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Role of cross-grooved type texturing in acceleration of initial running-in under lubricated fretting

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ABSTRACT

Continuing efforts have been made towards fretting minimization. Simultaneously, texture studies have also been actively pursued as ways toward solving tribological problems. However, few studies focusing on both fretting and texture have been conducted. Therefore, we conducted fretting tests under lubrication for cross-grooved type textured, dimple textured and mirror-finished surfaces and evaluated their initial running-in periods. Our results showed that cross-grooved type texturing is the most effective for acceleration of the initial running-in period. Furthermore, our numerical analysis of contact pressure on these surfaces showed that the highest local contact pressure occurs when cross-grooved type texturing is used. This indicates that high contact pressure promotes surface plastic deformation that leads to an acceleration of the initial running-in period.

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1. Introduction

An effective measure for retarding fretting is lubricant application [1]. Additionally, texturing is effective for improving tribological characteristics. In recent years, studies of textured surfaces under lubrication conditions have been actively pursued [2–5]. However, while numerous studies have examined issues such as one-way slip, only a few studies focusing on fretting under various texturing conditions have been conducted [6–8]. At the minimum displacement amplitude in oil-lubricated fretting situations, it is not easy to supply lubricating oil to sliding surfaces. Furthermore, the influence of wear particles on surface conditions show different amplitudes [9,10]. Under the fretting, the abrasive effects of wear particles interposed at contact surfaces can also impose difficulties. In such conditions, texturing provides relief in the form of oil grooves and pockets to facilitate even lubricant distribution and to collect wear particle away from the surface [5]. Thus, texturing can be considered as a useful method for minimizing fretting.

In this study, we focus on the initial running-in period, where a significant reduction in the coefficient of friction is observed in the early stage of fretting, in order to assess lubricating conditions. While in our previous study we investigated dimple texturing [11], this study focuses on cross-grooved type texturing. Fretting tests are conducted and compared with dimple textured and mirror-finished surfaces. The tests are conducted under constant load and speed conditions, during which the influence of the fretting stroke is investigated. The results are then discussed in light of the results of numerical analyses of the contact pressure of these surfaces.

2. Experimental

2.1. Apparatus

Fig. 1 shows a schematic of the fretting test setup. As can be seen in the figure, the driven specimen is attached to a cantilever. Fretting stroke A is then supplied by a motor and a crank chain to a cantilever (*A* is a setting stroke, not a relative stroke). The fixed specimen is attached to an upper holder and loaded against the driven specimen, after which the relative stroke between both specimens is measured by an eddy current pick up. The frictional force is measured by strain gauges mounted on upper holder.

2.2. Specimens and experimental conditions

Specimens used for the fretting test were HV760 steel ball bearings (9.525 mm in diameter) for the side driven surface, and HV760 flat bearing steel for side fixed surface. Before texturing, the surfaces of the flat specimens were first machined to a mirror finish process ($Rz = 0.23 \pm 0.04$ μm), after which cross-groove type

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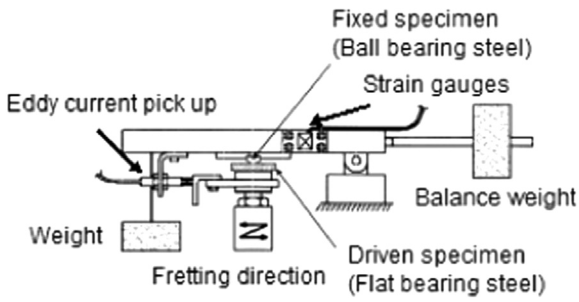

Fig. 1. Schematic illustration of micro reciprocating test apparatus.

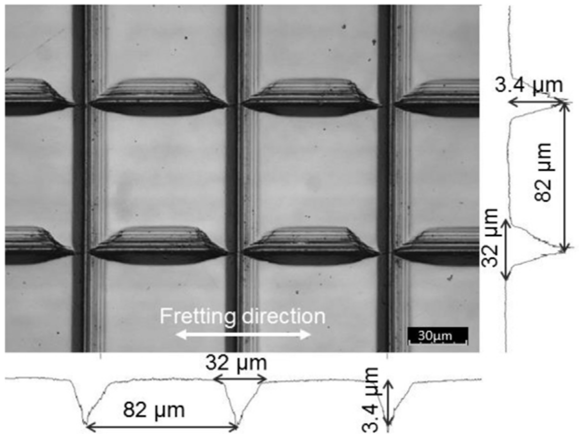

Fig. 2. Micrograph of cross-grooved type texturing.

and dimple texturing were applied to individual specimens. We used a diamond tipped contact probe profilometer with a tip radius of 5 µm and a resolution of 2 nm to measure surface roughness. The trace length was 4.0 mm, the filter was 2CR, and the cutoff was 0.8 mm. The trace speed was 0.1 mm/s.

