two stage charging
- >150 engines delivered