Return to Session Directory

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THRUSTERS

DP Drilling Operation Success - Electric Pod Thrusters Extend Maintenance Intervals

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Introduction

In 2004, sixteen electric pod thruster units (3.3 MW power each) were installed on two semisubmersible vessels under construction in Singapore. These vessels were delivered by the shipyard in Spring 2005, and sailed from Singapore to the Gulf of Mexico, self-propelled by the new electric thrusters.

After a challenging initial service period in the Gulf (summer included two major hurricanes, Katrina and Rita), the vessels finally started operation as 2005 drew to a close.

The vessels carried one spare thruster unit on their initial journey; the thuster pods are designed for underwater removal and installation. It is common practice to change thrusters in the field, eliminating a trip to the dock (and providing significant cost savings).

Four additional thruster units were delivered in 2008 for maintenance rotation, and thruster maintenance sequencing began in 2009. This paper describes findings from the thruster units that have been overhauled, focusing on the most important components, including photos from disassembled components.

Some of the thrusters are still operating with initial components; since the underwater part of the thruster cannot be maintained *in situ*, the components inside the unit must be designed to be as reliable as possible, and that reliability has proven itself in the field. The rugged thruster design technology is also reviewed in this paper.

Vessels

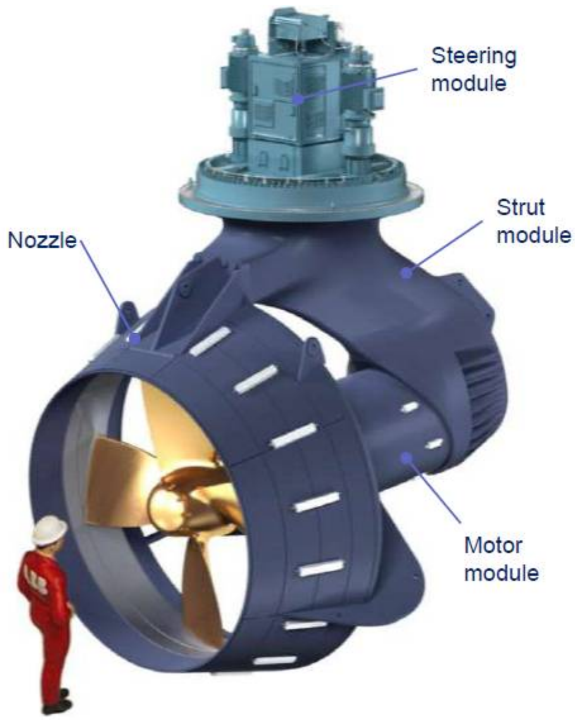
The semisubmersible vessels *Development Driller I* and *Development Driller II* were designed by marine architects Friede & Goldman for ultra-efficient production (development) drilling in nominal operating water depths to 7,500 ft. The vessels, built by the Jurong shipyard in Singapore, are designed to operate in moderate environments such as the Gulf of Mexico, West Africa, and Brazil. *Development Driller II* started operation at the end of 2005, followed by *Development Driller I* at the beginning of 2006. Since then, the vessels have been operating at various locations in the Gulf of Mexico.

Pod thrusters were selected for both vessels, with eight pod thrusters installed in the design, two thrusters at each end of both pontoons.

In the *Development Driller* series' design, dynamic positioning operations can accommodate thruster failures (within the designated maximum environment conditions). However, even with this capability, a thruster failure can result in operations interruption and vessel downtime. Should a thruster fail, the time to repair can be costly; with the high operational costs of deep water development vessels, downtime is unacceptable, and therefore, reliability is the highest priority.

Pod thruster

The pod thruster has an electric permanent magnet motor module operating in submerged conditions and cooled directly by the surrounding seawater. It differs remarkably from mechanical thrusters by having a totally gearless drive train from motor to propeller; thus, the pod thruster is immune from gear-related drivetrain issues, and does not need to be filled with lubricating oil. The pod thruster's shaft bearing lubrication can be selected according to bearing needs alone.



