FROM LAB TO FIELD: NEW HIGH PERFORMANCE WATER LUBRICATED BEARINGS

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ABSTRACT
Recent independent lab testing and field trials have verified significant wear and friction reductions are possible with a new family of polymer alloy bearings. Advanced water-lubricated bearings with projected pressures in the range of 3448 to 6895 kPa (500 to 1,000 psi) are possible with length-to-diameter (L/D) ratios as low as 0.2 without end leakage. Much higher pressures are made possible by dimensionally controlling the “stiffness” (shape factor) of the rubber/plastic alloy bearing.

INTRODUCTION
The need to develop the new polymer alloy arose because rubber bearings had reached the end of improvement possibilities. Minimum L/D ratio of four and maximum projected pressure value of 276 kPa (40 psi) had been set by regulatory agencies back in the 1930s. Discovery of Plasto-Elastohydrodynamic pocket-forming lubrication (PEH) in the 1970s resulting from thinner rubber molded with very smooth and flat bearing surfaces resulted in hydrodynamic lubrication for the first time. Reductions of over ninety-five percent in friction and wear resulted. By the 1990s further improvement was required to meet performance expectations in military and commercial marine and industrial bearing applications. The challenge was two-fold: reducing the low-shaft speed friction to eliminate stick/slip noise and to significantly improve the load-carrying capability.

THE APPROACH
The project plan was to attain the low wear and high speed friction advantages of the water-lubricated nitrile rubber bearing combined with the toughness and low speed friction of Ultra High Molecular Weight Polyethylene (UHMWPE). UHMWPE was chosen for its unique characteristic of having dry low speed friction values almost as low as those of PTFE (Polytetrafluoroethylene). Additionally, UHMWPE is much harder than PTFE and does not depend on an easily washed-off transfer film being formed. The proposed formulation was to use the thermoplastic UHMWPE as a binder with a thermostet nitrile rubber filler to obtain a polymer alloy with both rubber and plastic properties.

BACKGROUND
Water-lubricated bearings have historically not been specifically designed for the application but rather, were developed to take advantage of naturally occurring materials (natural rubber, lignum vitae and maple woods), readily available industrial materials (fabric-reinforced phenolics) or easily manufactured liquid cast materials (polyurethanes). Efforts to make polyurethane materials useful despite their history of excessive bearing and journal wear have resulted in the development of closed circuit systems which utilize special lubricants and very expensive shaft sleeve materials. The use of these inefficient closed systems negates the simplicity and reliability of open water-lubricated systems. To date, none of the phenolic resin composites or polyurethanes listed by Gilbert et al (1) can meet the very stringent wear and friction requirements of the U.S. Navy (2).

RESULTS & DISCUSSION
The test results for the water-lubricated polymer alloy (DMX®) bearing have exceeded expectations. Two wear tests were specifically chosen for their ability to evaluate the test samples at opposite ends of the wear spectrum. The main screening test was the 28-day clean water Heavy Load Wear Test (HLWT) (3) which simulated highly loaded clean water applications. At the other end of the spectrum was the U.S. Navy Kommers bearing/journal system abrasive wear test (2) that simulated highly abrasive low speed applications.

During the first test the new DMX® bearing had a HLWT specific wear value in the same range as rubber (3). Unexpectedly, it was next discovered that when the axial length of the DMX® sample was reduced by 50 percent (doubling the radial projected pressure) the specific wear dramatically decreased from 1.06 to 0.21 (3). This was due to the “shape factor” reduction of the shorter DMX® sample allowing formation of a Plasto-Elastohydrodynamic (PEH) lubricant-trapping pocket at the higher pressure. Previous to the development of DMX® the best bearing material tested was a nitrile rubber sample that when identically tested showed increased specific wear of 458 percent.

