

WEAR BEHAVIOR OF W-DLC COATING UNDER RECIPROCATING SLIDING MOTION

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ABSTRACT

Tungsten containing diamond like coatings have been used to improve reliability and durability of rubbing surfaces, thus their degradation becomes critical to predict component life. The gradual wear of such coatings is studied in this work using a high frequency reciprocating rig with the ball (coated)-flat configuration. In order to study the relationship between wear behavior and coating properties, two deposition recipes are used to deposit coatings on steel balls and these specimens have been tested in an interrupted manner under the same loading, frequency, and lubrication conditions. The coating wear quantified by measuring the wear scar on the balls with a surface profilometer shows nonlinear relationship with sliding distance. Recipe B with more Tungsten content in the top layer has better wear resistance.

1. INTRODUCTION

Tungsten containing diamond like coatings (W-DLC or WC/C) have been received considerable attention for tribological application in the past decade [1]. Examples of its microstructure and characterization could be found in literature [2-4]. This type of coating can improve reliability and durability of rubbing surfaces, such as gears and plungers in a fuel system. In considering that component failure occurs when coating is penetrated with the exposure of substrate, coating degradation becomes critical to predict component life. Samples from laboratory testing were inspected and analyzed in order to gain understanding and subsequently model wear process [5-6]. Recent study [7] of coated gear testing has indicated that W-DLC coating wear mechanism consists of gradual (or polishing) wear and fracture-based cohesive wear.

The focus of this experimental study is on the gradual wear. In order to study the relationship between wear rate and coating properties, two coating deposition recipes are used to deposit coatings on steel ball specimens. These specimens have been tested under the same loading, frequency, and lubrication conditions with a high frequency reciprocating rig (HFRR). The coating wear is quantified by measuring the wear scar on coated steel ball.

2. EXPERIMENT DETAILS

The HFRR is schematically shown in Fig. 1. The lubricant is SAE 50, which has viscosity of 198 cSt at 40°C and 17.6 cSt at 100°C. The flat is immersed in the oil heated to 93 °C. The load is initially set at 5N and ramped to 30N after the

reciprocating motion is stable. The velocity is a sinusoidal function with a peak value of 0.27 m/s. The corresponding stroke length is 6.83mm and frequency is 20Hz. The mark on the ball holder ensures proper restore of the contact after wear scar measurement at each stop.

Two different recipes were used to deposit W-DLC coatings on ball samples with the Hauzer 1200 coating system. The one-fold rotation of substrate table results in the multilayer structure of the W-DLC coating. Both recipes consist of same steps but with different parameters such as the rate of acetylene (C₂H₂) flow and the table rotation speed. The coating structure is shown in Fig. 2, where the 52100 steel substrate is covered in sequence by a pure Cr adhesion layer, Cr and WC transition layer, and two outermost W-containing hydrocarbon layer. Coating's properties are listed in Table 1 obtained from flat dummy coupons. The two types of coatings have similar thickness but exhibit significant different hardness and modulus. The ratios of H/E are slightly different as well.

The counterpart is a hardened disk of 3mm thick and 10mm diameter. Within a region of 405 by 306 μm, the disk surface has both Sa and Sq less than 5 nm. By nanoindentation tests with penetration less than 200nm, the hardness and elastic modulus of the disk are determined to be 9.7±0.5 and 227.6±7.2 GPa, respectively. At each stop, the ball-holder assembly is cleaned and the wear scar and its surrounding area are measured by a three-dimensional surface profilometer. A sphere, which is determined by the digitized surrounding surface, is subtracted from the measured surface and the volume of the resulting pit is recorded for the total volume loss of material.

3. RESULTS AND DISCUSSIONS

The average coefficient of friction under the conditions specified above for each stop is within the range of [0.05, 0.08] and is insensitive to the coating recipes. Although the Lambda value is around 0.2, the high values of contact potential suggest effective lubrication is established at the contact interface. The contact potential for recipe A generally shows more variations than for recipe B, meaning the tribological system with recipe A has more asperities contact than that with recipe B.