4.5 MW pod thruster

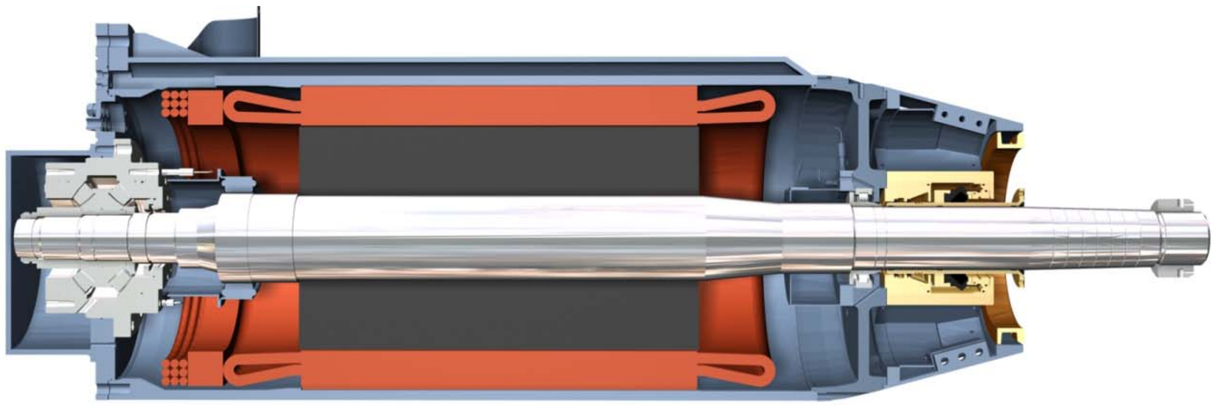
Motor module

The motor module is a simple mechanical design—only the necessary components to provide propulsion thrust are included. The main parts are the permanent magnet motor with frame, bearings, seals and service brake; any other control or monitoring systems are installed in the thruster room inside the vessel (with the exception of monitoring sensors in both the motor module and bearings).

The motor can be driven in both directions of rotation with full torque capacity (however, due to the propeller's hydrodynamic features, negative direction rotation produces reduced thrust).

The propulsion motor, bearings and seals are directly cooled by the surrounding seawater. The motor's interior is pressurized with the vessel's compressed air supply. A slight positive internal pressure is created, and the small airflow pumps liquids out from the water-lubricated outer seal chamber.

Both bearings are cooled by surrounding seawater. The drive-end (DE) bearing is a grease-lubricated cylindrical rolling bearing, while the Non-drive-end (NDE) bearing is an oil-sump-lubricated spherical thrust bearing (refer to the crosssectional image below). Oil in the thrust-bearing oil sump (less than 100 liters per unit) can be changed from inside the vessel by using the internal pressure of the motor module. The bearing is designed to withstand full-thrust force in both directions, and the housing is equipped with electric insulation to eliminate possible bearing currents.

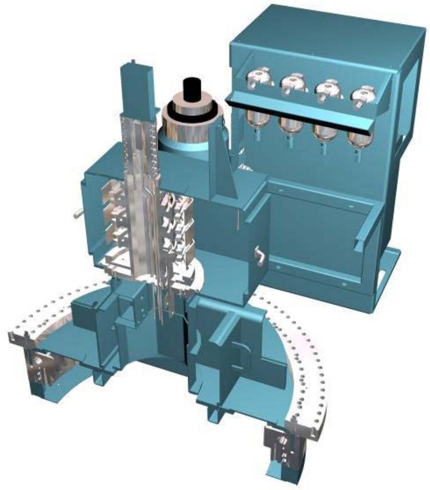


Cross section of Motor Module

The shaft seal system is a combination of a face-type outer seal and additional lip seals. The outer seal is a water-lubricated ceramic type; the original design of two grease-lubricated lip-type seals to provide redundancy between the water seal and the bearing has been increased to three seals. Lubricating water from the outer seal can be pumped into the thruster room and monitored from inside the vessel using monitoring cups.

Steering module

The steering system is a fully electric steering drive. The steering module (refer to the image below) incorporates the sliprings for the main power supply and control lines; a swivel joint for grease, oil, and pressurized air supplies; a slewing bearing with seals and steering motors with planetary gears; an automatic greasing unit with piping; and, main and auxiliary terminal boxes.

