Bearing up under the pressure

Developments in design and are improving the reliability and lifetime of low and medium speed engine main and bottom end bearings

Main bearings in low speed engines are normally associated with very long lifetimes and in the 20 years from 1970 to 1990 very few failures occurred. Any failures are of concern to operators, however, as the consequences may be fatal.

Failures in more recent years could well be a function of higher mean effective pressure ratings in modern engines as well as the latest ship designs, reports the CIMAC Engine Users working group. An investigation by the group showed that bearing failures in long-stroke engines clearly outweighed those in short stroke designs. The reason could be due to less stiffness of the crankshaft or because most long-stroke engines are installed in tankers and bulk carriers.

CIMAC's study also revealed that most of the failures are found on seven-cylinder engines, which are typical in the above ship types. The aft bearings are especially vulnerable, with a definite relationship to weak aft bodies of the ships concerned. It might appear that the requirement for total stiffness is lost between engine and ship designers, the working group suggests.

Engine designers have carried out R&D to address the problems, evolving new bearing designs to handle the higher demands imposed. New calculation techniques are applied to track local high pressure peaks or areas with limited oil film thickness, helping to ensure that current and future engines will perform more safely.

Excellent performance is claimed by Wärtsilä for the crosshead and bottom end bearings of its Sulzer low speed engines, which are of the thin shell white metal type. The main bearings have white metal running layers and are of either thick or thin shell design depending on the engine model.

Although the mean loads on the main bearings are lower than those on the bottom end bearings, some white metal damage was reported from the small bore RTA48T and RTA48T-B engines, and also from some RTA96C engines. Proper design of main bearings is very demanding, Wärtsilä notes, because the crankshaft is distorted by the shaft torque and the aft bearings in the engine are influenced by the intermediate and propeller shafts.

Inside the engine, distortion of the crankshaft main pin leads to an uneven distribution of bearing load which leads to edge pressure on the bearing shells. To verify and calculate this influence on the main bearings, it is essential to create full 3D finite element models of the engine structure along with the complete crankshaft and intermediate and propeller shafts.

Very precise predictions are made by using elasto-hydrodynamic bearing calculation methods. The results from such calculations confirm the findings from ships in service. Knowing the exact load distribution at each main bearing, it is possible to tune the bearing design accurately to adjust such parameters as oil film pressure and minimum film thickness to the allowable values.

An improvement package introduced by Wärtsilä is designed to overcome the problems with main bearings. It embraces an optimum horizontal bearing clearance, precise centring of the bearing cover with the bearing shell, back relief of the shell to reduce the edge pressure at the running surface, as well as ensuring that the white metal quality and bonding are according to specification.

Introduced over three years ago, the improved bearings are now the valid standard design for Sulzer engines, with shipboard service results are reportedly very promising.

Occasional failure of a main bearing can never be excluded, however, because so many factors are involved, says Wärtsilä. Even so, no ship has had to be stopped by any main bearing failure and no secondary damage has occurred, it claims. Both thin and thick shell main bearings of Sulzer RTA engines are specified with thick white metal layers to avoid the crankshaft journal touching the base material in the event of bearing failure.

Changes in bearing shell design for MAN B&W Diesel MC and MC-C low speed engines
Wärtsilä has also developed main bearings with running layers of aluminium alloy, the layer thickness the same as those for white metal. The bearings have been tested in the Sulzer 4RT-flex58T-B research engine since 2001 and are running successfully in a 6RTA48T-B engine at sea.

New recommendations from MAN B&W Diesel aim to simplify and reduce the frequency of bearing checks and enhance the reliability of its low speed engines. Main, crankpin and cross head bearings in two stroke engines traditionally have been subject to 'open up' inspections every four years, as required by the classification societies.

MAN B&W two-stroke engine bearings all feature soft, tribologically-forgiving materials such as tin-based white metal or AlSn40. Over the years a number of design improvements, as well as changes to installation practices and alignment recommendations, have been introduced to enhance manufacturing efficiency and reduce the number of bearing damage cases. Damage statistics are shown in the bar charts, and changes to the two types of main bearings detailed in the diagram.

The situation has now been reached, says MAN B&W, where the scheduled open-up inspections are the most frequent cause of main bearing damage. This is because the procedure involves a risk of inappropriate handling, incorrect assembly or introducing foreign matter to the bearing. Main bearings are more demanding than crankpin and crosshead bearings to work with and the most difficult to access (especially the lower part). It might be thought that opening-up inspections are required to monitor the bearing wear, but the wear of both white metal and AlSn40-lined bearings of the types mentioned is virtually nil, MAN B&W claims. The designer has therefore discussed with classification societies waiving the present requirement for such four-yearly inspections.

MAN B&W seeks to promote the following change to the recommendations regarding bearing inspections: comprehensive external checks, including bearing clearance record checks, checks of bearing edges as well as visual checks, and checks of the oil pan for possible bearing metal debris are to be carried out at least once a year. Such a step implies that open-up inspections are only to be carried out if the checks indicate any abnormalities or bearing damage, thus reducing the possibility of introducing damage to good components.

