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Theoretical investigation of texture depth effect on the lubrication performance in slip pocketed bearing including cavitation

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ABSTRACT - This paper show results of the investigation on the combined effect of the pockets and boundary slip for simple parallel sliding bearings including cavitation. Cavitation was of particular interest with respect to pressure generation and shear stress. It was shown that slip over the whole surface could retard the presence of cavitation and therefore the generated pressure and shear stress can be optimal.

1. INTRODUCTION

Surface texturing is an effective approach to increase the tribological performance of mechanical components. It is shown that by introducing textured surfaces that it affects friction and load support of sliding bearings [1-6]. In most of the previous works the cavitation mechanisms is neglected and the validity of their results becomes questionable.

Recently, the presence of the cavitation in textured slider bearings is researched [7-8]. As is known, the slip as well as texturing can be engineered to alter the flow characteristic with respect to the improvement of the performance. The present paper proposes a novel analytical equation based on Reynolds equation considering cavitation and combined with boundary slip model.

2. METHOD

Figure 1 gives the schematic illustration of a parallel textured (pocketed) sliding bearing with boundary slip on the stationary surface. The main characteristics of the bearing studied are presented in Table 1. To solve the lubricated system a modified Reynolds equation is derived including cavitation (see Equation 1).

Eq. (1) is obtained by following the usual approach to deduce the Reynolds equation from the Navier-Stokes equation by assuming classical assumptions except that boundary slip is applied on pocketed surfaces as depicted in Figure 1.

In the following computations, the dimensional pocket depth HD is defined as ratio of the pocket depth h_d over minimum film thickness h_o (see Fig. 1). The HD of 5 and 10 are chosen due to the possibility of the presence of the cavitation in bearing.

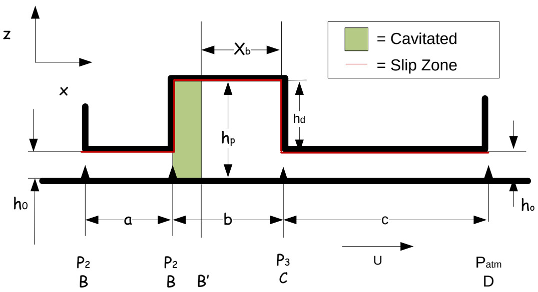

Figure 1 Schematic diagram of parallel sliding pocketed bearing. (Note: h_d = pocket height, h_p = texture thickness, X_b = no cavitation area in pocket, P_2 = pressure inlet pocket, P_3 = pressure outlet pocket).

Table 1 Main characteristics of the bearing analyzed.

Parameters	Symbols	Value
Bearing length	B_o	0.02 m
Inlet length	a	0.002 m
Pocket length	b	0.003 m
Exit land length	c	0.015 m
Atmospheric pressure	p_{atm}	100 kPa
Cavitation pressure	p_{cav}	0 kPa
Min. film thickness	h_o	1 μm
Moving surface velocity	u	1 m/s
Slip coefficient	α	0.02 m^2s/kg
Dynamic viscosity	μ	0.01 Pa.s

$$P_2\left[\left(h_p^3+3h_p^3K_p\right)\frac{ab+bc}{ab^2}+\left(\frac{h_o^3+3h_o^3K_o}{a}\right)\right]$$
$$=P_{atm}\left[\left(h_p^3+3h_p^3K_p\right)\frac{ab+bc}{ab^2}+\left(\frac{h_o^3+3h_o^3K_o}{a}\right)\right] \quad (1)$$
$$-6\mu U\left[\left(h_p+h_pK_p\right)-\left(h_o+K_o\right)\right]$$

Where $K_o=\dfrac{\mu\alpha}{h_o+\mu\alpha}$; $K_p=\dfrac{\mu\alpha}{h_p+\mu\alpha}$;

3. RESULTS AND DISCUSSION

In the present study, the zero shear stress in the region of cavitation (see Fig. 1), which is defined by the length of X_b, is assumed [8].

