Lubrication for High Load Duplex Bearings

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LUBRICATION FOR HIGH LOAD DUPLEX BEARINGS

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R. G. Steinhoff, Project Leader

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Abstract

Three ES&H-compatible lubricants (Environment, Safety and Health) for high load duplex bearing applications were evaluated and compared against trichlorotrifluoroethane (Freon) deposition of low molecular weight polytetrafluoroethylene (PTFE) bearing lubricant extracted from Vydax™. Vydax is a product manufactured by DuPont consisting of various molecular weights of PTFE suspended in trichlorotrifluoroethane (Freon) which is an ozone-depleting solvent. Bearings with Supercritical CO_2 deposition of PTFE extracted from Vydax AR/IPA, bearings with titanium carbide coated balls, and bearings with diamond-like carbon races and retainers were evaluated. Bearings with Supercritical CO_2 deposition of PTFE from Vydax AR/IPA performed as well as bearings with Freon deposition of PTFE from Freon-based Vydax.

Summary

Three ES&H-compatible (Environment, Safety and Health) lubricants for high load duplex bearing applications were evaluated and compared against Freon deposition of PTFE from Vydax™ bearing lubricant. Vydax is a product manufactured by DuPont consisting of various molecular weights of polytetrafluoroethylene (PTFE) suspended in trichlorotrifluoroethane (Freon). Manufacturing of Freon has been curtailed in response to environmental, safety, and health concerns regarding damage to the earth's ozone layer. Exemptions at AlliedSignal Federal Manufacturing & Technologies (FM&T) are required in order to use Vydax and Freon.

The high load duplex bearing placed the highest demand on bearing lubrication because of the high contact stresses caused by the large load required to bring the inner races together. This bearing was designed specifically for use in a stronglink C-Module to add a controlled amount of friction in the pattern wheel shaft to correct for over-travel rotation of the pattern wheel due to rebound of the solenoid during high voltage actuation. This problem was designed out of the C-Module as a result of production activities. Hence the need for this type of bearing and evaluations using this bearing were discontinued after 1993. Information from this evaluation is valuable because if a lubricant can pass the demanding requirements of this bearing, the lubricant would most likely be suitable for any bearing application.

Bearings with Supercritical CO_2 deposition of Vydax AR/IPA, bearings with titanium carbide coated balls, and bearings with diamond-like carbon races and retainers were evaluated and compared against bearings with Freon deposition of filtered Vydax.

The results indicate that Supercritical CO_2 deposition of Vydax AR/IPA provides nearly the same lubrication effectiveness as Freon deposition of filtered Vydax. Further investigation into determining an optimum process is still needed. Even though Vydax AR/IPA is ES&H compatible, Freon is still used by DuPont in the manufacture of this product. DuPont will have to cease manufacture of this product but is working on a product that does not require Freon during manufacturing. An evaluation program was being developed with Phasex Corporation to further develop the Supercritical CO_2 process, but this was put on hold until a replacement for Vydax that does not use Freon in the process is available. The molecular weight distribution of the replacement material may affect the extraction process using Supercritical CO_2.

The bearings with TiC coated balls did not perform adequately for this application, but they may warrant further evaluation for lower load applications.

The results indicate that DLC coated races are not a viable alternative to the high contact stresses seen in the high load duplex bearings. Further investigation may be warranted for low load applications.

Discussion

Scope and Purpose

The objective of this project was to identify potential ES&H-compatible (Environment, Safety and Health) lubricant candidates for high load duplex bearings and evaluate the most promising candidates against current baselines. This project was undertaken because the current lubricant, filtered Vydax™, contains PTFE suspended in Freon and requires Freon for dilution during the application process. Manufacturing of Freon has been curtailed in response to environmental, safety, and health concerns over damage to the earth's ozone layer. Exemptions at AlliedSignal Federal Manufacturing & Technologies (FM&T) are required in order to use Vydax and Freon.

The following ES&H-compatible lubricant candidates were evaluated to replace filtered Vydax for high load duplex bearings:

A. Diamond-like Carbon (DLC) coated races
B. Supercritical CO_2 deposition of Vydax AR/IPA
C. Titanium Carbide (TiC) balls

Prior Work

A high load duplex bearing has two rows of balls, one outer race, two inner races, and no retainer, as shown in Figure 1. The inner races, which have a gap between them when unloaded, are pushed together, which causes the balls to be compressed between the inner and outer races. This stabilizes the bearing with no end play and very little radial play. A high load duplex bearing requires a large force to bring the inner races together. This causes high contact stresses between the balls and races. The high load duplex bearing placed the highest demand on bearing lubrication because of the high contact stresses. This bearing was designed specifically for use in a stronglink assembly C-Module to add a controlled amount of friction in the pattern wheel shaft to correct for over-travel rotation of the pattern wheel due to rebound of the solenoid (also called G-Kick) during high voltage actuation. This problem was designed out of the C-Module as a result of production activities. Hence the need for this type of bearing and evaluations using this bearing were discontinued after 1993. Information from this evaluation is valuable because if a lubricant can pass the demanding requirements of this bearing, the lubricant would most likely be suitable for any bearing application.