Tests for each recipe are carried out on the same ball but at two different spots, which are adjacent to each other. The wear volume evolutions for two samples with coatings of recipe A and B are obtained with respect to duration (or sliding distance), and are shown in Fig. 3 (a). One can see that recipe

A results in more wear than recipe B. This behavior can be attribute to the coating properties and structure, where the two recipes have different top layer (Fig. 2). It should be noted that due to the spherical shape, the coating is not removed in a layer-by-layer pattern, but in a complicated manner. The wear volume for each recipe changes nonlinearly with the duration, except for spot A_a. This disagrees with the Archard model. For the wear volume at the first stop (30min), it is believed that lots of factors play a role, particularly local surface features and running-in process. If the value of initial wear is offset from each curve, Fig. 3(b) is obtained which suggests that the data after a running-in period is more relevant to the polishing wear behavior of interest.

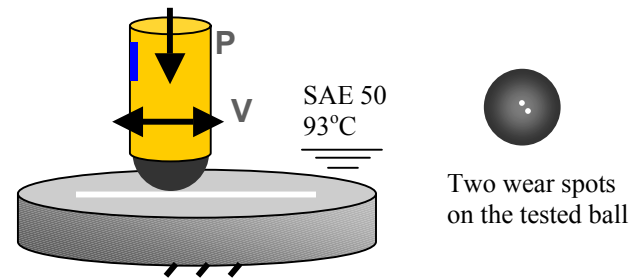


Fig. 1 Schematic of HFRR

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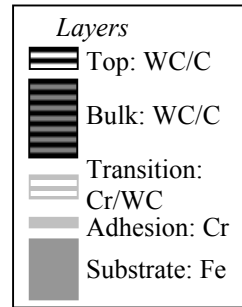


Table 1 Coating's properties (standard deviation is marked with parentheses)

	Recipe A	Recipe B
H,Gpa	9.58 (3.61)	17.71 (6.09)
E,Gpa	125.43 (8.35)	207.2 (29.14)
h, μm	2.6	2.7

Fig. 2 Coating Structure

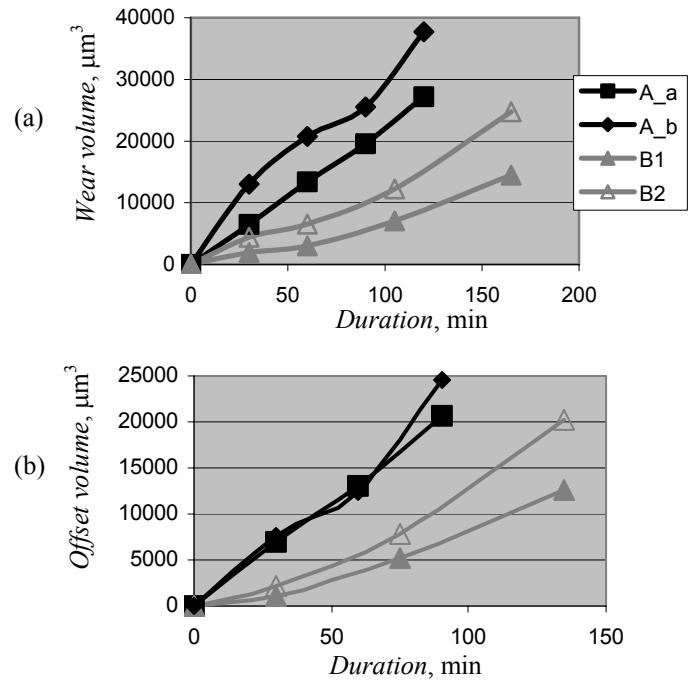


Fig 3. Wear volume vs test duration: a) original data, and b) offset data where volume at 30 min is subtracted.