Figure 2 shows that for HD = 5 (HD = h_d/h_o), the cavitation will occur in the pocket when slip is applied or not. However, as depicted in Fig. 2, the length of X_b

in the full slip case is higher than for the no-slip condition. From physical point of view, it means that the application of slip tends to prevent the occurrence of cavitation. For a higher pocket depth, for example, HD = 10, cavitation will occur for the no-slip pocketed bearing while for the full slip bearing it does not exist. Before cavitation occurs, the value of P_3 is the same both for both the slip and no-slip situation. When cavitation occurs, P_3 decreases while P_2 increases (see Figure 1). At the leading edge of the contact, the inlet pressure which is set to equal atmosphere pressure decreases to cavitation pressure, i.e zero (see Table 1).

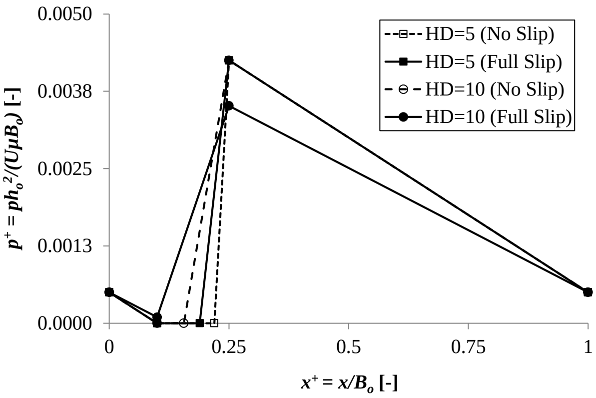

Figure 2 The effect of texture depth HD on the dimensionless pressure p^+. (Note: p^+ = dimensionless pressure, x^+ = dimensionless length).

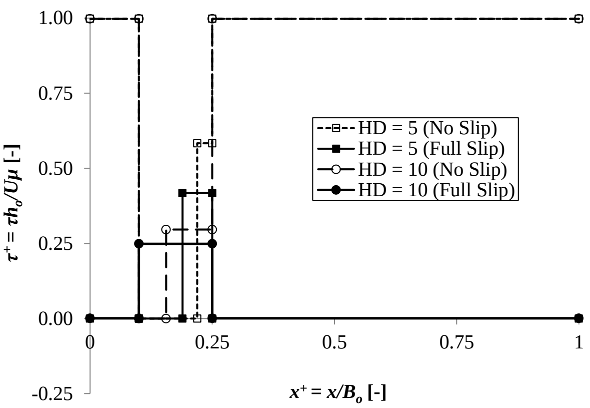

Figure 3 The effect of relative texture depth HD on the dimensionless shear stress τ^+.

For the no-slip case, the shear stress is relatively high at the inlet and outlet, but in the pocket area, the shear stress is low. In the cavitation area, the shear stress is zero. When slip is introduced, the shear stress becomes very low (close to zero) at the inlet and outlet. If we compare the no-slip case with HD = 5 with HD = 10, it can be concluded that the shear stress at the inlet and outlet is the same, but in the pocket there is a decrease in the shear stress. Observing the shear stress distribution, the slip boundary condition generates a lower friction force compared to the no-slip case.

4. CONCLUSIONS

A hydrodynamic lubrication model for a pocketed bearing combined with boundary slip was proposed, and it was shown that the pocketed slip bearing can give many advanced properties compared with solely textured slider bearing (without slip). The following conclusions summarize the results of the present study:

a) In a pocketed bearing with slip the occurrence of the cavitation may decrease compared to the traditional (no-slip) bearing.
b) For the no-slip case of a slider bearing, increasing the pocket depth will decrease the value of shear stress in the pocket. This result is opposite when slip in the pocket is present.
c) When cavitation occurs in the bearing, the generated load support will be higher if the slip condition is applied compared to the no slip situation.

5. REFERENCES

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