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MATERIALS AND LUBRICATION FOR GEAR AND BEARING SURFACES IN UHV*

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Abstract

During design and construction of the SLAC polarized LEED (PLEED) system, a search was made for a dependable gear, bearing, and lubrication system for the computer-controlled Faraday cup used to measure diffracted beams. Components must be nonmagnetic, bakeable to 250° C and at room temperature must operate at pressures in the 10^{-9} to 10^{-10} Pa range. A test system was constructed which incorporated a meshed pair of dissimilar pitch diameter spur gears, one of which was confined to (by bushings) and rotated on a fixed shaft, while the other gear was driven by a commercial rotary motion feedthrough which was rotated by a servo motor driven in sine fashion with a direction reversal every six turns and peak speeds of 50 rpm. The criterion for a successful pair was $\sim 10^5$ turns, the life rating for the feedthrough. Pairs had actual turn counts from less than 1 to 91,000. Materials for gears included stainless steel, beryllium copper, and aluminum alloys. Lubricants used singly and in concert were MoS_2, WS_2, Ag, hard chrome, and a MoS_2-graphite-sodium silicate mixture. The successful gear pair was Ag-plated Aℓ alloy and MoS_2-graphite-sodium silicate-coated Be-Cu. Subsequent performance in the PLEED system after repeated bakeouts will also be discussed.

1. Introduction

During design of the SLAC polarized low energy electron diffraction (PLEED) system {1}, it became apparent that a critical choice was to be made in material selection for the gears, bearings, and lubricants used in the computer-controlled Faraday cup motions. The materials and lubricants had to be 1) UHV (10^{-10} Pa range) compatible and bakeable repeatedly to 250° C, 2) rigorously nonmagnetic because stray fields would not only deflect the electron momentum but alter the polarization as well, 3) outlast the commercial motion feedthroughs used to drive the gears, and 4) be capable of tolerating without damage both the continuous and stepping type motions found in this type of experiment.

Our previous experience using 300-series stainless steel worm gearing with MoS_2 lubrication in a Mott polarization analyzer indicated that we ought to avoid using gear pairs with like surfaces, and gears which incorporated sliding friction between teeth. Both of these situations encourage cold weld of the teeth. We chose spur gears and rack and pinion sets using unlike materials as being most suitable in these respects.

A small UHV test system was set up to test various materials and lubricants in a purely technical sense. A range of materials and lubricants were chosen which were known to satisfy 1) and 2); tests would show which satisfied 3) and 4).

2. Experiment

The test chamber was an 8ℓ/sec ion-pumped cylinder of 2.5ℓ volume with a window on one end and motion feedthrough on the other. After bakeout to 250° C with gearing in place, the pressure was < 10^{-8} Pa, as indicated by the pump current. No pressure gauging was used and the actual pressure was probably considerably lower than this.

Test gearings consisted of spur gear pairs of 3.125 and .625 inch pitch diameter, 24 diametral pitch, 20° pressure angle. The larger gear was mounted free rotating on a

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shaft fixed to the flange and constrained to the shaft by bushings. The smaller gear was fixed to the rotary motion feedthrough and set in mesh with the larger gear. Spacing between the pair's teeth was set for minimum backlash without binding (generally .03 mm).

The rotary motion feedthrough was sine-function driven by a servo motor and speed reducer. The driver gear made a direction reversal every six revolutions with 0.6 Hz average and 0.83 Hz peak frequencies. Gear pairs were run semicontinuously until gear or feedthrough failure occurred.

Gear condition such as chatter, tooth damage, and cold welding could be observed via telescope, during running, through the window. The materials tested are given in Table I.

