Crosshead bearing design meets new challenges

Proposed improvements to crosshead bearings rely on new materials and processes

by Doug Woodyard

New approaches to bearing materials, bearing design and production methods for low speed engines are driven by higher firing pressures.

Bearings need to be engineered to balance load capability with the tribological requirements of the application.

The crankshaft of a two-stroke, low speed engine is connected to the piston via a connecting rod, crosshead and piston rod. Crosshead bearing movement is solely oscillating and the load vector is always directed downward; reliable hydrodynamic lubrication and oil supply thus become difficult to ensure. One solution is for hydrostatic lubrication with an oil pressure of around 12 bar in specially created oil pockets. The crosshead pin is thereby raised briefly at each revolution to ensure the oil supply.

Two different crosshead bearing designs and lining materials are currently used: either a single lower bearing shell or a divided lower bearing shell, depending on the engine size. The common lining materials are aluminium-based A1Sn40 and whitemetal-based HM07.

Future crosshead bearing designs must be robust and combine a high safety margin with high performance, Austrian bearing specialist Miba advises, requiring bearing designs based on A1Sn40 linings to be further improved. Extra wide lower crosshead shells rather than divided designs are proposed for long-stroke engines with a minimum bore of 400mm.

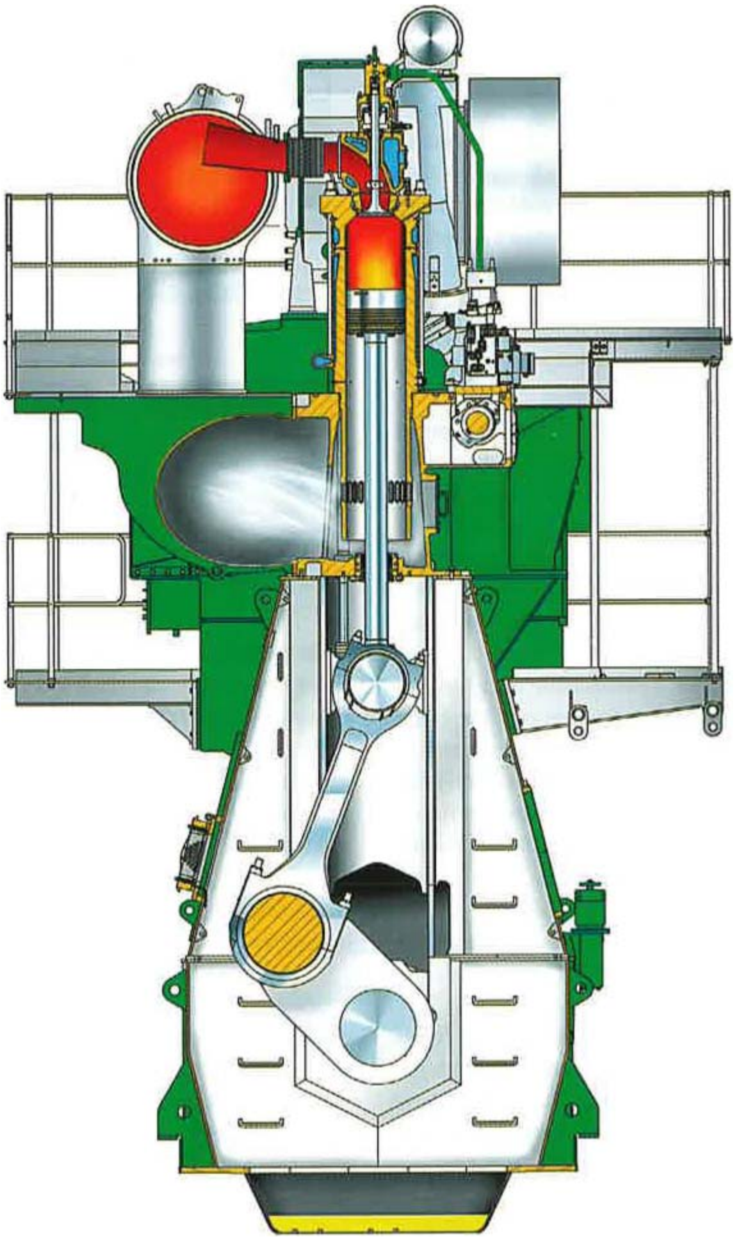
Miba's new lower crosshead bearing design, termed a Patch-Work-Bearing, is based on a tri-metal configuration of steel-aluminium-tin 40-Synthec for Tier II engine platforms. Extra wide crosshead bearings comprise a steel back with a roll-bonded A1Sn40 bearing alloy that is finally coated with a Synthec layer.

A new prefabricated material production process has been introduced to manufacture these semi-bearing shells. The first step sees the bearing segments Sl , S2 and S3 produced by advanced roll-bonding processes. The segment size is variable and depends on the final bearing dimensions, the segment length defining the bearing width.

In the second step the segments are welded together, the position of the weld seam being in axial alignment. Different welding methods can be applied, depending on the full thickness of the bearing shell. The most appropriate techniques are fusion welding processes such as laser welding or electron-beam welding, particularly when higher wall thicknesses are involved.

Electron-beam welding secures the highest quality of all fusion welding processes, Miba reports, and is valued for manufacturing critical parts where safety and reliability are important. Electron-beam welded joints are characterised by having very small distortion with relatively large welded depths of up to 20mm. Compared with laser beam welding, the technique has a higher process stability and allows an optimised working distance, resulting in leaner weld seams with a low tendency to distortion.

