Converting An Icebreaker From An Oil Lubricated Stern Tube Bearing System To A Seawater Lubricated Stern Tube Bearing Considering Environmental And Operating Costs

Mr. Ken J. Ogle, C.Eng, MIMarEST.
Director of Engineering, Thordon Bearings Inc.
Burlington, Ontario, CANADA
keno@thordonbearings.com

and

Mr. Craig D. Carter, MBA
Director of Marketing and Customer Service, Thordon Bearings Inc.
Burlington, Ontario, CANADA
craigc@thordonbearings.com

ABSTRACT

Operational discharges of oil from the stern tube is a common occurrence for ice breakers as propellers are prone to impact from ice causing shafts to flex and seals are unable to maintain a complete barrier to keep seawater out or lubricating oil in the stern tube. Whereas solar radiation generally speeds the break-down of contaminants, the reduced level of sunlight in the Arctic lengthens the degradation process and increases the likelihood that toxic substances in the stern tube lubricating oil will find their way into the food chain. Hence, deemed “biodegradable” lubricants may not be as biodegradable in the Arctic operating environments. However, there exists a proven, viable option for vessels operating in the Arctic to eliminate stern tube oil pollution. This paper outlines the process for converting the sterntube bearings from oil-lubricated white-metal bearings to Thordon COMPAC seawater lubricated bearings, based on recent works on a twin screw ice breaker at a shipyard in Canada.

KEY WORDS

ice breaker; stern tube bearings; propeller shaft bearings; oil pollution; lubricating oil; COMPAC

INTRODUCTION

Ice breakers are an important asset to any ship owner operating in ice conditions, especially during the winter months maintaining northern waterways. Any vessel downtime due to maintenance issues could mean shipping lanes may not be open. The increased use of ice breakers and number of ships operating in Arctic trading routes have raised concerns of environmental threats to the Arctic ecosystems

While owners implement measures to prevent accidental spills, one of the major issues encountered by vessels in ice is the maintenance required to the shaft seals that contain oil in the stern tube. Even a new seal must leak a small amount to operate, ice-milling can cause shaft movements so fast that the sealing elements cannot follow the shaft quickly enough and increased leakage results. Interaction with any fishing line or similar and seal operation is seriously compromised.

It is generally solar radiation that breaks down an oil spill, however the reduced level of sunlight in the Arctic must surely lengthen the degradation process and increase the likelihood that toxic substances from stern tube lubricating oil will find their way into the food chain. Those biodegradable lubricants may not be so biodegradable after all when exposed to the harsh and uncompromising Arctic environments.

The trend towards zero tolerance for any kind of ship source pollution continues and international regulations are becoming more stringent, however the Arctic presents a significantly more serious situation. Detection, monitoring, and cleanup are difficult (and consequently expensive in cost and environmental impact) due to climatic conditions, remoteness, and the shifting interplay between land and sea-ice.

The simplest way to completely eliminate oil leakage from the stern tube is to use seawater as the lubrication and cooling medium with Thordon non-metallic bearings in place of the white metal bearings. The seawater is taken from the sea, pumped through the bearings and returns to the sea. The seawater enters the forward section of the stern tube immediately aft of the seal. The seawater passes through the forward and then aft bearing prior to re-entering the sea as shown in Figure 1.

Figure 1. Thordon COMPAC seawater lubricated stern tube bearing system

BACKGROUND

First discussion between the ship owner and Thordon Bearings regarding the possible conversion of the closed oil lubricated stern tube with forward and aft seals to an open water lubricated system with only a forward seal began in late 2006. The Thordon Engineering team reviewed the existing stern tube and shaft arrangements, bearing drawings, shaft alignment and load calculations for the ice breaker.

The vessel is 70m in length with a breadth of 14m and a draft of 5.2m. There are four main engines each 2210 horsepower (1725kW) coupled in pairs through Valmet gearboxes to drive two Wartsila controllable pitch propellers at maximum shaft speed of 240rpm. The propellers operate inside nozzles.

The major topics reviewed by Thordon Engineering included: 1) that space was available for fitting of shaft liners to Class required thickness, 2) that bearing loads were acceptable to Class limits for water lubricated bearings and 3) determination of bearing offsets and machining such as required etc. to maintain the existing shaft centerline alignment. Once these topics were reviewed and achievable, Thordon advised the customer the conversion was possible. The proposal from Thordon Bearings included the design, supply and installation of Thordon COMPAC water lubricated propeller shaft bearings in carriers, bronze shaft liners, Thor-Coat shaft coating, Thordon Water Quality Packages, and forward seals. Arrangement drawings for the conversion project were supplied by Thordon.