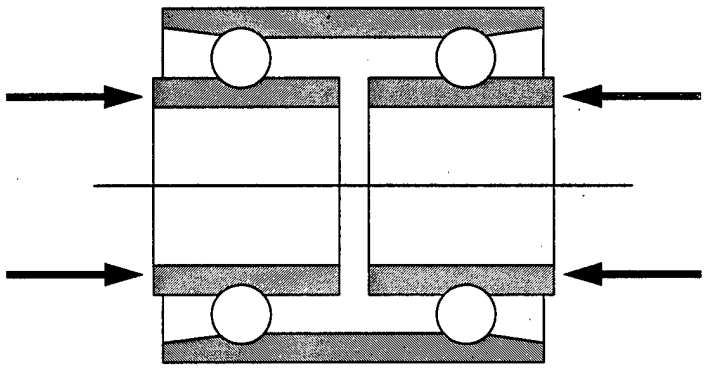

Figure 1. Cross Section of a Duplex Bearing

Stronglink switches designed since 1974 have required lubrication of preloaded bearings in order to operate reliably under various environments. The bearing lubricant of choice in these mechanisms is Freon deposition of low molecular weight PTFE extracted from Vydax. Vydax is a product manufactured by DuPont consisting of various molecular weights of polytetrafluoroethylene (PTFE) suspended in trichlorotrifluoroethane (Freon). The application process consists of siphoning off the soluble portions (low molecular weight PTFE particles) of a settled Freon/Vydax mixture and further diluting the siphoned off portion in Freon. This diluted mixture is then applied to bearings. The Freon is evaporated off, leaving a light film of PTFE "grease" on the bearing. This "grease" is then baked on the bearings. For use in high load duplex bearings, the Vydax mixture is specially filtered in order for the unit to pass in-process requirements.

Activity

Tester and Test Procedure

Functional testing of high load duplex bearings was performed on the bearing torque tester. This tester preloads the duplex bearing and rotates it at 0.5 rpm while it records torque data. The tester also can rotate the bearing at 24 rpm without taking torque measurements in order to put cycles on the bearing. Outputs from this tester are Average Torque, Standard Deviation, Range, Max. Torque, and Min. Torque. Figure 2 shows the torque tester. The bearing test procedure is to take measurements on the cycles (revolution) 1, 2, 5, 10, 25, 50, 100, 200 300, 400, 500, 1000, 1500, and 2000.

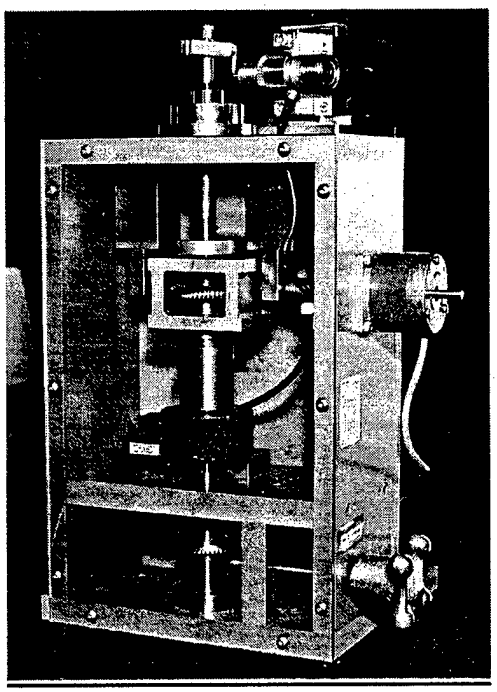

Figure 2. Bearing Torque Tester

Baseline Lubricant

The baseline lubricant for this bearing is a specially filtered Vydax. In all the figures showing average torque versus number of cycles, average torque of bearings lubricated with filtered Vydax is shown for comparison (Figure 3).

