Casualty Information

Information from DNV to the maritime industry No. 4 June 2006

Damage to stern tube bearing and seals

Ship type: Tanker **Ship size (grt): 80,000–90,000** **Year built: 2001**

Course of events

The stern tube oil was found to contain a high percentage of water during a routine inspection. During the next couple of months closer monitoring of the water content in the lubricating oil in the stern tube was carried out in order to allow the vessel to remain in service. Finally, while the ship was afloat it was decided to replace the stern tube seals.

Extent of damages

The aft seal was found with the springs broken. Two pieces of the white metal bearing was found loose after the seal was removed, Fig. 1. Further survey of the damage in dry dock verified that the aft stern tube bearing was damaged. The condition of the aft stern tube bearing is seen in Fig. 2. Additionally, the propeller shaft was found to be cracked and bent.

If the vessel had continued without a thorough assessment of the situation and if no appropriate corrective/preventive action were taken, there might have been a substantial risk of causing further damage, even pollution, or loss of vessel.

Probable cause

The damage to the aft stern tube bearing and propeller shaft is most probably caused by loss of hydrodynamic lubrication due to excessive amount of water in the stern tube oil.

Firstly, the increase in friction between the propeller shaft and the white metal bearing had heated up and displaced the white metal throughout the entire length of the bearing. Secondly, the increased friction had overheated the propeller shaft, and upon cooling of the shaft longitudinal heat cracks had formed. As a result of the overheating the shaft had also become bent.

Fig. 1: Pieces of white metal found in the aft stern tube bearing after removal of seal.

Fig. 2: Condition of white metal bearing found in the aft stern tube bearing.

Lessons to be learned

In the following some hints are given on actions to prevent similar damages from occurring:

1. Bearing

- Check the report from last lubricating oil analysis and that content of water is normal.
- Verify that the stern tube temperature sensor is working, if fitted.
- Verify if any abnormal vibrations have been experienced.
- Seals to be removed if a stern tube bearing damage is suspected.
- Check the packing for unusual wear.
- Check whether any white metal is coming out.

2. Seals

- Check the report from last lubricating oil analysis and that content of water is normal.
- Check if a high temperature in the shaft has been noticed.
- Check if the oil consumption reported in the log book is normal.

3. Shaft alignment

- Maintaining optimal alignment of a shaft line throughout its service life is important to reduce the risk of premature failure, expensive repairs, and unscheduled dry-dockings.

  Two common methods to verify the alignment are used:

  Jack method.
  The advantage with the jack test is that it can be done with the shaft-line connected. A hydraulic jack is placed under the shaft close to the bearing to be checked. The jack load is plotted as a function of the displacement, while the shaft is being lifted and lowered. See Fig. 3.

  Gap and sag measurements.
  The gap is the horizontal distance and sag is the vertical distance between two disconnected flanges. See Fig. 4.

For more detailed information please refer to the enclosed Appendix A and B!

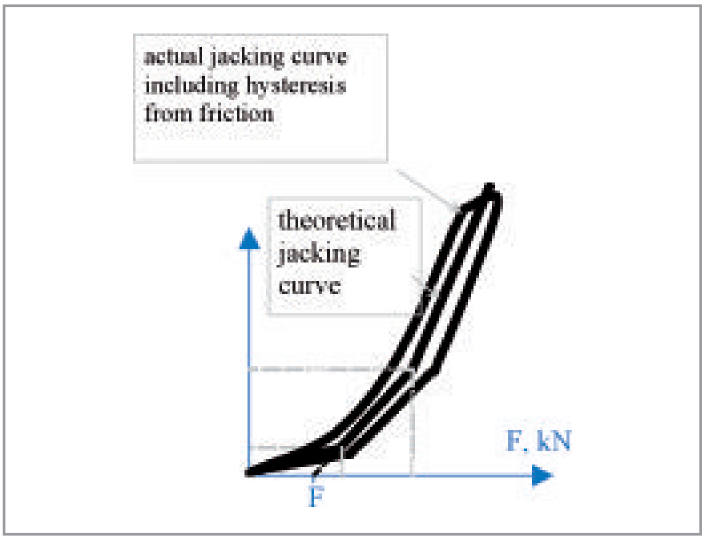

Fig. 3: Jack method.

