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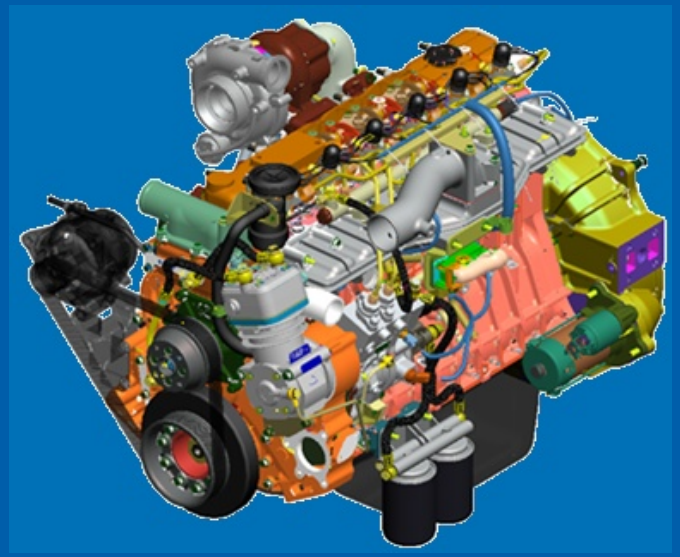

Advanced Downsizing Techniques

Applied to a heavy Duty Diesel Engine

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Deputy Manager

Engine R&D

ASHOK LEYLAND

HINDUJA GROUP

Contents

- Downsizing – concept and definition
- Advantages of downsizing
- Base Engine Specification
- Target Engine Specification
- Techniques adopted to improve power density
- Comparison
- Future Trends

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Downsizing- A Concept

- Downsizing is increasing power density of engines
  - Generating more power for the same engine displacement.
    - E. g. Increasing the power of 5.7 L engine from 70 kW to 165 kW

70 kW from 5.7 L engine

165 kW from 5.7 L engine

- Reducing displacement of the engine to generate same power.
  - e. g. , Reducing the engine displacement from 5.7 L to 3.8 L to generate 70 kW

70 kW from 5.7 L engine

70 kW from 3.8 L engine

- Downsizing is often presented as a new strategy
- Engines have been progressively downsized since the beginning of automotive industry, step by step,
  - depending on technologies availability.

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Advantages of Downsizing

- **Pumping losses reduction : work done to move air in and out of the cylinder**
  - **Less total volume swept on each engine per kilometer**
  - **Higher average load on driving cycle (higher average intake pressure)**
  - **Lower energy consumption per rotation (reduction of moving parts' speed)**
- **Gas-to-wall heat transfer reduction**
  - **Reduced internal surface area**
- **Friction losses reduction**
  - **Lesser moving parts (in case of reduction of engine displacement)**
  - **Reduction Friction Power as a percentage of Indicated power**
- **Reduces concept-to-market time for new engine**
- **Cost involved is less than developing a new engine platform**

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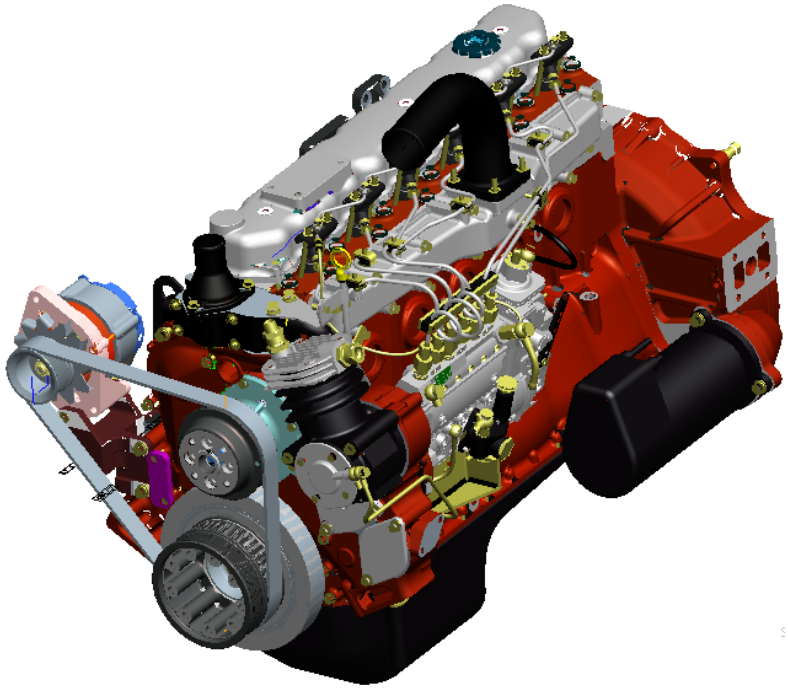
Base Engine Specification

ENGINE SPECIFICATION	
Configuration	6 Cylinder NA, Direct Injection
Bore x Stroke (mm)	104 x 113
Valves per cylinder	2
Max. Power	70 kW @ 2400 rpm
Max. Torque	320 Nm @ 1800 rpm
Fuel Injection System	Plunger type Jerk pump, 600 bar
Peak Cylinder Pressure	105 bar
Emission Norm	Pre Euro-1



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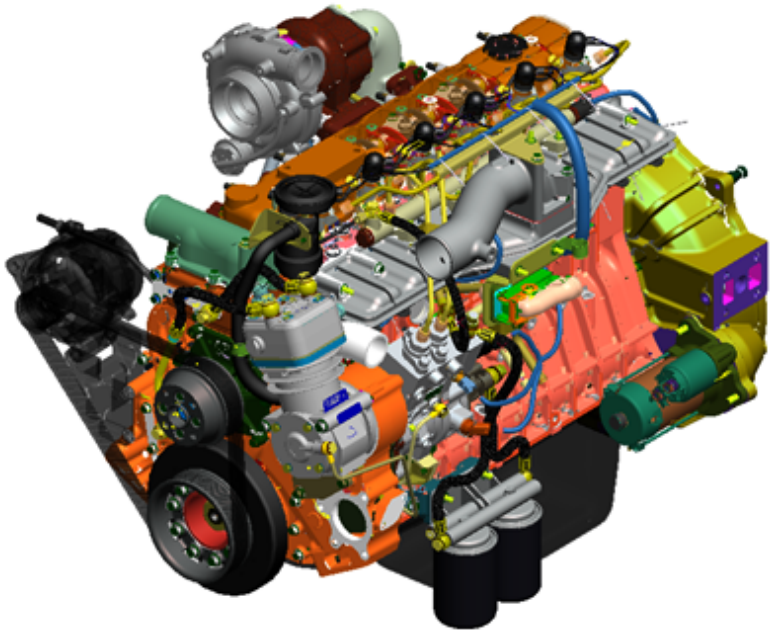
Target Engine Specification

ENGINE SPECIFICATION	
Configuration	6 Cylinder TCIC, Direct Injection
Bore x Stroke (mm)	104 x 113
Valves per cylinder	2
Max. Power	165 kW at 2500 rpm
Max. Torque	800 Nm at 1400-1900 rpm
Fuel Injection System	Gen 2,Common Rail, 1600 bar
Peak Cylinder Pressure	140 bar
Emission Norm	India, Bharat Stage-4 (Euro IV)