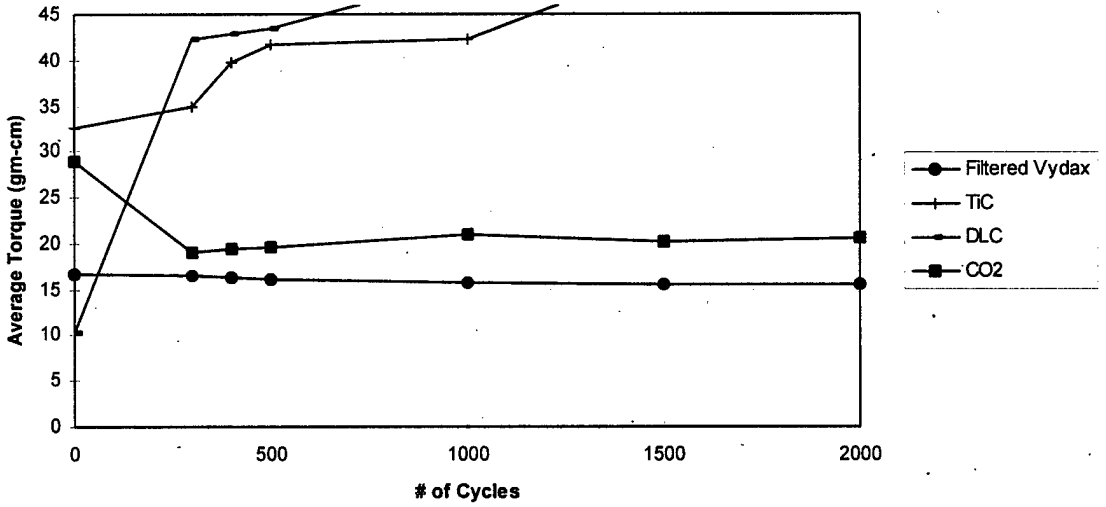

Figure 3. Average Torque Comparison—All Candidates

Supercritical CO_2 Deposition of Vydax

Processes were developed by Phasex Corporation, Lawrence, MA, for using Supercritical CO_2 as a carrier for extracting low molecular weight portions of PTFE from Vydax AR/IPA (PTFE suspended in alcohol) and redepositing the PTFE on a bearing. Seventeen bearings were processed in six batches with varying amounts of PTFE applied to each batch. The processing parameters of each batch were known only by Phasex Corporation due to the proprietary status of their process, but a summary of what is known about each batch is shown in Table 1.

Table 1. List of Batches—Supercritical CO_2

Batch #	Description
ASK-1	Heavy coating on races and balls; excess blown off before torque testing
ASK-8	Uneven application, light on races, thin on balls
ASK-11	Full coverage on races, thinner than ASK-12; only thin coverage on balls
ASK-12	Heavy coating on balls and races; thinner than ASK-1
ASK-13	Light, even application with occasional small clumps
ASK-16	Light, even application, heavier than ASK-13; lowest concentration of PTFE in CO_2

The different batches caused bearings to exhibit different torque performance. The initial batch, ASK-1, had an excessive amount of PTFE. These bearings were "cleaned" by high-pressure air to remove the excess lubricant from the bearing. This was discontinued prior to testing subsequent batches. Figure 4 shows average torque is close to the Freon-deposited filtered Vydax. This was surprising considering the excessive amounts of PTFE on the bearings. These bearings were stable throughout the 2000 cycles.

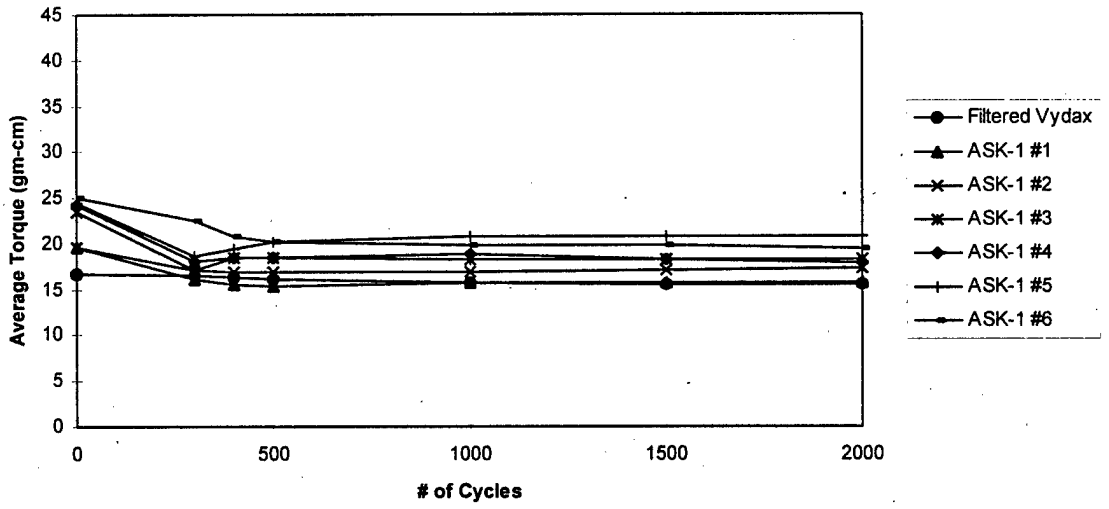

Figure 4. Average Torque Comparison—Supercritical CO_2/Vydax Batch ASK-1

The next batch received was ASK-8. It was quite a bit lighter application and it held up well during testing, as shown in Figure 5. It performed like the Freon-deposited filtered Vydax.

