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Lubricant Replacement in Rolling Element Bearings for Weapon Surety Devices

Abstract

Stronglink switches are a weapon surety device that is critical to the nuclear safety theme in modern nuclear weapons. These stronglink switches use rolling element bearings which contain a lubricant consisting of low molecular weight polytetrafluoroethylene (PTFE) fragments. Ozone-depleting solvents are used in both the manufacture and application of this lubricant. An alternate bearing lubrication for stronglink switches is needed that will provide long-term chemical stability, low migration and consistent performance. Candidates that were evaluated include bearings with sputtered MoS_2 on the races and retainers, bearings with TiC-coated balls, and bearings with Si_3N_4 balls and steel races. These candidates were compared to the lubricants currently used which are bearings lubricated with PTFE fragments of low molecular weight in a fluorocarbon solvent. The candidates were also compared to bearings lubricated with a diester oil which is representative of bearing lubricants used in industrial applications. Evaluation consisted of cycling preloaded bearings and subjecting them to 23 gRMS random vibration. All of the candidates are viable substitutes for low load application where bearing preload is approximately 1 pound. For high load applications where the bearing preload is approximately 10 pounds, bearings with sputtered MoS_2 on the races and retainers appear to be the best substitutes. Bearings with TiC-coated balls also appear to be a viable candidate but these bearings did not perform as well as the sputtered MoS_2.

Introduction

Electromechanical switches such as stronglink switches are weapon surety devices that are critical to the nuclear safety theme in modern nuclear weapons. These stronglink switches use rolling element bearings for movement of rotary actuators and other mechanical parts critical for function. These rolling element bearings use a lubricant which consists of low molecular weight polytetrafluoroethylene (PTFE) fragments. The lubricant is deposited from solution in an ozone-depleting solvent and, as such, has been reformulated in response to environmental safety and health concerns over damage to the earth's ozone layer. An alternate bearing lubrication procedure is needed to meet current and future production needs.

The subject of the present work is the examination of alternate bearing materials and lubricants to replace the current bearing lubrication process. The basic requirements of the materials or processes are long term chemical stability, low migration, and consistent performance.

Experimental Procedure

Instrument bearings tested consist of 440C races and balls, with a 430 steel retainer. The bearings have a 1/8" diameter inner race, 5/16" diameter outer race, and 6 balls of 1/16" diameter. These bearings were chosen for evaluation of alternate materials because of their extensive use throughout weapon surety devices in multiple weapon systems.

The present bearing lubrication process uses a commercially-available slurry of PTFE particles in a fluorocarbon solvent. The slurry is mixed with additional solvent, and the mixture allowed to settle. The PTFE solids settle to the bottom of the container, and the clear liquid is decanted off the top of the mixture. This liquid contains PTFE fragments of low molecular weight (< about 800) in solution in a fluorocarbon solvent. The lubricant is applied to bearings by submerging bearings in the solution and allowing the solvent to evaporate. This leaves behind a waxy, clear coating of PTFE fragments on the bearing surfaces. The bearings are baked at 138 °C to drive off excess solvent and physically adhere the PTFE to the substrate surface.

Candidates that were investigated include various solid lubricants for bearings, and alternate bearing materials that do not require lubrication. These candidates are bearings with sputtered MoS_2 on the races and retainers, bearings with TiC coated balls, and bearings with Si_3N_4 balls and steel races. Two baselines were used for comparison. One is bearings lubricated with PTFE fragments of low molecular weight in a fluorocarbon solvent. This is currently used in stronglink switches. The other is bearings lubricated with a diester oil which is representative of bearing lubricants used in industrial applications.

