Preventing shaft bearing damage

A good shaft alignment is one in which all the supporting bearings are well loaded in the static condition and the system is flexible enough to withstand hull deflections and imposed forces so that the bearings remain well loaded in all operating conditions. For container ships, this requirement has historically been easier to fulfill than for other commercial vessel types such as oil tankers and bulk carriers. This has been due to the inherent flexibility of the shafting systems on container vessels as a result of the mid-position of the main engine and the subsequently long shaftlines.

It is somewhat counterintuitive that long shaftlines with many bearings are in fact easier to align than short shaftlines with few bearings. However, theory and practical experience demonstrate that the short, stiff systems found on vessels with high-powered machinery placed as far aft as practicable are the most problematic.

With the advent of ever larger and more powerful container vessels, it has become necessary to pay greater attention to shaft alignment design and propulsion shafting installation.

These design trends make the coupled propulsion shaft and engine system more sensitive to changes in bearing position. In order to prevent bearing failures, it has become necessary to pay greater attention to shaft alignment design and propulsion shafting installation on container ships.

**Sensitivity of shaft systems**

The design stage is crucial in establishing a suitably flexible shafting system. It is important for the designer to minimise the value of the bearing influence numbers (the measure of shaft stiffness). It is also important to keep the static bearing loads high enough to prevent them from unloading during operation. In simple terms, this means that the sterntube forward bearing and...
Plummer bearings need to be spaced sufficiently far apart. As a rule of thumb, the length/diameter ratios of the bearing spans should be kept above 10:1. To achieve this it may be necessary to omit the sterntube forward bearing in place of an aft plumper bearing located on the propeller shaft, immediately inboard of the engine room aft bulkhead seal.

Table 1 compares the parameters of several selected container ship and oil tanker designs and shows the theoretical influence numbers. As a measure of sensitivity, the downward offset from the design position required to unload the sterntube forward bearing or, where no forward bearing is fitted, the aft-most plumper bearing is shown.

When combined with a design bearing load of 12 tonnes, it only takes 0.88 mm of downward displacement for the sterntube forward bearing to unload. A better design is the 6,000 teu vessel, which has a span of 11.0 metres between sterntube bearings, producing an L/D ratio of 11.3:1. Despite the larger shaft diameter, the sterntube forward bearing’s influence number is kept down to 6.7 tonne/mm.

The 6,000 teu design also has the advantage of a longer shaftline with more plumper bearings (six, compared to only three in the 4,500 teu design), which helps to reduce the influence number at the sterntube forward bearing.

Of the container ship designs studied, the 4,500 teu vessel has the most sensitive system, comparable to that of the oil tankers. An important aspect of the particular 4,500 teu design studied is that the shaft span between the forward and aft sterntube bearing supports is only 6.5 metres. This produces an L/D ratio of only 8.2:1 with a subsequently high influence number of 13.6 tonne/mm.

**Bearing failure investigations**

The need to achieve a good static load on the sterntube forward or aft plumper bearing has been highlighted in recent investigations undertaken by Lloyd’s Register’s Technical Investigations. Measurements conducted on container vessels demonstrated how the bending moments imposed upon the propeller shaft change significantly during manœuvring turns, causing the sterntube forward bearing to unload and the propeller shaft to run cross-axis in the aft bearing. This typically occurs during turns to starboard. The measurements additionally confirmed that successful sterntube aft bearing performance is dependent on achieving a static slope mismatch between the journal and bearing surfaces to within Lloyd’s Register’s limit of 0.0003 radians (0.30 mm/m).

These results are in line with the findings of numerous sterntube aft bearing failure investigations conducted by our Technical Investigations. The most common forms of propulsion shaft bearing damage are wiping or overheating at the aft end of the sterntube aft bearing. In a number of cases, such damage has occurred during starboard turns when increased bearing load and slope mismatch between the journal and bearing surfaces has adversely affected the development and maintenance of a satisfactory oil film.

Although the shaft alignment design calculations normally consider the hydrodynamic forces and moments generated by the propeller, we have found that overly simplistic assumptions
are often made which have led to poor alignment designs being submitted for class approval.

It must be remembered that the propeller hydrodynamic forces and moments are predicted for the zero rudder condition only and often at one vessel draught condition. When the vessel turns or operates in different ballast conditions, the propeller hydrodynamic forces and moments can change significantly due to wake field variations. This causes the centre of propeller thrust to move from its predicted position, thereby invalidating the values assumed in the calculations.

We have recently amended our shaft alignment Rules (Part 5, Chapter 8, Section 5) to require a sufficient static load on the sterntube forward bearing to prevent it from unloading in all operating conditions, including the transient conditions experienced during manoeuvring turns.

The amended Rules also introduce formal requirements for bearing load measurements to be performed at the verification stage of the alignment process.

When applied to container vessels, this will mean that shipyards will need to conduct jack-up load tests on the sterntube forward bearing, all the plunger bearings and the aft three main engine bearings at acceptance sea trials.

Final adjustments to the plunger bearing height will be made, where necessary, to optimise the alignment. The final bearing load measurements required by Lloyd’s Register are to be conducted in a sailing draught condition, with the engine warmed through in order to minimise the uncertainties of hull deflections, machinery thermal rise and propeller buoyancy effects.