MAN B&W Low Speed Small Bore Engines Now with Electronic Control

Contents:

MAN Diesel A/S, Copenhagen, Denmark

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Introduction

The MAN B&W 35MC engine was launched in 1982 as the L35MC with 500 kW/cylinder and a mean effective pressure of 14.8 bar at 200 rpm. Several design updates, often combined with a power up, have been introduced since then, and with today's Mark 6 rating, the power per cylinder is 650 kW/cylinder with a mean pressure of 18.4 bar at 210 rpm.

To meet the market demand for lower propeller speed, and thereby higher propulsion efficiency, the long-stroke S35MC (see Fig. 1) was launched in 1993 with 170 rpm and a mean pressure of 18.4 bar, resulting in 700 kW/cylinder.

Since then, the S35MC engine has been extensively used in the propulsion of a wide variety of vessels ranking in sizes from 5,000 to 25,000 dwt.

To cater for the increasing market demand for higher power, an uprated version of the S35MC was introduced in 1998 with a mean effective pressure of 19.1 bar at 173 rpm, thus providing 740 kW/cylinder.

The market also required direct coupled two-stroke engines in the 5-10,000 kW output area. The S42MC was therefore introduced with 136 rpm with a cylinder power of 995 kW/cylinder at a mean effective pressure of 18.5 bar.

Based on an increasing market demand for higher-powered super long-stroke small bore engines, the S42MC was uprated in 1999. The mean effective pressure was increased to 19.5 bar at 136 rpm, thus providing 1,060 kW/cylinder.

Since the delivery of the first L35MC in 1982, a total of ~1000 L35MC, ~500 S35MC, ~200 L42MC and ~250 S42MC engines are on order or have been delivered. More than 1000 S50MC-C has been delivered since 1997.

The above-mentioned small bore two-stroke engines have been the world leaders in their market segment for decades. However, the market is always moving, and requirements for more competitive engines, i.e. the lowest possible propeller speed, lower fuel consumption, lower lube oil consumption and more flexibility regarding emission and easy adjustment of the engine parameters, call for a re-evaluation of the design parameters, engine control and layout.

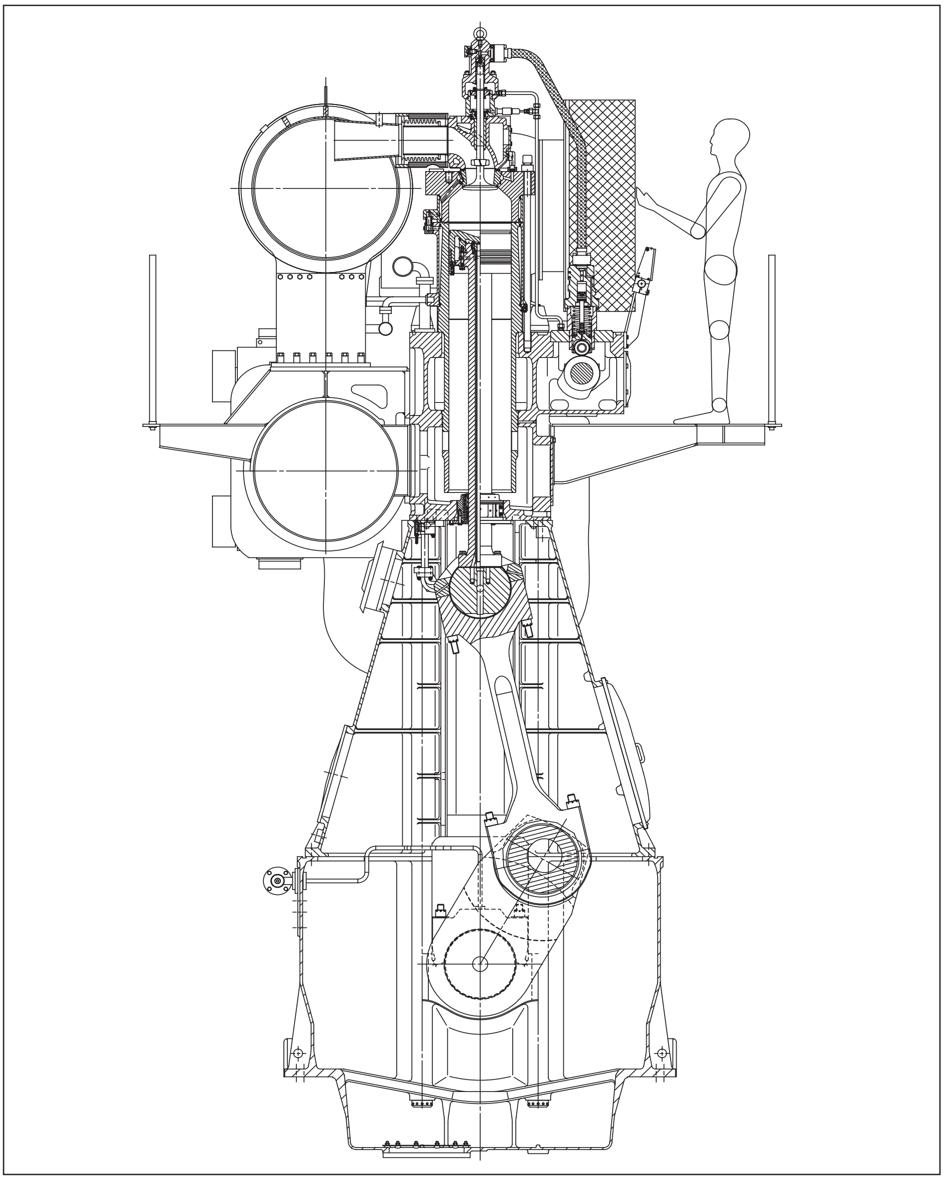


Fig. 1: MAN B&W S35MC cross section

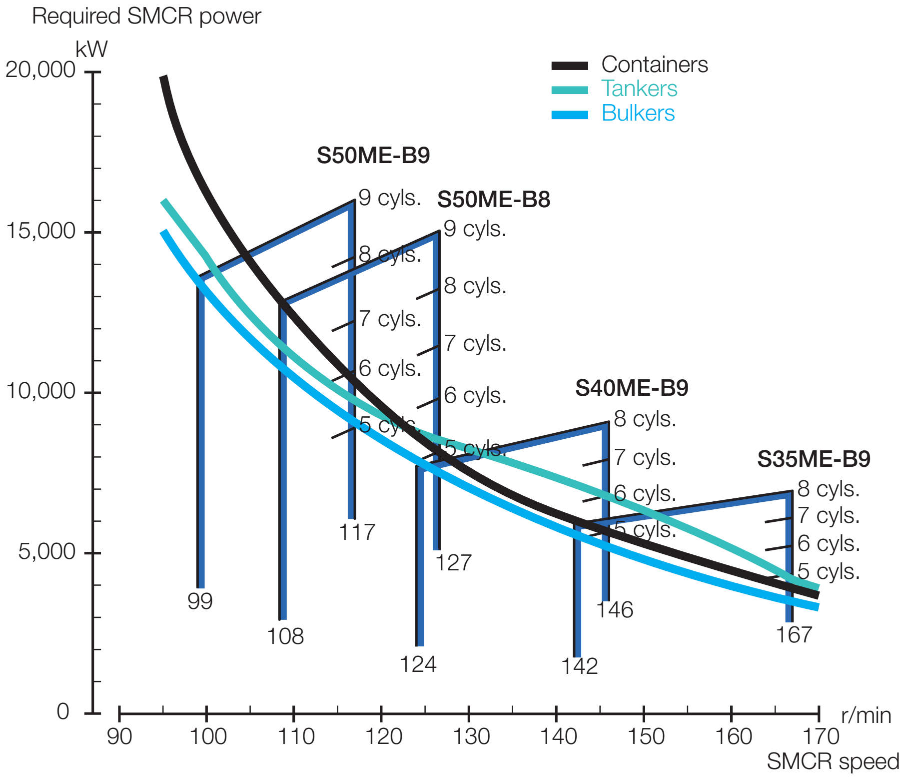
Our marketing investigation into this segment, including scrutinising the power against propeller speed for tankers, containers and bulkers, has shown that a 35 cm bore engine with a slightly reduced speed and a higher engine power will suit well. In the segment for the S42MC type, a 40 cm bore engine with 146 rpm will, together with an updated 35 cm bore engine, cover the required output area between the S35 and the S46MC-C very well,

The continuous developing of merchant ships to be even more efficient is never ending. The aft body of the ships for example may be designed to fit even larger propellers, which again have a higher propeller efficiency, but a lower optimum propeller speed.

As the two-stroke main engine is normally coupled directly to the propeller, thereby avoiding the reduction gear and its loss of efficiency, the design of modern main engines has to be based on a continuously lower engine speed (r/min).

With the new S50ME-B, which will be designated Mk 9, we have introduced a competitive engine designed for new modern hull designs, based on more efficient propellers with a lower optimum propeller speed. The engine will adopt the design features introduced on the smaller ME-B engines, and will be introduced with a mep of 21 bar at 117 rpm.

