WEAR AND FRICTION IN LIQUID NITROGEN WITH
AUSTENITIC STAINLESS STEEL HAVING
VARIOUS SURFACE COATINGS

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Introduction

Cryogenic fuels, oxidants, and inert working fluids are important to propulsion systems for missiles. Turbo­pumps for handling these fluids may have bearings, seals, and other parts lubricated by the cryogenic liquids. The physical and chemical properties of most cryogenic liquids of interest are such that they might be expected to have very poor lubricating ability. It is therefore advantageous to utilize compatible slider materials in these cryogenic liquids.

Austenitic stainless steel is one of the primary types of structural materials used in cryogenic engineering. Stainless steel such as type 304 is a very poor slider material, since it is highly susceptible to surface galling or welding during sliding even in a cryogenic liquid\(^1\),\(^2\). Because it has good mechanical properties at cryogenic temperatures, however, methods of surface modification or coatings to gain surface compatibility during sliding merit consideration.

This investigation was conducted to study the wear and friction of several types of surface treatments for type-304 stainless steel. Commercial treatments were employed in each

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case; these included diffusion coatings with nitrogen\(^3\), sulfur\(^4\), chromium\(^3\), and chromium electroplating. Also several lubricating surface coatings utilizing molybdenum disulfide (MoS\(_2\)), polytetrafluoroethylene (PTFE) and polytrifluorochloroethylene (PTFCE) were studied. The data were obtained with a hemisphere-tipped (3/16-inch radius) rider specimen sliding in a circumferential path on the flat surface of a rotating disk submerged in liquid nitrogen. The surface speed was 2300 feet per minute, and the load was 1000 grams. Coatings were applied to the disk specimens. Rider specimens of both type-304 stainless steel and a commercial carbon used for sliding contact seals were employed.

**Apparatus and Procedure**

The apparatus used in this investigation is shown in Figure 1. The basic elements consist of a rotating-disk specimen (2 1/2-inch diameter, 1/2-inch thick) and a hemisphere-tipped (3/16-inch radius) rider specimen. The rider specimen slides in a circumferential path on the lower flat surface of the rotating disk submerged in liquid nitrogen.

The disk specimen was driven by a 5-horsepower hydraulic motor through a 6:1 speed increaser. Surface speed was 2300 feet per minute for the data reported herein.

The rider specimen was supported by an arm assembly that allowed the measurement of friction force outside the test chamber. The vertical shaft of this assembly was pivoted through a bearing assembly mounted in the top housing. The shaft was sealed at the top and bottom of the pivot by flexible metallic bellows. In operation, the enclosed volume between the bellows was pressurized (7 psig) with helium. Friction force was measured by a strain-gage dynamometer ring connected to the top of the shaft. The deflection necessary for friction measurement was so small (0.003 inch at the top) that the restraining spring action of the bellows was negligible.

The rider specimen was loaded with a helium-pressurized piston assembly. The loading piston and rider

\(^3\)Metals Handbook, ASM (1948).

\(^4\)G. B. Troup, Sulfurizing—A New Surface Treatment—Reduces Scoring and Seizing, Materials and Methods, 44, No. 3, 110 (1956).