Due to demand for its service, scheduling the ice breaker for a stern tube bearing conversion was a difficult decision for the customer and it was mid-2009 before the order was placed for all conversion parts from Thordon. The vessel was then to drydock in the fall of 2009. It is important to note that shaft liners and bearing carriers where needed, can have long delivery lead times so it is prudent to begin the planning of an oil lubricated stern tube conversion to water lubricated Thordon COMPAC at an early stage.

BEARING CONVERSION

With the vessel drydocked, all oil was drained from the stern tube system and the tailshafts removed. Check measurements from the intermediate shafts to the aft bulkhead and sterntube bearing positions showed that surprisingly the vessel did not fully conform to the 1984 original build drawings! The variances however were small enough that it was possible to accommodate them within the parts already supplied.

A piano wire was strung through reference points and measurements from it as a datum were taken to determine the relative position of the shaft within the original bearings – this shaft position would need to be replicated with the new bearings. The forward and aft white metal bearings were then removed and their geometries verified as parallel and concentric, i.e. they had not been machined with offsets nor slope.

The stern tubes were stripped of all internal pipeworks which were becoming redundant with the new water lubricated bearings. The new bearing carriers were entered in the stern tube and the piano wire datum re-established. The carrier design included jacking screws at 120° spacing at each end and these were used to correctly position the carriers relative to the piano wire.

Since the new bearings would have a larger clearance than the originals, the carriers needed to be installed offset upwards, by an amount equal to 50% of the clearance difference, to replicate the shaft centerline alignment.

The spaces at ends of the carriers were then dammed and Chockfast orange was injected around the carriers – since this was in Canada and getting late in the year, heating of the stern tube vicinity was required for the chocking operation. Since curing of the chocking resin is exothermic and COMPAC bearings should not be exposed to temperatures above 60°C (140°F), it is preferable to chock the carriers in place empty. The carrier bores had already been fitted with bronze anti-rotation keys for the COMPAC bearing elements. After curing of the resin, repeat measurements to the piano wire confirmed the carrier positions were still correct.

All stern tube internals were then thoroughly cleaned, sandblasted and painted with anti-corrosion coating. Note - due to delivery time constraints for bronze, the ship owner had opted for mild steel bearing carriers here so these were also coated, etc.

Thordon COMPAC bearings had been pre-machined to the design dimensions ready for installation. The bearings were slotted to mate with the anti-rotation keys already fitted in the carriers. The bearing elements were freeze-fitted into the carriers - liquid nitrogen was used as coolant and only 10-15 minutes immersion time was needed to shrink the bearings enough that they were inserted into the carriers by hand. The retaining rings were then fitted and secured to complete the bearing installation.

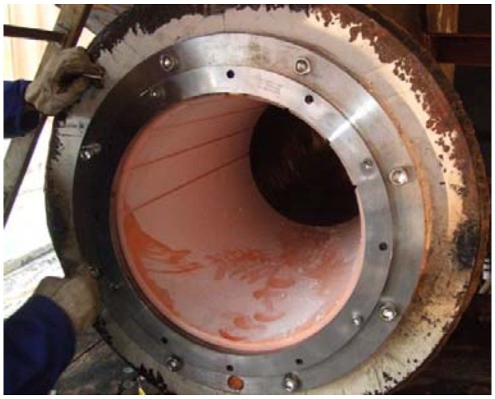

Figure 2. Retaining ring fitted to COMPAC bearing carrier

The installed bearing must be allowed to thoroughly thaw to ambient temperature before the bearing bore is measured – preferably, the bearing is left overnight and bore measurements recorded the next day.

SHAFT CORROSION PROTECTION

The steel tailshafts will now be exposed to seawater inside the stern tubes, where previously they had operated in an oil bath - consequently they need protection against corrosion.

Bronze liners were fitted to the shafts in way of the bearings and the intervening shaft surfaces coated with Thor-Coat, a 2-part epoxy coated specially developed by Thordon Bearings as a marine propeller shaft coating. The coating is designed to remain flexible to accommodate the shaft bending and torsional strains in service. The liners were of centrifugally cast gunmetal, dimensioned and hydrostatically tested all in accordance with Classification Rule requirements – in this case Lloyd's Register of Shipping.

The shafts were cleaned and linished with a 400-grit belt in preparation for the liners. The liner bores were machined to give 0.5mm (0.020") interference to the shafts. The liners were heated to 300ºC (570ºF) using electric heating elements and then slid into position on the shafts and allowed to cool. The aft liner extended to just in front of the propeller flange radius (the radius was left uncovered as is a Class survey item) so it can be finally sealed to the flange shroud with an O-ring. The forward liner extended through the seal position and into the shaft alley. In this instance, the liners were fitted with the shafts vertical as shown in Figure 3, however it is also common to slide heated liners into position along shafts horizontally as in Figure 4.