However, as the ME-B technology has clear cost benefits for engines in the lower power bracket, we have decided to make this available also for the existing S50 Mk 7/8 range. This will make it possible to benefit from this technology also in existing ship designs if application of the advanced S50ME-C type is not considered feasible.



Average power and speed demand curves for container vessels, tankers and bulk carriers:

ME-B types:

S50ME-B7/8 (19.0/20.0 bar)
Stroke = 2,000 mm (S/D = 4.00)
NMCR = 1,580/1,660 kW/cyl x 127 r/min

S50ME-B9 (21.0 bar)
Stroke = 2,214 mm (S/D = 4.43)
NMCR = 1,780 kW/cyl x 117 r/min

S40ME-B9 (21.0 bar)
Stroke = 1,770 mm (S/D = 4.43)
NMCR = 1,135 kW/cyl x 146 r/min

S35ME-B9 (21.0 bar)
Stroke = 1,550 mm (S/D = 4.43)
NMCR = 870 kW/cyl x 167 r/min

Fig. 2: Power against propeller speed

The S50ME-B7/8 will have the same performance and installation data as the S50MC-C/ME-C7/8. Main data for the two series appear in the table.

Both types will also be available in conventional turbocharger versions with +2g/kWh higher SFOC, respectively.

The layout diagram of the ME-B9 engine types, superimposed on the expected combination of speed and power of the target ship groups; container ships, tankers and bulk carriers, are shown in the enclosure.

The S50ME-B7/8 and 9 engines will be available in configurations of five to nine cylinders.

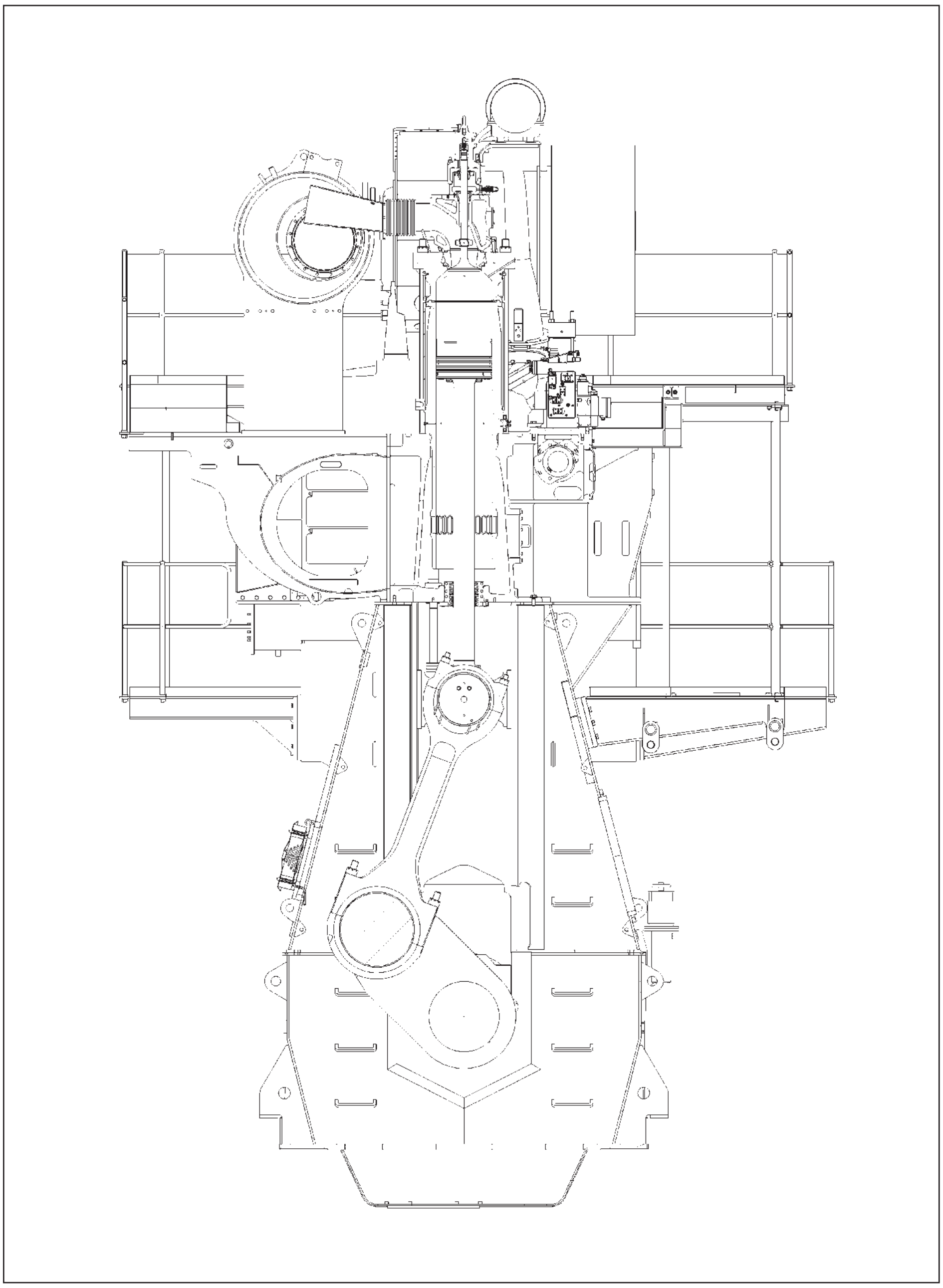
In addition, the market acceptance of electronically controlled engines is now turning into a market demand. Therefore, the new engine with a future electronic fuel system control will be designated ME-B, i.e. S35ME-B, S40ME-B and S50ME-B respectively.

Engine data

The new 35, 40 and 50 ME-B9 engines will have a stroke bore ratio of 4.4:1 (the same as that of our research engine 4T50ME-X) to facilitate low propeller speed; 167 rpm for the S35ME-B. The S50 ME-B8 has a stroke bore of ratio 4:1 (the same as the S50MC-C) 146 rpm for the S40ME-B, and 117 rpm for the S50ME-B.

The new engines will be introduced with a mean effective pressure of 21 bar offering the following engine data, see Fig. 3.

The specific fuel consumption for the Mk 9 versions has been reduced by 2 g/kWh by using a higher firing pressure.



Cross section S40ME-B

Engine comparison

A comparison between a 6-cylinder of the new MAN B&W S35ME-B and a 7-cylinder of the existing S35MC has resulted in 40 kW more power, 0.42 m shorter engine length, 3 ton lower engine mass and 2 g/kWh lower SFOC, Fig. 4.

A comparison between a 6S40ME-B and the existing 6S42MC shows that the 6S40ME-B can supply 5% more power and is 0.42 m shorter.

The engine weight is 16 tonnes less (11% lighter).

A comparison of 8S50ME-B9 and 9S50MC-C7 shows that the S50ME-B has 20 kW more power than a 9S50MC-C7, and a more efficient r/min of 117 r/min instead of the 127 r/min making it possible to use a propeller of larger diameter which is more efficient.

Furthermore, the new 8S50ME-B7 is 0.37 m shorter and 22 tonnes lighter.

All of the ME-B engines has a 2 g/kWh lower SFOC.

As mentioned earlier, electronically controlled fuel injection has been chosen for the new engines.

L_1	Unit	5-8S35ME-B9	5-8S40ME-B9	5-9S50ME-B9	5-9S50ME-B7/8
Bore	mm	350	400	500	500
Stroke	mm	1,550	1,770	2,214	2,000
MEP	bar	21	21	21	19/20
Speed	r/min	167	146	117	127
Mean piston speed	m/s	8.6	8.6	8.6	8.47
Power	kW/cyl.	870	1135	1780	1580/1660
SFOC	g/kWh	171-176	170-175	162-169	159-170

Fig. 3: Engine data

Engine Type	6S35ME-B9	7S35MC	Deviation
Power	5,220	5,180	+ 40 kW
Speed	167	173	- 6 r/min
Length	4,990	5,409	- 419 mm
Mass	81	84	- 3 ton
Specific weight	15.5	16.2	- 0.7 kg/kW
SFOC	176	178	- 2 g/kWh

Fig. 4: 6S35ME-B against 7S35MC

Engine Type	6S40ME-B9	6S42MC	Deviation
Power	6,810	6,480	+ 330 kW
Speed	146	136	10 r/min
Length	5,700	6,117	- 417 mm
Mass	127	143	- 16 ton (11%)
Specific weight	18.6	22.1	- 3.5 kg/kW
SFOC	175	177	- 2 g/kWh

Fig. 5: 6S40ME-B against 6S42MC

Engine Type	8S50ME-B9	9S50MC-C7	Deviation
Power	14,240	14,220	20kW
Speed	117	127	-10 r/min
Length	8,950	9,324	-374 mm
Mass	289	311	-22 tom
Specific weight	20.3	20.8	-0.5 kg/kW
SFOC	169	171	-2 g/kWh

Fig. 6: 8S50ME-B7 against 9S50MC-C7

ME-B fuel injection control system

The ME-B system is shown in Figs. 7 and 8.

