COMPUTATIONAL MODEL OF AXIAL OIL FLOW FROM A ROUGH HOLE

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ABSTRACT

The aim of the present study is to propose an innovative computational model, which describes the influence of surface roughness on axial flow from a hole. For roughness the stochastical averaging of Christensen and Tonder's model has been applied to form a computational mathematical equation.The closed form solution is obtained for the axial flow as a function of different physical parameters. The effect of such parameters is discussed through graphical as well as tabular form representation.It is found that the effect of surface roughness is to decrease the axial flow significantly, in general. Of course, in augmenting the performance of the system, the eccentricity ratio plays a central role.

Keywords:film thickness, axial flow,roughness

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1. INTRODUCTION

Ina bearing what is most important is the make-up flow, i.e. the total side leakage, which is the oil that has to be pumped into the bearing to keep it full.

This flow is made up of two components; the first is the difference between the oil flowing at the start of the pressure curve and at the finish. The second part is the oil that flows out of the bearing, near the entry, due to the pressure feeding.The basic theory of axial flow rate has been discussed in Cameron [1], who obtained a way out for feeding oilthrough a hole which is usually on the load line. Recently, Zhang et al. [2] investigated the working performance of the flow characteristics of an axial piston pump with software, which uses computational fluid dynamic technology.

By now, it is a well know fact that the bearing surfaces, as particularly after having some run-in and wear develop roughness. Even, the contamination of the lubricant contributes to the roughness through chemical degradation of the surface as contribute the roughness. The roughness appears to be random in character which does not seem to follow any particular structural pattern. Moreover, it is well recognized that the friction increases with average roughness. This means that roughness parameters are therefore, important in applications such as automobile break lings, floor surfaces and tires.The randomness of the roughness was recognized by several investigators to analyze the effect of surface roughness. Christensen and Tonder [3]-[5] proposed a comprehensive general analysis for surface roughness (both transverse and longitudinal) based on a general probability density function by developing the approach of Tzeng and Seibel [6]. Shukla and Deheri [7] embarked on the performance in a rough porous journal bearing. It was observed that the bearing suffers in general owing to the transverse roughness.

In this paper a computational mathematical model is presented to predict the roughness effect on the performance of axial flow from a hole.

2. ANALYSIS

The geometry and pattern of the hole structure is presented in Fig. 1.

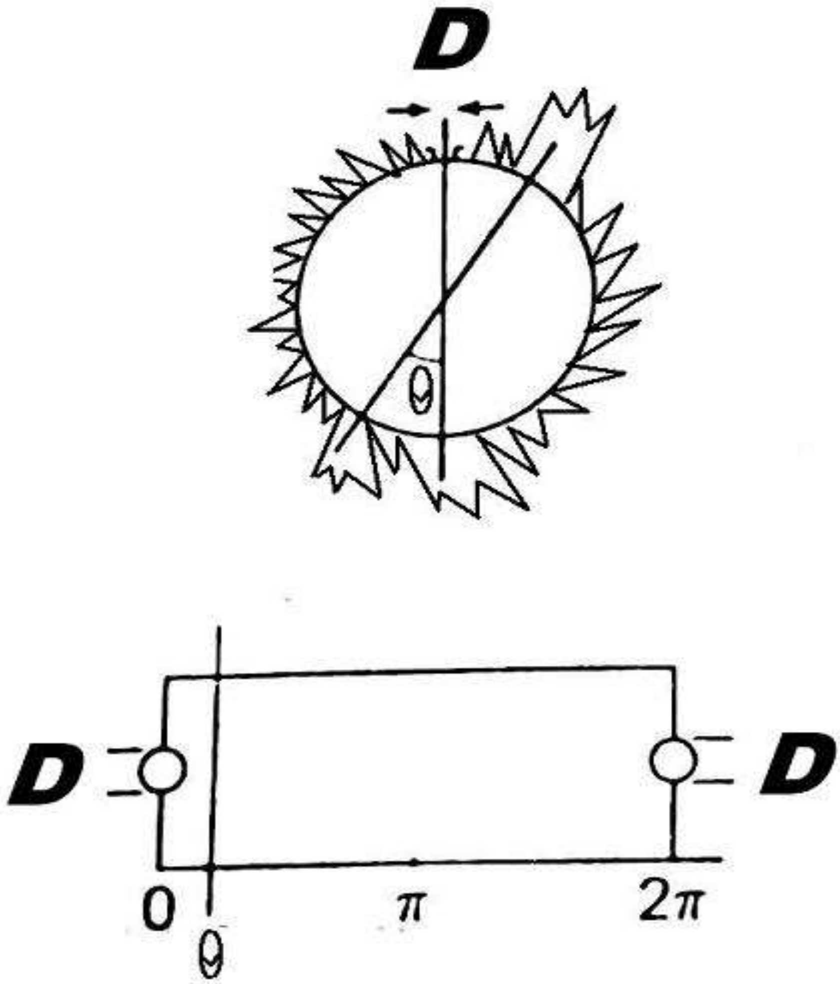


Fig.1 The configuration of a rough hole structure

The oil is fed in through a hole which is usually on the load line, opposite the load. The local film thickness, which is the dominant factor for the flow, is then

$$h = c(1 + e\cos\theta)(1)$$

Oil is normally fed into journal bearing in one of the way, which is a feed hole at the bearing split, $\pm 90^0$ to the load line. Assume the pressure drops linearly from groove to the outside bearing edge, so$\frac{dy}{dx} = p_0/(L/2)$. The total flow, Q, will be

$$Q = 2\int_0^{2\pi} \frac{h^3 dpRd\theta}{12\eta dx}(2)$$

On the assumption $\frac{dp}{dx} = \frac{2p_0}{L}$, and $D = 2R$, and ${Q_d}^* =$ flow per unit length