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Increasing Power Density

- Essentially power increase is dependent upon fuel quantity
- Consequentially
  - Increase Air flow
  - Increase Peak Firing Pressure and thermal stresses Capability

Increasing Power Density

- Increase Air flow
  - Turbocharging
  - Intercooling
- Increase Peak Firing Pressure and thermal stresses Capability
  - Cylinder block
  - Connecting rods
  - Crankshaft
  - Cylinder head gasket
  - Cylinder head bolt
  - Lubrication system
  - Cooling pump
  - Viscous damper
  - Cylinder liners

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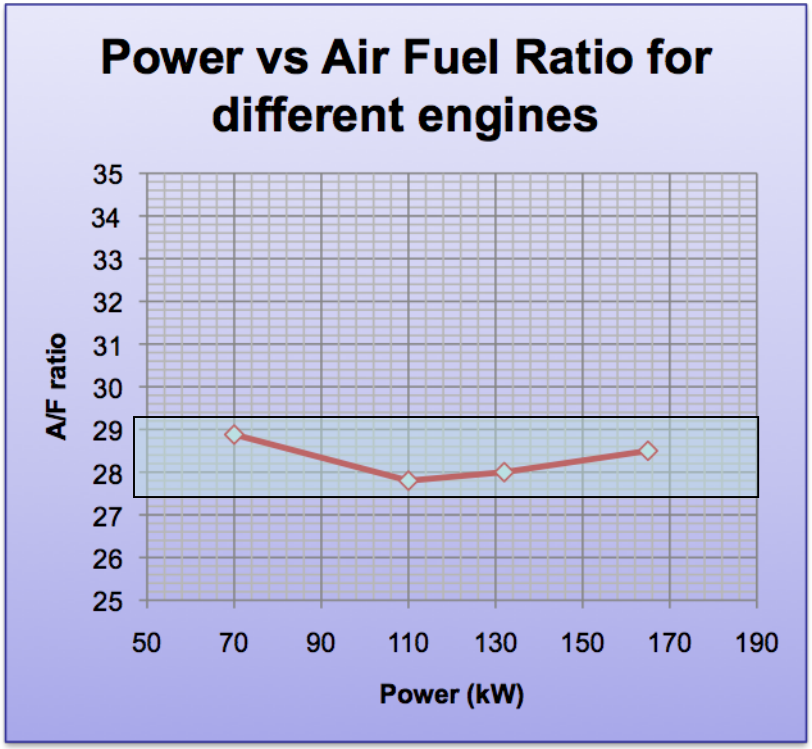
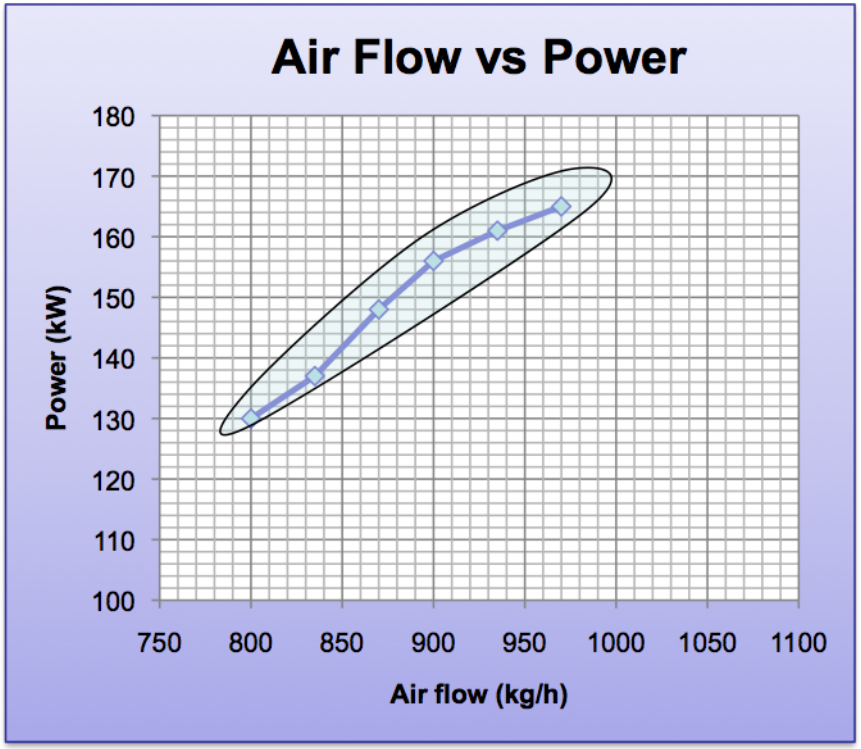
Effect of Air Flow

- To maintain λ (excess air ratio) about 1.8
  - Air-Fuel ratio has to be between 27 to 29
  - Increase air to achieve higher power density