While a light camshaft operates the exhaust valves in the conventional manner, fuel injection is performed by one fuel booster per cylinder, similar to the present ME engine. The boosters are mounted on hydraulic cylinder units (HCU), two boosters on each unit. The hydraulic oil is supplied to the HCUs via a single oil pipe enclosed in the camshaft housing. The hydraulic system pressure is 300 bar.

Two electrically driven pumps provide the hydraulic power for the injection system. In case of failure of one pump, more than 50% engine power will be available, enabling around 80% ship speed.

Injection performance

The ME-B system will have the same possibility of rate shaping as the present ME engines. The injection is controlled by a proportional valve enabling continuous change of the injection pressure. Typically, a gradual pressure increase during the injection is desired.

The injection profile influences the SFOC as well as emissions. One profile is often favourable for SFOC, however at a cost of high NO_x emissions, while the opposite applies for a different injection profile. The injection profile reflects a compromise between SFOC and NO_x. Thus, the freedom to choose the injection profile is a tool that can be used to minimise the SFOC, while keeping emissions within given limits.

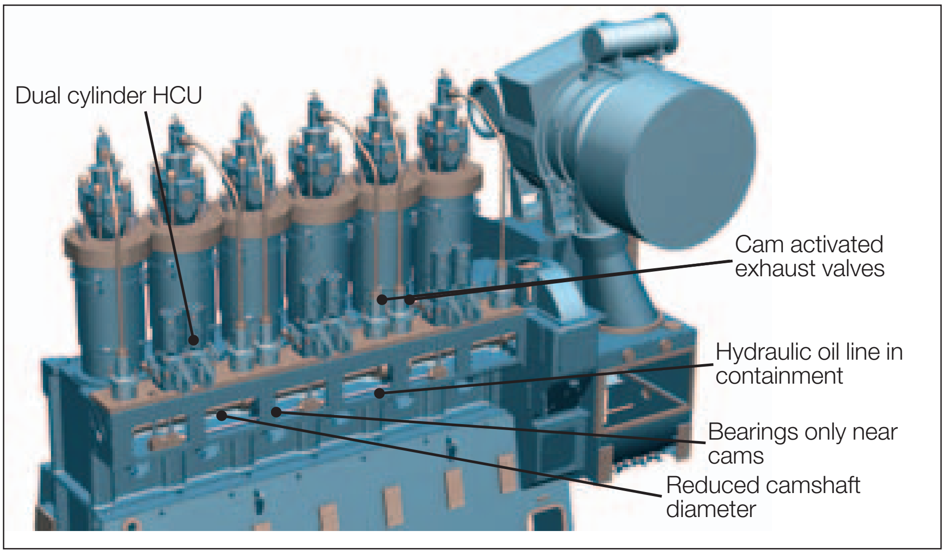


Fig. 7: ME-B engine

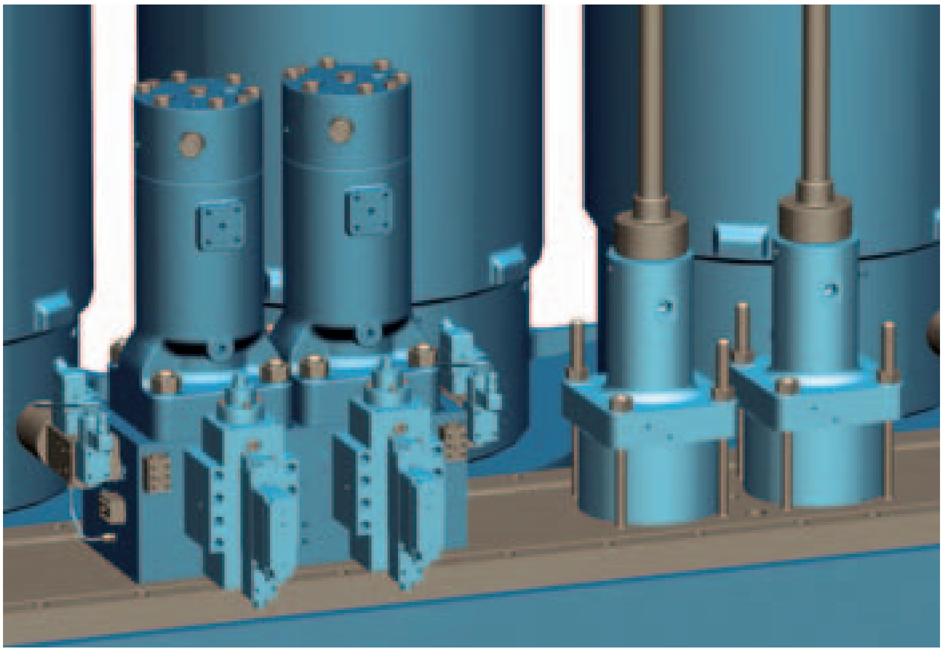


Fig. 8: HCU for two cylinders

Engine control system

Several factors serve to reduce the necessary extent of the Engine Control System (ECS).

- A number of features included in the present ME system can be omitted as these may be provided from the engine surroundings as for MC engines
- Capacity for control of exhaust valve movement is no more required
- Starting air control
- Auxiliary blower control
- Pump control simplified

Fig. 9 shows the layout of the engine control system for the ME-B. The system will utilise the same MPCs as the traditional ME control system. One Multi Purpose Controller (MPC) can control the injection on two cylinders. The EICU placed in the engine control room will control the hydraulic pressure and is also connected to the Bridge control system.

It should be noted that a 6-cylinder ME-C engine requires 13 MPCs whereas the corresponding small bore ME-B may require four MPCs only.

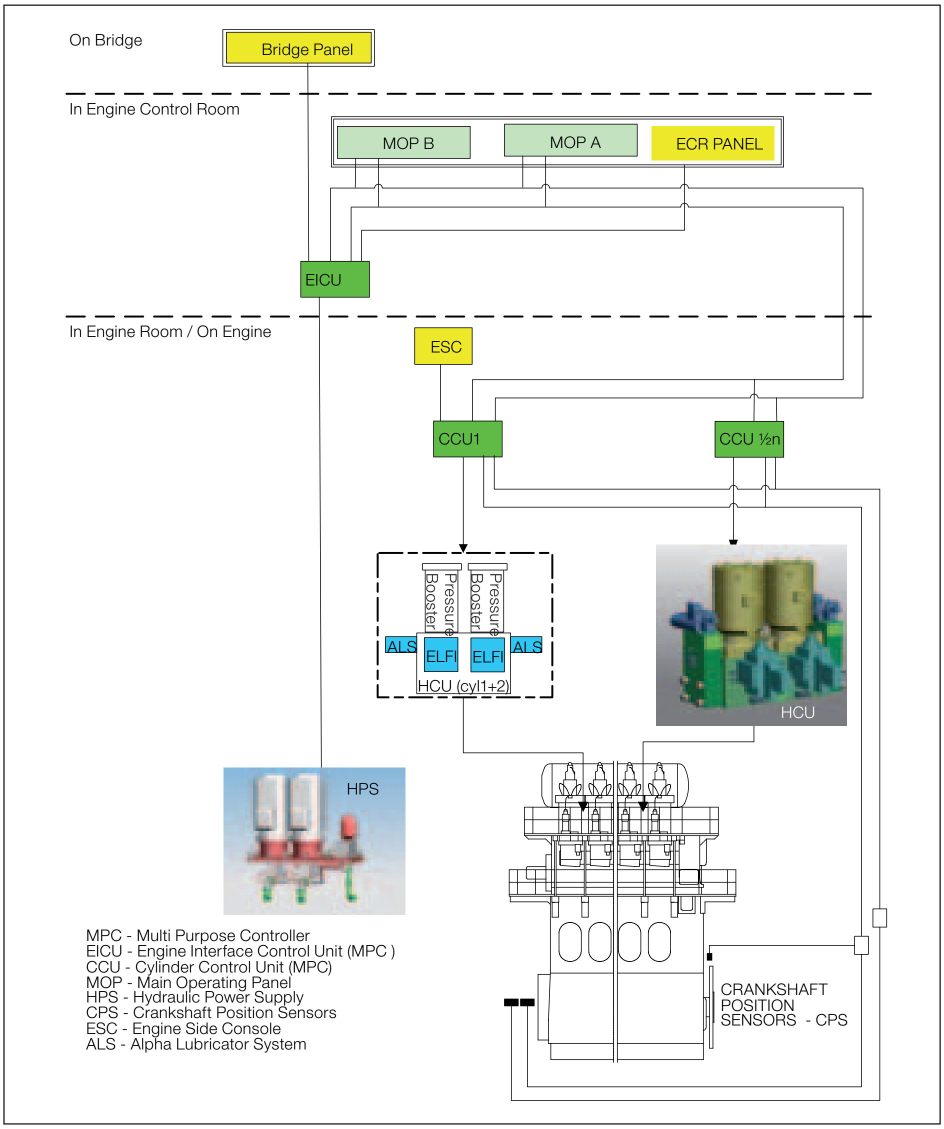


Fig. 9: Engine Control System for ME-B

Engine Design S35/40/50ME-B

Bedplate, framebox and cylinder frame

The structural parts have been designed with respect to rigidity and strength to accommodate the higher output for these engines. See Fig. 10.