Mirror finish processing was applied using emery papers (#80∼#3000) and diamond paste. All three surfaces (mirror, cross-grooved type, and dimple) were used in our tests. The texture processing method was the same as used in previous report [11], and a diamond indenter was used to create textures. Post-processing for removing pile-ups was performed using emery paper (#3000) and diamond paste. The created texture pattern was observed in detail using a confocal laser-scanning microscope (CLSM). The images are shown in Figs. 2 and 3. Table 1 shows the detailed experimental conditions. The CLSM specifications are shown below. The lateral resolution is 0.30 µm, the z-axis resolution is 0.05 µm and the measurement range is 256×192 µm^2.

3. Results

3.1. Coefficient of friction μ

Fig. 4 shows changes to the coefficient of friction μ during a fretting test ($A=70$ µm). As can be seen in the figure, μ rises sharply for approximately 500 cycles after the test starts, and then becomes stable at about 0.5 for each test piece. After approximately 900 cycles, μ for the cross-grooved type texturing drops drastically, indicating that the running-in process had been completed. In contrast, the same μ drop for the dimple textured surface occurs at approximately 4000 cycles. Finally, for the mirror finished specimen, a μ decline phenomenon is seen at about 30,000 cycles. It should also be noted that the final coefficient of friction is approximately 0.2 for all test specimens.

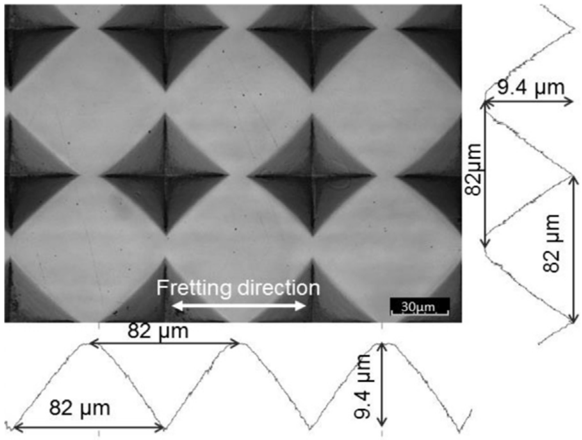

Fig. 3. Micrograph of dimple texturing.

Table 1
Experimental conditions.

Specimen	Fixed	Flat bearing steel (HV760)
	Driven	Ball bearing steel (HV760), ⌀9.525 mm
Configuration		Ball on flat point contact
Fretting stroke A		30–200 µm
Normal load		9.8 N
Atmosphere		Lubrication condition
Lubricant		Poly-α-olefin (Base oil, 75 cSt @ 40 °C)
Test duration		2×10^5 cycles
Frequency		7.0 Hz
Temperature, Relative humidity		24 ±2 °C, 45±20%

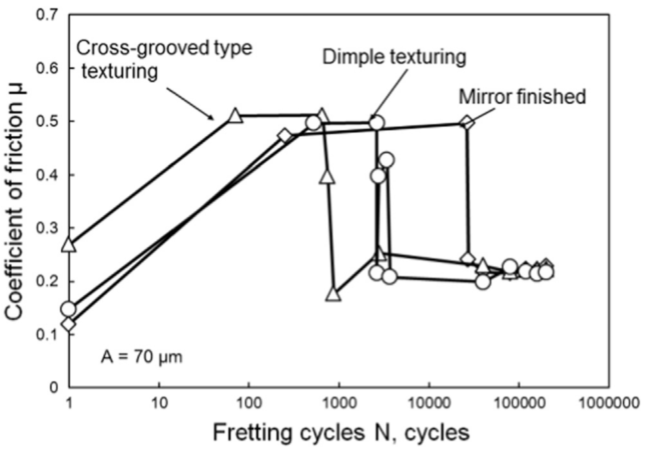

Fig. 4. Change in coefficient of friction ($A=70$ µm).

Fig. 5 shows the relationship between the number of cycles needed for completion of the running-in period (Nr) and fretting stroke A. As A becomes larger, Nr becomes smaller. Arrows at approximately 200,000 of Nr show when the running-in period could not be observed during the tests. In contrast, an Nr of 1 shows that coefficient of friction was low from the starting point. Regardless of fretting stroke, the running-in process completed first for the cross-grooved type textured, then the dimple textured, and finally the mirror finished surfaces.

3.2. Wear scar observations

The width and the cross-sectional form of the wear scars were measured using a laser microscope. Fig. 6 shows a comparative laser microscope image of each test specimen for a fretting stroke

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