Increasing Air Flow

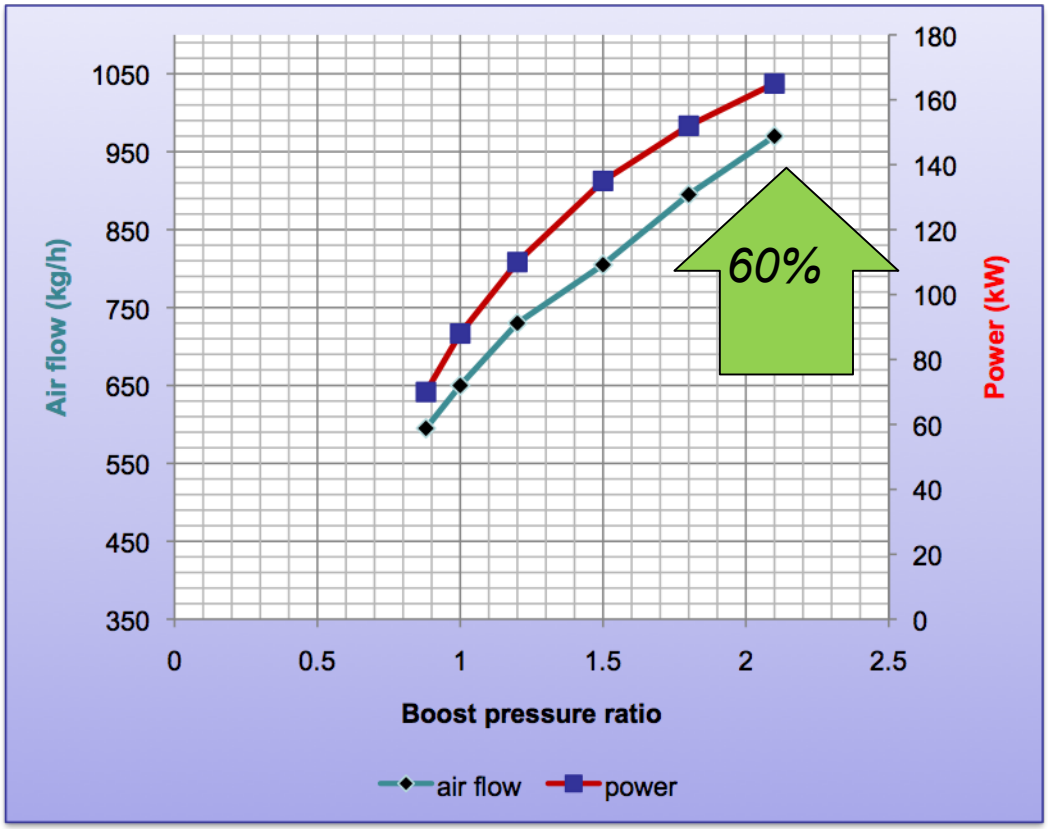
- Turbocharging
- Intercooling

Increasing Air Flow

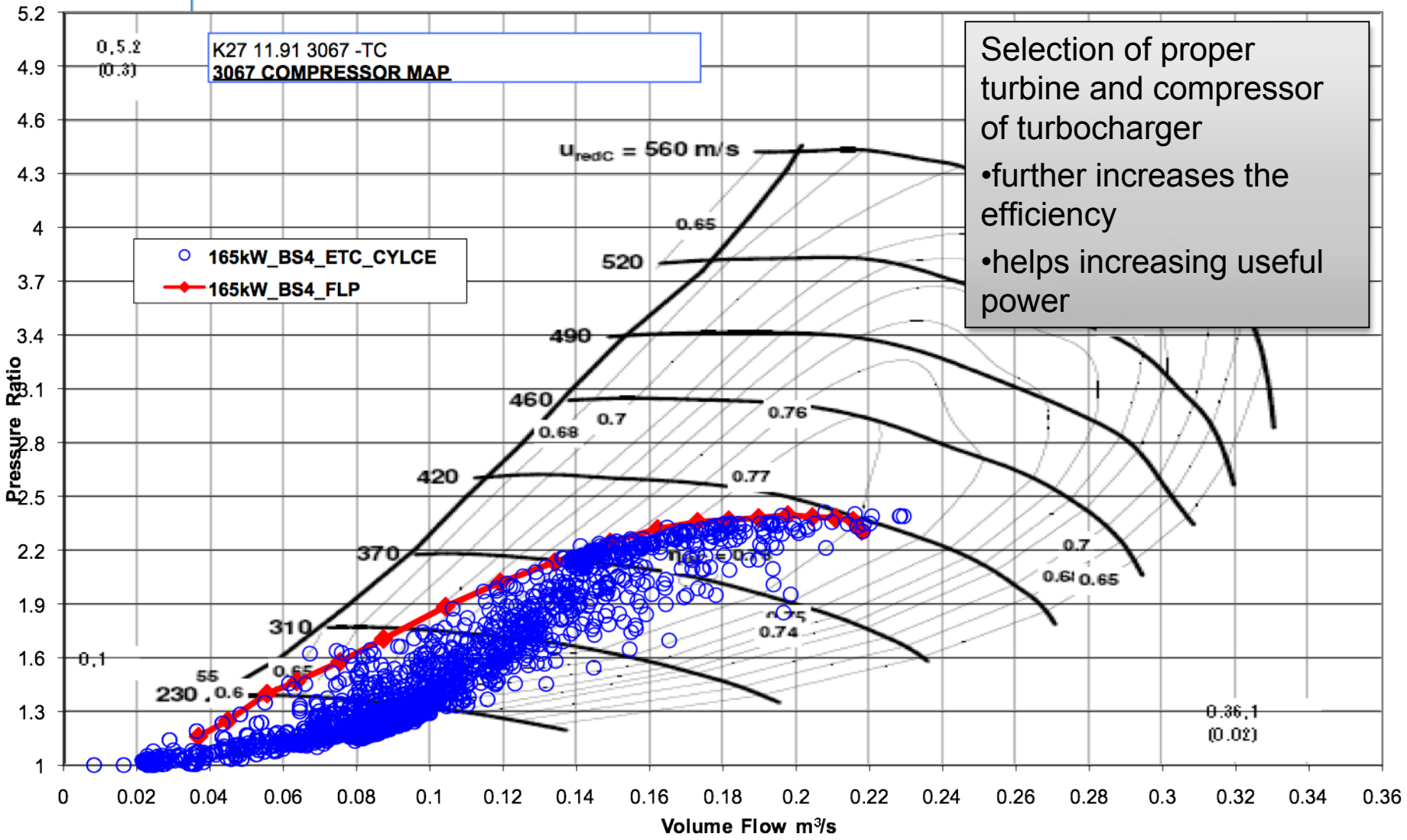
- Turbocharging
- Intercooling

Turbocharging

- a compressor driven by turbine: forces more air into the cylinder
- increased air flow allows higher fuel flow for combustion for constant Air-Fuel Ratio of 27~29



Turbocharging



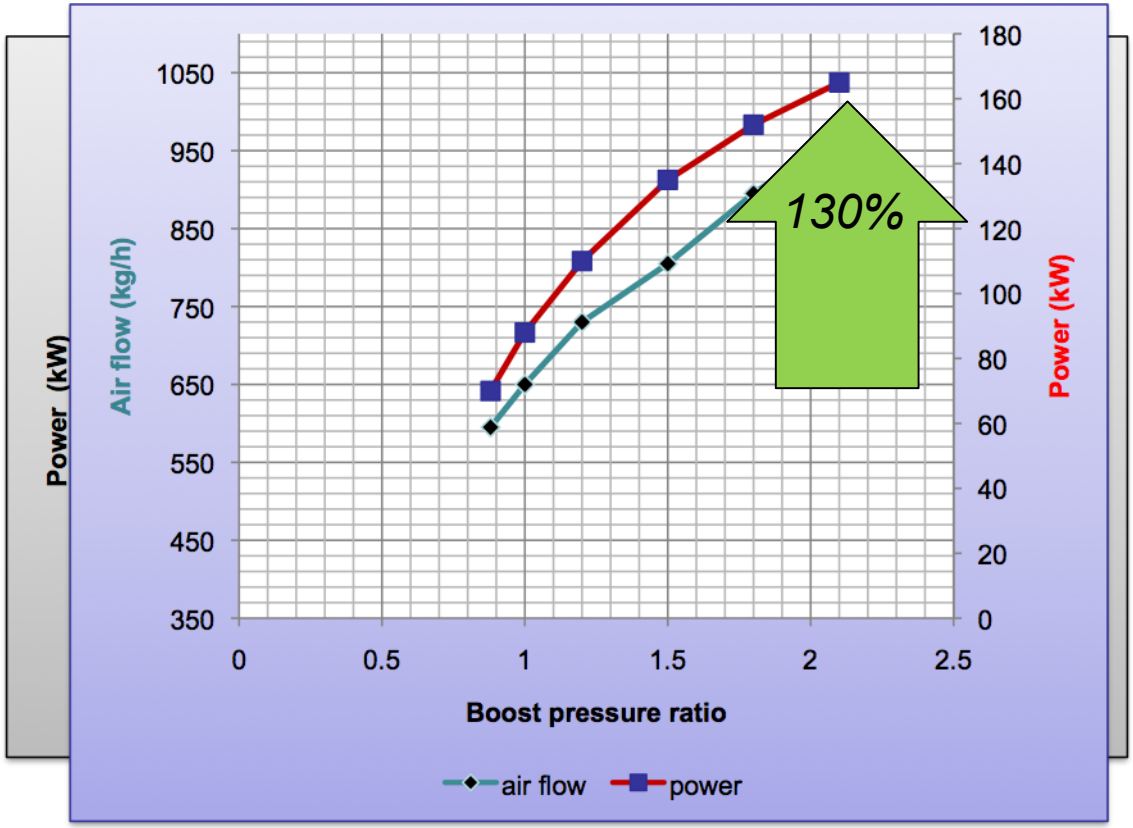
Selection of proper turbine and compressor of turbocharger