The bedplate is of the welded design. For the new engines, the normally cast part for the main bearing girders is made from rolled steel plates. This secures homogeneity of the material used for the main bearing area with no risk of casting imperfections occurring during the final machining.

The framebox is of the well-proven triangular guide plane design with twin staybolts giving excellent support for the guide shoe forces. This framebox is now standard on all our updated engine types.

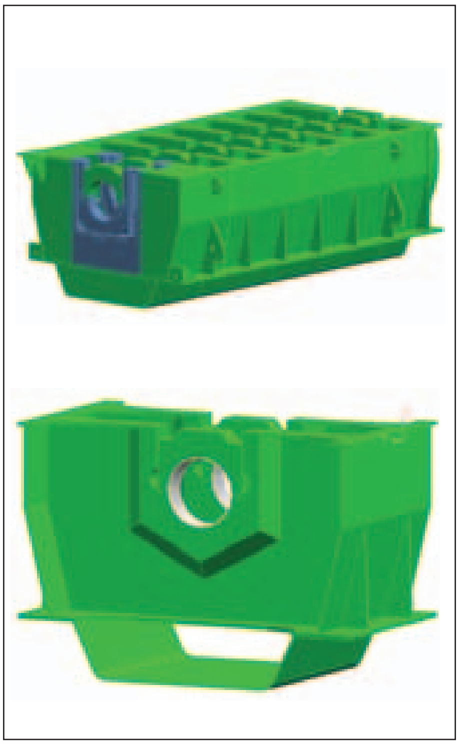


Fig. 11: Existing and new main bearing designs

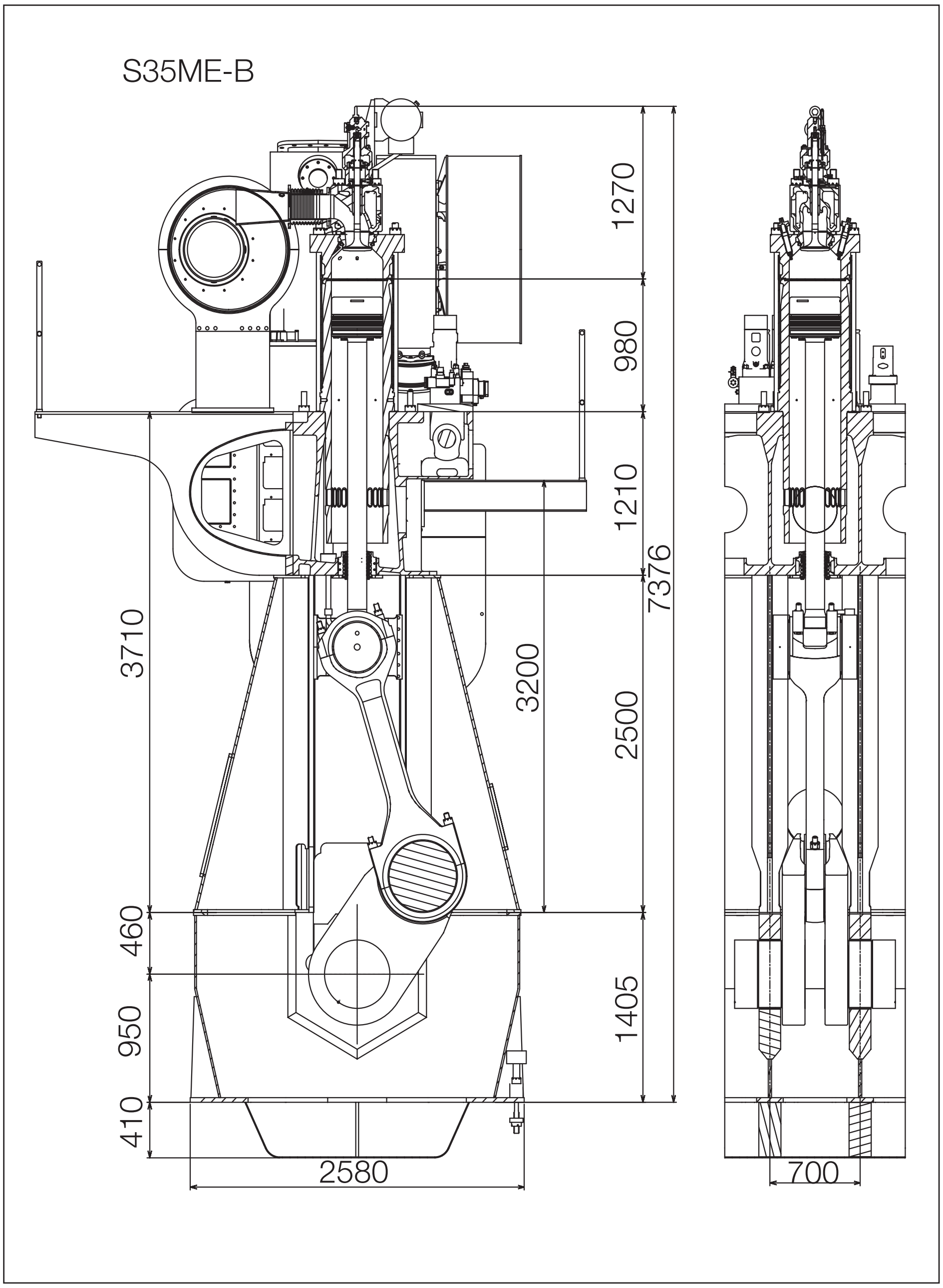
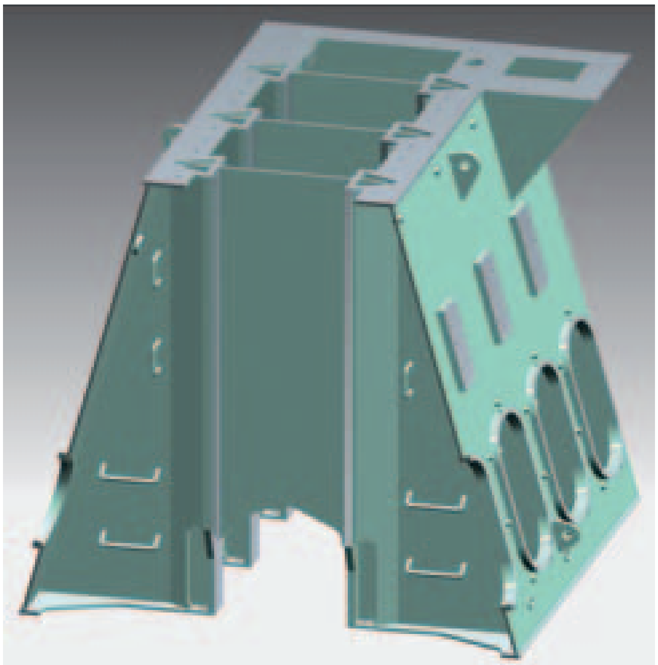
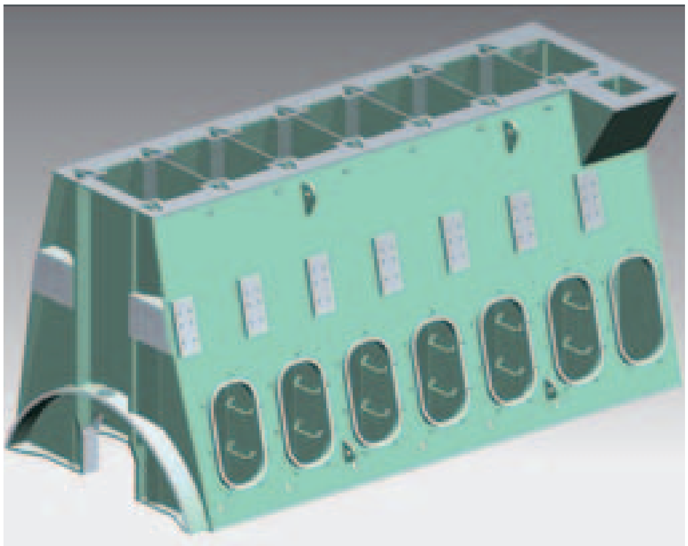


Fig. 10: Cross section S35ME-B



Triangular staybolt tube design



OMD and PCO sensors mounted on the manouvering side

Fig. 12: Frame box

For the cylinder frame, two possibilities are available, see Fig. 12.

- Nodular cast iron
- Welded design with integrated scavenge air receiver.

It has been decided to use nodular cast iron due to its high strength and high E-modulus for this material to counteract the high ignition force. Compared with C3Cu material, the weight of a 6S35ME-B cylinder frame can be reduced by 3 ton, corresponding to a 12% cost down for the cylinder frame.

The stiffness and stress level have been carefully evaluated for the main structure with FEM calculations (see Fig. 13), and all deformations and stresses are lower or equal to the level used for our existing engines, i.e. the reliability of the engine structure will be at least at the same level as the existing engines, which have proven very good performance.