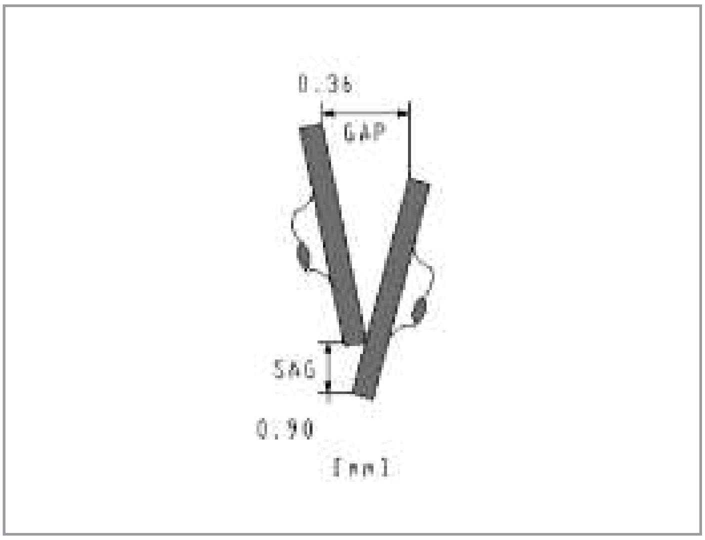

Fig. 4: Gap and sag.

We welcome your thoughts!

Casualty Information is published by DNV Maritime, Maritime Technology and Production Centre (Dept. for Ships in Operation).

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The purpose of *Casualty Information* is to provide the maritime industry with 'lessons to be learned' from incidents of ship damage and more serious accidents. In this way, Det Norske Veritas AS hopes to contribute to the prevention of similar occurrences in the future. The information included is not necessarily restricted to cover ships classed with DNV and is presented, without obligation, for information purposes only.

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Appendix A: What to check in order to prevent damages to the stern tube bearings and seals

1. Bearings

Check the report from last lubricating oil analysis and that content of water is normal.

High water content (alarm point over 3 %) might have led to an insufficient oil film due to the reduced viscosity. A practical hint on how to check the content of water is to take a sample of oil and put in a container for half an hour. The oil will separate from the water and it will be possible to see how much water is in the sample. Furthermore, some ships have the possibility to connect the stern tube oil pipes to the purifier. This may be a good option for eliminating the water until repairs can be carried out. It is important to check the trend with respect to content of tin, copper and lead. High values may indicate contact between shaft and bearing. Filtering the oil through a cloth can be useful: if there has been contact, pieces of white metal might be found in the cloth.

Verify that the stern tube temperature sensor is working, if fitted

Check if any measurement was showing excessive temperature, in general above 70°C. Compare the water temperature with the reading from the sensor. With the shaft in cold condition the two values should be comparable. Remember, records of too low temperature are also a possible indication that the sensor is not working properly. If the white metal around the sensor is not in contact with the sensor anymore, a temperature increase will not be indicated.

Verify if any abnormal vibrations has been experienced

Check bolt connections, couplings, and investigate if any damage has occurred to the propeller. An unbalanced propeller can create severe damage to the stern tube bearing due to hammering.

Seals to be removed if a stern tube bearing damage is suspected

This may give substantially more information and is often feasible without dismantling the shaft. Generally, the aft bearing is more subject to wear due to higher loads. It is sometimes possible to trim the ship to get the propeller out of the water, the seal can then be released and the bearing checked to a certain extent. The forward bearing may also be damaged and this is easier to access, although in both cases it is necessary to drain the oil.

Check the packing for unusual wear

The seals can create grooves in way of contact area. When replacing the seal it is important to remember that the seal's hardness has to be compatible with the liner material. The manufacturer recommendation should be followed.

Check whether any white metal is coming out

Particles or pieces of white metal may be found behind the seals, indicating unusual wear of the bearing, contact with shaft and/or lost bonding. A feeler gauge should be used for checking clearances. It is difficult to give general values as it depends on the shaft diameter. The maker's recommendation should be checked in this respect.