Table I. Material and Lubricant Combinations Employed

Test Set	Large Gear	Small Gear	Shaft	Bushings
1	Al + Electro + MoS_2	Al + Electro	W + MoS_2	Be-Cu + MoS_2, Be-Cu + Ag
2	Al + Ag	Al + Electro + MoS_2	Mo + MoS_2	Be-Cu + MoS_2, Be-Cu + Ag
3	Al + Ag	Al + Electro	Mo + MoS_2	Be-Cu + MoS_2
4	Al + WS_2	Al + Electro + WS_2	W + WS_2	Be-Cu + WS_2
5	Al + Ag	303 St. Stl. + MoS_2	W + WS_2	Be-Cu + WS_2
6	Al + Ag	303 St. Stl. + 811	W + MoS_2	304 St. Stl. + MoS_2
7	Al + Ag	Be-Cu + 811	W + MoS_2	304 St. Stl. + MoS_2
8	Al + Ag	Be-Cu + MoS_2	W + MoS_2	304 St. Stl. + MoS_2
9	Cu-Ni	Cu-Ni	Mo + Ag	Be-Cu + MoS_2

Notes:
Al - 24 ST aluminum alloy
Be-Cu - copper alloy #UNS-C17200
Ag - .03 mm plate
WS_2 - air impact sprayed {2} (Ref. 2)
MoS_2 - air impact sprayed {3}
811 - Everlube 811 {4}
Electro - hard chrome coating {5}
Cu-Ni - AP4 alloy {6}
St. Stl. - stainless steel

3. Results

The results of the various pair tests are given in Table II. Failures of the meshed teeth resulted from a breakthrough of the lubricant after which the metals welded together. Material was subsequently torn from a tooth and carried around the gear, thereby damaging further teeth. The resulting tooth appearance is shown in Fig. 1a.

Two gear sets outlasted their respective feedthroughs, although one of these feedthroughs failed prematurely. These gear pairs actually ran more easily after bakeout than before. The Everlube 811 compound had a distinctly soot-like appearance

Table II. Summary of Results

Test Set	Total Revolutions	Results
1	42K	Tooth gouges and chips after 100 turns, cold welds at failure; moderate wear on Be-Cu + Ag bushing.
2	20K	Gouges on small gear after 250 turns, vibration after 1400, cold welds at failure; severe wear on Be-Cu + Ag bushing.
3	27K	Gouging and chips from small gear after 2K turns, cold welds at failure; shaft and collars in good condition.
4	3.8K	Gouging and chips after 25 turns; severe damage to both gears at termination.
5	5.4K	Some gouging on small gear; insufficient WS_2 on bushings caused uneven motion; feedthrough failure.
6	31K	Even wear on all parts without signs of damage; feedthrough failure.
7	91K	Little wear; feedthrough failure.
8	36K	Couges on small gear, breakthrough of MoS_2.
9	0.25	Bare metals cold weld teeth.

after application, the excess of which came off after a short running period. The coating redistributed continually during running, thereby assuring that bare metal was never exposed to welding.

4. Conclusions

1. Pair materials should be as dissimilar in hardness as is practically possible.
2. Lubricants should be non-brittle to prevent flaking. MoS_2 coatings are best on hard materials, Ag on softest.
3. Lubricants which redeposited during running protected gear teeth from cold welding (MoS_2, Everlube 811).

(a) (b)

Fig. 1. Tooth appearance at test completion: (a) Test 4, (b) Test 7.

A spur gear pair and rack and pinion set based on Test Set 7 were used on the cup mechanism which has been installed on the PLEED system for two years, encompassing three one-week long bakeouts and operation in both continuous and stepping motion without sign of failure or binding. In that time, the external bearings of the commercial motion feedthroughs have had to be relubricated twice.

References

*Work supported by the Department of Energy under Contract DE-AC03-76SF00515.

1. E. L. Garwin and R. E. Kirby, Proc. 7th Int. Vac. Congress & 3rd Int. Conf. Solid Surfaces, Vienna, Austria, 12-16 Sept. 1977, p. 2399.
2. Northwest Dicronite, Mountain View, CA.
3. E/M Lubricants, Inc., Mountain View, CA.
4. E/M Lubricants; a proprietary mixture containing MoS_2, graphite, and sodium silicate binder.
5. Electrolizing, Inc., Santa Clara, CA.
6. Arcap, Puteaux, France; a 51-49 at.% Cu-Ni alloy reputed by the manufacturer not to require lubricant when running against itself in air.

Commercial products and organizations are identified to fully describe experimental conditions. No endorsement is intended.