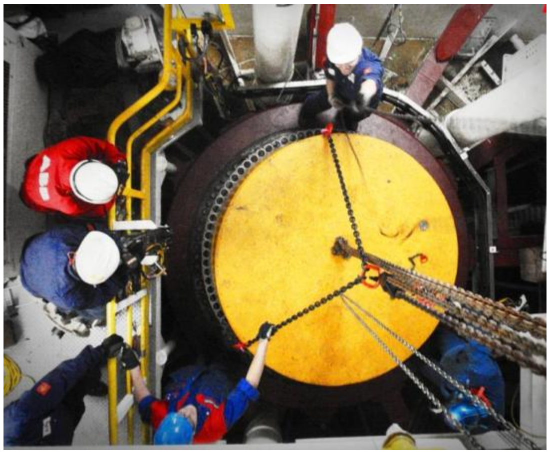
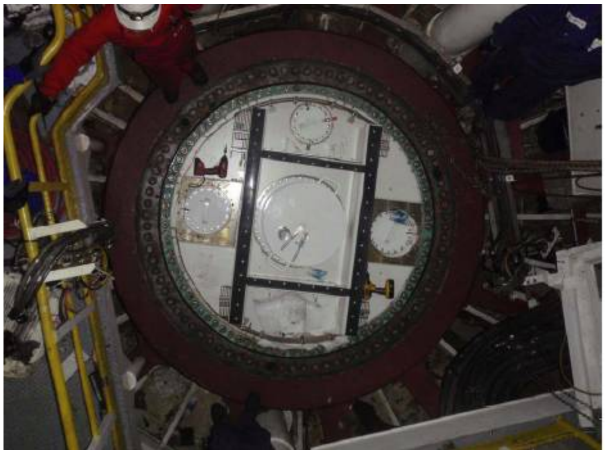


Cross section of Steering Module

Experiences

Operational experience with the pod thrusters has been generally very good. No reduction of semisubmersible drilling rig performance has been attributed to the pod thrusters and, according to the drilling rig operator, the pod thrusters have delivered the reliability needed for drilling operations.

The underwater parts of several thrusters have been replaced with new or refurbished ones as part of maintenance operations. The thruster change-outs have been performed while the drilling rigs have been floating. The thrusters have generally been in good condition after years of operation; all the thrusters that were removed for planned maintenance were still fully capable of continuous operation.

Photos from thruster room during thruster assembly

The changeout and overhaul schedule was based on the vessel owner's drilling schedule; all the operations were conducted while the vessel was in transit, or out of drilling operations for some other reason.

Maintenance rotation started in June 2009 with a first set of four thrusters dismounted from *Development Driller II* (refer to the photos below). These units had been in operation over 32,000 hours. The second set of five pod thruster units from *Development Driller I* was changed in June 2010 after approximately 40,000 operating hours. A third overhaul set of four units from *Development Driller II* was changed in February 2011 after 47,000 hours of operation; the rest of the thrusters are planned to be replaced after about 60,000 hours of operation.

Lifting a used thruster

Thrusters onboard transportation vessel

Shaft Seals

The shaft seal packages have worked well; some design improvements have already been applied to overhauled units. No major leakages have been reported by the system leakage indicator; however, during maintenance on some of the thrusters, corrosion was found on the connecting hoses between the strut module and the motor module. To eliminate this corrosion, the hose has been changed to a PTFE-coated type, and this improvement has been applied to all thruster units during overhaul.

All shaft seals have been replaced during overhaul, and the seal packages have been dismantled and inspected visually. There has been visible weardown of the ceramic face seal, mainly due to the original setting of the compression force on the face seal, which was unnecessarily high.

The springs compressing the face seal have been observed to be in good condition; there has been deformation in the sliding ring, and dezincification in the intermediate sleeve.

Visible grooves have been found in the liner of the lips seals (refer to the image below), but they have not been so deep that seals would not be capable of continuous operation. In a couple of the thrusters, there have been signs of crevice corrosion between the liner and the propeller shaft. These corroded spots have been repaired during overhaul and the assembly process quality assurance protocols have been improved to mitigate the risk of crevice corrosion under the shaft seal liner.

Disassembled seal liner

Three shaft seal packages were sent to the seal manufacturer for further investigation. The manufacturers measured wear rates for face seals, lip seals, and lip seal liners, and conducted materials tests to determine seal material aging.

Based on the manufacturer's examinations, the estimated lifetime of the original seals would have been approximately 7.5 years; this is the estimate for the outer seal–there is still redundancy due to secondary seals and pressurization system of the thruster unit. Shaft seals can also be replaced *in situ* by divers, if necessary.

