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Abstract	In this paper, a computational investigation of thermohydrodynamic performance of a Rayleigh step thrust bearing with a hydrophobic coating is presented. Here, a computational fluid dynamics (CFD) based thermohydrodynamic modeling approach is used to calculate the performance of the bearing. The hydrophobic coating arrangement on the bearing surface, that is, partial slip and full slip, is of particular interest. Also, an attempt is conducted to explore the effects of runner surface velocity on the lubricant hydrodynamic pressure and temperature profiles. To obtain more accurate results, the cavitation modeling based on a multi-phase approach is considered. The slip phenomena induced by the hydrophobic coating are modeled by the Navier-slip model. One of the main findings shows that the hydrophobic coating reduces the maximum temperature irreversible of the Reynolds number.

Keywords (separated by '-')	Cavitation - Computational fluid dynamics (CFD) - Hydrophobic coating - Rayleigh step bearing - Thermohydrodynamics

Author Proof

Thermohydrodynamic Analysis of a Hydrophobic Rayleigh Step Bearing Considering Cavitation: Effect of Hydrophobic Coating Arrangement

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AQ1 **Abstract.** In this paper, a computational investigation of thermohydrodynamic performance of a Rayleigh step thrust bearing with a hydrophobic coating is presented. Here, a computational fluid dynamics (CFD) based thermohydrodynamic modeling approach is used to calculate the performance of the bearing. AQ2 The hydrophobic coating arrangement on the bearing surface, that is, partial slip and full slip, is of particular interest. Also, an attempt is conducted to explore the effects of runner surface velocity on the lubricant hydrodynamic pressure and temperature profiles. To obtain more accurate results, the cavitation modeling based on a multi-phase approach is considered. The slip phenomena induced by the hydrophobic coating are modeled by the Navier-slip model. One of the main findings shows that the hydrophobic coating reduces the maximum temperature AQ3 irreversible of the Reynolds number.

Keywords: Cavitation · Computational fluid dynamics (CFD) · Hydrophobic coating · Rayleigh step bearing · Thermohydrodynamics

1 Introduction

The general purpose of lubrication is to minimize friction, wear, and heating of machine components that move relative to each other. In the last years, many experimental works have evinced the presence of slip on a hydrophobic surface, for example [1]. It has been revealed that the slip velocity on a hydrophobic coating surface generates a notable friction reduction in bearing [2–4].

Based on the literature survey, however, concerning the hydrophobic bearing analysis, the assumption of an isothermal lubricant condition has been adopted by most of the numerical works. Such an assumption contradicts a recent analysis [5]. Therefore, in this research, to obtain more understanding of the thermal indices of hydrophobic Rayleigh step bearing, the solution of the energy equation in the fluid domain is considered. Further, the multiphase flow analysis is employed to capture the cavitation inside the step.

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2 Analysis

In this study, a computational fluid dynamics (CFD) procedure has been utilized to solve the lubricant problem in particular heat dissipation in the fluid domain. For a continuous fluid medium, the momentum and continuity equations from the principles of classical fluid mechanics are employed to calculate the performance of the lubricant.

The temperature-dependent viscosity is taken into account in this numerical framework and modeled according to the McCoull and Walther relation [6]. For modeling the hydrophobic, the modified Navier-slip model [1–3] is considered.

Figure 1 reflects the schematic representation of hydrophobic Rayleigh step bearing. As a note, for calculations, the arrangement of hydrophobic coating is varied, namely, partial layout and full layout.

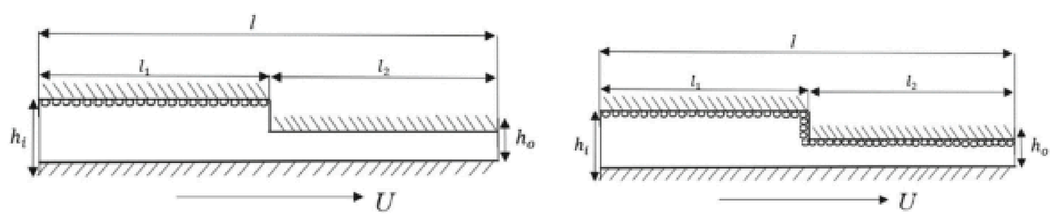


Fig. 1. Representation of hydrophobic Rayleigh step bearing. **Left:** with partial layout. **Right**: with full layout. **Note**: circle marker refers to the hydrophobic coating.