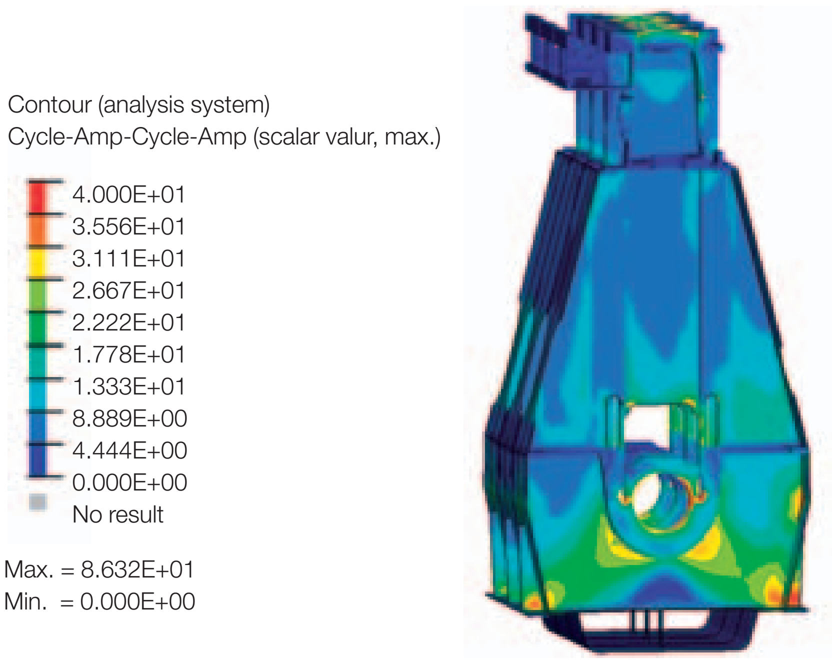


Fig. 13: Stress calculation

Crankshaft

The crankshaft is of the semi-built design, in one piece, and made in material S34CrNi or S42Cr1, Fig. 14.

Even though the stroke/bore ratio has been increased for the new engines, the cylinder distance has been only slightly increased, (only Mk 9).

Comprehensive FEM calculations were performed to ensure that the geometry (incl. journal diameters) of the shaft had been optimised keeping the rigidity, shrink fit and stresses on the same level as for our MC-C engines.

Connecting rod

The connecting rod is based on the well-known design used for our entire small bore engine programme initially introduced for the L35MC.

To reduce the production cost and oscillating forces, the new design is made of slim design of the crosshead end see Fig. 15.

Also a new crosshead bearing without oil groove in the loaded area has been introduced. See Fig 16.