A test plan was developed that would mimic the life cycling and vibration that a bearing in a stronglink mechanism would see. The more demanding applications where lubricants are required are in preloaded bearings that support oscillating solenoid rotors. Test fixtures were developed that could preload the bearing pairs and maintain this preload through testing and environmental conditioning. The bearing pairs were axially preloaded in the test fixtures to two preload levels: 1 pound and 10 pounds. This represents the range of bearing preload that exists in stronglink mechanisms. Each bearing pair was torque tested initially after preloading. Torque testing consists of measuring average torque, standard deviations and range of the bearing torque through one revolution. The bearing pair in the test fixture are torque tested after the following number of cycles: 3600, 7200, 10800, 18000, 36000, 54000, and 72000 (each cycle is a forward and reverse rotation of the bearing through approximately 30 degrees). The bearing cartridge is environmentally conditioned after 18000 cycles by vibrating it to a 23.5 GRMS random vibration spectrum for 20 minutes along a radial axis and 20 minutes along an axial axis. The bearing is torque tested again after vibration, prior to any additional cycles.

Results

Test results indicate that all the alternates examined are viable for replacing PTFE lubrication in low bearing preload applications. Figure 1 shows that all of the candidates produced a stable average torque that was below the PTFE baseline and comparable to the diester oil baseline. For bearings with high bearing preload, only bearings with TiC-coated balls and bearings with sputtered MoS_2 on the races and retainers are suitable replacements for PTFE-lubricated bearings. Figure 2 shows that the bearings with Si_3N_4 balls do not produce a stable average torque during cycling. Even though the TiC-coated balls produced higher average torque than either baseline, the average torque was relatively stable. A better choice for high bearing preload applications appears to be bearings with sputtered MoS_2 on the races and retainers. The average torque produced by this bearing is comparable to the PTFE baseline or the diester oil baseline after an initial run-in period.