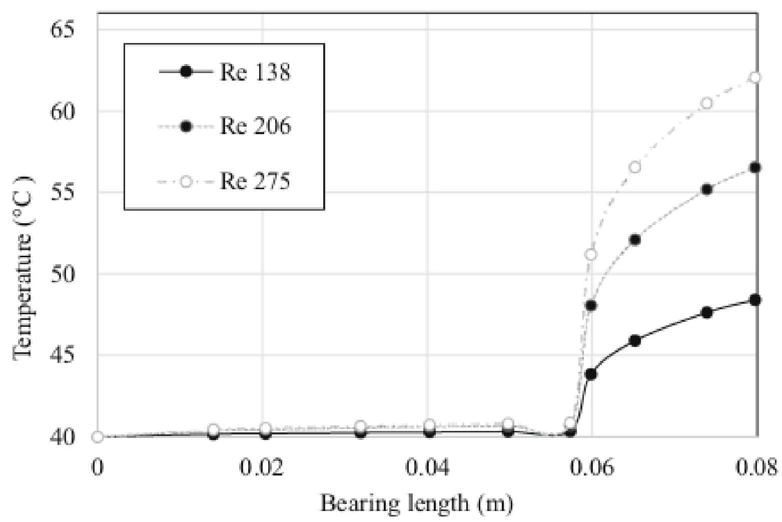
3 Results and Discussion

In this section, the maximum temperature of the lubricant is of particular interest. Two observations can be made based on Table 1. At first, it can be revealed that introducing the hydrophobic coating reduces the maximum temperature irrespective of the Reynolds number and the hydrophobic coating arrangement. Secondly, hydrophobic bearing with a full layout generates lower thermal indices compared to conventional bearing (23% lower) and hydrophobic bearing with partial layout (3% lower).

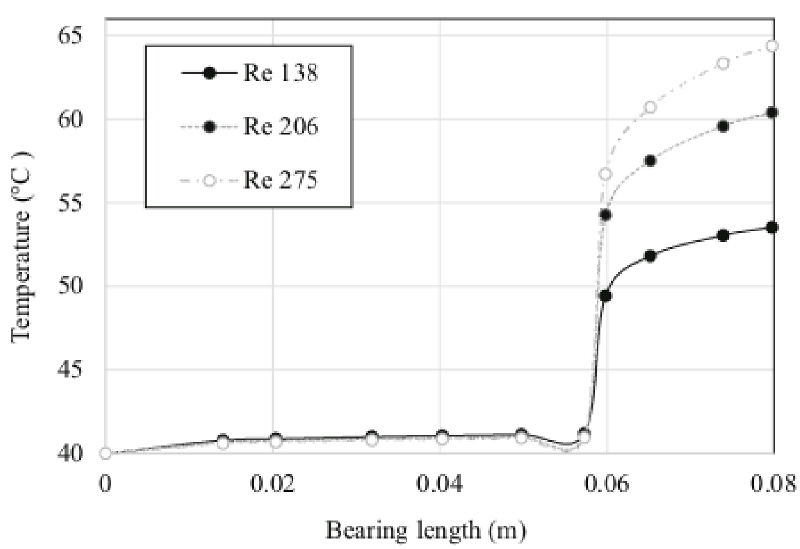
Table 1. Maximum temperature for two different arrangements of hydrophobic coating.

Reynolds number	Conventional bearing	Hydrophobic bearing with partial layout	Hydrophobic bearing with full layout
138	62 °C	53 °C	48 °C
206	71 °C	60 °C	56 °C
275	80 °C	64 °C	62 °C

Figure 2 shows the temperature distribution over the bearing length for two bearing configurations varying Reynolds numbers. It can be seen from Fig. 2 that introducing the hydrophobic coating on the overall surface can reduce the temperature trend more significantly in comparison to the partial layout irrespective of the Reynolds number. The temperature jump is also observed at the location in which the step is finished. Overall, it is beneficial to apply the hydrophobic coating to the Rayleigh step bearing either in partial or full layout. The positive effect of the hydrophobic is more pronounced on the thermal indices when the full layout is applied.



(a)



(b)

Fig. 2. Effect of Reynolds number on the thermal distribution for two hydrophobic arrangement: (a) Full hydrophobic Rayleigh step bearing, (b) Partial hydrophobic Rayleigh step bearing.

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