Repair of stern tube bearings

The bearing is normally re-metalled with similar type of white metal. Before re-installation, an examination should be carried out to verify bonding between the white metal and the base metal. This can be done by ultrasonic measurement or by a wood hammering test. A correct bearing clearance should be verified, and the alignment for correct line bore and slope should be check by means of optical or laser measurements.

2. Seals

Check the report from last lubricating oil analysis and that content of water is normal.

Water in the lubricating oil is a clear indicator that the aft seal is leaking.

See also above under "Bearings".

Has a high temperature in the shaft been noticed?

If the temperature has risen to above 110°C it is possible to have hardening of the seals, causing leakage. From the sealing point of view it may not be critical, but the consequences of overheating can be significant, causing hard spots and fatigue cracks on the shaft.

Has any increased oil consumption been reported in the log book?

This is the first indication that the seals are leaking. Compensating with a gravity tank may help to maintain the lubrication, but can lead to pollution if combined with a leakage of the seal in contact with sea water. In some cases it may help to use oil with higher viscosity. This may slow the leak, and allow the ship to sail to a repair yard, avoiding pollution issues. Have in mind that a leakage might develop into a violation of MARPOL Annex I.

Repair of seals

The most used seals today are the Simplex type. Typically a "lip seal" assembly consists of a number of rubber rings of special cross-section. Each rubber lip seal is held in contact with a renewable sleeve fitted on the shaft. The rubber rings are renewed by vulcanizing the new ones in situ. In case the seals have created wear grooves, this can lead to leakages. One solution may be to add/remove a distance piece to move the seals and ring assembly axially.

Have in mind that a leakage might develop into a violation of MARPOL Annex I.

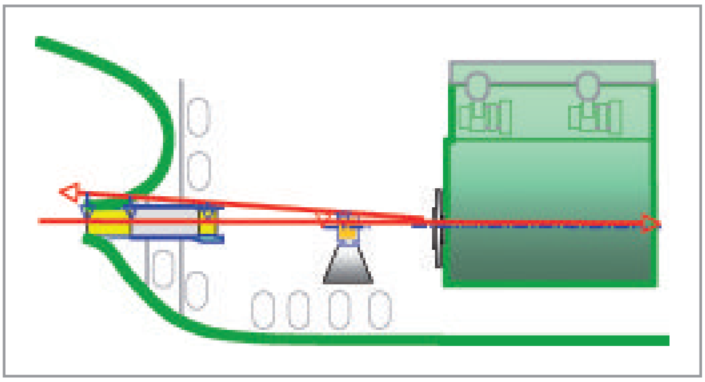

Fig. A1: Reference line from stern tube to engine and from engine to stern tube.

3. Shaft alignment

Verification of alignment

Recommended practice is to obtain the reference condition of the alignment onboard the ship before any component in a shaftline is removed for survey or repair. This is extremely helpful if there is no alignment calculation available for the ship. The baseline is useful for checking the alignment after installation of the shaft-line.

Jack Method

The preferred method is to measure bearing load using the jack test method. The advantage with the jack test is that it can be done with the shaft-line connected. A hydraulic jack is placed under the shaft close to the bearing to be checked. The jack load is plotted as a function of the displacement, while the shaft is being lifted and lowered.

A jack load diagram is shown in Fig. 3. The change in slope of the theoretical jacking curve means that the bearing has been lifted free of its support. The jack load is found at the intersection of the theoretical jacking curve and the horizontal axis. The bearing reaction is found by multiplying the jack load with the jack factor.

Be aware that the jack test cannot be used to establish the alignment if the shaft is bent. This is also true if the bearing locations have been disturbed due to a grounding or collision. But, the jack test can be used to verify if the shaft is bent.