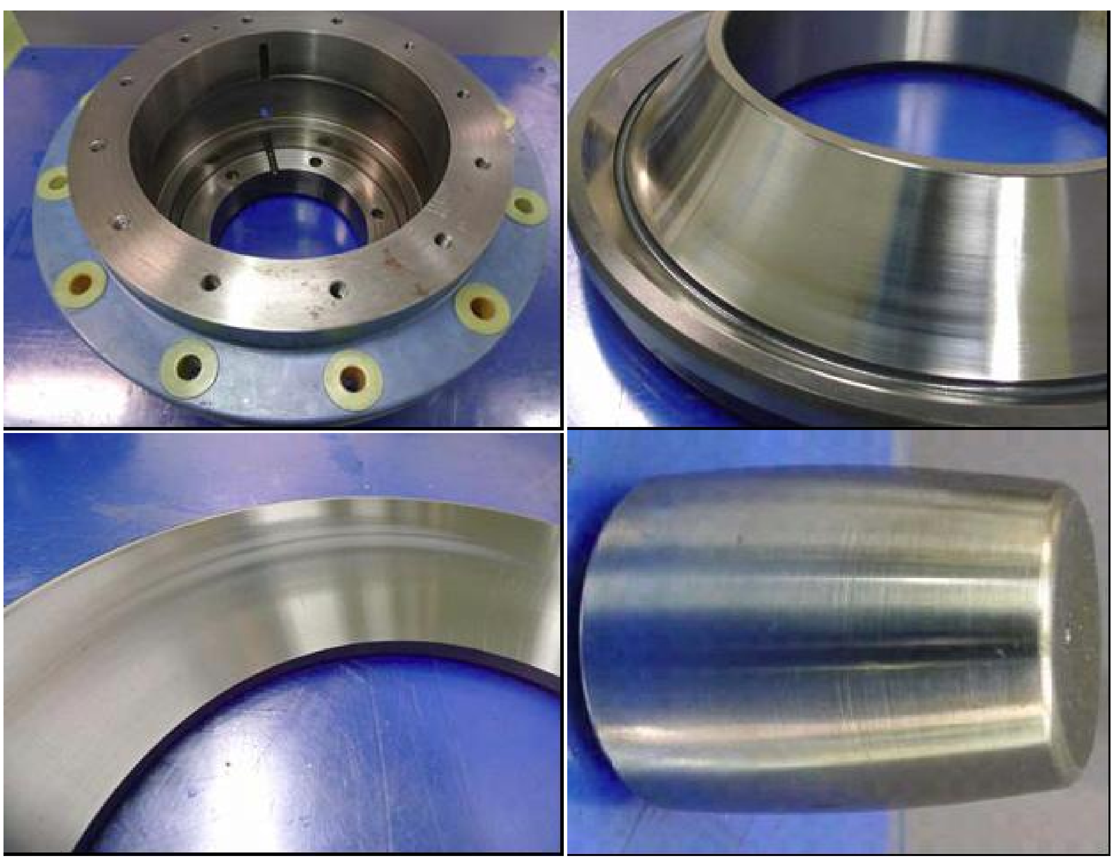
The original seal design has now been modified to extend the lifespan to over ten years. The spring compression force has been adjusted to reduce load on the ceramic face seal, and both the counterpart of the sliding ring design and the type of sliding ring glue have been changed.

Liner material has also been changed to further increase the lifespan, and the intermediate sleeve material has been changed to avoid possible corrosion of the sleeve. On the secondary seal, a third seal lip has been added to increase the lifespan and redundancy of the seal package, and the lip material has been changed to reduce the seal hardening during aging.

Shaftline Bearings

Non-drive end bearings, also known as thrust bearings, have not shown any indication of problems during operation. After dismantling of the thrusters, the non-drive end bearing units were sent to the bearing manufacturer for investigation. The bearing manufacturer dismantled the roller units and conducted investigations on bearing elements.

There have been visual circumferential path patterns in all of the raceways of the thrust bearing unit, and the same kind of circumferential lines can also be seen in the rollers (refer to the images below); however, this wear has been only a polishing of the surface, and has not yet caused any grooves affecting the performance of the bearing. The inboard seals of the bearing units have been in good condition, with no signs of oil leakage from the seals.



Disassembled Thrust Bearing (from upper left corner: housing, inner race, outer race, and roller)

The bearing manufacturer has stated that bearings are in good condition and capable of continued operation. The housing parts and the sleeve have been re-used, while the raceways and rollers have been replaced.

Drive end bearings, also known as propeller bearings, have all been replaced during thruster overhauls (refer to the images below). All the replaced drive end bearings have been in very good condition and would have been capable of continued operation.

Disassembled DE-bearing (outer race, inner race, cage and rollers)

Slewing Gear

Slewing gears have been in good condition (refer to the images below). Gear tooth mating has been good, and only cleaning has been performed during the overhaul.

