

Numerical optimization of load support of the single textured lubricated contact with boundary slip

by Mohammad Tauviqirrahman

Submission date: 19-May-2020 08:19AM (UTC+0700)

Submission ID: 1351028518

File name: Tauviqirrahman_2018_J_Physical_ICCSE_2017_Paper.pdf (616.78K)

Word count: 2471

Character count: 12944

PAPER • OPEN ACCESS

Numerical optimization of load support of the single textured lubricated contact with boundary slip

2

To cite this article: M Tauviqirrahman *et al* 2018 *J. Phys.: Conf. Ser.* **1090** 012068

7

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices
to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of
every title for free.

Numerical optimization of load support of the single textured lubricated contact with boundary slip

M Tauviquirrahman*, M F Noorkarim, Arijanto, Muchammad

Laboratory for Engineering Design and Tribology, Mechanical Engineering
Department, Engineering Faculty, Diponegoro University, Semarang, Central Java,
50275, Indonesia

*mohammad.tauviquirrahman@ft.undip.ac.id

Abstract. Textured surfaces containing macro texture in one of the surfaces are the subject of a great deal of research to enhance tribological characteristic (higher low support but lower friction) of the bearing. In this paper, a general parametric model of the groove texture profile of single textured contact with boundary slip is developed and the exact optimization method is adopted to obtain the global-optimum texture profile of the lubricated sliding contact. The optimization objective is the maximization of the load support of the lubricant. The results show that there is a shift of the texture location to the centre of the contact with lower texture length. It is also found that the optimal single textured bearing can help to improve the load support up to 75%.

1. Introduction

Recent technological advances have presented some new methods such as grafting, coating, laser surface texturing, and micro machining to improve the tribological characteristic (higher low support but lower friction) of the bearing. Within the broad area of tribology, the researches relating to the lubrication have paid much attention to surface texturing, as is reflected in many recent papers. Buscaglia et al. [1] studied the effect of one-dimensional and two-dimensional textures on the load support of a bearing with a "homogenized" effect and a homogenization error. Scaraggi et al. [2] investigated the friction properties of the lubricated laser textured surface by tuning microhole depth. With the aim of minimizing the friction, different surfaces characterized by different micro hole depths, but same void ratio have been explored.

Related to the optimization of the texture shape, many researchers have explored new method to improve the lubrication performance. Uddin and Liu [3] introduced the design and optimization of what-so-called star-like texture shape for improving tribological performance. The main result was that the triangle effect is the most dominant in reducing the friction. The other result proposed by Zhang et al. [4] stated that either bullet or fish shape was the preferable texture shape than those of circular shape based on genetic algorithm. In recent publication, Wang et al. [5] used the GA-SQP hybrid method to obtain the global-optimum profile of the groove texture bottom. The maximization of the load support of the oil film was of particular interest. The authors also highlighted the superiority of the proposed GA-SQP hybrid method.

It is also known that in addition to surface texturing, another technique to enhance the bearing performance is by introducing the boundary slip on the lubricated surface via coating technique. However, the available literature survey indicates that the studies related to optimization of the



combined effect of slip and texture of lubricated contact are rather very limited. In addition, most of the previous studies on the slip-texture shape optimization were based on pre-determined shapes and distributions, for example [6,7]. In these references [6,7], the global-optimum shapes were uncertain.

Therefore, more work is required in the area of slip-textured lubricated contact to provide the needful information for the design process. The contribution of this paper is to numerically study the texturing geometry (i.e. pocket texture profile) based on a general parametric model. In particular, single texture cell is investigated with maximizing the load support. The modified Reynolds equation with slip is proposed to analyze the lubrication characteristic.

2. Methodology

2.1. Lubrication model

A schematic representation of the single textured lubricated sliding contact is shown in Fig. 1. The non-textured lower surface slides with a uniform velocity. The upper surface with groove texture remains stationary. The bearing is fully lubricated by a Newtonian, incompressible lubricant, with a constant viscosity. The modified Reynolds boundary condition is used to solve the lubrication problem. It reads:

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

The physical meanings of the symbols in Eq. (1) are as follows: h the film thickness (gap), p the lubrication film hydrodynamic pressure, α the slip coefficient on the stationary surface, U = Sliding velocity and η the lubricant viscosity.