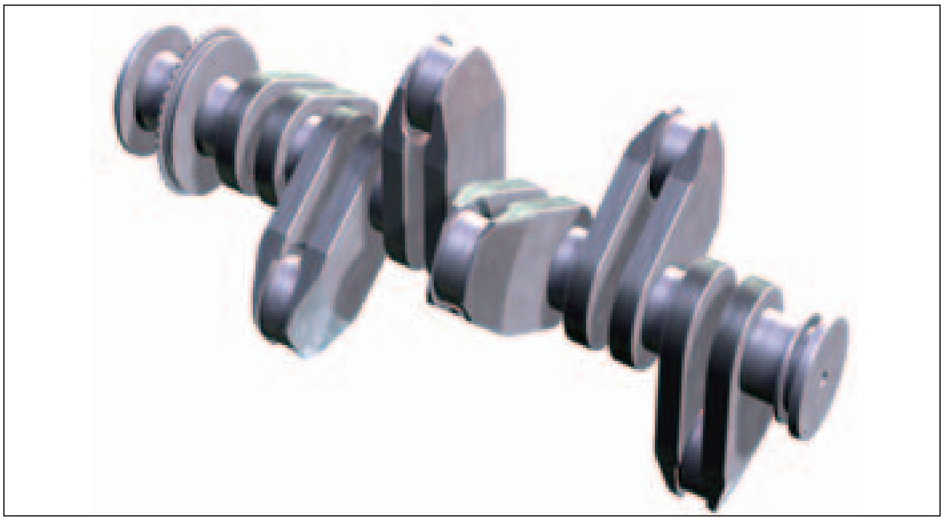


Fig. 14: Semi-built crankshaft for ME-B

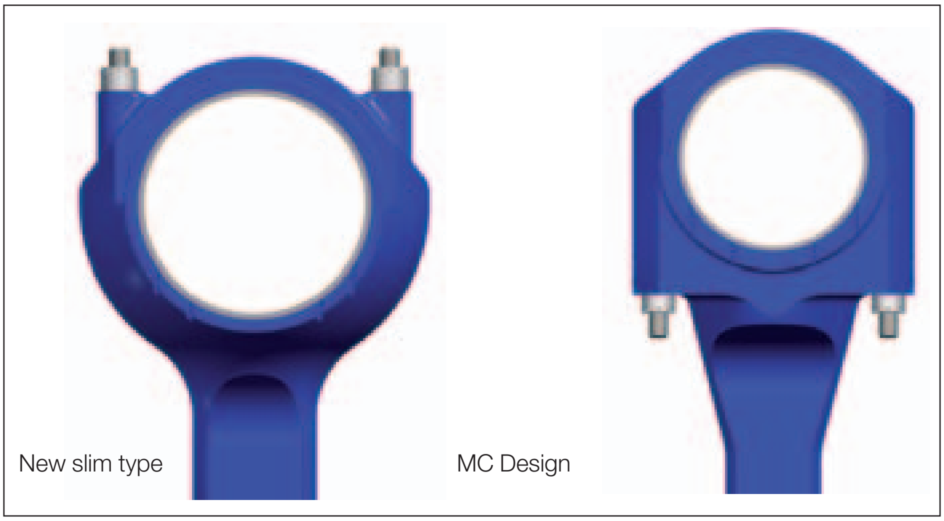


Fig. 15: Connecting rod

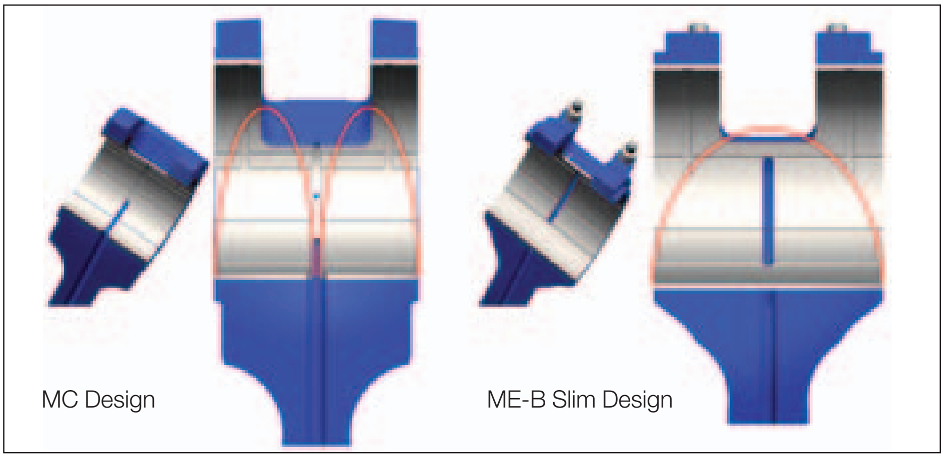


Fig. 16: Connecting rod, new crosshead bearing

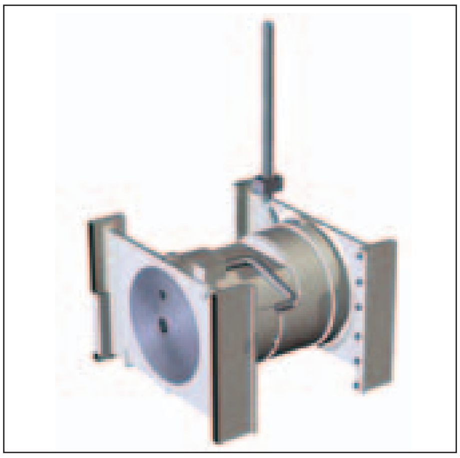


Fig. 16: New crosshead design

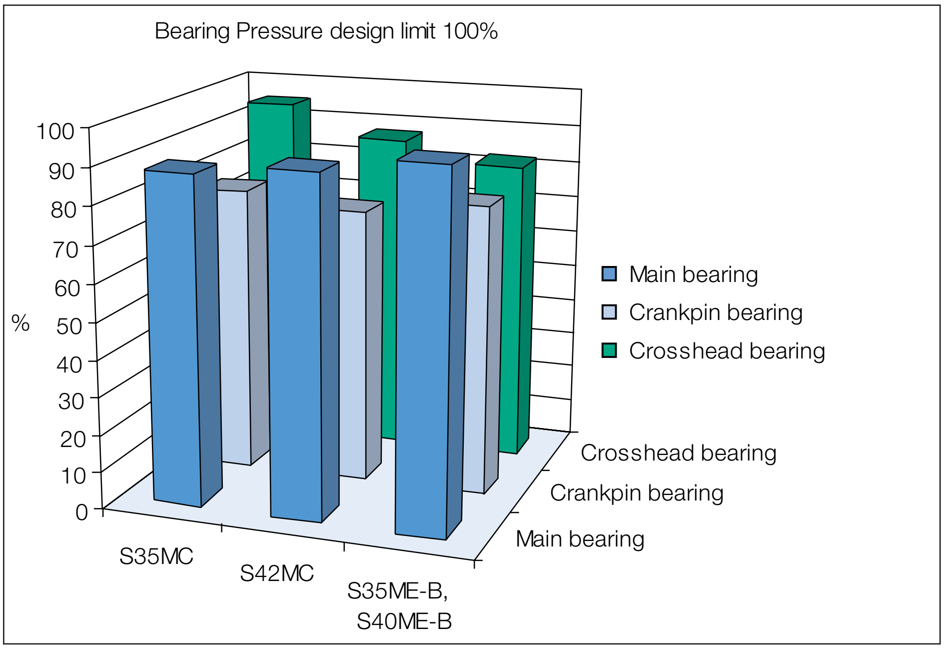
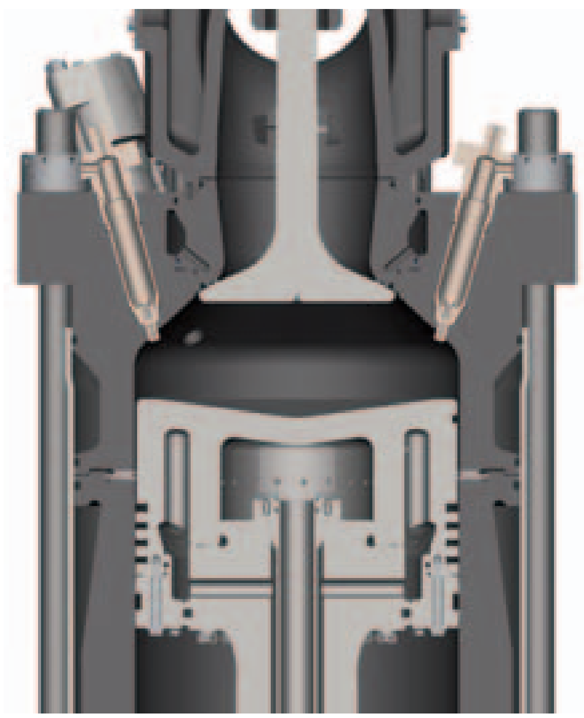


Fig. 17: Bearing load



- Slide Fuel valves
- Alpha ACC
- High Piston Topland
- Slim cylinder liner
- PC ring
- Piston rings with Alu-coat
- Piston skirt with bronze band
- Known to give excellent cylinder condition and long TBO

Fig. 18: Combustion chamber

Bearings

The bearings used for the new engines are of the same design as the one used with very good results on our other small bore engines for now more than 15 years. The bearing is of the thin-shell design, and the bearing metal on all the large bearings is of Sn40Al. The relative loads on the large bearings are in all cases well below our design targets, Fig. 17.

Combustion chamber

With the increased power of the new ME-B engines, the combustion chamber has been carefully investigated to compensate for the higher ignition pressure and higher thermal load – but also to increase the reliability of the components and further increase the TBOs. The combustion chamber is shown in Fig. 18.

Cylinder liner

A slim cylinder liner which is also used on our other small bore MC-C/ME engines is possible for both engine types, but the material for the cylinder liner has been upgraded to Tarkalloy A to counteract the higher ignition pressure. The PC ring has been introduced to prevent bore polish.

Piston

The piston is bore-cooled and with a semi-high top land (see Fig. 20). The shape of the piston crown against the combustion chamber has been carefully investigated to cope with the increased power of the new engine. Comprehensive FEM calculations have been made to develop the piston crown geometry to make it able to withstand the high firing pressure and high mean pressure, Fig. 21.

The piston ring pack will be similar to the rings used for the existing small bore engines, i.e. No.1 piston ring, high CPR, Nos. 2 to 4, piston rings with angle cut. All rings are with Alu-coat on the running surface for safe running-in of the piston ring. If prolonged time between overhauls is requested, a special ring pack with hard coating on the running surface for piston rings No. 1 can be supplied as an option.

As for the larger bore ME engines, the Alpha Lubricator is standard on the new small bore engines. The ACC lubrication mode is, therefore, now also available for our small bore engines with the benefit of a very low total lube oil consumption and still keeping very good cylinder condition.

The calculated temperature level for the combustion parts is well inside our design value as shown in Fig. 22.

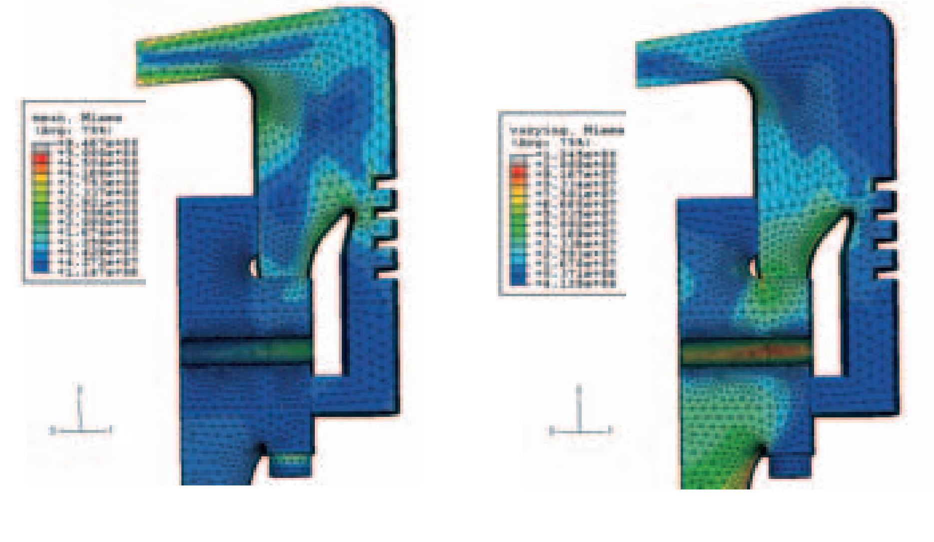


Fig. 21: FEM investigation of stresses in new piston crown

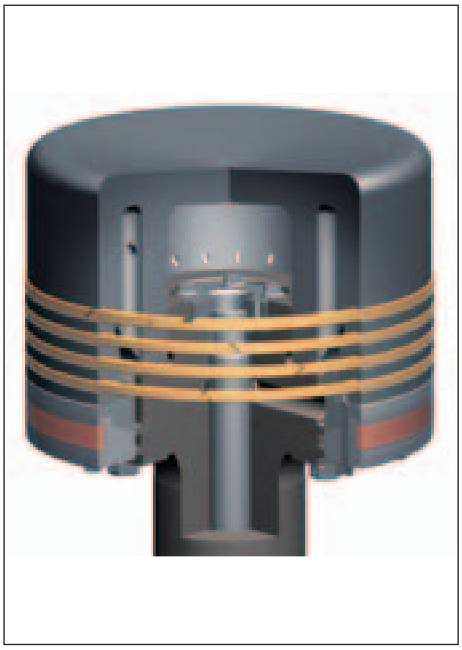


Fig. 20: Piston

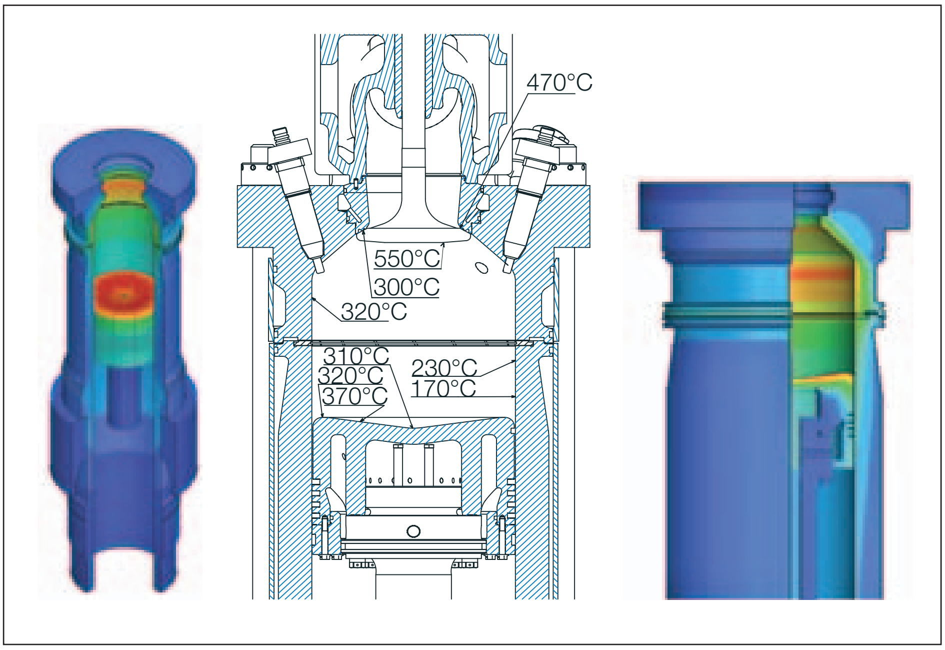


Fig. 22: Temperature level in combustion parts

Exhaust valve

The exhaust valve is activated by a light camshaft (smaller shaft diameter and smaller size exhaust cam), driven by a chain drive placed in the aft end of the engine. The size of the chain is reduced compared to the MC type.