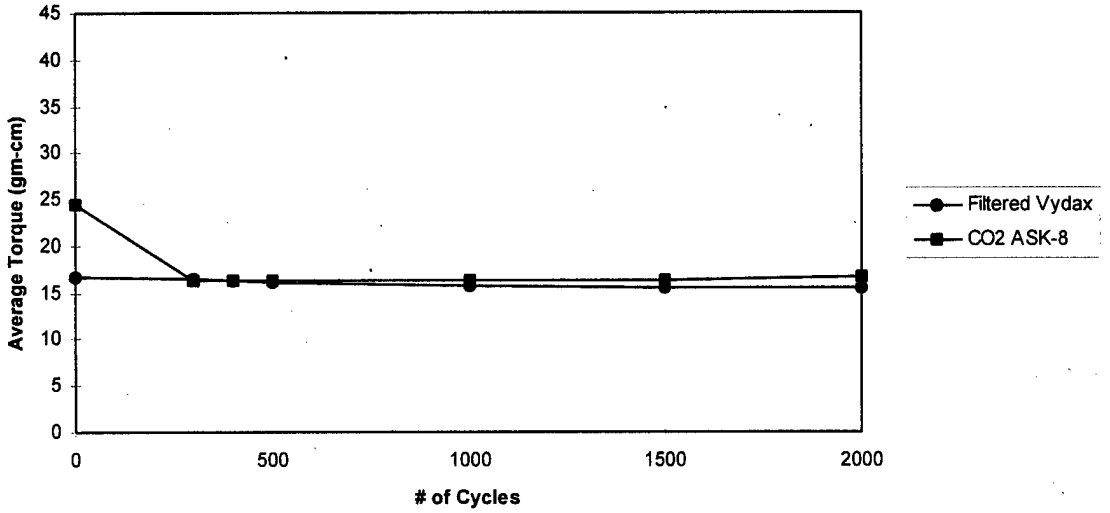

Figure 5. Average Torque Comparison—Supercritical CO_2/Vydax Batch ASK-8

Batches ASK-11 and ASK-12 had heavier coatings, not as heavy as ASK-1. These were not "cleaned" prior to testing. These bearings had high initial torques and took longer to reduce to a stationary level as shown in Figures 6 and 7. The initial high torques could be due to the balls having to push the large clumps out of the way. Either the "cleaning" process used in ASK-1 was more effective in removing the large clumps than originally thought or the coating of ASK-1 was somehow superior to ASK-11 and ASK-12.