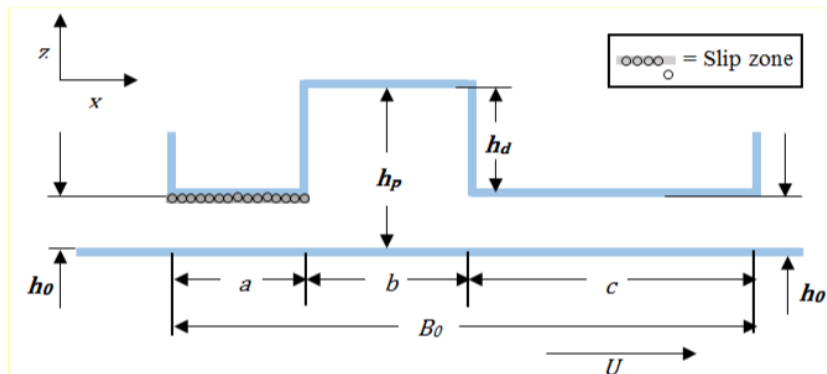


Figure 1. Schematic representation of slip-textured bearing (Note: a = inlet length; b = texture length; c = exit length; h_d = texture depth; h_p = total texture depth; h_o = land film thickness; B_o = total bearing length; U = sliding velocity)

2.2. Discretization

In this paper the modified Reynolds equation is solved numerically using a finite difference equations obtained by means of the micro control volume approach. The entire computed domain is assumed as a full fluid lubrication. The lubricant fluid is in a laminar flow since the Reynolds number is really small. By employing the discretization scheme, the computed domain is divided into a number of control volumes.

The mesh number obtained from grid independent study is approximately 5,000 nodes. In the present study, as seen in Fig. 1, the boundary slip is located at the leading edge of the contact to obtain the maximum lubrication performance [8]. In this work, the inlet length a , the texture length b and the exit length c are varied, while the total texture depth h_p as well as the texture depth h_d is assumed to constant.

2.3. Optimization

In order to conduct the optimization performance of the configuration of slip-textured lubricated contact, the same basic parameters (i.e., working parameters and boundary conditions) are used in the calculations. These parameters are listed in Table 1. Recently, in mathematical programming several methods have been introduced to solve nonlinear constrained optimization problems for the most generic subjects regarding the texture profile in the case of parallel sliding contact. In this section, the exact optimization algorithm is developed to optimize the texture profile of the lubricated sliding contact. The detail parameters for the optimization process is shown in Table 2.

Table 1. Parameters for computations

Total bearing length	B_o	0.02 m
Sliding velocity	U	1 m/s
Viscosity	η	0.01 Pa s
Atmospheric pressure	P_{atm}	100 kPa
Land film thickness	h_o	1 μ m
Pocket depth	h_d	2.5 μ m
Slip coefficient	α	0.02 m ² /kg

Table 2. Parameter settings for optimization procedure

Objective Function	Maximize the load support
Constrain	Total bearing length
Design Variable	<i>Inlet Pocket</i> Lower bond: 0.001 m Upper bond: 0.01 m
	<i>Pocket</i> Lower bond: $inlet + 0.001$ m Upper bond: $inlet + 0.01$ m
	<i>Outlet</i> Lower bond: $inlet + pocket + 0.001$ m Upper bond: $inlet + pocket + 0.01$ m

In the present study, the object of the optimization is to maximize the load support. The load support satisfies two main functional purposes: (1) carry the external load, and (2) reduce the contact between the solids and thus reducing the wear. The optimization analysis attempts to satisfy both functional requirements with various design parameters. i.e. slip inlet length (a) texture length (b) and exit length (c), as seen in Fig. 1. The computer code contains the finite volume method used to solve the hydrodynamic pressure and thus the load support, in combination with a numerical optimization library based on the exact optimization method.

3. Results and Discussion

In the present study, for optimization process, the influence of texture dimension as well as texture position should be exempted. Optimization predictions for this study are initiated by presetting the parameters of: (i) inlet length a as 0.004 m (Fig. 1), (ii) texture length b as 0.006 m, (iii) outlet length c as 0.010 m. In order to ensure that the lubricated interface was under hydrodynamic lubrication regime, the film thickness parameter ($h_o = 1 \mu\text{m}$) is kept constant throughout the computation processes.

Figure 2 depicts the comparison between the hydrodynamic pressure of the initial configuration and that of the optimized pattern. It can be observed that based on the optimization process, the hydrodynamic pressure profile increases significantly along the contact area. In the textured area, it can also be highlighted that the pressure peak in the case of optimized pattern increases up to two times compared to the initial pattern.

Based on Figure 2, it can also be reflected that there is a shift of the starting point of the texture profile. On the other words, the inlet length containing slip becomes larger, that is, up to 150% compared to initial configuration of the bearing. It means that the slip condition has more role to alter the flow characteristic. From the physical point of view, the slip boundary decreases the pressure gradient along the slip area (i.e. inlet length), and this generates the increased hydrodynamic pressure. Other interesting result is that the texture length of the optimized pattern is half the texture length of the initial pattern. Again, it strengthens the previous statement that the slip has more dominant effect in enhancing the tribological performance than the texturing effect (i.e. texture length in this case). This result is in a good agreement with recent publication [9].