Figure 3. Steel shaft and liner, vertical.

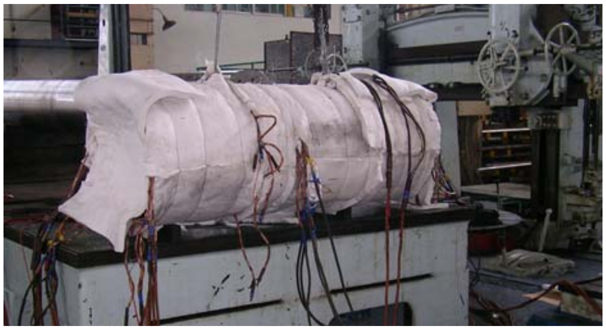

Figure 4. Liner heated for installation, horizontal.

The liner OD's were then final machined to size and with 0.4 -0.8µm Ra surface finish. For transition to the Thor-Coat, the liner ends were profiled with a grooved taper to ensure watertight transition to the Thor-Coat.

The shafts were sand blasted and thoroughly cleaned with MEK to remove any grease or other residue. The Thor-Coat was applied as the shafts were slowly rotated in a lathe. The coating was applied to a minimum of 2mm (0.080") thickness, with checks made periodically during the application using a wet coating thickness gauge.

Again, this was in Canada during the Autumn season, so four twin heating lamps at 2x500W each were used to warm the shafts towards 30ºC (86ºF) for seven hours to ensure efficient curing of the coating.

Figure 5. Thor-Coat shaft coating applied to shafts.

Next day, the Thor-Coat was visually inspected and the coating continuity checked with a "Holiday" detector set to 11.1kV. The dry film thickness was also verified as not less than 2mm (0.080") using a Positector 6000 coating thickness gauge. To discourage marine growth on the Thor-Coat surface, a tin free anti-fouling paint from Ameron Marine Coatings was then applied by brush and roller as shown in Figure 6.

Figure 6. Shaft coated with a tin-free anti-fouling paint.

The shafts were installed in the stern tubes. When handling it is important to protect the Thor-Coat shaft coating from mechanical damage - rubber sheeting was used under the slings. Liquid hand or dish soap was used as a temporary lubricant as the bronze liners were slid through the COMPAC bearings.

Figure 7. Propeller shafts installed

NEW FORWARD SEALS

New seals were procured from Sternkeeper of Japan. The new seal is of the axial type and uses a rotating rubber sealing lip acting axially against a stationary Chrome-steel face. The unit also includes an ‘emergency seal’, pneumatically energized to seal against a stopped shaft and enable maintenance of the operational seal without having to drydock the vessel.
The seals were installed to the maker’s specifications and tested successfully to 3bar water pressure.

Figure 8. Installation of forward axial seal

WATER QUALITY PACKAGE

The COMPAC bearings require a minimum water flow for cooling and Thordon Bearings’ standard requirement is 0.15 litres per minute per mm (1 U.S. gal. per minute per inch) of shaft diameter. The recommended method of supplying water to the stern tube is with a dedicated pump to supply minimum water flow requirements at all shaft speeds, a flow sensor should be provided to activate an alarm in event of low flow. Normally, seawater supplied to the bearing should be as cool as possible, not preheated from cooling other equipment and water above 40°C (104°F) should be avoided. (For strut bearings, water flow is normally provided by the motion of the vessel relative to the water and there needs to be sufficient openings at the forward and aft ends of the strut to encourage sufficient water flow through the bearing)

An important consideration in the wear life performance of any bearing system is the quality of the lubrication in which the bearing operates – in this case, the supplied seawater. Removal of abrasive particles significantly extends the wear life of the bearing and Thordon experience indicates that filtration to 150µm, or preferably 100µm, can extend bearing life to beyond 10 or even 15years.

Thordon Bearings offers Water Quality Packages which include pumps, cyclonic separators and automation as a “plug-n-play” unit as shown in Figure 9. The separators are rated to remove particles greater than 80µm with specific density greater than 1.2. The collected debris is automatically purged overboard on a timed basis. For this vessel, 2 units were supplied, one per shaftline.

Figure 9. Thordon Bearings Water Quality Package

TESTING AND SEA TRIAL

The vessel left dock and conducted trials in Lake Ontario. The bearings performed satisfactorily and after correction of some issues with the Water Quality Package, automation link-ups to the vessel’s control systems, those packages worked well also. The conversion was considered a success.