To verify that the shaft is bent four separate jack tests are then performed at 90 degree intervals at the same axial shaft location. A bent shaft will produce different jack loads for each measurement. In this case the alignment needs to be checked after the shafts are removed. The procedure is as described above. A reference through the centerline of the aft and forward stern tube bearing needs to be established. In addition, it is necessary to measure the bearing position from a reference line normal to the gear or the engine flange center towards the stern tube. This measurement will tell if the gear or engine is tilted with respect to the stern tube, see Fig. A1.

Gap and Sag method

Gap and sag measurements can also be used to verify the alignment of a shaft-line. The gap is the horizontal distance and sag is the vertical distance between two disconnected flanges, as shown in Fig. 4.

Recorded gap and sag measurements can be compared to the calculated gap and sag values when the measurements are taken under the same conditions as calculated. This means that temporary supports are in the same location, applied loads are identical in magnitude and location and the vessel draft and loading condition is as calculated.

The tolerance on the gap and sag value should not be less than 0.05 mm.

Appendix B:
Shaft alignment – Theoretical calculations

A shaft alignment program is used to analyze the loading of the components in the shaft-line based on geometry and bearing location. The applied loads are as follows:

- Point load due to the weight of propeller and flywheel
- Distributed load due to the weight of the shaft sections
- Bending moment caused by the hydrodynamic load from the propeller
- Forces from hull deflections

Shaft alignment calculations are evaluated for cold and hot condition. The shaft-line is installed based on the calculations for the cold condition. This is a static condition with zero engine power and zero bending moment from the propeller. The hot condition simulates the ship under full power. Thermal expansion of the gear and the engine is also accounted for due to the temperature rise at the operating condition. Both cold and hot condition is modeled by offsetting the bearings vertically from a straight line through all bearings. Additionally, local temperature variations need to be accounted for if a service tank with a hot fluid is located close to the bearing supports, gear, or engine.

The results from the shaft alignment calculation are as follows:

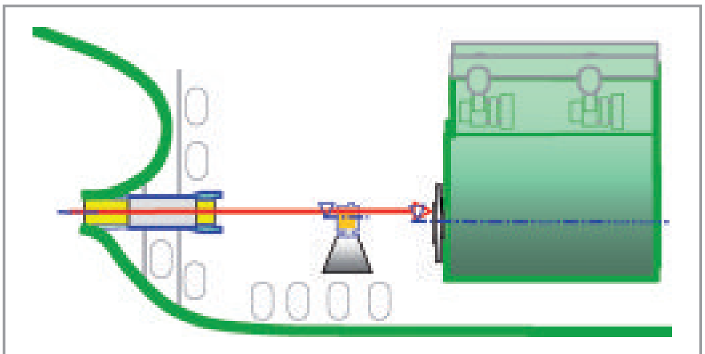

Fig. B1: Reference line from stern tube to engine.

Bearing reaction force

Gear manufacturers specify limits to force and difference in force on bearings supporting the output gear. Engine manufacturers also give limits to the force which the shaft-line can exert onto the crankshaft. Specific bearing load on intermediate bearings and stern tube bearings is calculated from the reaction force.

Shaft deflection and slope

The results of the given offsets used in cold and hot condition. The critical factor is the deflection in the aft stern tube bearing, which is used to determine if the bearing needs to be slope-bored.

Moments and shear force

Engine manufacturers give limit to permissible values in the crankshaft.

Bearing reaction influence number (RIN)

The RIN numbers describe how the bearing reactions will change due to an offset of any bearing in the system.

Gap and sag value

The gap and sag value is calculated at mating flanges with disconnected shafts. This calculation condition requires that each shaft section is supported on at least two bearing supports. Temporary supports can be added as needed. A force can be applied to the shaft at any location to keep the shaft in contact with the bearing during assembly.

Jack factors

The jack factor takes into account the difference in bearing reaction between the point where the load test is applied and the actual bearing location.

The common practice during new-building is to start the alignment procedure from the aft and working its way forward. In theory a reference line through the center of the aft stern-tube bearing and the forward stern-tube bearing is used to set the location of intermediate shaft bearings, reduction gear, and engine, see Fig. B1. In practice the offsets from this reference line is used to obtain gap and sag values, which are used in the field to carry out the alignment. Bearing load measurements are used to verify final alignment.

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