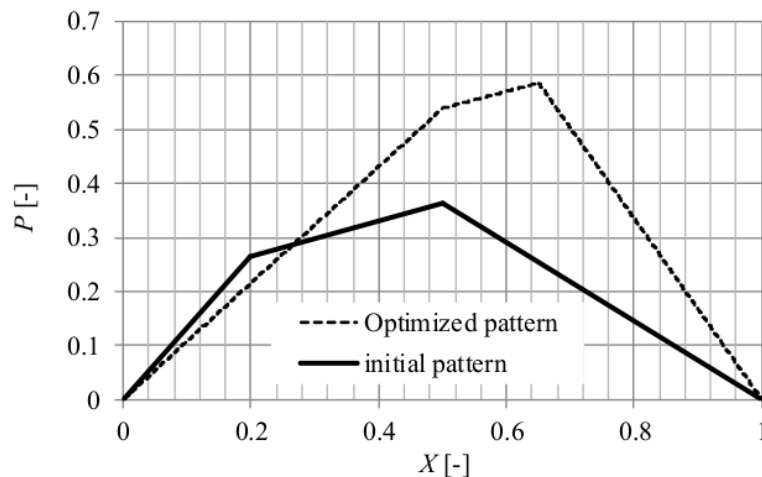


Figure 2. Hydrodynamic pressure profile before and after optimization

The comparison of the textured bearing configuration between “before” and “after” optimization is presented in Fig. 3. It can be observed that at the optimal textured lubricated contact, the texture length becomes shorter than the initial pattern of textured contact ($b' < b$ as seen in Fig. 3). In addition, the value of slip inlet length of the optimal contact becomes larger than the initial condition ($a' > a$ as shown in Fig. 3). It can be said that the combined effect of longer slip area and shorter texture length makes the hydrodynamic pressure increase significantly.

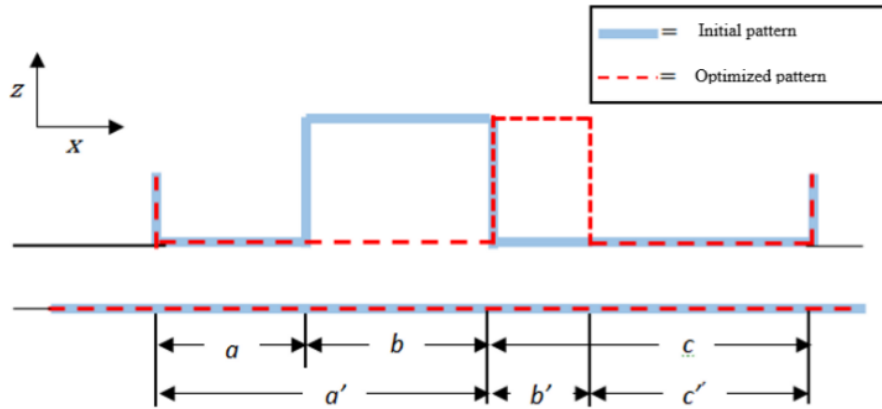


Figure 3. Comparison of the textured pattern profile for the case of “before” and “after” optimization

Generally, by design the improvement in pressure generation at textured lubricated contact (i.e. higher load support) is wanted condition of lubrication. The load support is obtained by integrating the hydrodynamic pressure over the surface area. In this section, the simulation result will be presented in the dimensionless form, i.e. the dimensionless load support W , in which $W = wh_o^2/U\eta B_o^2$ (where w is the load support, h_o is the land film thickness, U sliding velocity, and B_o is total length contact). Figure 4 shows the global solution of dimensionless load support W for each textured pattern during optimization process. It can be seen that the load support increases with increasing the number of combination data (i.e. slip and texture pattern) and finally reaches the steady condition.

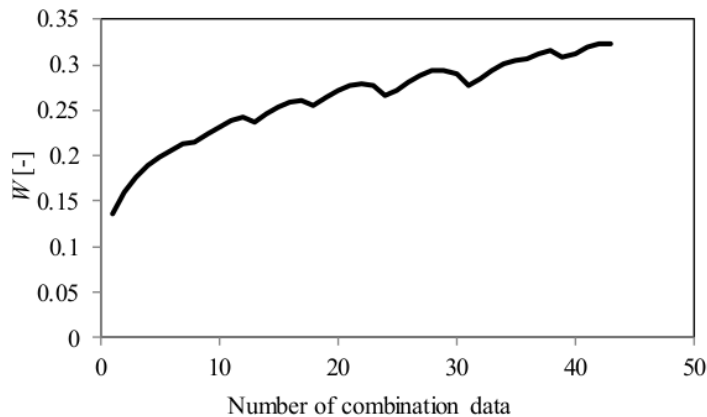


Figure 4. Prediction of dimensionless load support W during optimization process

Finally, it is necessary to show the characteristic of the lubricated textured contact for the case of initial pattern and the case optimized pattern in more detail with respect to the load support as shown in Table 3. It can be observed that the load support of the optimized pattern can be increased to up 75% compared to initial condition.