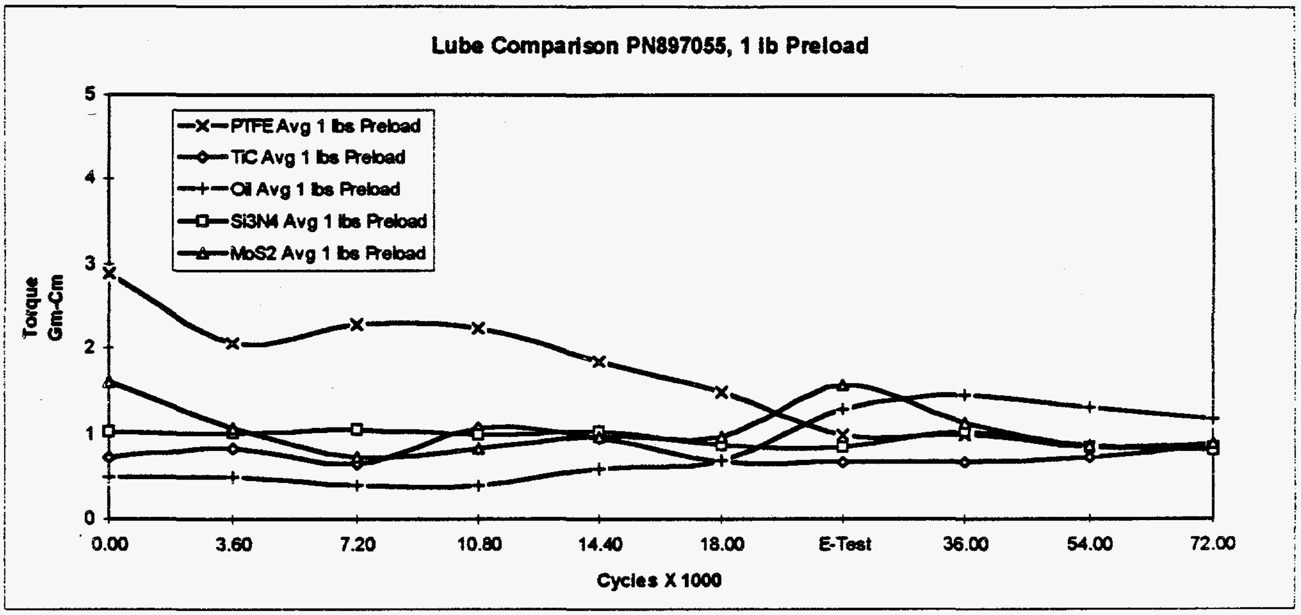
Conclusion

Test results indicate that any of the candidates tested are viable replacements for bearings with PTFE-lubricated bearings in low load applications. In high load application, bearings with sputtered MoS2 races and retainers is the best replacement candidate. Bearings with TiC-coated balls are also viable alternatives for high load application though these candidates did not perform as well as the MoS2-coated bearings. The major disadvantage to using these candidates is the high cost of these bearings and the long lead time needed to procure them.

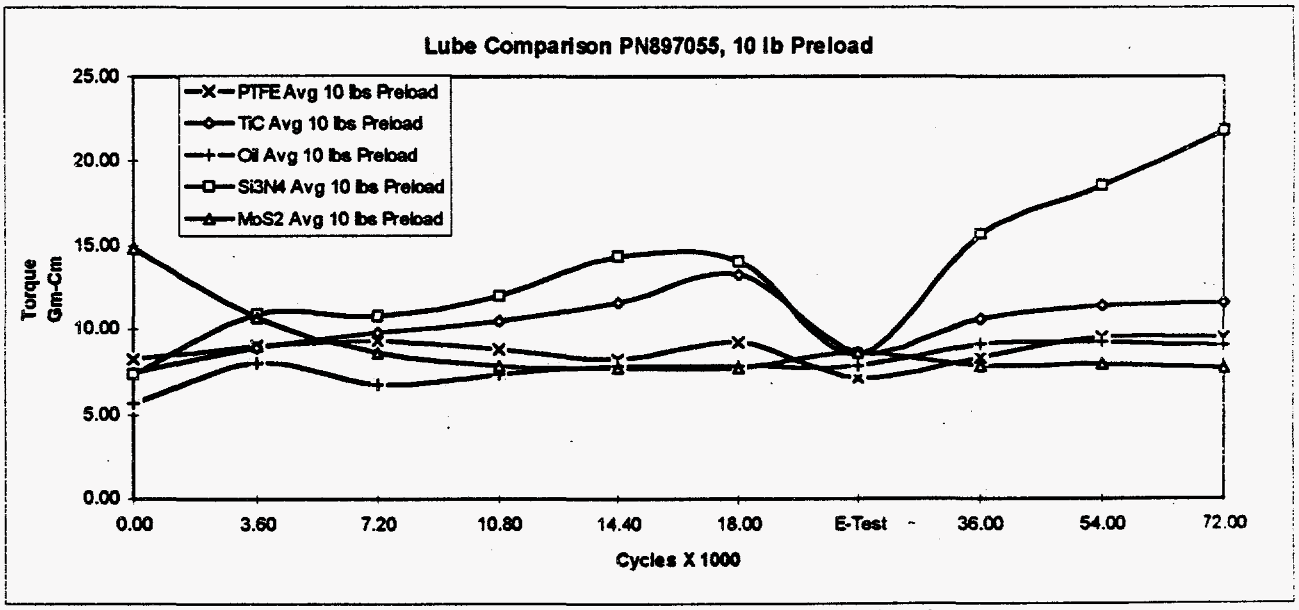
Future Work

Studies are ongoing to investigate the use of perfluoropolyethers with functional end groups as a replacement for PTFE. This lubricant appears to be very promising due to initial laboratory tests and is appealing because it could be used on bearings that are already available and qualified for use in stronglink switches.

Work is also progressing on documenting the amount and type of debris generated in each to the bearing candidates and bearing baselines. The wear condition of the balls and races of the bearings is also being documented.



Average Torque vs. Cycles - 1 lb. Preload
Figure 1



Average Torque vs. Cycles - 10 lb. Preload
Figure 2