Effect of texture shape on the hydrodynamic lubrication performance of the sliding textured contact: a numerical approach

by

Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Effect of texture shape on the hydrodynamic lubrication performance of the sliding textured contact: a numerical approach

To cite this article: Susilowati *et al* 2018 *J. Phys.: Conf. Ser.* **1090** 012027

IOP Conf. Series: Journal of Physics: Conf. Series **1090** (2018) 012027 doi:10.1088/1742-6596/1090/1/012027

Effect of texture shape on the hydrodynamic lubrication performance of the sliding textured contact: a numerical approach

Susilowati[1,2], M Tauviqirrahman[2], J Jamari[2], AP Bayuseno[2]

[1]Laboratory for Research and Unit Operation of Chemical Engineering, Chemical Engineering Department, Industrial Technology Faculty, Universitas Pembangunan Nasional "Veteran", East Java, Indonesia

[2]Laboratory for Engineering Design and Tribology, Mechanical Engineering Department, Engineering Faculty, Diponegoro University, Indonesia

zuzisukasno@gmail.com

Abstract. Currently, there is a great interest in the use of texturing as well as the slip because these surface are able to improve the lubrication performance and thus higher life time of the bearing. In the present work, the modified Reynolds equation considering mass conserving cavitation model is established on the basis of Navier-slip model, in which the slip-textured bearing is considered. The texture shape of the single textured bearing with slip located at the inlet is of particular interest. Various shapes of texture, i.e. triangular, rectangular, and parabola are explored with respect to the hydrodynamic lubrication performance (i.e. the load support and the friction). The inlet length containing slip condition is also varied. The results show that triangular shape of texture gives the higher load support compared to other shape for all value of the inlet length. However, with respect to the friction force, rectangular shape gives the lowest friction force, whilst the triangular shape produces a contrary result.

1. Introduction

Surface texturing as a tools for improving the tribological characteristics of mechanical components has been under intensive exploration over the last two decades. Many techniques have been introduced to create surface texture of various geometries and patterns by several researchers. Ma and Zhu [1] have paid attention to the elliptical-shape dimples with various depths, diameters, area ratios and different operation parameters. The friction coefficient was of particular interest. With the same focus for improving the friction, Uddin and Liu [2] presented the design of a new 'star-like' texture shape. They showed that triangle effect is the most dominant in reducing the friction. They also found that the new optimum star-like texture reduces the friction coefficient by 80%, 64.39%, 19.32% and 16.14%, as compared to ellipse, chevron, triangle and circle, respectively. In recent lubrication, Zhang et al. [3] confirmed that the elliptical-shaped textures have preferable tribological behaviors of low friction coefficient for light load situation.

Recently, it is also well-known that the performance of the lubricated sliding can be improved by combining the surface texturing with the boundary slip. Aurelian et al. [4] presented the results about a partially textured bearing with wall slip conditions. One of their findings was that inadequate locating of the textured-slip pattern can lead to the deterioration of the bearing performance. Rao et al. [5]

IOP Conf. Series: Journal of Physics: Conf. Series **1090** (2018) 012027 doi:10.1088/1742-6596/1090/1/012027

investigated the effects of texture/slip configuration on the enhancement in load support and the reduction in coefficient of friction for slip-textured pattern both in slider and journal bearing. Extensive work of combined effect of slip and texture has been carried out by Tauviqirrahman et al. [6]. They showed that in comparison with a solely textured surface, the load support of the combined textured/wall slip pattern can be increased by around 300% using the optimized slip parameters. Later, Lin et al. [7] explored the effect of large-area texture/slip surface, especially the area and position of large-area texture surface on journal bearing considering cavitation. They concluded that texture/slip surface would not affect the pressure and load-carrying capacity when it locates at cavitation zone. In recent publication, related to the slip position, it is confirmed that adding slip at the leading edge of the single-textured contact is considered more efficient than extending the slip to the textured region with respect to the load support and friction force [8].

While considering this scientific context, the main aim of this work is to study the effect of texture shape on the performance of the sliding contact with the slip located at the leading edge of the contact varying the slip inlet length. A numerical approach is proposed based on modified Reynolds equation for the choice of texture shape with respect to the load support as well as the friction force. The load support and the friction force are of particular interest.