After joining, the semi bearing shell is finally formed by roll forming and subsequent pressing. A key specification for the weld seam is 100 per cent root penetration to secure maximum connection of each segment; additionally, the weld seam must be free of cracks and foreign material. Pores and inclusions are accepted up to a certain size, distribution and area percentage. Different segment-joining face geometries - no groove, triangular groove and rectangular groove - were tested to ensure these demands were met. A major advantage was offered by designs with machined grooves, even though they required more effort and added complexity during machining.



Crossheads form a *crucial connection between the con rod and the piston rod of low speed two-stroke engines (MAN B&W S50ME-B design illustrated)*

The high energy input during welding leads to selective re-melting of the steel followed by solidification, with extreme high cooling rates resulting in the formation of the weld seam. When applying higher welding energies/beam intensities, however, no degradation of the aluminium-based lining will occur and damage of the bonding steel to aluminium lining can be avoided as the groove provides a certain distance between the lining and weld seam from the heal affected zone.

Final design of the Patch-Work-Bearing was optimised by placing the oil grooves in axial alignment with the weld seams. Such a configuration ensures a proper oil supply for lubrication while removing - by machining - any material inhomogeneity caused by the weld seam root. High quality and performance are thus fostered for the bearing.

Metallographic investigations demonstrated a uniform weld seam structure over the entire length and welding depth; no cavities, cracks or impurities could be found, and the positioning of the seam was almost in the centre of the oil groove. The structure of the A1Sn40 bearing alloy as well as the bonding to the steel was unaffected by the welding procedure.

Non-destructive testing by X-ray and dye penetration analysis revealed minor porosity in a tenth of a millimetre size range.

A simplified Finite Element Analysis (FEA) and fatigue analysis were executed lo quantify the operational risk of inhomogeneities, particularly porosity. Dynamic mechanical properties were investigated by alternate bending fatigue testing as the basis for fatigue analysis.

A flat sample was used for the test and sampling carried out before roll forming. The welded samples were inspected before testing by X-ray technology to check for porosity, none being found. Analysis of the dynamic mechanical performance showed that the non-welded and welded samples behaved similarly; no reduction in fatigue performance caused by the weld seam was found. The extended endurance limit for defect-free welded parts is 240 MPa.

Tests carried out with notched samples show a different characteristic; the location and size of the hole can be varied as required. On one hand, this allows crack initiation during the cyclic fatigue testing to be enforced either in the weld seam or in the heal-affected zone of the base material; on the other hand, the overall cross-sectional area of the seam is reduced significantly. Both resulted in a decreased endurance limit of 175 MPa.

The FEA calculation data showed compression stresses between 100 MPa and 230 MPa in the welded area, mainly caused by the bearing assembly with an appropriate crush height. The dynamic load during operation affected by a peak firing pressure of 190 bar showed only an insignificant influence on the overall stress level in the bearing shell.

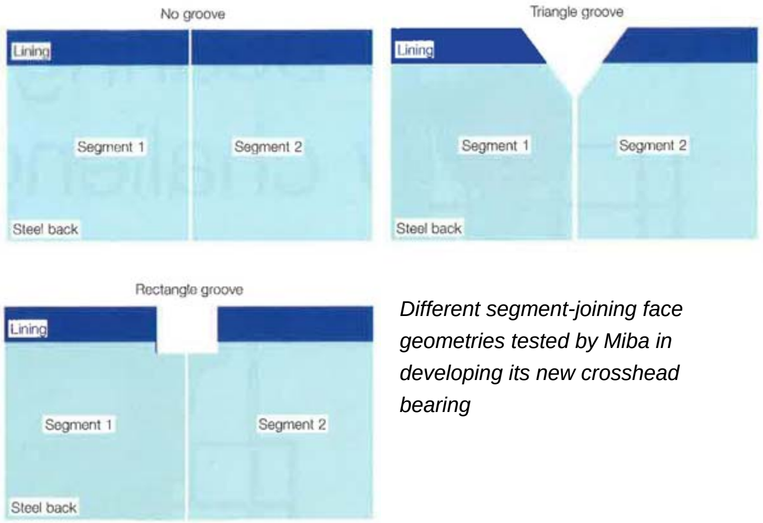
The simplified fatigue calculation showed a fatigue safety factor of around 10 for the welded crosshead bearing shell, taking into account a notched specimen with a notch factor of 1.5 for evaluating the endurance limit of the welded material. Even with a higher notched factor of 3.0, describing the worst case scenario, the minimum safety factor will still be above a critical value of 2.0.

After successful approval of the new crosshead bearing design for an initial engine test, two units were installed on an MAN B&W S50 low speed engine powering a container ship. An inspection was undertaken after the shells had been in service for around 2,400 hours. Visually, the surface and steel back of both bearing shells were found to be in a good condition. The coating had a few polished areas and traces of some slightly harder contacts in the areas adjacent to the grooves where the bearing material was polished by the pin. Clearance measurements were carried out before and after inspection, all the readings being within recommendations.

A dye penetration check was performed on the welded zones of the steel back and side faces to verify the condition of these areas as well. All the weld seams were in good condition and indications of cracks were observed. Specimens were also taken from one of the shells for microscopic examination, the structure appearing to be in perfect condition with no defects.

MAN Diesel &Turbo has approved Miba's new crosshead bearing design with the aluminium-tin 40-Synlhec lining material combination for its two-stroke low speed engines with bore sizes from 260mm to 500mm.

Ongoing development work for future bearing designs by Miba is also directed at incorporating lubrication chemistry not just for corrosion resistance but for improving seizure behaviour and adapting bearing area design to the load demands of those areas. Bearings will thus be refined to achieve the lowest possible operational risk and a service life underwriting the most economical solutions.



Different segment-joining face geometries tested by Miba in developing its new crosshead bearing

Source: Marine Propulsion Feb/March 2014