In addition, the unanticipated and significant findings from the U.S. Navy Kommers bearing/journal Abrasive Wear Test (KAT) showed that DMX® performed as well as rubber and the journal wear was an unprecedented zero. A final Friction test of a shorter bearing having a lesser number of staves showed a very significant reduction in friction (3) due to the substantial increase in surface pressure (fig. 1).
Finally, one of the most important findings during the testing of the DMX® bearings was the noticeable absence of noise and vibration. Typical bearing noise including “stick-slip” and “squeal” were eliminated.

INDEPENDENT CONFIRMATION OF RESULTS

Independent testing of the DMX® material and bearing design was completed by BMT Defense Service Limited. Their findings confirmed our laboratory test results. A general description of BMT’s overall testing program is given in ref. (1).

The first test program conducted at BMT was a comparative trial on a 200-mm shaft for 650 hours at loads of 4.5 bar (66.2 psi) and 6 bar (88 psi). The test sample bearing had a L/D ratio of 2 that when combined with 2 load-carrying staves, increased the contact pressure to the desirable range for the test. Shaft speed was varied from breakaway to 200 rpm. Some of the tests were run with gritted water. Wear was very low, occurring during the first 350 hours of clean water operation. (We believe the BMT’s wear results were slightly higher than actual wear because their results were determined dimensionally...although still very good, this method of testing does not consider the deflection change from the pocket-forming action due to Plasto-Elastohydrodynamic lubrication (PEH). Our internal wear testing methods remove this deflection dependence by using dry weight loss values as criteria.)

Water temperature increase was minimal. Further testing was recommended based on superior bearing test performance during the first program. Subsequent testing programs found similarly favorable results after evaluating the bearings for 2000 hours, on a larger diameter (500-mm) shaft and on an Inconel® 625 shaft. Additionally a test simulation of a misaligned Hunt Class stern tube bearing was conducted. The misalignment condition in this class of composite vessel is typically caused by the machinery raft sagging as the ships structure ages. Performance of DMX® in this test against Inconel® 625 was rated excellent and the Hunt Class bearing misalignment had no appreciable effect on bearing performance or shaft wear.

Once again, all tests conducted by BMT showed the same lack of noise or vibration even after shaft rotation reversals. After the DMX® break in period on all tests, the friction characteristics remained very low and the excellent wear results remained unchanged.

OTHER DMX® BEARING APPLICATIONS

There have been a number of other interesting applications of the DMX® material in bearings and flat wear plates. One situation involved a riverboat in which a rope wrapped around the shaft of the DMX® bearing thereby blocking the water flow. No trouble had been reported. Grit and dirt was pressed into soft surface of the overheated staves. No particular shaft damage was noted. The bearing was operated for some time after the rope was removed and lubricating water flow restarted. After final removal it was discovered that the staves had started to heal themselves; several of the irregular contact areas in the load zone had repolished and were operating hydrodynamically. The calculated contact pressure was well within the acceptable range for DMX® staves. (With DMX® any shape contact area can develop hydrodynamic lubrication). The binder being thermoplastic means it may deform and flow somewhat when overheated but it will not char as do thermostet bearing materials.

Another application involved wear plates lining the notch in the stern of a barge in which the bow of a tugboat was linked while the barge was pushed to and from Europe (fig 2). Initially the sides of the notch were lined with polyurethane slabs to protect against tug-barge relative vibratory abrasion. However the stick/slip noise was so loud and annoying that the crew had to use a grease lubricant. The water-lubricated DMX® plates were not noisy because there was no stick/slip action.

CONCLUSIONS

The new DMX Bearings showed by every measure low water lubricated friction in all four regimes: dry, boundary, mixed and hydrodynamic. Especially noteworthy was the very low breakaway, and low speed friction coefficients where most of the wear occurs during start-up and shut-down.

Both in-house and the independent full size lab test results showed low bearing and shaft system wear. These results were further substantiated through actual field use.

Today when ecological and natural resource concerns and laws are increasingly restrictive, a long life bearing system whose very slight wear debris is benign and whose readily available lubricant is 100% recyclable is extremely important.

REFERENCES