2. Analysis

The most common shape of texture used in modeling the slider bearing is rectangular. However, in real application, other texture shapes can also be used as seen in Figure 1. Following this insight, in this work the effect of the comparison of the texture variation on the lubrication performance is of particular interest.

In the present study, the shape used is triangular, rectangular, and parabola as seen in Figure 1. For all following computations, the parameters used with respect to the bearing characteristics as well as their operating conditions are described in detail in Table 1. The bearing configuration studied here as reflected in Fig. 1 is single texture bearing with slip located at the leading edge of the contact. It should be noted that introducing slip at the inlet gives the positive effect on improving the load carrying capacity of the bearing [8,9]. In this work, the inlet length containing slip boundary condition is also of particular interest.

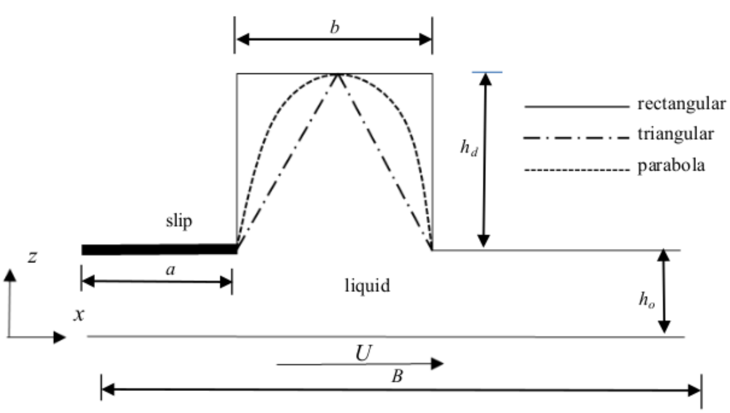

Figure 1. Three texture shapes studied here.

IOP Conf. Series: Journal of Physics: Conf. Series **1090** (2018) 012027 doi:10.1088/1742-6596/1090/1/012027

Table 1. Single texture bearing configuration studied here

Bearing length	B	0.02 m
Inlet length	a	0.0004-0.0136 m (a/B = 0.02-0.68)
Pocket length	b	0.006 m (b/B = 0.3)
Sliding velocity	U	1 m/s
Viscosity	η	0.01 Pa s
Atmospheric pressure	P_{atm}	100 kPa
Minimum film thickness	h_o	1 μm
Pocket depth	h_d	2.5 μm
Slip coefficient	α	0.02

In the present study, the modified Reynolds equation is adopted based on the work of Susilowati et al. [10]. The model of lubrication presented here is based on the fact that slip at the interface between lubricant and surface will exist. It is worth noting that the slip length model is used to address the modeling of the boundary slip for the hydrodynamic analysis after the shear stress exceeds the limiting shear stress. Equation 1 represents the lubrication model as follows:

$$\frac{\partial}{\partial x}\left(h^3\frac{h^2+4h\eta(\alpha_a+\alpha_b)+12\eta^2\alpha_a\alpha_b}{h(h+\eta(\alpha_a+\alpha_b))}\frac{\partial p}{\partial x}\right)=6\eta U\frac{\partial}{\partial x}\left(\frac{h^2+2h\alpha_a\eta}{h+\eta(\alpha_a+\alpha_b)}\right)$$

$$-6\eta\tau_{ca}\frac{\partial}{\partial x}\left(\frac{\alpha_a h(h+2\alpha_b\eta)}{h+\eta(\alpha_a+\alpha_b)}\right)+6\eta\tau_{cb}\frac{\partial}{\partial x}\left(\frac{\alpha_b h(h+2\alpha_a\eta)}{h+\eta(\alpha_a+\alpha_b)}\right)-12\eta U\frac{\alpha_a\eta}{h+\eta(\alpha_a+\alpha_b)}\frac{\partial h}{\partial x}$$

$$\frac{\partial}{\partial x}\left(h^3\frac{h^2+4h\eta(\alpha_a+\alpha_b)+12\eta^2\alpha_a\alpha_b}{h(h+\eta(\alpha_a+\alpha_b))}\frac{\partial p}{\partial x}\right)=6\eta U\frac{\partial}{\partial x}\left(\frac{h^2+2h\alpha_a\eta}{h+\eta(\alpha_a+\alpha_b)}\right) \quad (1)$$

The physical meanings of the symbols in Equation 1 are as follows: h the film thickness (gap) at location, p the lubrication film pressure, α the slip coefficient, τ_c the critical shear stress (subscripts a and b denote the stationary and moving surface, respectively), and η the lubricant viscosity. It should be noted that when the slip is located at the stationary surface as indicated in Figure 1, the α_b will be equal zero as well as the τ_{cb}. For all following computation, the slip is assumed to occur on the stationary surface.

