FRICTION PROPERTIES OF MILLING MICRO-TEXTURED SURFACE ON AL-SI ALLOY UNDER SLIDING BOUNDARY CONDITIONS

TRACK OR CATEGORY

Surface Engineering (including Hard Coatings)

AUTHORS AND INSTITUTIONS

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INTRODUCTION

With the increasing research on micro-size texture in recent years, micro size effects such as boundary slippage in the lubrication of bearings and pistons have gradually entered the field of view. When the ratio of the molecular mean free path to the characteristic geometric length is between 10^{-3} and 10^{-1}, the velocity of the fluid and the velocity of the solid at the boundary are not equal. The difference is called the slip velocity, which is expressed by the product of the slip length b and the velocity normal gradient on the boundary [1]. The variation of surface texture parameters and slip length influences the flow of fluid in the flow field [2], and optimal structures are sought to improve the friction performance.

This article combines the Reynolds equation and the Stokes equation to investigate the effects of slip boundary conditions and texture on microchannels. The Navier slip boundary condition is applied to the Reynolds equation to solve the slip velocity. Stokes equation is employed to calculation the fluid field. In addition, friction and micro-milling experiments are performed to verify this method is correct. Many simulations are tried to research the influence of slip boundary and texture on pressure of fluid.

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Methods

Considering that triangle is the simplest and most stable structure, the influence of different parameters on lubrication performance of surface grooves is studied under the condition of slip boundary. The two-dimensional flow model is shown in figure 1, where the lower surface slides at a velocity U_0 along x direction and the velocity of the upper surface with texture is zero. Moreover, the height of triangular element is h, and the width and depth of the elements are a and D, respectively. The slip velocity boundary condition is set as equation (1).

$$\begin{aligned} y=0: u &= U_0 + b_2 \frac{\partial u}{\partial y}\Big|_{y=0} \\ y=h: u &= -b_1 \frac{\partial u}{\partial y}\Big|_{y=h} \end{aligned} \tag{1}$$

According to the assumption that the pressure is constant in the direction of film thickness based on Reynolds equation, the variable governing equation is derived as equation (2),

$$\frac{\partial}{\partial x}[(h^3+6bh^2)\frac{\partial p}{\partial x}]=6\mu U_0\frac{\partial h}{\partial x} \tag{2}$$

where μ is the dynamic viscosity. The variational finite element method is used to discrete and solve the functional equation [3], and the pressure distribution and velocity distribution could be obtained in the flow field. In order to prove the accuracy of the solution, conical micro-grooves are machined on aluminum alloy workpieces by micro-milling to carry out friction experiments.

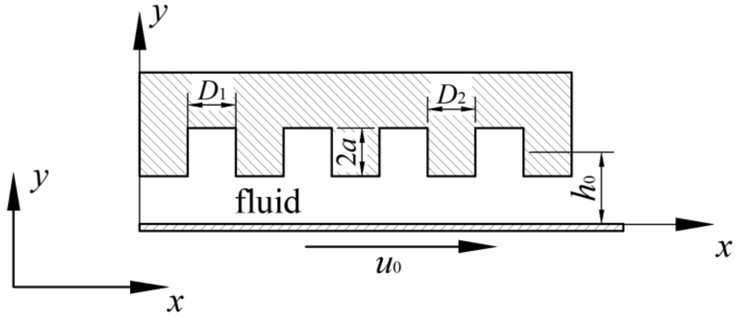


Figure 1. Reflections on two-dimensional flow model

Experiments

In the process of experiment, the five-axis micro-machining center KERN-2522 was used to micro-mill the surface micro-textures [4], as shown in figure 2. The cutting tools were made of 100μm micro-conical and micro-end milling cutter, and the cutting material was aluminum alloy. The micro-milling experiment was conducted under the constant spindle rotational speed of 20,000 rpm, the axial depth of cut of 20μm, and the feed rate of 50mm/min. After micro-milling the grooves, the aluminum alloy specimens were polished and washed in the ultrasonic cleaning machine. And the surface roughness of the specimens could be observed by confocal microscopy at about 1μm, as shown in figure 3. The designed micro-friction tester was used to carry out the friction experiments of hydrodynamic lubrication.

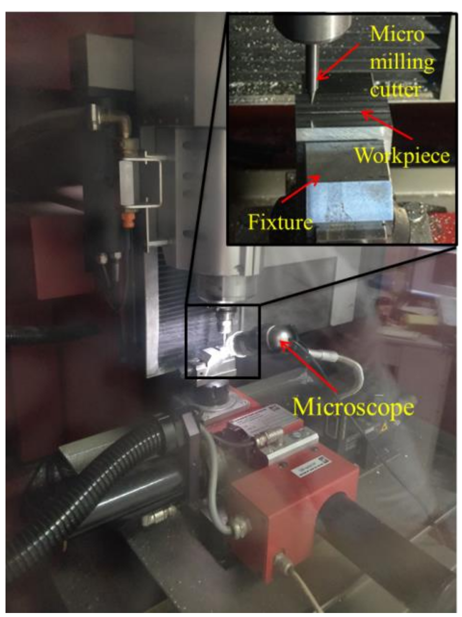
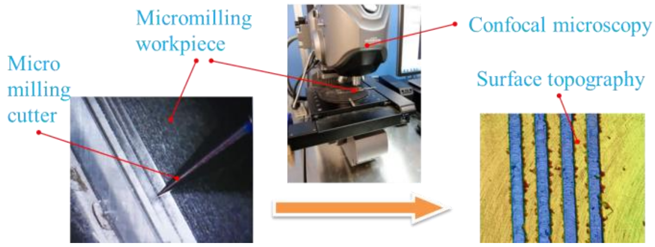
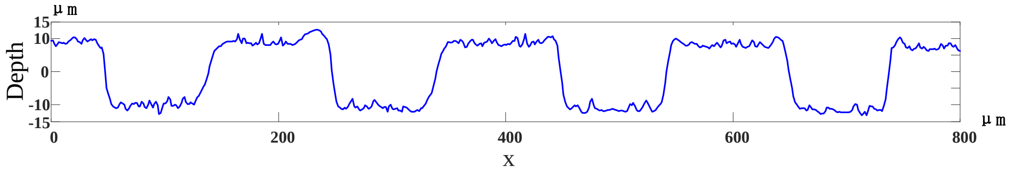


Figure 2 View of micro-milling experiment device



(a)



(b)

Figure 3 (a)View of rectangular texture sample processing experiment (b) Roughness curve

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KEYWORDS

Micro-textured surface; slip boundary; hydrodynamic lubrication