MAN B&W, however will still recommend that the crankpin bearings are opened up for inspection every eight years and crosshead bearings within the first year of service.

The crosshead bearing recommendation is introduced because the overlay in the bearing during the initial running-in period will adapt to the pin: a process that could lead to excessive material accumulating in the oil wedges. The open-up is desirable to check that these wedges are not blocked; subsequently, the crosshead bearings should only be opened up every six years.

Bearing materials inevitably involve a compromise between different characteristics. Bearings with high load capacity frequently have low corrosion resistance but high load capacity can lead to poor adaptability; conversely, high corrosion resistance and high adaptability can lead to poor load capacity.

According to Zollern BHW, the main problem for bearing manufacturers has been to find a material that can match the load requirements of new generation diesel engines, while providing sufficient corrosion resistance for heavy fuel and gas applications.

The standard SnSb7 overlay, which has very high corrosion resistance and has been used successfully for many years for these applications, has now reached the limits of its fatigue strength. And the Rillenlager types, which are made with the same overlay material, have lower corrosion resistance and poor adaptability; they are also expensive to manufacture.

Zollern BHW has now developed a new trimetal bearing using a lead-bronze backing, a nickel diffusion barrier and a new overlay material (PbSn14Cu8) to create the bearing material Z-BHW 81. Increases in the Sn and Cu contents significantly improve the corrosion resistance, it is claimed, while the load capacity is greater than that of both the standard Z-BHW 40 material and the Rillenlager. The new material reportedly performs well in all areas (see chart) to promise superior technical performance at a reasonable production cost.

A new tin-copper two-layer overlay developed by Daido Metal of Japan is said to be very suitable for marine medium speed engines when a long bearing life is sought. Engine ratings have imposed more arduous operating conditions and increased the severity of loading on Developments in medium speed ratings have imposed more arduous operating conditions and increased the severity of loading on crankshaft and connecting rod bearings. At the same time, economic factors have dictated longer intervals between overhauls as well as a longer lifetime for key running components.

Commonly, the plain bearings for these engines consist of three basic layers: a steel backing for rigidity; a lead-bronze lining for a safe long term life; and a thin soft surface layer (or overlay) to increase the ability to tolerate adverse assembly and running conditions.

The lifetime of such bearings is often dictated by the removal of the overlay, whose loss is frequently due to fatigue, abrasive wear, corrosion or cavitation. In many cases, it can be a combination of these factors, the end result being that the underlying lead-bronze lining is exposed. If the lifetime of the surface overlay can be extended, therefore, the overall bearing lifetime will also improve.

The traditional overlay is a lead-based material, typically with tin and copper. Fatigue and cavitation resistance thus become limiting factors for high performance engines with a high combustion pressure. In many engine applications, sensitivity to corrosion is particularly a problem.

Addressing these limitations, and the more demanding requirements of the overlay, Daido Metal investigated overlay compositions based on tin, the choice reflecting its inherent resistance to corrosion in an engine environment.
Tests quickly established that incorporating the correct level of copper was influential in raising the fatigue and abrasive wear resistance. Diffusion of copper to the bond line during a long lifetime, however, diminishes its effectiveness. Thus a major part of the development programme concentrated on establishing an effective construction to inhibit the diffusion phenomenon.

An additional intermediate layer between the surface overlay and the lining was developed as a result of the investigation. This layer incorporated a significantly higher level of copper than that in the surface layer and inhibited diffusion from the latter.

Various rig tests carried out on the newly developed Sn-Cu overlay were followed by full-scale engine trials in a service application to establish the level of improvement and confirm the effectiveness of the development. Endurance tests in a medium speed engine in service compared the performance of the new overlay with the existing lead-based version.

Summarising its results, Daido Metal reports:

- The new tin-copper overlay has excellent wear, corrosion and cavitation resistance compared with conventional lead-based overlays, with no loss of fatigue or seizure performance. Wear and cavitation resistance was confirmed by service in a medium speed engine.
- The double layer tin-copper structure is effective in reducing the copper diffusion from the overlay to an acceptable level.
- Overlay removal can be caused by a complex mix of abrasive wear, corrosion, fatigue and cavitation mechanisms. The new tin-copper two-layer overlay resists the effects of these mechanisms and is therefore highly suitable for use in marine medium speed engine bearings where a long lifetime is desired.

Significant merits are claimed by Austria-based MIBA for its new synthetic bearing overlay.

For many years large medium speed engines have used steel-backed aluminium based bimetal bearings, mainly AlSn20, and trimetal bearings. The introduction of a new generation of high strength aluminium-tin bearings in 1998 (AlSn25) not only satisfied demand for higher load-carrying capacity without loss of running properties; it also offered an economic solution for replacing trimetal bearings in moderately-loaded applications.

In higher performance low speed engines, MIBA reports, AlSn40Cu has widely replaced babbitt materials which have too low load carrying capacity.

Both engine types benefit from continual performance improvements which have to be matched by enhanced bearing capabilities.