To have common spare parts for all four engines, the exhaust valve used for the S35 and S45ME-B is the same as the one used for the S35MC and S42MC, respectively. The exhaust valve is of the DuraSpindle type with a W-seat bottom piece, Fig. 24.

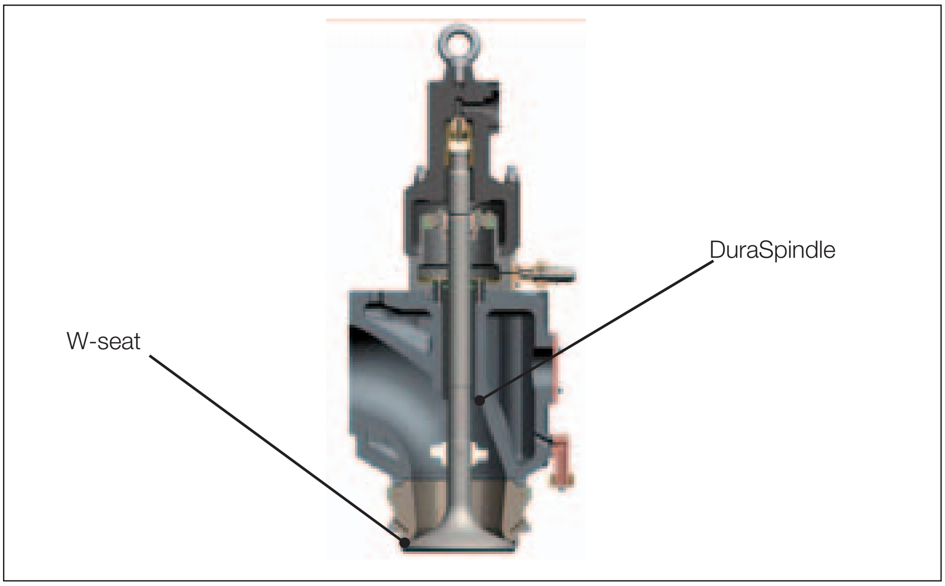


Fig. 24: Exhaust valve

Fuel injection equipment

As mentioned earlier, the fuel injection is electronically controlled via a pressure booster like the one used for the large ME-C engines. There is one Hydraulic Cylinder Unit (HCU) per two cylinders. The HCU is equipped with two pressure boosters, two ELFI valves and two Alpha Lubricators and one accumulator. Thereby, one HCU is operating two cylinders. Fig. 25.

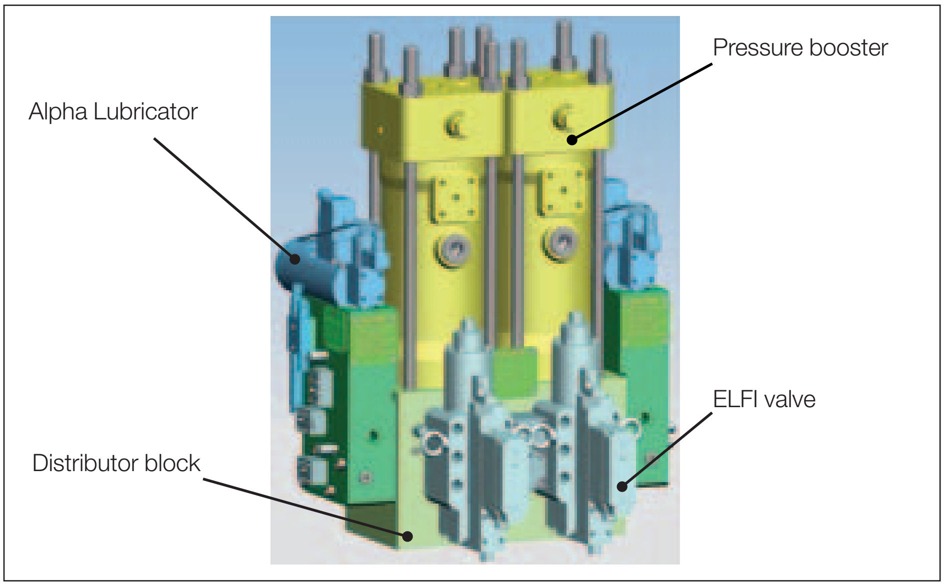


Fig. 25: Hydraulic Cylinder Unit (HCU)

The Hydraulic Power Supply (HPS) used for the new small bore engine is installed together with 6 µm filters in the front end of the engine. The HPS is electrically driven and consists of two electric motors each driving a hydraulic pump, see Fig. 26.

The pressure for the hydraulic oil for the new system has been increased from the 250 bar used for the normal ME -C system to 300 bar. Each of the pumps has a capacity corresponding to 55% of the engine power, approximately 80% speed. In case of malfunction of one of the pumps, it is still possible to operate the engine with 55% engine power.

The same fuel valve type as used on the MC/MC-C will also be used for the new ME-B engines. The fuel nozzles are of the well-proven slide type already introduced as standard on all small bore engines.

Thrust bearing

The thrust bearing design is based on the very compact design introduced with our MC-C engine. As the propeller thrust is increasing due to the higher engine power, a flexible thrust cam has been introduced to obtain a more even force distribution on the pads. The overall dimension of the parts can therefore be smaller than with the old design. See Fig. 27.

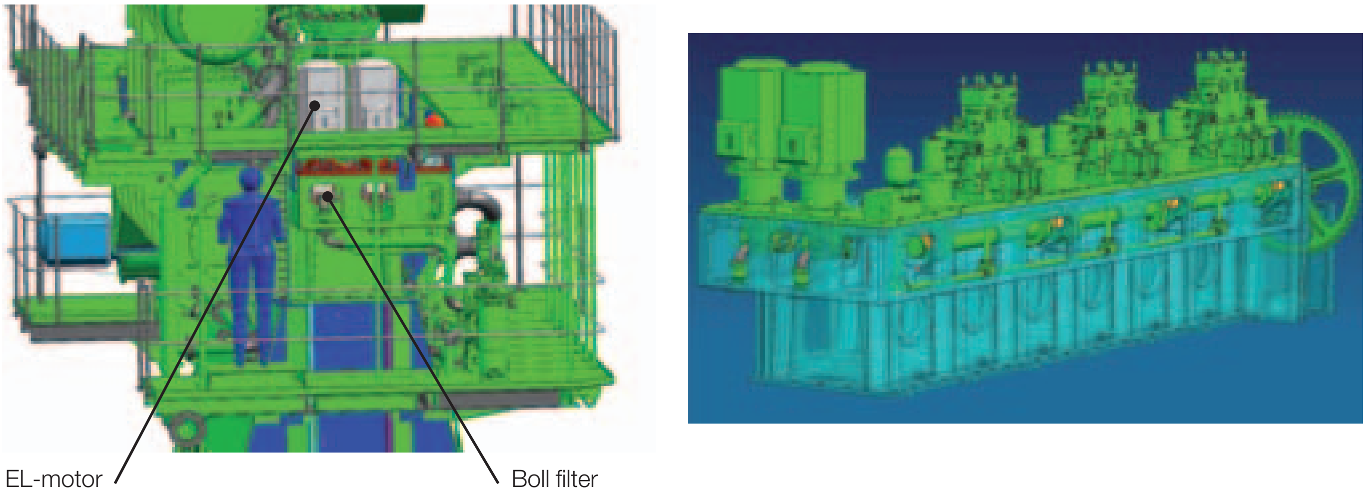


Fig. 26: Hydraulic Power Supply (HPS)

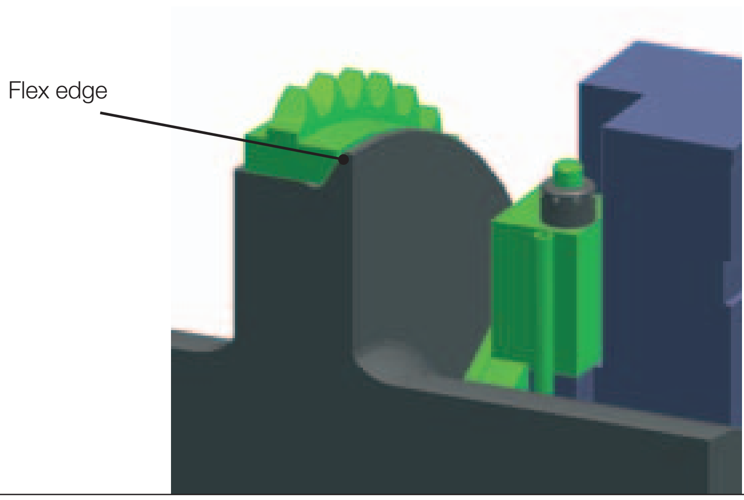


Fig. 27: Thrust cam with flex edge

Engine control system

For a 6-cylinder engine, the engine control system consists, of four to five MPCs (Multi Purpose Controller) compared to 13 MPCs necessary for the standard ME systems, Fig. 28.

