A guide to shaft alignment

Achieving a satisfactory shaft alignment is paramount for the safe and reliable operation of a ship during its lifetime. Lloyd's Register EMEA's Technical Investigations provides a comprehensive range of measurement and advisory services to help owners, operators and yards to help to ensure that the best possible results are achieved during the process of shaft alignment.

Modern risk assessments and technical reviews often highlight the propulsion shafting system of a ship as one of its most important assemblies, especially for single screw ships.

Powerful modern engines often feature large-diameter propulsion shafts and relatively stiff shafting systems which can adversely affect main engines and gearboxes.

On the other hand, the more flexible shafting systems used to mitigate these effects can suffer from whirling (lateral bending vibration modes). If whirling frequencies coincide with rotational speeds, catastrophic resonant response results can occur.

It is clear that a delicate balance must be struck during the processes of shaft design, installation and alignment in order to avoid costly repairs and delays later in the ship's life. An unexpected shafting system problem, for example, failure of a stern tube bearing due to misalignment, leading to an emergency dry-docking and consequent loss of availability, can cost well in excess of $250,000 per incident for a small vessel.

After the grounding of the Keymar in heavy weather, its owners engaged Lloyd's Register to check the vessels shaft alignment during each of the major stages of the vessels's repair

More serious problems, for example, involving a bent shaft and replacement for a larger vessel, can cost in excess of $1 million.

The risk of lost earnings and the potential threat to the safety of the ship make the issue of shaft alignment a critical one for owners, operators and yards.

Methods

The four most popular methods of controlling shaft alignment are:

- the gap and sag method
- optical or laser sighting
- jacking
- the strain gauge (bending moment) method.

These methods can be used either singly or in combination.

The **gap and sag method** uses precalculated flange measurements to establish the alignment, to be carried out whilst the flange couplings are disconnected. The advantages of this method include the simplicity of the measuring equipment and the ease of control in both the horizontal and vertical directions. The disadvantages are limited accuracy and the lack of applicability in the service condition. The latter is significant, as it is advisable to check the alignment of the shafting system whilst the machinery is hot.

The **optical sighting or laser sighting method** is more accurate than the gap and sag method. It uses high-quality sighting equipment and is generally used before the shafts are installed and coupled up. Optical sighting is often used to establish the reference line and the position of the engine supports and for determining how to bore the stern tube. Alignment and verification follows by means of the gap and sag method and final alignment control by the jacking and/or strain gauge method.

Optical sighting is one of four popular tried-and-tested methods used, either singly or together, to align shafts.

The **jacking method** lifts the shaft line clear of each bearing in turn by means of a hydraulic jack and calibrated load cell. The shaft is lifted in steps, whilst deflections are recorded on a dial gauge and plotted against the applied load. This method uses simple equipment and is employed when the shaft line is coupled up, ready for operation.

However, it is not suitable for the control of horizontal alignment and the yard may need to arrange for special supports for the jacks. Finally, as the jacks have to be positioned beside the bearings, adjustments have to be made to the relevant calculations to evaluate the true bearing load.

Lloyd's Register is able to provide owners, operators and yards with effective advice and guidance on shaft alignment.

The **strain gauge method** requires a combination of computation and strain measurements. If a shaft line rests on a number of bearings, a theoretical distribution of bending stress may be calculated. If the bending stresses, determined from the measured strains at an appropriate number of stations, deviate from the theoretical, this is taken to be caused by an alignment that differs from the theoretical straight-line case.

Using the strain gauge method, both the horizontal and the vertical direction may be controlled. Loads on normally inaccessible bearings can sometimes be determined. Readings can easily be taken after the gauges are fitted, and the effects of oil film formation and propeller thrust may be studied.

The disadvantages are that the method requires the skilled fitting and operation of strain gauges and suitable data acquisition and analysis software and time is required for calculations after taking the strain readings.

Checking alignment after grounding

It is not only during the installation stage that shaft alignment is a critical issue. In the event of a grounding, for instance, small movements at the shaft bearings can impact bearing loads, leading to premature alignment failure. One owner who recognised the importance of monitoring shaft alignment was Stelmar, following the grounding of its aframax tanker *Keymar*.

In early 2003, the vessel was blown onto the North African coast, along with three other tankers, by severe force 11 winds.

The grounding severely damaged 11 of the 16 double-bottom tanks in the cargo region, leaving the ship effectively floating on its tank tops. The damage eventually resulted in the replacement of over 1,500 tons of steel, and a total repair bill in excess of $10 million. In view of the significant size of both the ship and the machinery it was considered prudent by the owners to engage Lloyd's Register EMEA's Technical Investigations to check the alignment at several stages during the repair process.

A first alignment check was carried out prior to entering the shipyard to assess whether the damage had significantly affected the shafting or not. The results of strain gauging and jacking and engine crank web deflection measurements showed that the alignment was still in a satisfactory condition and that the shaft line was unlikely to need major repair A second alignment check, once the ship had settled on the blocks, showed that the significant change of stressing in the hull during settling had not further jeopardised the shafting system and that shafting repair was unlikely to be necessary.

A final alignment check, after rebuild of the hull and floatation, led to some minor adjustments to optimise the arrangements but again eventually confirmed that the propulsion shafting alignment was satisfactory. The structural repairs and associated hot work in the engine room had the potential to significantly affect the alignment, but in this instance little change occurred. "We have carried out a large number of theoretical and practical shaft alignments on a wide range of ships over many years," says Peter Filcek, Technical Manager, Technical Investigations, Lloyd's Register EMEA. "The owner was keen to avoid the risk of shaft line failure, and we were able to provide the necessary technical expertise and capability to help to mitigate that risk."

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