COMMERCIAL SPOOL PUMP BEARING PERFORMANCE TESTING

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ABSTRACT
Canned motor pumps have been used for decades in nuclear power systems to eliminate seal leakage by using water coolant lubricated hydrodynamic bearings. Other process fluids like pressurized hazardous propylene also need such pumps. Hydrodynamic propylene bearings run with high-loss turbulent flow, which requires high cooling flow that is not available. Therefore, an alternative, almost frictionless, bearing system has been tested successfully for propylene and similar process fluid canned motor Spool Pumps™. This innovative double-row hybrid-ceramic ball bearing uses patented AEROFLOAT® design cages to reduce ball/raceway lubricant film shear stresses and patented solid-lubricant supply components called RINGLUBE®, thus eliminating the need for any external lubrication. After accelerated life testing for the equivalent of almost two months of continuous pump service, there was so little wear on the ball tracks and the RINGLUBE® that the projected continuous pump service life is likely 10 to 20 years.

INTRODUCTION
Early prior research demonstrated the existence of elastohydrodynamic (EHD) lubricant films at ball and roller contacts (1) and the superiority of ceramics for bearings (2). These concepts are now used in the design of lubrication systems with solid lubricants that operate in much more severe environments than oils and greases (2, 3). Proprietary computer codes and unique patented bearing configurations for optimizing the performance of bearing/solid-lubricant systems have been developed (5, 6 and 7). In this way, patented self-contained solid-lubricated all-steel and hybrid-ceramic ball and roller bearings are now available for environments that do not contribute to their lubrication, such as in air or vacuum.

TEST BEARING AND RIG DESIGN
Starting with the above experience, a solid-lubricated RINGLUBE® hybrid-ceramic AISI 52100 steel double-row 319-size ball bearing was designed for a canned motor Spool Pump(TM) with optimum performance at 28,000 gal/min (106,000 liters/min) of 500 psi (3,450 kPa) propylene. This design consists of solid-lubricant-coated rings and 16 bearing-quality 1" (25.4 mm)-diameter ceramic balls per row on a 6" (153 mm) pitch diameter with 30-degree contact angles. At 1,200 rpm speed under 150 lbs (667 N) radial load, 5,000 lbs (22,240 N) axial load and 1,450 in-lbs (164 N-m) overturning moment, a target life of ten years' continuous operation with no re-lubrication was desired, with inspection after three years in initial pump service.

A Spool Pump™ bearing test system was designed and manufactured for running under accelerated test conditions to verify the successful performance of the test bearing. The mechanical test fixture for this system is shown in the photograph in Fig. 1. In order to avoid the toxicity and flammability of propylene, the test bearing was submerged in a liquid simulating propylene, Mobil's Velocite 3, having a viscosity of only two centistokes at the mean test bearing and fluid operating temperature of 115 F (46 C) in these bearing tests, selected to avoid approaching in the test rig the 169 F (76 C) flash temperature of Velocite 3. The test rig components were manufactured, assembled and checked-out to assure proper performance of all systems.

FIGURE 1. CLOSE-UP OF RIG WITH TEST BEARING HOUSING AT THE BOTTOM & LOAD ARM ON TOP
TEST RESULTS

The test bearing was tested in the test rig shown in Fig. 1 under accelerated test conditions of 2,400 rpm, 7,000 lbs (31,140 N) axial load and 1,450 in-lbs (164 N-m) overturning moment for a total of 216.5 hours, 97% of which running time was at the full above test conditions. Disassembly of the bearing after testing revealed no visible sign of wear on the ceramic balls and no significant wear in the ball tracks on the rings, only a smooth track surface with the original finish marks still visible. There also was a minimum amount of wear on the soft solid-lubricant-film-replenishing carbon-graphite patented RINGLUBE®, only a polished track where it contacted the balls during running, as intended, and as shown in the photograph in Fig. 2. The total wear depth on the RINGLUBE® where it contacted the lower row of balls is less than .001 inch (.025 mm). The loaded half of the test bearing inner ring after testing is shown in Fig. 3, with the wear track in its groove barely visible. From Talyrond traces across the groove wear-track in Fig. 3, a mean wear depth of only about five to ten micro-inches (.00013 to .00025 mm) occurred in the inner ring ball track during the test.

The equivalent Spool Pump™ continuous service life of the test bearing run for 210 hours under full accelerated test conditions of twice the service speed and 1.4 times the service load, with ball bearing fatigue life varying as the cube of the load and directly as the speed, is 1.4^3 x 2 x 210 = 1,152 hours, or .13 years. An estimated 300 micro-inches (.0076 mm) total wear depth on bearing-ring ball tracks is considered the end of the useful life for this type of bearing, due to loss of preload.

Assuming a linear wear rate, the projected bearing wear life from this test is estimated as 0.13 x 300/(5 to 10) = 3.9 to 7.8 years. However, bearing wear rates are typically higher by about a factor of three during the initial run-in than during most of the bearing life, so that a more realistic projected bearing wear life is (3.9 to 7.8) x 3 = 11.7 to 23.4 years. The minor wear of the patented RINGLUBE® solid-lubricant-film replenishment component after the above testing, compared to its cross-section, could be multiplied by one to two hundred times before any significant weakening of its section would occur, indicating 13 to 26 years’ continuous service life, well in excess of the target life.

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REFERENCES