- further increases the efficiency
- helps increasing useful power

Increasing Air Flow

- Turbocharging
- Intercooling

Intercooling

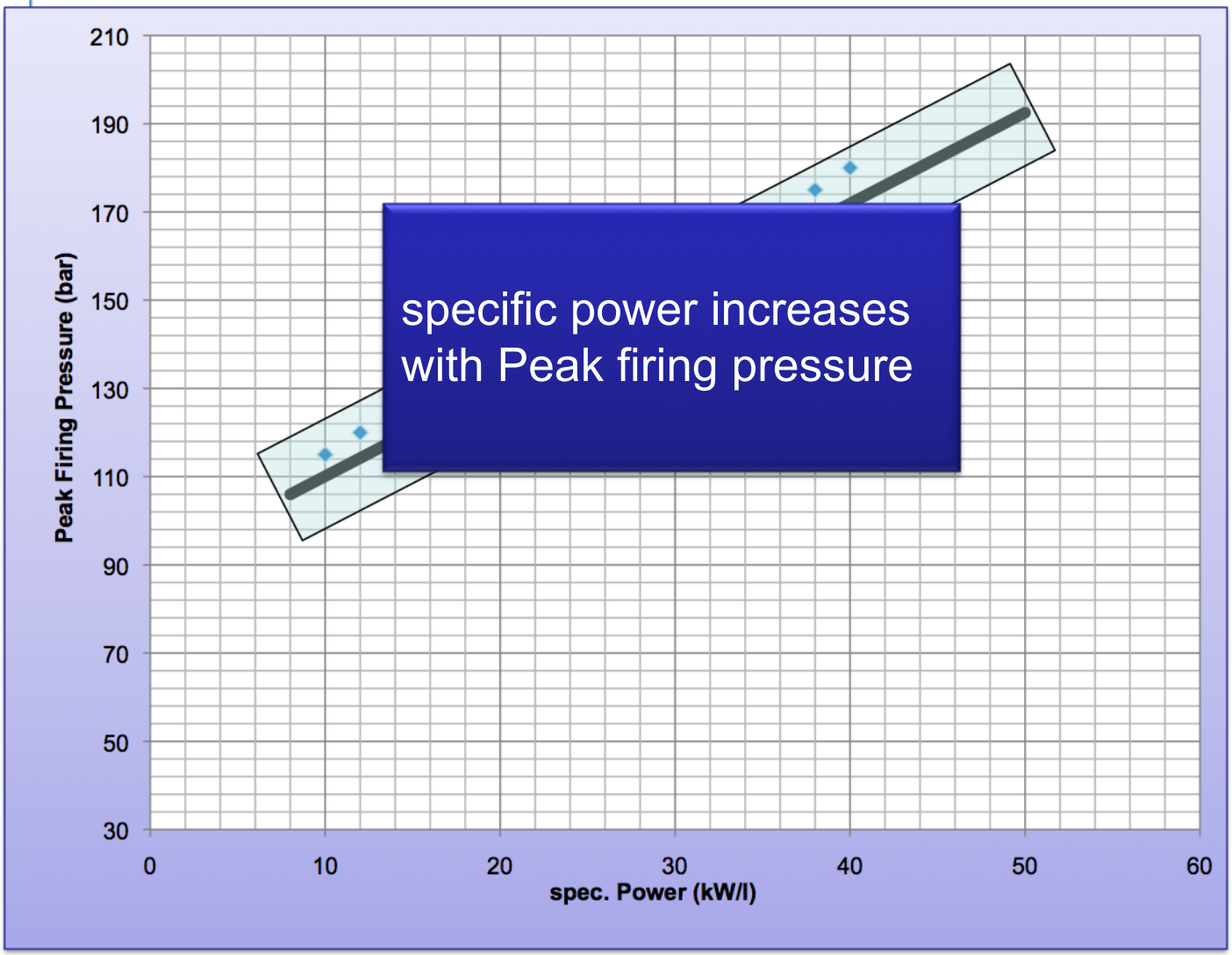


- Cools charged air to increase intake air density
- Increases mass of air flow to the cylinder
- increase the overall volumetric efficiency of the induction system
- Aids combustion of more fuel and produce more power for the same volume of the cylinders

Increasing Power Density

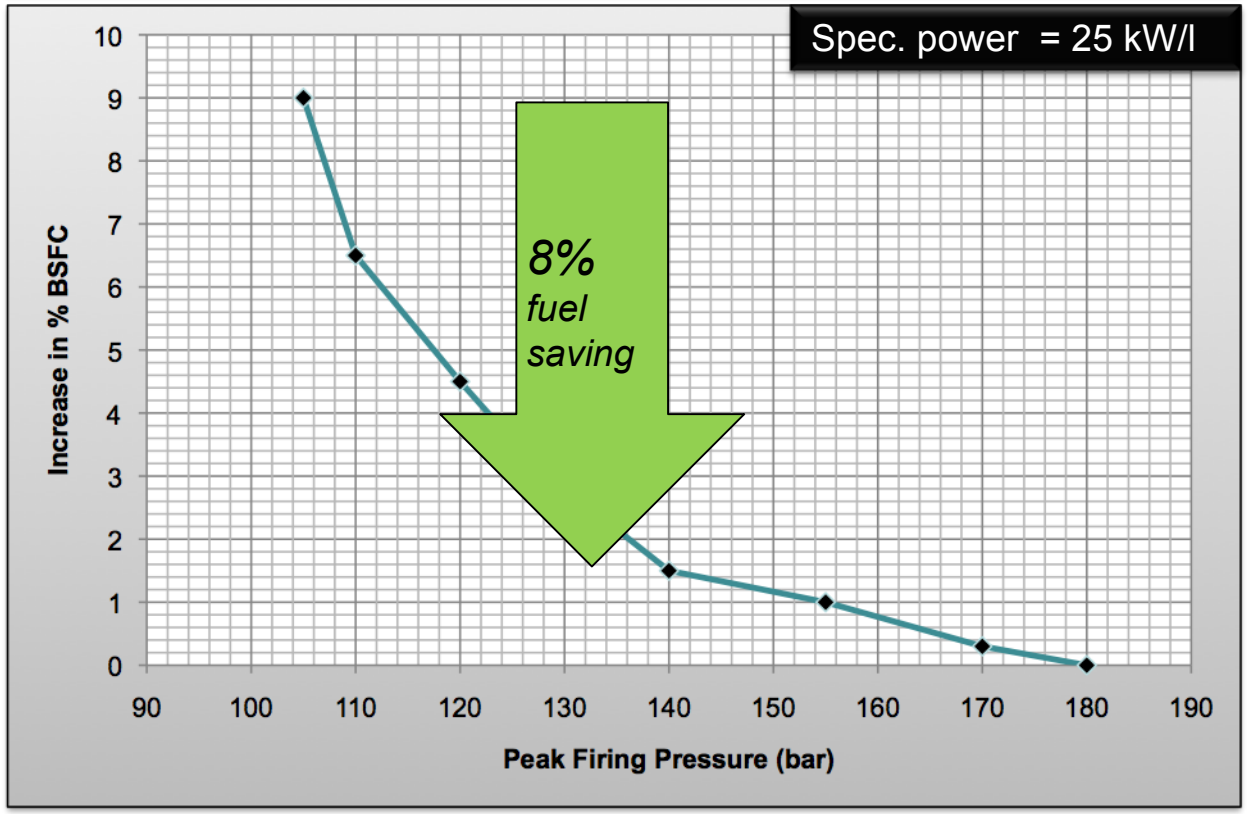
- Increase Air flow
  - Turbocharging
  - Intercooling
- Increase Peak Firing Pressure and thermal stresses Capability
  - Cylinder block
  - Connecting rods
  - Crankshaft
  - Cylinder head gasket
  - Cylinder head bolt
  - Lubrication system
  - Cooling pump
  - Viscous damper
  - Cylinder liners