Table 3. Comparison of contact characteristics between “before” and “after” optimization

	Before optimization	After Optimization
Inlet length [m]	0.004	0.010
Pocket length [m]	0.006	0.003
Outlet length [m]	0.010	0.007
Load support [N]	8.60×10^5	1.20×10^6

4. Conclusion

The numerical optimization of a single textured lubricated contact with boundary slip was considered. Textured pattern was optimized pointing out the importance of the position of the texture cell as well as the texture length to increase the load support. The flow analysis based on Modified Reynolds equation has been linked with an optimization strategy with the exact optimization method. The main conclusions involved are as follows:

1. There exists a shift of the texture location to the center of the contact with lower texture length, which leads to improved load support.
2. The optimization results show that the load support can be enhanced with as much as 75% compared to the initial pattern.

References

- [1] Buscaglia GC, Ciuperca I and Jai M 2007 *J. Math. Anal. Appl.* **335** 1309
- [2] Scaraggi M, Mezzapesa FP, Carbone G, Ancona A, Sorgente D and Lugarà PM 2014 *Tribol. Int.* **75** 123
- [3] Uddin MS and Liu YW 2016 *Biosurf. Biotribol.* **2** 59
- [4] Zhang H, Hua M, Dong GZ, Zhang DY, Chen WJ and Dong GN 2017 *Tribol. Int.* **115** 222
- [5] Wang W, He Y, Zhao J, Li Y and Luo J 2017 *Tribol. Int.* **109** 69
- [6] Rao TVVLN, Rani AMA, Nagarajan T and Hashim FM 2012 *Tribol. Int.* **56** 121
- [7] Tauviquirrahman M, Muchammad, Jamari and Schipper DJ 2014 *Tribol. Trans.* **57** 134
- [8] Tauviquirrahman M, Ajie WK, Yohana E, Muchammad M and Jamari J 2016 *Int. J. Eng. Tech.* **8** 913
- [9] Muchammad M, Tauviquirrahman M, Jamari J and Schipper DJ 2017 *Lubr. Sci.* **29** 133

Numerical optimization of load support of the single textured lubricated contact with boundary slip

ORIGINALITY REPORT

14%

SIMILARITY INDEX

%

INTERNET SOURCES

14%

PUBLICATIONS

%

STUDENT PAPERS

PRIMARY SOURCES

- 1** Wei Wang, Yongyong He, Jun Zhao, Yang Li, Jianbin Luo. "Numerical optimization of the groove texture bottom profile for thrust bearings", Tribology International, 2017
Publication 7%
- 2** A M Hashim, M A M Ali, B Ahmad, R M Shafie, R Rusli, M A Aziz, J Hassan, M Z C Wanik. "A Preliminary Analysis of Solar Irradiance Measurements at TNB Solar Research Centre for Optimal Orientation of Fixed Solar Panels installed in Selangor Malaysia", IOP Conference Series: Earth and Environmental Science, 2013
Publication 2%
- 3** RICHARD F. SALANT, ALICIA E. FORTIER. "Numerical Analysis of a Slider Bearing with a Heterogeneous Slip/No-Slip Surface", Tribology Transactions, 2004
Publication 1%
- 4** Wei Wang, Yongyong He, Yang Li, Bin Wei, Yutong Hu, Jianbin Luo. "Investigation on inner 1%

flow field characteristics of groove textures in fully lubricated thrust bearings", Industrial Lubrication and Tribology, 2018

Publication

5

Michele Scaraggi, Francesco P. Mezzapesa, Giuseppe Carbone, Antonio Ancona, Donato Sorgente, Pietro Mario Lugarà. "Minimize friction of lubricated laser-microtextured-surfaces by tuning microholes depth", Tribology International, 2014

Publication

1%

6

M.S. Uddin, Y.W. Liu. "Design and optimization of a new geometric texture shape for the enhancement of hydrodynamic lubrication performance of parallel slider surfaces", Biosurface and Biotribology, 2016

Publication

1%

7

Chandan Kumar Chakrabarty, Abd Halim Bin Shamsuddin, Ibrahim Bin Ahmad, Mohamed Nor Bin Mohamed Desa et al. "4th International Conference on Energy and Environment 2013 (ICEE 2013)", IOP Conference Series: Earth and Environmental Science, 2013

Publication

1%

Exclude bibliography On

Numerical optimization of load support of the single textured lubricated contact with boundary slip

GRADEMARK REPORT

FINAL GRADE

/10

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7