Slewing gear teeth

Slewing Seals

During operations, no major leakages have occurred from the slewing seals. On disassembly, there have been visible grooves in the sealing liner (refer to the images below), but the seal profile and liner has still been in such good condition that the sealing could have been used for a longer period; however, all the seals have been replaced in overhaul and the liner has been polished.

Slewing seals after disassembly

Slewing seal liner

Slewing Bearings

Slewing bearings have been generally in good condition. When the bearings have been dismounted, the elements have been polished to remove small wear-and-tear marks and then reassembled with old elements (refer to the images below). Some bearings have shown marks of etching and corrosion and, in those cases, the bearing balls have been replaced and the raceways polished. Even though there have been marks of corrosion, all the slewing bearings have been in operative condition. No changes have been noticed in torque needed by steering motors when rotating the thruster.

Slewing bearing components during maintenance

Propulsion Motor

All propulsion motors have been inspected during maintenance. The insulation resistance of the stator has been measured to define the stator condition, and insulation resistance levels of all the stators have been within acceptable tolerances; this performance parallels the experiences of electrical podded drives in other types of vessels.

Some of the rotor shafts have been inspected with dye penetrant; eccentricity of the shafts has been checked with a dial indicator.

The permanent magnet motor typically does not require much maintenance. When thrusters have been dismantled in the maintenance facility, it has been easy to clean and re-lacquer the stators and the rotors, even though this procedure is not mandatory for the motors (refer to the images below).

Disassembled stator and permanent magnet rotor

Equipment in thruster room

Equipment in the vessel thruster room has also been maintained during the operational period. Some of this equipment requires replacement at shorter intervals than the overhaul period for the thrusters, but this does not affect the main maintenance interval – replacement of consumable parts and worn components can be performed during normal operation breaks.

One component was found to require more maintenance than anticipated – the rotary fluid joints have worn down faster than originally designed. While the joint is on top of the slipring unit (refer to the image below) and easily reached, maintenance will still require the thruster to be stopped; however, the work can be planned in advance, and performed relatively quickly, one-by-one, on the thrusters.

Studies to improve the design have been conducted; however, the final solution is still in development.

Rotary fluid joint

In general, since there are no hydraulics systems, lube oil circulation system, nor cooling system needed on the thruster, thruster room maintenance needs are relatively quite small.

Class requirements

ABB has started discussions with ABS and DnV to verify requirements and extended maintenance schedules. Classification societies do not make specific requirements with regard to maintenance scheduling; the recommended schedule is mainly based on original design-life calculations and manufacturer's recommendations. In this case, the original recommended intervals were based on five-year maintenance intervals for the main wearing components (such as shaft bearings and shaft seals, slewing bearing and slewing seals); Due to improvements that have been made already during operations (especially for the new build and refurbished units), the schedule is planned to be extended to ten years.

After five years of operation, monitoring of main components will become more important. To monitor components, shaft bearings are equipped with temperature sensors and vibration sensors; the shaft seal can be monitored from the thruster room by following up possible leakages from different sections of the shaft seal using indicating sightglasses. In case of a leak in the main seal, the redundancy available with the lip seals can be activated.

Conclusions

Based on the examinations and inspection results, the maintenance interval is primarily driven by shaft seal life. Investigations performed on used seal packages show that life expectancy exceeds the originally planned five years. Since the first two vessels' delivery, vast improvements have been made on shaft seal design, and seal life. Even if a malfunction were to occur in a single component of the shaft seal system, there would be no immediate need to overhaul the thruster, because of the redundant design of the shaft seal system…and, if a major malfunction were to occur in the shaft seals, the seals could be changed underwater.

Almost no wear has been observed in the slewing bearings; only minor corrosion marks have been found. This corrosion or etching has neither affected the operation nor caused damage to slewing bearings. In the slewing seal liner, only been minor grooves, not affecting sealing performance, have been found.

The shaft line bearings inspected have been in very good condition, with no signs of premature wear or damage; these findings confirm that the lubrication has worked very well. The electrical insulation of the non-drive end bearing is also preventing shaft currents efficiently, and these results are well in line with the original design calculations. Shaft-line bearing life is not seen as a constraint in units that are operating mainly in DP mode.

The performance of the permanent magnet motor has achieved expectations. During the lifetime of the gearless propulsion motor, there should not be any need for major maintenance actions.

Based on the well-documented operational and maintance history, and the findings of the maintenance overhauls, a ten-year recommended maintenance interval for a podded thruster operated on a dynamically positioned vessel is certainly justified.