Effect of Peak Firing Pressure Capability



Effect of Peak Firing Pressure Capability

- Effect of peak firing pressures(PFP) on BFSC
- Helped us decide target PFP as 140 bar



Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
- Viscous damper
- Cylinder liners

Increasing Peak Firing Pressure and Thermal Stresses Capability

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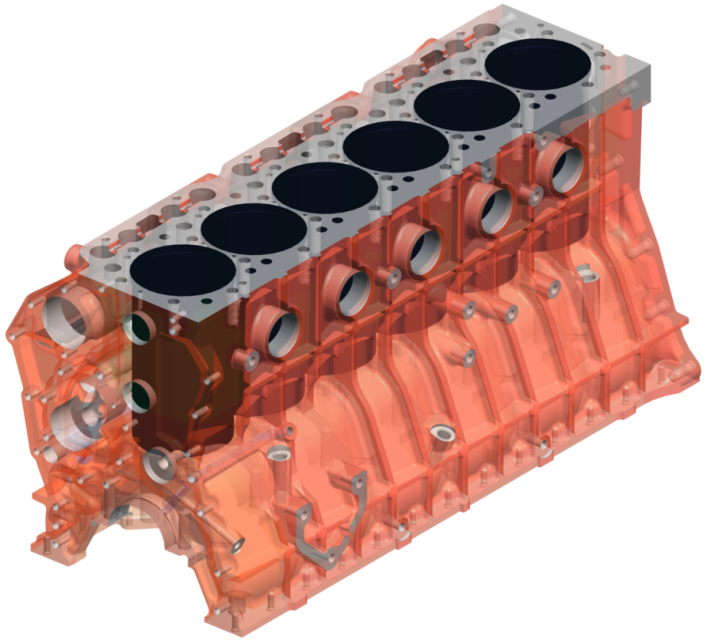
Cylinder Block

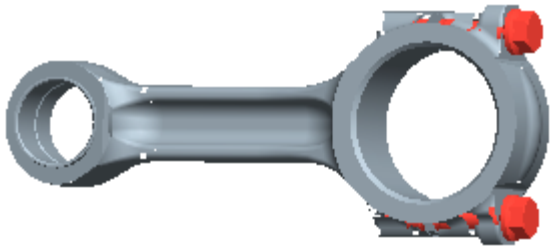


Cylinder block	unit	Base engine	Target Engine
PFP capability	bar	105	140
Outer shape		-	Ribs added for strength and noise reduction
Material		Grey cast iron	Higher grade Cast Iron
Main Journal width		-	Increased by 5%

Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
- Viscous damper
- Cylinder liners

Connecting Rods

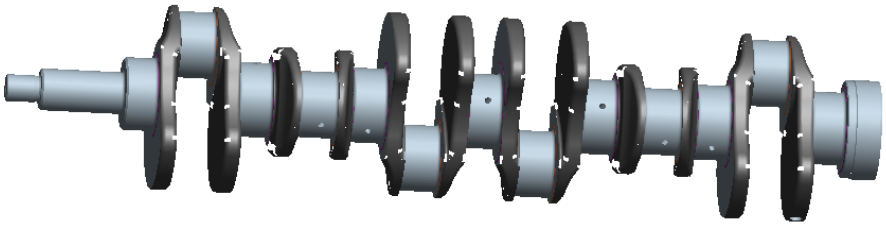


Connecting Rods	unit	Base engine	Target Engine
PFP capability	bar	105	140
Trapezoid angle		-	increased
Con-rod big end diameter	mm	-	increased
Material upper bearing shell		3 Layer	Special coating

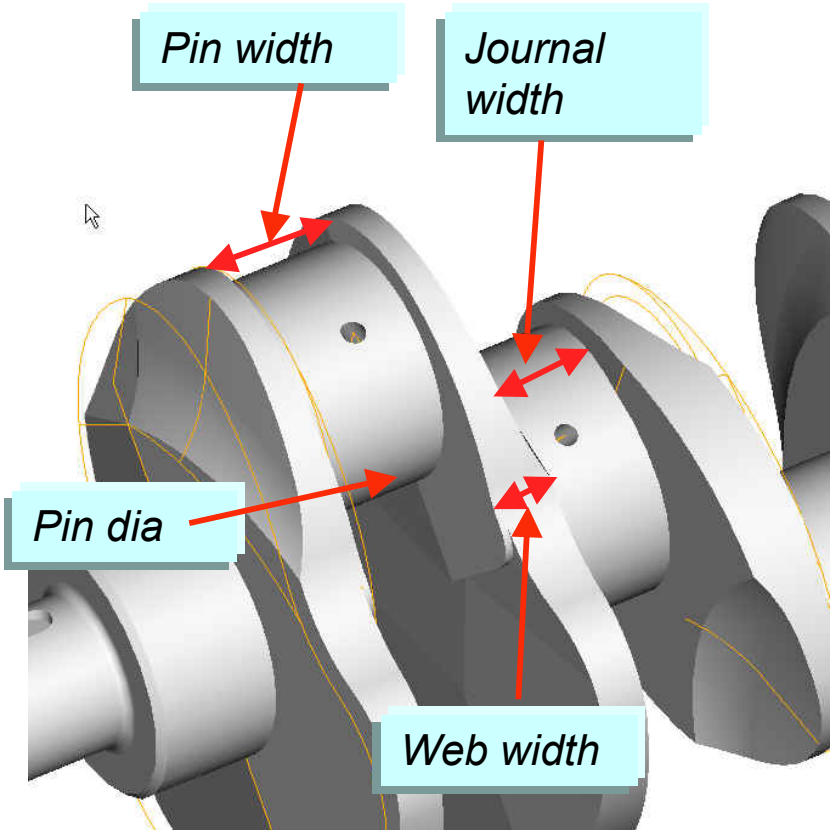
Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
- Viscous damper
- Cylinder liners