In this study, dealing with the derivation of modified Reynolds equation the conditions for cavitation are based on the Reynolds cavitation theory to model the rupture zone for the textured surface. The modified Reynolds equation (Eq. (1)) is discretized over the flow using the finite volume method, and is solved using tridiagonal matrix algorithm (TDMA). By employing the discretization scheme, the computed domain is divided into a number of control volumes using a grid with uniform mesh size. The grid independency is validated by various numbers of mesh sizes.

3. Results and Discussion

3.1. Effect of inlet length on the load support

In this work, the lubrication performance of the slider bearing is represented by the load support. It is obtained by integrating the hydrodynamic pressure over the surface area. Figure 2 shows the effect of the slip inlet length a on the load support W. It is noted that in Figure 2, the inlet length is rationalized by the bearing length B. It can be observed based on Figure 2 that the trend of load support profiles for three texture shapes is similar, i.e. increasing the inlet length to certain value enhances the load carrying capacity. However, after that, increasing the a will reduce the W significantly. When the inlet length is 0.45 times the bearing length, the maximum load support is achieved for all texture shapes studied here. Based on this figure, it can be observed that the shape of triangular texture gives the best performance of the slider bearing with respect to the load support for all range of the inlet length. However, the difference of the predicted load support for three texture shapes is relatively small, especially when $a/B = 0.45$. The highest difference of the prediction of W occurs when $a/B = 0.1$. It can be observed that the triangular shape seems superior to other shapes.

Other interesting result is there is a critical value of the inlet length a/B. Based on the simulation results, this point is 0.45. On the other words, for inlet length values which is below critical value (i.e. $a < 0.45\ B$), the difference of the prediction of the W increases by reducing the inlet length with slip. It is also noted that when the dimensionless inlet length exceeds the critical value of the a/B, such difference increases with increasing the inlet length. From the physical point of view, it indicates that in addition to the slip condition, the texture itself has significant effect on altering the flow characteristic.

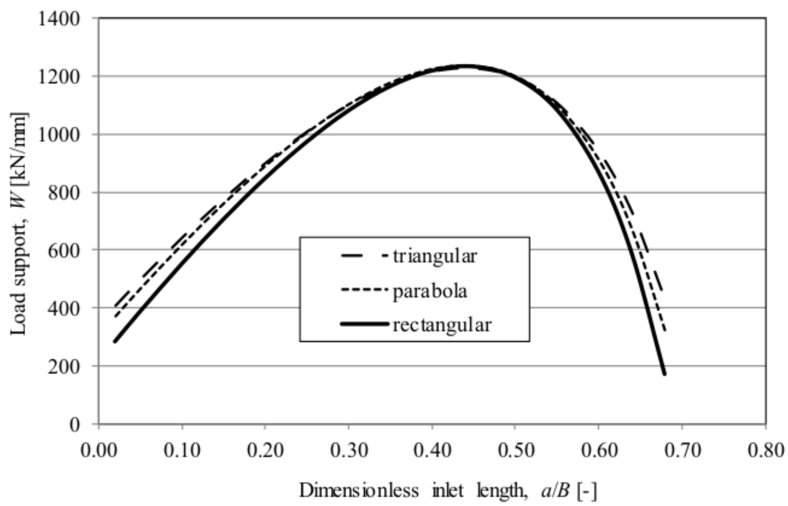

Figure 2. Effect of inlet length with slip a/B on the load support W varying the texture shapes

3.2. Effect of inlet length on the friction force

Figure 3 depicts the correlation between the dimensionless inlet length a/B and the friction force F. It can be observed that the same trend of friction force profile for three textures shapes considered here is highlighted. Increasing the inlet length with slip condition reduces the friction forces significantly. This is as expected due to the nature characteristic of the slip boundary which is hydrophobic. High wetting of the surface containing slip leads to the decrease in the friction reduction.