PERFORMANCE ADVANTAGES

Zero Pollution Risk from Leaking Shaft Seals

The COMPAC seawater lubricated stern tube bearing system eliminates stern tube oil leakage as the lubricant is sea water. There is no aft seal, no storage of oil, no sampling of oil, no disposal of stern tube oil and no worry of seawater ingress to contaminate the oil and cause bearing problems.

Expensive, multiple chamber aft seals designed to ‘trap’ oil leakage and drain it inboard for further processing and disposal are not required.

Thordon’s COMPAC system ensures ship owners/operators that there will be no environmental violations resulting from stern tube oil leakage.

Low Friction

Thordon COMPAC stern tube bearings are designed to operate hydrodynamically. The lower (loaded) portion of the bearing is smooth and the upper half is designed with water grooves to assist lubrication and cooling. The smooth lower surface promotes generation of a hydrodynamic film at lower shaft speeds than other, fully grooved, water lubricated bearings.

Power losses with hydrodynamic operation are attributable to shearing of the fluid film. Since water is less viscous than oil, operation with water should theoretically result in less power loss within the bearing as shown in Figure 10 - with potential fuel savings.

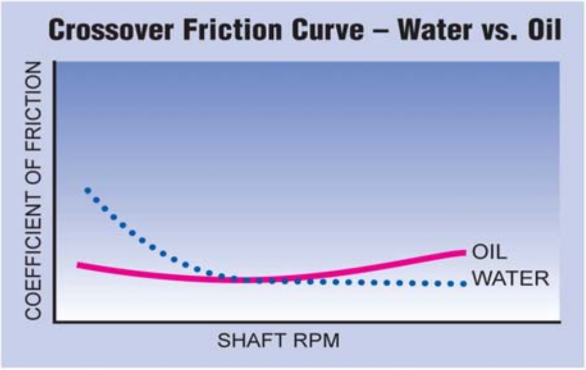

Figure 10. Friction curves, water vs. oil

Reduced Drydocking Costs

Scheduled drydocking costs are a major part of any vessel’s operating budget and the expense of an unscheduled emergency drydock is particularly distressful for any shipowner. Those emergency drydockings are often to repair leaking stern tube seals. There are also the fines levied by authorities and bad publicity for vessels leaking stern tube oil. Replacing that stern tube oil with water eliminates the source of the stern tube oil pollution. The ship owner is free from worry about fines and court costs, and will never again have to pay for a drydock because of stern tube oil leakage.

The need for bronze liners and corrosion protection of the shaft typically means a higher up-front dollar cost for a seawater lubricated COMPAC system compared to an oil lubricated white metal stern tube system for the same vessel.

However, that extra cost up-front is recouped with lower in-service costs - reduced seal maintenance, no oil sampling, not to mention the unexpected costs associated with leakage.

Based on existing experiences with Thordon COMPAC stern tube bearing systems, the overall vessel life cycle costs have been reduced for these ship owners. Indeed, there has been considerable interest from many ship owners to converting existing vessels from oil lubricated stern tubes to water lubricated COMPAC.

Survivability

During operation of a white metal bearing, interruption or compromise of the oil-film from water contamination can have serious consequences. Significant frictional heat is produced and the babbit metal melts – the bearing ‘wipes’ and there can be considerable consequential damage to the shaft also. Such is somewhat catastrophic and can incapacitate the vessel - if in Arctic waters, the survival conditions for the vessel and crew are likely to be less than hospitable.

Should cooling water flow to the COMPAC bearing fail permanently, or the bearing get into distress for other reasons, the scenario is much less dramatic. The bearing will overheat and the polymer will soften. The softened polymer will wear faster than normal but there is no shaft damage. Operation of the bearing can continue for considerable time – days, perhaps weeks depending on how cool the bearing can be maintained so the vessel can continue passage to safe port or until assistance is available.

CONCLUSION

Currently, many of the ships operating in the Arctic have propulsion systems using propeller shafts supported by oil lubricated metal bearings with the oil contained in the stern tube by forward and aft shaft seals.

According to seal manufacturers, the seal must leak (aft-into the sea or forward-into the ships bilge) at the shaft/seal interface in order for the seal to function properly.

Introduction of any simple fishing line or net, or any rope caught on a ships rotating shaft can also damage the aft seal allowing stern tube oil to swiftly flow out into the sea.

With experience with seawater lubricated propeller shaft bearings with many of the world’s Navies and Coast Guards that have traditionally used seawater lubricated bearings for safety reasons and the non-catastrophic failure mode, Thordon’s COMPAC seawater lubricated bearings eliminate the potential for any pollution risk to the Arctic ecosystem while offering performance benefits and lower overall operating costs - surely that makes sense for both the owner and operator?