Crankshaft



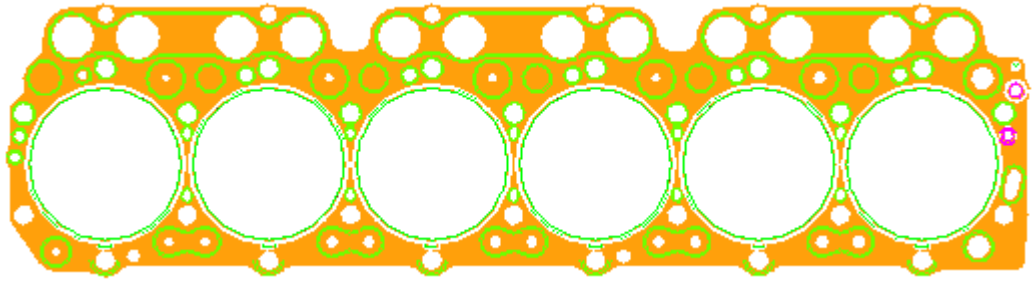
Crankshaft	Unit	Base engine	Target Engine
PFP capability	bar	105	140
Main journal width	mm	-	Reduced
Pin width	mm	-	Reduced
Pin diameter	mm	-	increased
Web width	mm	-	5% increased



Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
- Viscous damper
- Cylinder liners

Cylinder Head Gasket

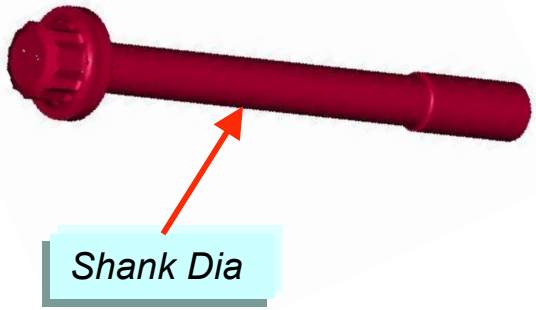


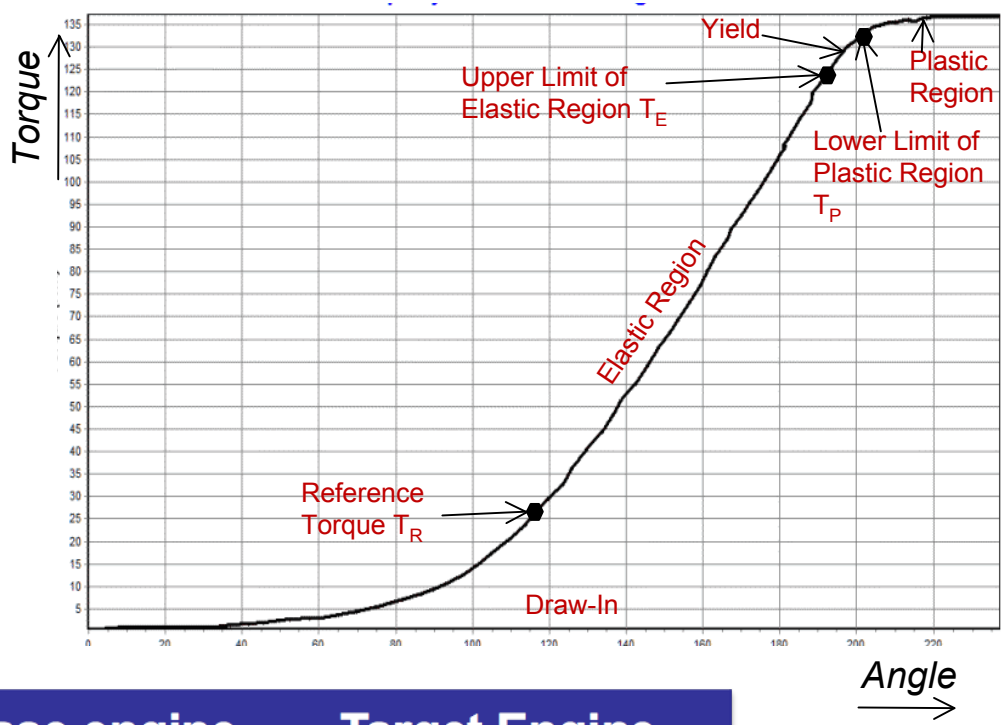
Cylinder head gasket	unit	Base engine	Target Engine
PFP capability	bar	105	140
Type		composite soft gasket	Multi-layer (3 layer) steel gasket

Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
- Viscous damper
- Cylinder liners

Cylinder Head Bolts



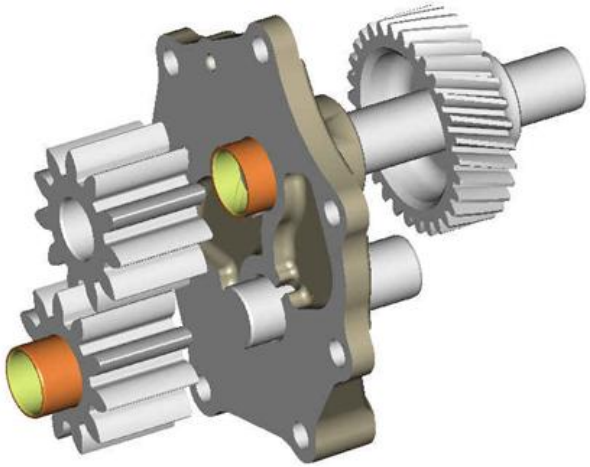


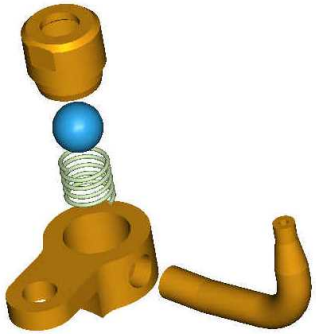
Cylinder head bolts	unit	Base engine	Target Engine
PFP capability	bar	105	140
Shank diameter	mm	-	reduced
Tightening type		Torque	Torque + angle

Increasing Peak Firing Pressure and Thermal Stresses Capability

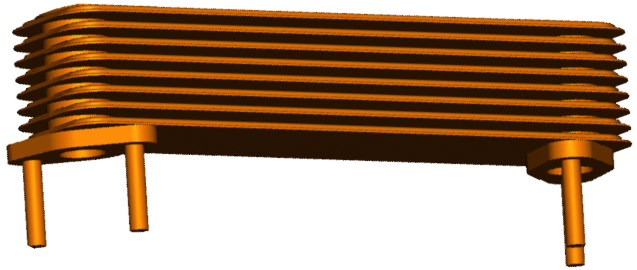
- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
- Viscous damper
- Cylinder liners

Lubrication System





- Oil pump capacity increased by 34%
- Introduction of Piston cooling nozzle reduced piston temperature by 30 degC



Lubrication System	unit	Base engine	Target Engine
PFP capability	bar	105	140
Nº of plates(oil cooler)		-	Increased by 3
Heat dissipation	kW	-	30% improved

Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
- Crankshaft
- Cylinder head gasket
- Cylinder head bolt
- Lubrication system
- Cooling pump
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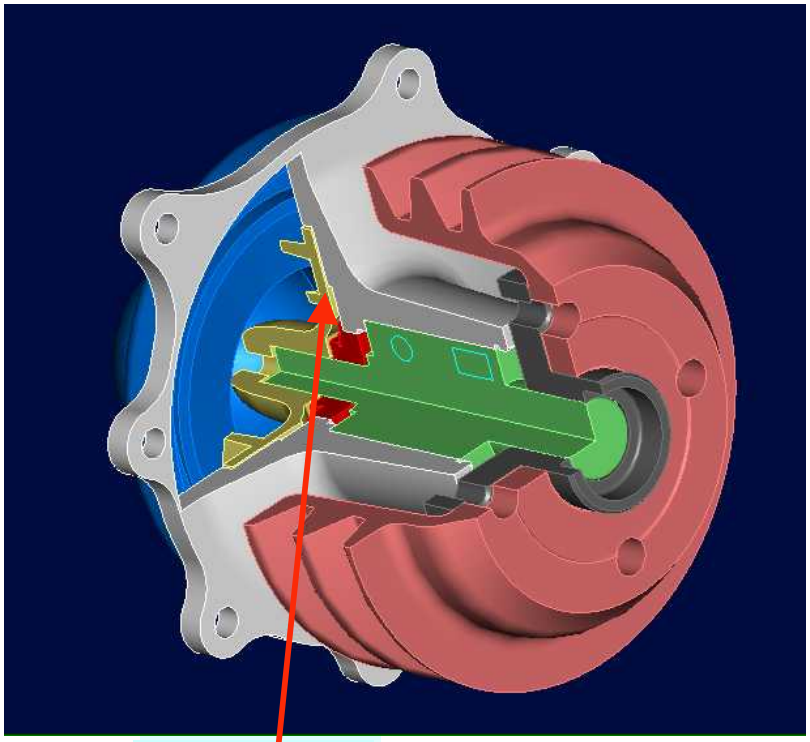
Cooling Pump

Cooling Pump	unit	Base engine	Target Engine
Impeller diameter	mm	85	100
Flow rate	lpm	-	100% increase
Flow Head	m	-	67% increase



Increasing Peak Firing Pressure and Thermal Stresses Capability

- Cylinder block
- Connecting rods
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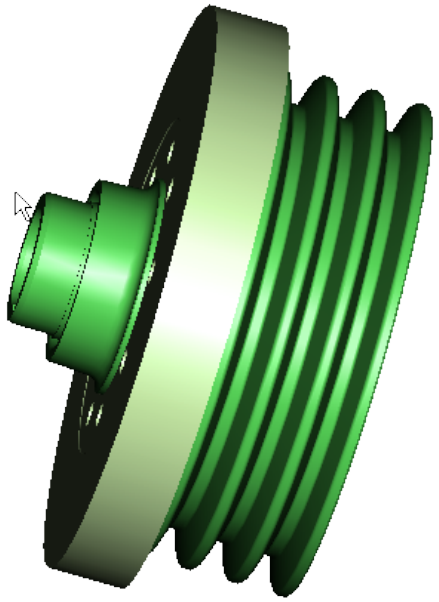
Viscous Damper



Damper	unit	Base engine	Target Engine
PFP capability	bar	105	140
Type		Rubber	Viscous

Increasing Peak Firing Pressure and Thermal Stresses Capability

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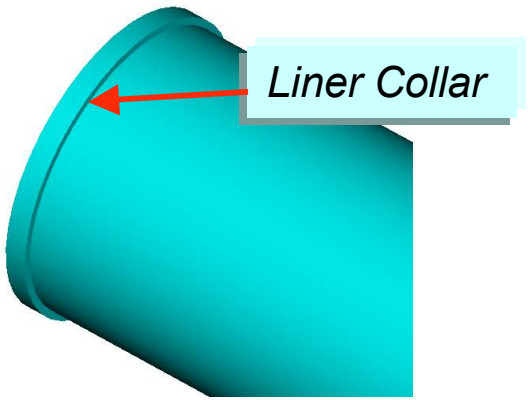
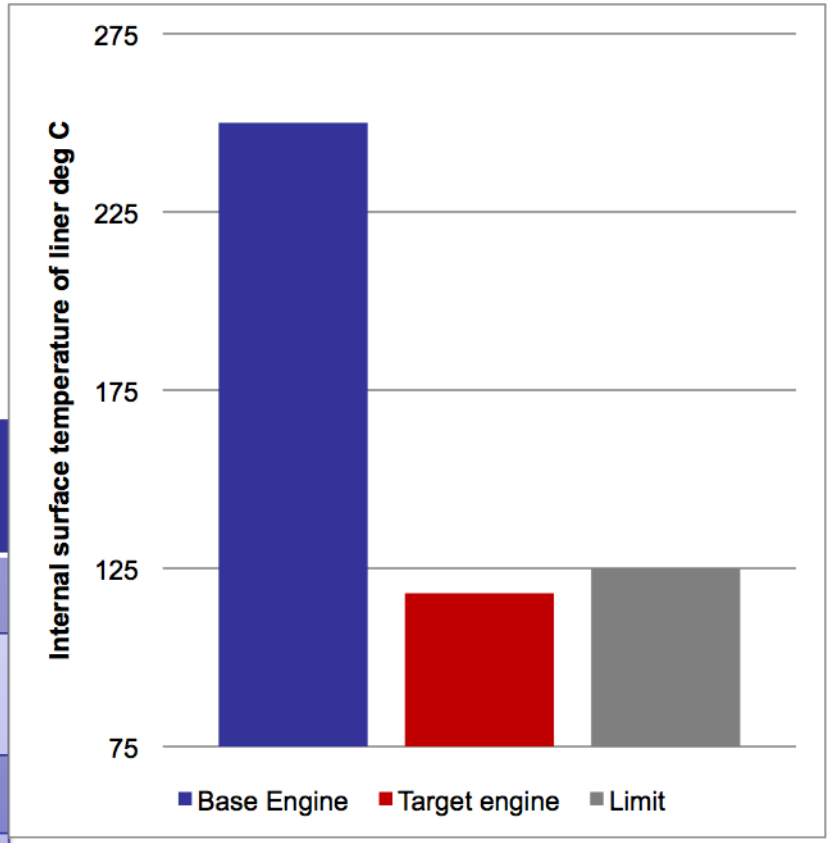
Cylinder Liners



Cylinder liners	unit	Base engine	Target Engine
PFP capability	bar	125	140
Type of fit		Slip fit	Mild Interference
Casting Process		Gravity die	Centrifugal
Hardness	RB	-	200% increase