Turbocharger and air cooler arrangement

Three turbocharger makes are available for the new ME-B engines, i.e. MAN, ABB and Mitsubishi.

The position of the turbocharger is, as for the existing engine, aft mounted, but will for the new ME-B also be offered as exhaust side mounted. See Fig. 29. The latest type of water mist catcher and water drain arrangement will be introduced in the new design.

As an option we can supply TCA T/C's with variable nozzle. Hereby better Part-load SFOC can be offered due to the possibility to control the ration between p_{max}, p_{comp} and MEP.

The auxiliary blower design will be of the new integrated type recently introduced on the S50MC-C version. Maintenance is also reduced as the belt drive is omitted for the integrated blowers, see Fig. 30.

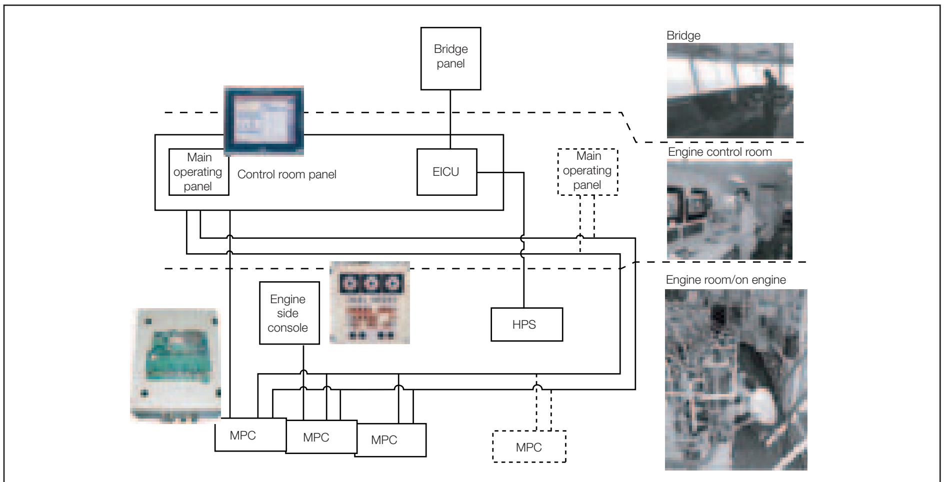


Fig. 28: Engine Control System

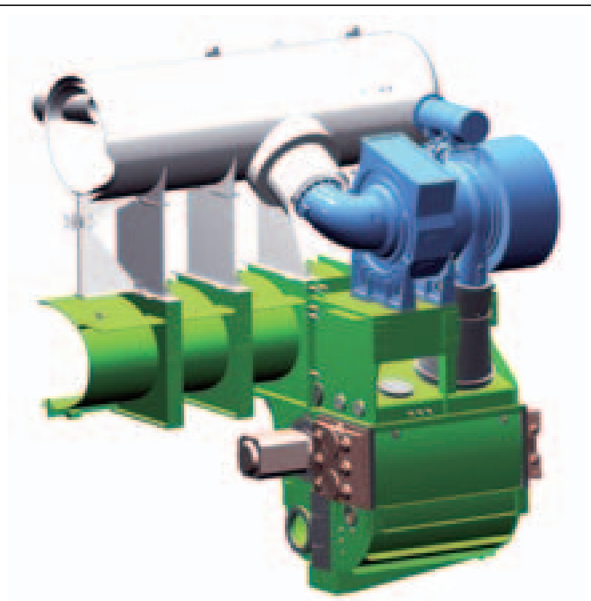


Fig. 29: Exhaust side mounted TC

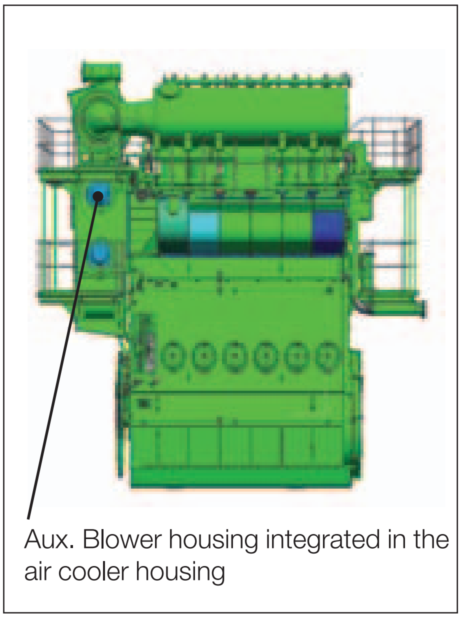
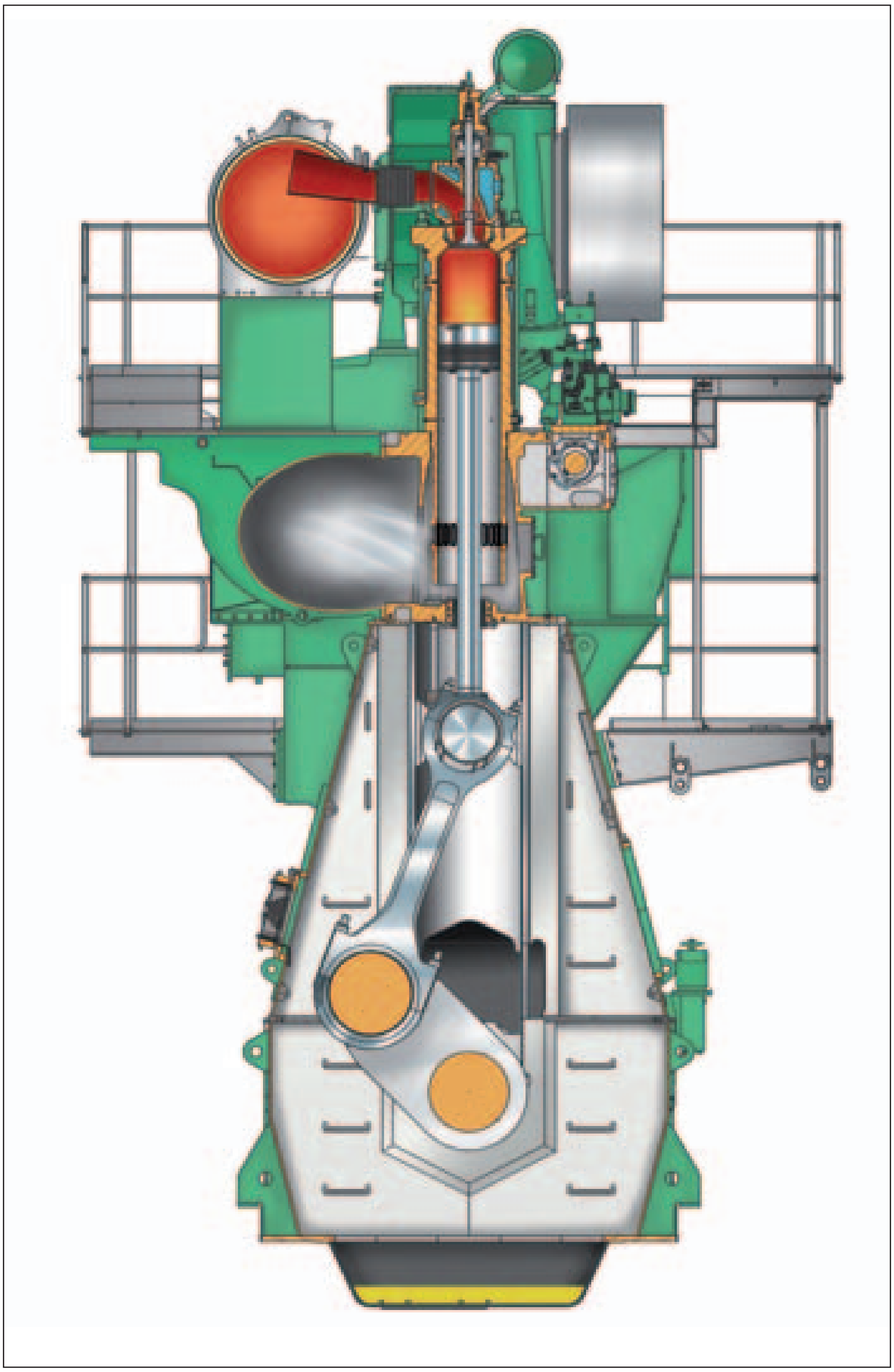


Fig. 30: Integrated blower design

Concluding Remarks

The introduction of the ME-B engine range marks a future step towards strengthening our small bore two-stroke engine position in the market, enabling the owner to select modern, future-oriented, electronically controlled, two-stroke engines as direct coupled prime movers, also in this segment.

Thanks to the design rationalisations introduced, an ME-B engine is expected to be sellable at roughly the same price per kW as a corresponding MC-C engine.



Cross section S50ME-B