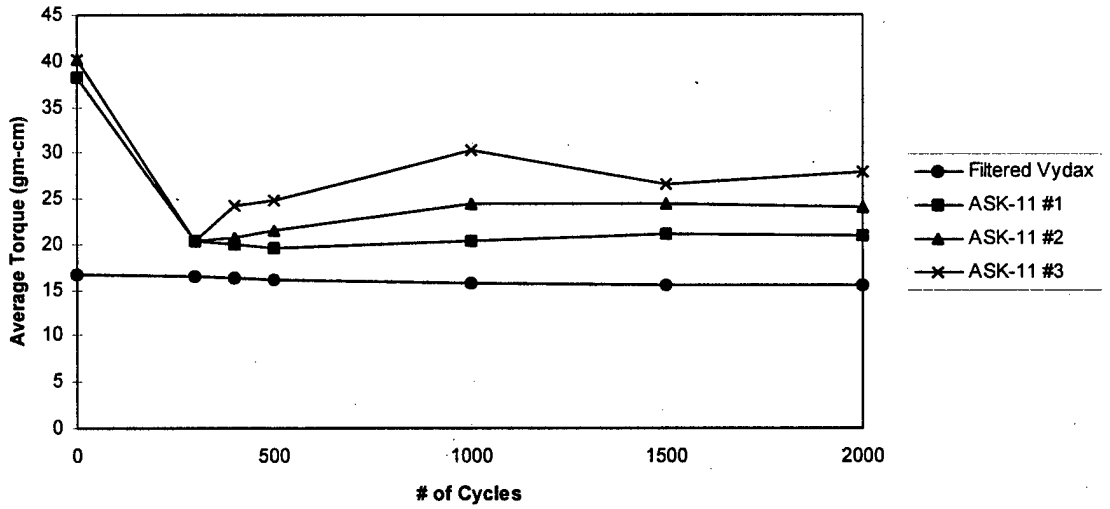

Figure 6. Average Torque Comparison—Supercritical CO_2/Vydax Batch ASK-11

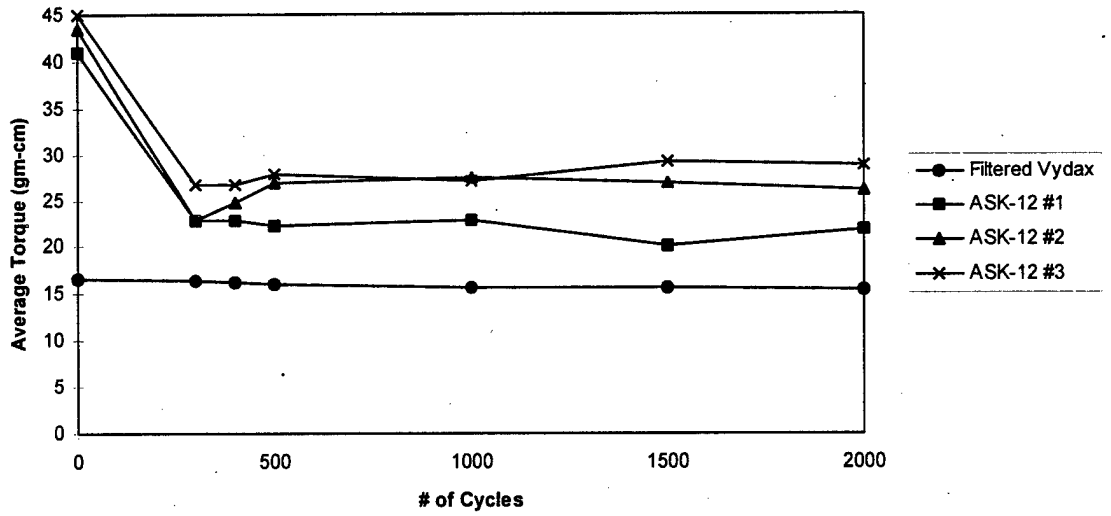

Figure 7. Average Torque Comparison—Supercritical CO_2/Vydax Batch ASK-12

Based on the results of ASK-11 and ASK-12, the batches ASK-13 and ASK-16 had reduced amounts of PTFE deposited and the molecular weight of the PTFE deposits were lower. This resulted in average torques very close to the Freon-deposited filtered Vydax as shown in Figures 8 and 9.