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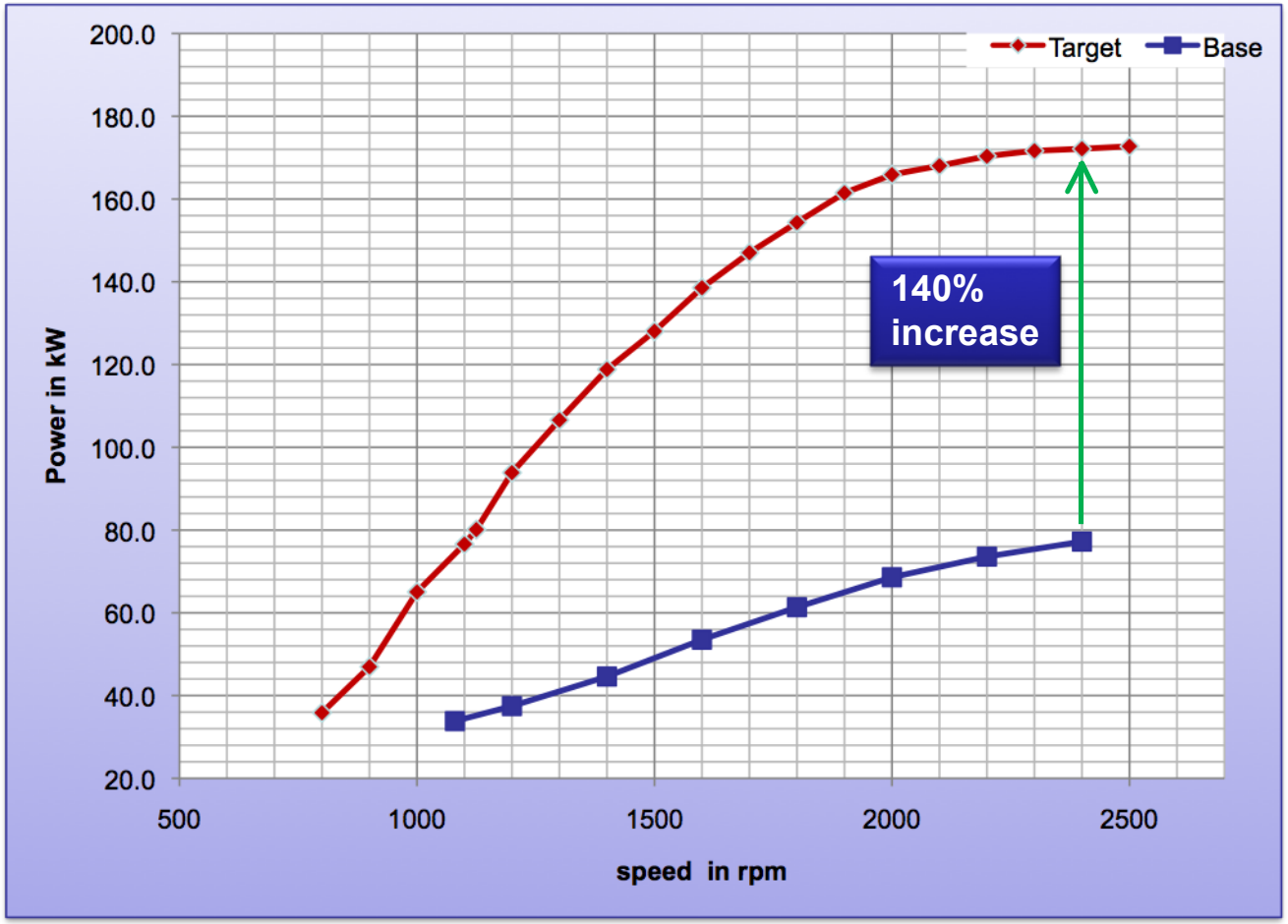
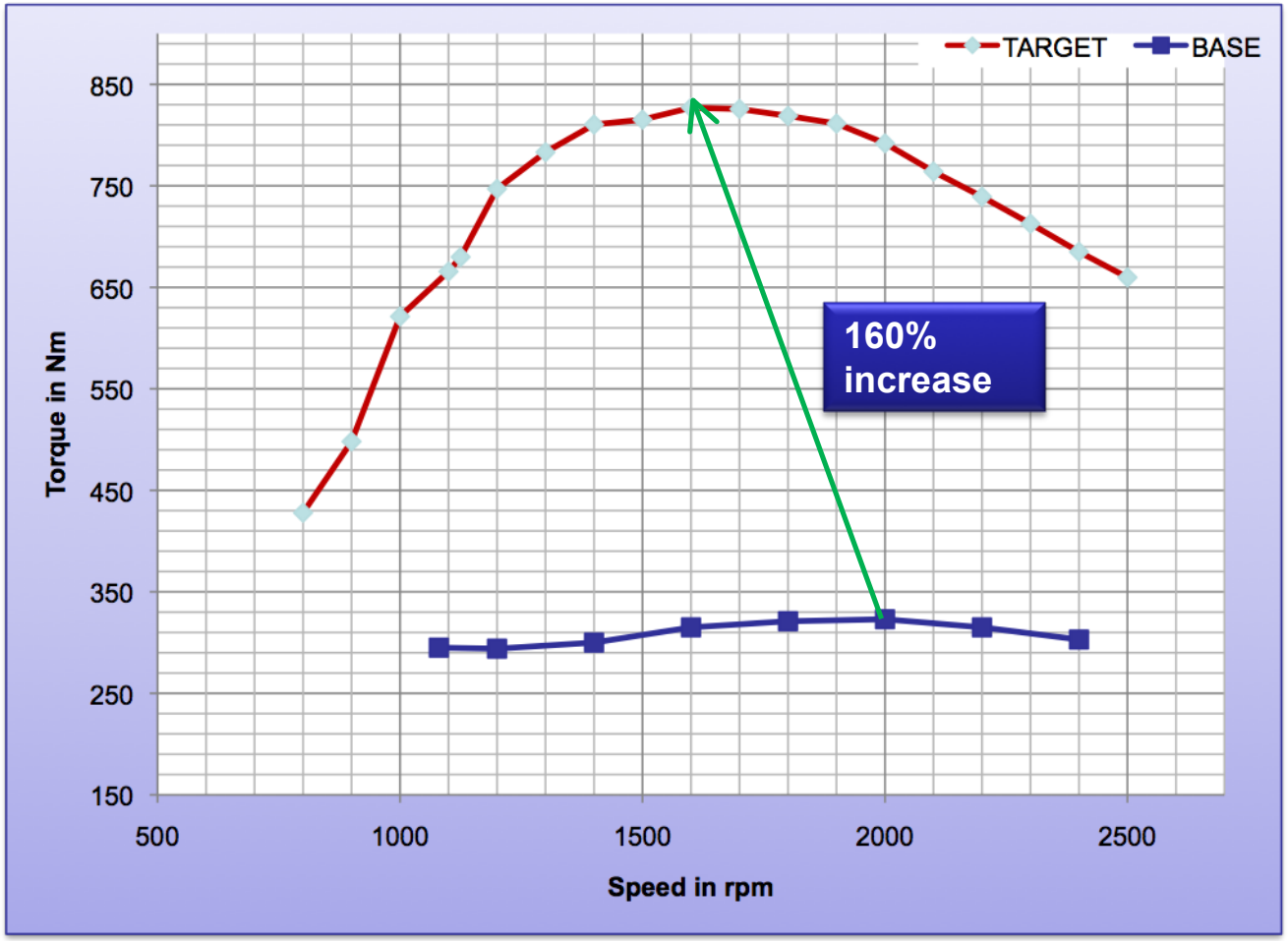
Comparison of Power

- 140% increase in power from same 5.7 L engine



Comparison of Torque

- 160% increase in torque from same 5.7 L engine



Comparison of SFC

- 14% reduction in minimum SFC to achieve 140% increase in power for same 5.7 l engine

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Future Trends

- Two stage turbocharging
- Variable geometry turbocharger
- Turbo-compounding
- Piston type: steel
- Piston rings : chromium ceramic face or physical vapor deposition
- Introduction of stepped connecting rod
- Cylinder block and head
  - material: CGI
- Reduced compression ratio

Thank You