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Effect of geometrical parameters in micro-grooved crosshatch pattern under lubricated sliding friction

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ABSTRACT

Tribological test was carried out using a pin-on-disc geometry with textured SKD11 pin on bearing steel disc, under sliding in paraffin oil. Micro-grooved crosshatch pattern has been fabricated with various angles and widths. The effects of geometrical parameters on friction were mainly examined in mixed and elastohydrodynamic lubrication. The results show that friction control can be achieved by fabricating the micro-grooved crosshatch pattern on a contact surface. It is observed that each geometrical parameter of texture influence on friction, especially decrease of groove aspect ratio and increases of groove sliding length show friction reduction performance. Crucial parameter G_l was proposed for micro-grooved crosshatch texture. The friction mechanism is explained by micro fluid flow with limited theoretical approach.

1. Introduction

Surface texturing, one of the methods to control the friction, is the technology to modify the surface by fabricating texture patterns to control the tribological properties in relative motion. In general, these properties play an important role in most industrial processes in the view point of energy dissipation and material squander. Future development of this technology requires clear understanding of the basic design guidelines to guide investment decisions in equipment and expertise.

There are many studies and reports that texturing technology improves load carrying capacity, and friction performance of tribological components significantly [1–6,18]. Theoretical studies also have been reported regarding geometric parameters of textures [7–9] and it emphasized that these parameters are one of the most important factor to optimize texturing benefits. The known results of "why these features work" can provide marked improvement in terms of friction and wear reduction. And mostly, discovery and optimization of the surface texturing are carried out in the form of Edisonian approach. There are no doubts that surface engineering is the next generation technology most relevant to industrial applications. But due to the complex nature of phenomenon the correlation and understanding of each parameter has not been completely known, and only in limited cases had been analytically described. Most of the known mechanisms were about discrete texture concerning a pit area ratio and a shape of pattern [10–14], besides few of work have been done for crosshatch groove surface texture, in the view point of geometric parameter.

There are two general types of textures, a discrete and a continuous texture (see Fig. 1). Various shapes of feature e.g. circle, rectangular, triangle, honeycomb, and etc. are being applied in discrete texture. Continuous texture has an array of straight line or curved line in parallel or crosshatch form. These differences in design of surface textures will change the contact pressure contours inside the contact. The technical challenge is to determine the critical dimensional relationships between the width, length, and depth of the feature, the distance between features (pitch, array, angle for directions), and the edge contour control (see Fig. 2). Those requirements cost money and vary depending on application and operating conditions of the components. Table 1 shows the major difference of each general texture regarding geometric parameters.

Discovery of the crucial design parameters and the correlation of geometrical parameters are necessary to get the maximum benefits so that it can improve the performance and pursue engineering applications of such concepts in gears, cams, bearings, and wear interfaces. In this study, the micro-grooved crosshatch pattern for sliding under lubrication was studied, and

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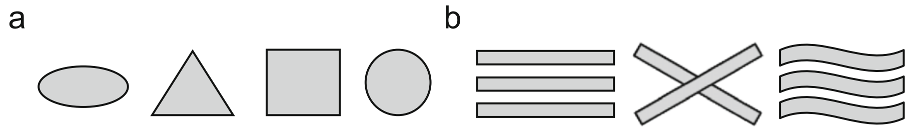

Fig. 1. Shape of features and classification of surface textures: (a) discrete textures and (b) continuous textures.

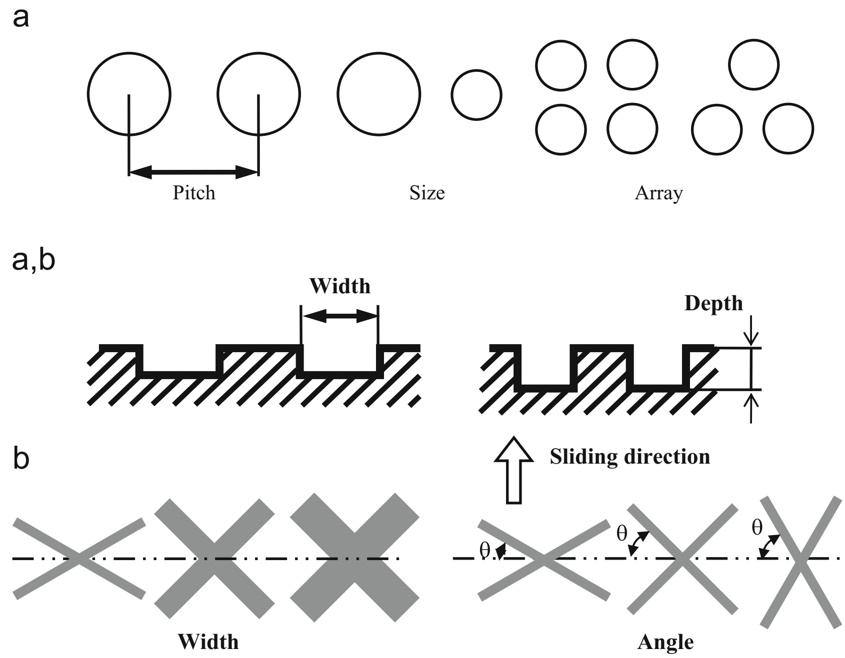

Fig. 2. Geometric parameters of surface texture for (a) dimple textures and (b) crosshatched groove textures.

Table 1
Geometric parameters of each general texture.

Type of texture	Geometric parameters							
	Width[a]	Length	Depth[a]	Pitch[b]	Angle[c]	Array	Edge contour	Texture area ratio
Discrete texture	✓	✓	✓	○	×	○	✓	✓
Continuous texture	✓	✓	✓	○	×	○	✓	✓
Crosshatch texture	✓	✓	✓	○	✓	×	✓	✓

✓ Important. ○ Marginal. × Unfavourable.

[a] Aspect ratio of width/depth is an important factor in terms of friction performance.
[b] Pitch has a dependence character with texture area ratio.
[c] Angle parameter is unique for crosshatched groove only, which was known as crucial factor in previous work [18].

the correlation of crosshatch angle and width for friction under regime of mixed and elastohydrodynamic lubrication were mainly examined.

2. Material and experimental procedure

2.1. Material

In the present study, the tribological behaviour of two steel pair material tool steels (SKD11, JIS) and the bearing steel was tested under sliding in paraffin oil with a pin-on-disc geometry. Before surface texturing, the upper pin specimens were ground and polished to a mirror finish with 3 μm diamond paste. The final surface roughness R_a before texturing was $0.05-0.10\,\mu m$.

Table 2
Geometrical parameters of test specimens.

Parameter of crosshatched groove texture	Value	Step
Angle, θ_R (deg)	20, 30, 40, 50, 60	5
Area ratio (%)	20	1
Depth, d (μm)	5 ± 0.5	
Width, w (μm)	40, 70, 100	3
Aspect ratio, G_r[a]	0.125, 0.07, 0.05	3

[a] G_r is an aspect ratio of groove depth over groove width (groove depth is considered fix at 5 μm).

Table 2 shows the geometrical parameters of specimens. Crosshatch angle varies in the range of 60° to 20° with combination of three different widths. Groove area ratio is a ratio of textured over untextured, in this study it is equally set to 20%.