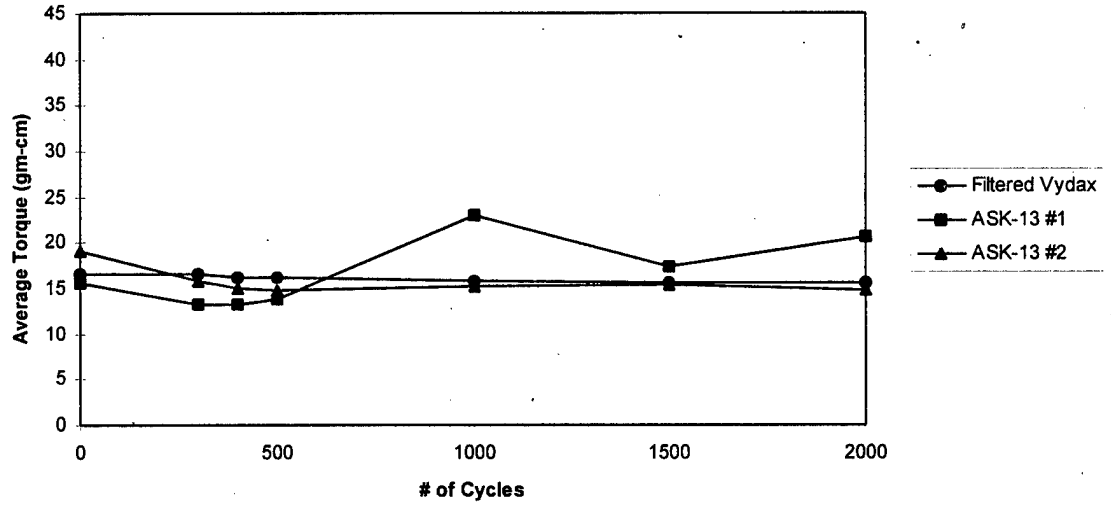

Figure 8. Average Torque Comparison—Supercritical CO_2/Vydax Batch ASK-13

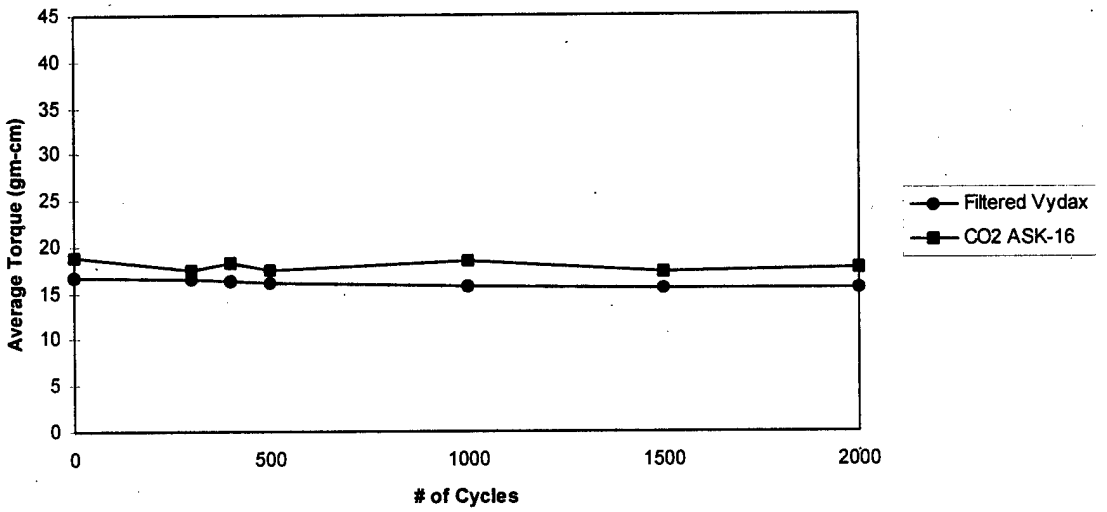

Figure 9. Average Torque Comparison—Supercritical CO_2/Vydax Batch ASK-16

The average torque results as shown in Figures 3-9 indicate that Supercritical CO_2 deposition of Vydax provides nearly the same lubrication effectiveness as Freon-deposited filtered Vydax. Further investigation into determining an optimum process is still needed. Even though Vydax AR/IPA is ES&H compatible, Freon is still used in the manufacture of this product. DuPont will have to cease manufacture of this product but is working on a product that does not require Freon during manufacturing. An evaluation program was being developed with Phasex Corporation to further develop this process, but this was put on hold until a replacement for Vydax that does not use Freon in the process is available. The molecular weight distribution of the replacement material may affect the extraction process using Supercritical CO_2.

Titanium Carbide (TiC) Coated Balls

Bearings with TiC coated balls were obtained and tested. The results of the torque versus number of cycles, as shown in Figure 10, revealed that the TiC coated bearings started out with higher average torque and stayed somewhat stable through 300 cycles. After that, they degraded quickly. These bearings did not perform adequately for this application, but they may do well for a lower load application. One downside to this type of bearing is that they are extremely expensive.

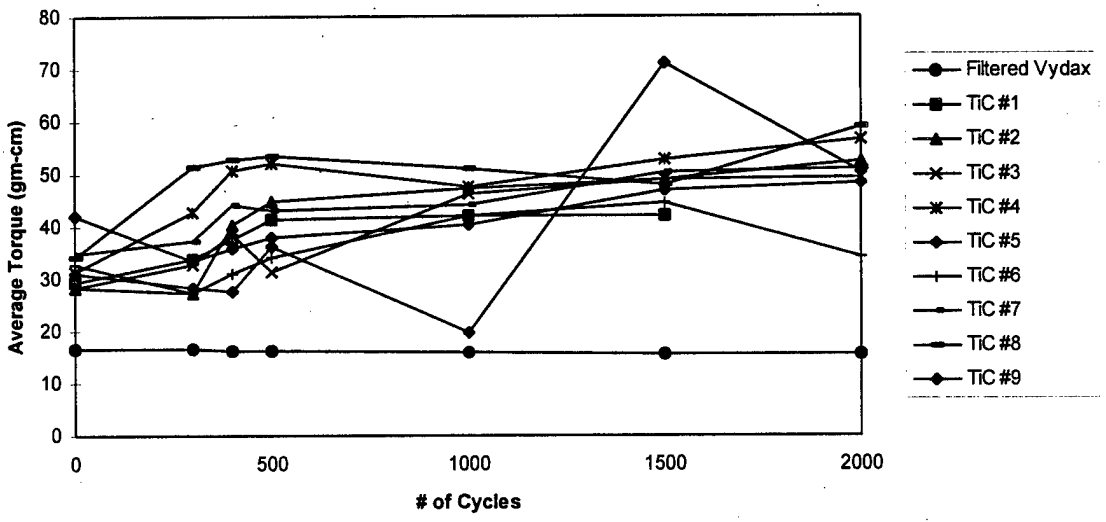

Figure 10. Average Torque Comparison—TiC

Diamond-Like Carbon (DLC) Coated Races

Diamonex Corporation coated inner and outer races of five disassembled high load duplex bearings with 3000 angstroms of diamond-like carbon using ion beam coating process. One of the bearings was reassembled at FM&T and tested. Results of the torque versus number of cycles is shown in Figure 11. The bearing torque started out low but immediately increased to unacceptable levels. Scanning electron microscopy (SEM) examination revealed that the coating was fractured and delaminated from the substrate as shown in Figures 12-14. Figure 12 shows an overall view of the inner race. The DLC is clearly shown to be damaged at the edge of the race where the 180-pound loading of the ball occurred. Figures 13 and 14 are enlargements of this same area. Figure 15 shows one of the ball bearings with DLC adhered to the surface.