Regarding to the textures shape, based on Fig. 3, it is also found that the rectangular texture produces the lowest friction force for all value of the inlet length, whilst the triangular gives the highest friction force. This result seems to be contrary with the previous finding which stated that triangular shape leads to positive effect in terms of the load support. The most possible explanation is that based on Fig. 3, the difference of the prediction of the friction force among the texture shapes is relatively small; it is just 5%. The highest difference is calculated when the inlet length is set to maximum, that is, when $a/B = 0.68$.

In real application, the rectangular texture shape seems become a technique that is easier to adopted compared to other shapes. Lowering the friction force by texturing the bearing with rectangular shape will enhance the life time of the bearing. This is because the stiction which may exist due to high friction can be prevented.

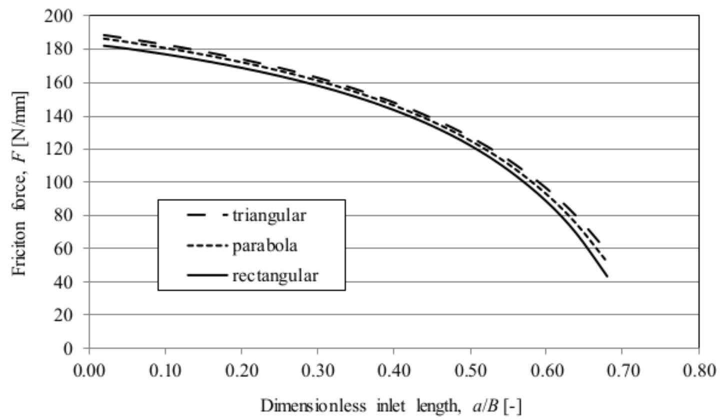

Figure 3. Effect of inlet length with slip a/B on the load support W varying the texture shapes

4. Conclusions

In the present paper, the texture shape of the textured contact with the boundary slip which may alter the flow characteristics of the textured contact was of particular interests varying the inlet length. Three texture shapes, i.e. triangular, parabola and rectangular were considered here. The modified Reynolds equation with slip was used to solve the lubrication. Based on the explanation above, the main conclusion can be drawn as follows:

1. With terms of the load support, triangular shape of textured contact is recommended to use.
2. With terms of the friction force, rectangular shape of textured contact is preferable.
3. The most interesting finding is that when the slip inlet length is set to 0.45 times the bearing length, the highest load support as well as the low friction can be achieved. This result can be regarded as a guideline for designing the textured bearing with slip.

References

[1] Maa C and Zhub H 2011 *Tribol. Int.* **44** 987
[2] Uddin MS and Liu YW 2016 *Biosurf. Biotribol.* **2** 59
[3] Zhang H, Dong GN, Hua M and Chin KS 2017 *J. Tribol.* **139** 011701
[4] Aurelian F, Patrick M and Mohamed H 2011 *Tribol. Int.* **44** 868
[5] Rao TVVLN, Rani AMA, Nagarajan T and Hashim FM 2012 *Tribol. Int.* **56** 121
[6] Tauviqirrahman M, Muchammad, Jamari and Schipper DJ 2014 *Tribol. Trans.* **57** 134
[7] Lin Q, Wei Z, Wang N and Chen W 2015 *Ind. Lubr. Tribol.* **67** 216

[8] Tauviqirrahman M, Ajie WK, Yohana E, Muchammad M and Jamari J 2016 *Int. J. Eng. Tech.* **8(2)** 913
[9] Muchammad M, Tauviqirrahman M, Jamari J and Schipper DJ 2017 *Lubr. Sci.* **29** 133
[10] Susilowati S, Tauviqirrahman M, Jamari J and Bayuseno AP 2016 *Tribol. - Mater. Surf. Interfaces* **10**(2), 85

Effect of texture shape on the hydrodynamic lubrication performance of the sliding textured contact: a numerical approach

ORIGINALITY REPORT

22%	22%	0%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	eprints.undip.ac.id Internet Source	22%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		