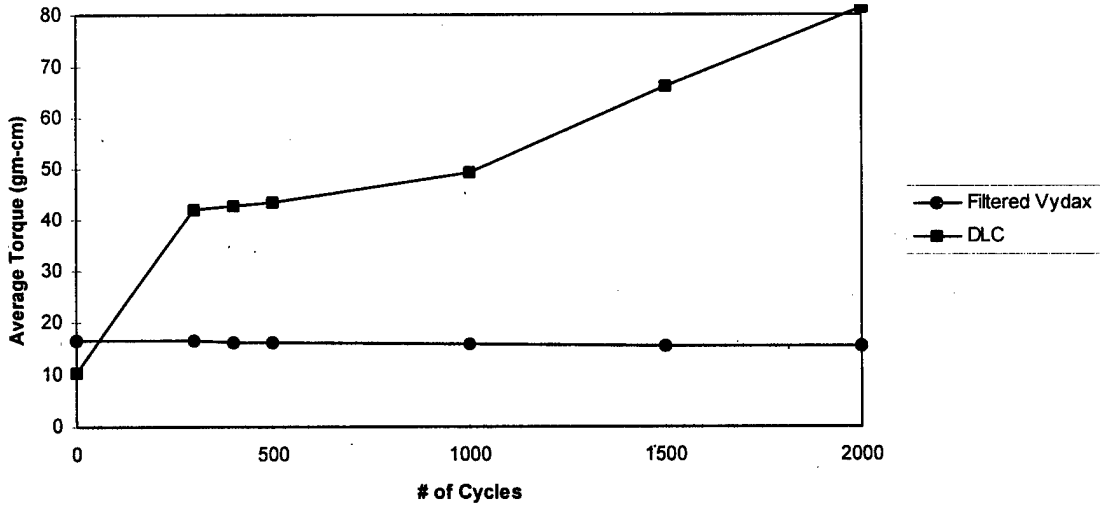

Figure 11. Average Torque Comparison—DLC

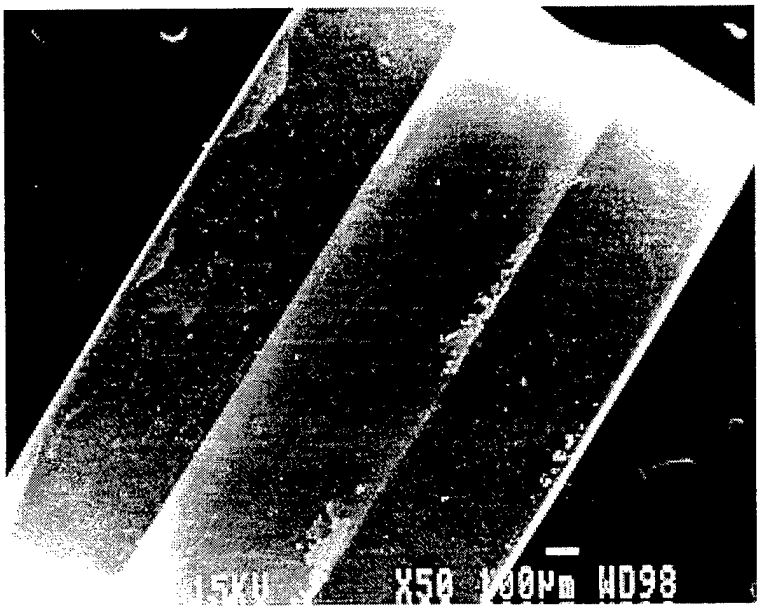

Figure 12. View of Inner Race With Damaged DLC Coating, 50x Mag.

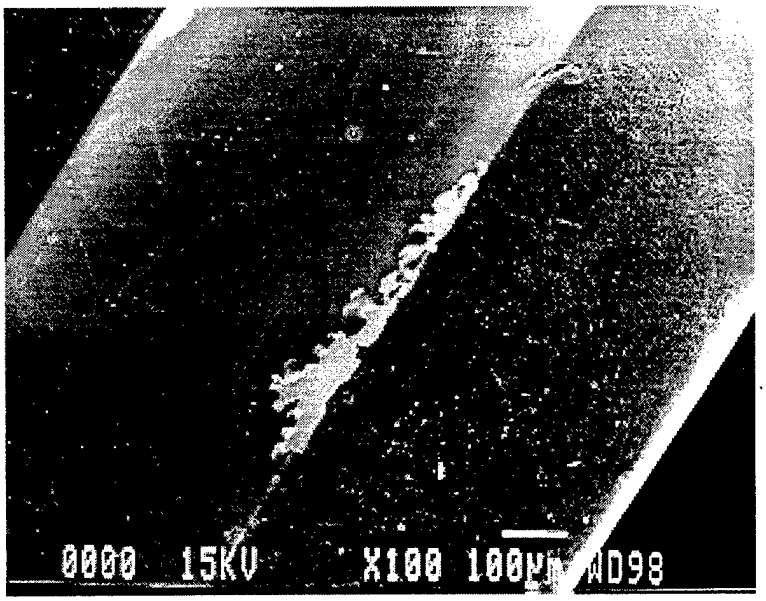

Figure 13. View of Inner Race With Damaged DLC Coating, 100x Mag.

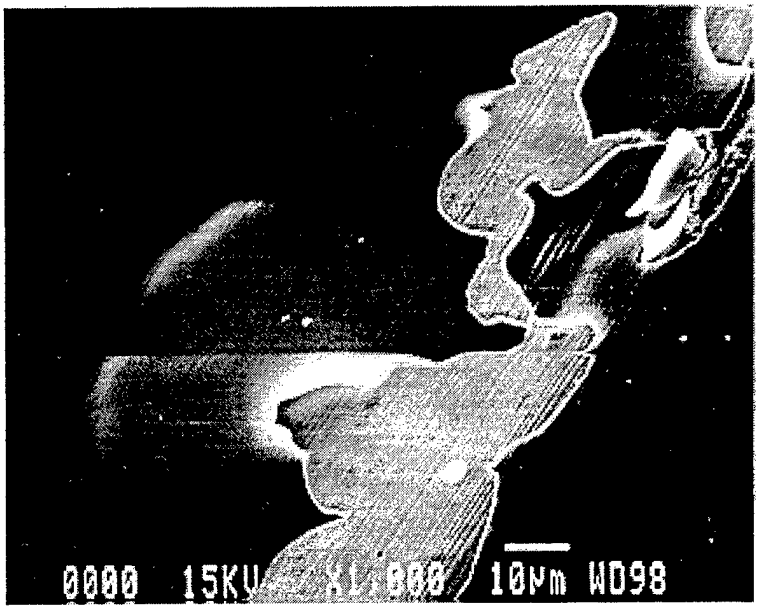

Figure 14. View of Inner Race With Damaged DLC Coating, 1000x Mag.

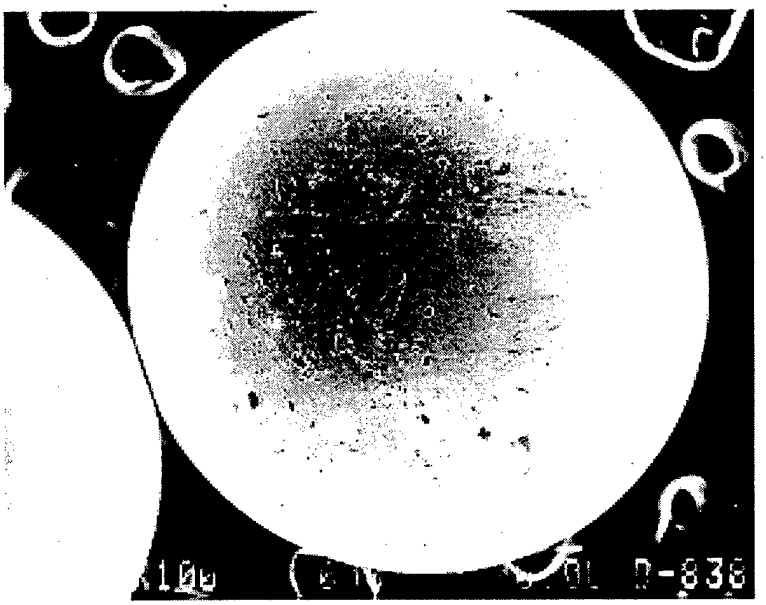

Figure 15. View of Ball From DLC Coated Bearing

Accomplishments

Three lubricant candidates for high load duplex bearings were evaluated and compared against filtered Vydax lubricant which is the current baseline. Only Supercritical CO_2 deposition of Vydax performed as well as the baseline. This candidate shows great promise as a viable replacement for the ES&H-unfriendly filtered Vydax process due to the fact that the low molecular weight portions of PTFE can be extracted by the Supercritical CO_2 process and be redeposited on bearings. Bearings with TiC coated balls showed some promise, but not in high load applications. Bearings with DLC coated races and retainers are susceptible to cracked coating and subsequent delamination due to high contact stresses.

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