Now, with the aid of stochastic average model of Christensen and Tonder [3]-[5], one is inclined to obtain

$$Q = \left(\frac{a(h)p_0 D}{12\eta L}\right) {Q^*}_d(3)$$

where

$$a(h) = h^3 + 3\alpha h^2 + 3(\sigma^2 + \alpha^2)h + \varepsilon + 3\sigma^2\alpha + \alpha^3$$

Introducing the dimensionless quantities

$$\varepsilon^* = \frac{\varepsilon}{c^3}, \sigma^* = \frac{\sigma}{c}, \alpha^* = \frac{\alpha}{c}, Q^* = \frac{12\eta L}{Rc^3 p_0}Q \quad A(h) = \frac{a(h)}{c^3}, A_1 = \varepsilon^* + 3\sigma^{*2}\alpha^* + \alpha^{*3}, A_2 = 3(\sigma^{*2} + \alpha^{*2}), A_3 = 3\alpha^*$$

and fixing the following symbols

$Q_1 = 1 + A_1 + A_2 + A_3$; $Q_2 = eA_2 + 2eA_3 + 3e$,

$$Q_3 = e^2 A_3 + 3e^2, Q_4 = e^3$$

One obtains the expression for axial flow rate in dimensionless form as

$$Q^* = \frac{1}{Q_1 + Q_2 cos\theta + Q_3 cos^2\theta + Q_4 cos^3\theta} Q^*{}_d \quad (4)$$

3. GRAPHICAL RESULTS AND DISCUSSION

It is easily noticed that the non-dimensional axial flow rate distribution is obtained from Equation (4).

The standard deviation has a substantial adverse effect on the performance of the axial flow rate which can be seen fromFig. 2 and Fig. 3 as well as Table-1. Roughness retards the motion of the lubricant and hence causes abridged pressure resulting in decreased axial flow rate.

Non-dimensional flow rate Q^*	$\sigma^* = 0$	$\sigma^* = 0.05$	$\sigma^* = 0.1$	$\sigma^* = 0.15$	$\sigma^* = 0.2$
	Characteristics Performance with Skewed Roughness				
$\varepsilon^* = -0.1$	1.7546	1.6131	1.4927	1.3890	1.2988
$\varepsilon^* = -0.05$	1.7346	1.5962	1.4782	1.3764	1.2878
$\varepsilon^* = 0$	1.6773	1.5475	1.4364	1.3401	1.2560
$\varepsilon^* = 0.05$	1.5898	1.4727	1.3717	1.2837	1.2062
$\varepsilon^* = 0.1$	1.4816	1.3794	1.2904	1.2122	1.1429
	Characteristics Performance with Mean Roughness				
$\alpha^* = -0.1$	1.3890	1.1884	1.0236	0.8873	0.7738
$\alpha^* = -0.05$	1.3764	1.1787	1.0160	0.8813	0.7690
$\alpha^* = 0$	1.3401	1.1504	0.9939	0.8638	0.7549
$\alpha^* = 0.05$	1.2837	1.1063	0.9590	0.8360	0.7326
$\alpha^* = 0.1$	1.1429	1.0499	0.9141	0.8000	0.7035

Table-1: The variation of σ^* with ε^* and α^*

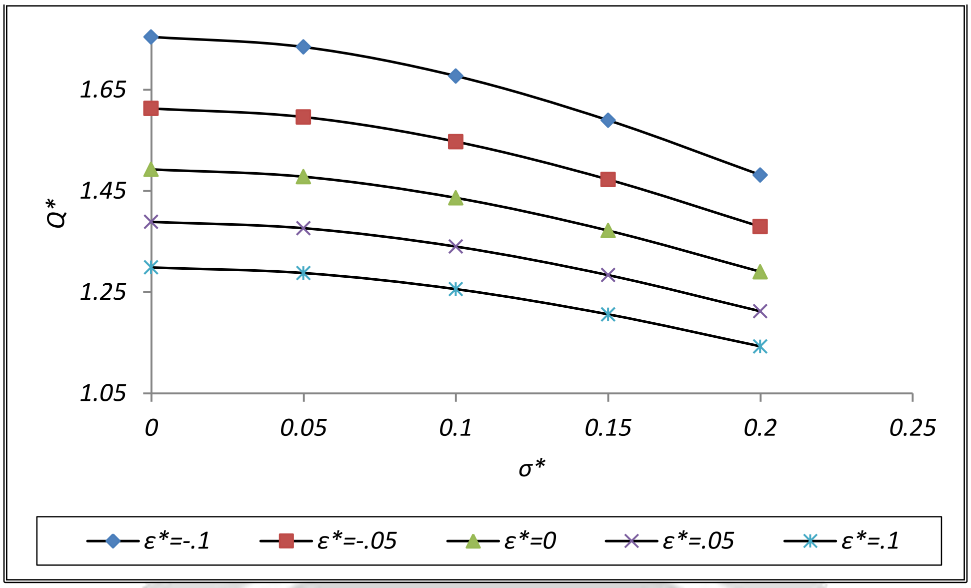


Fig.2.The variation of flow rate with σ^* and ε^*

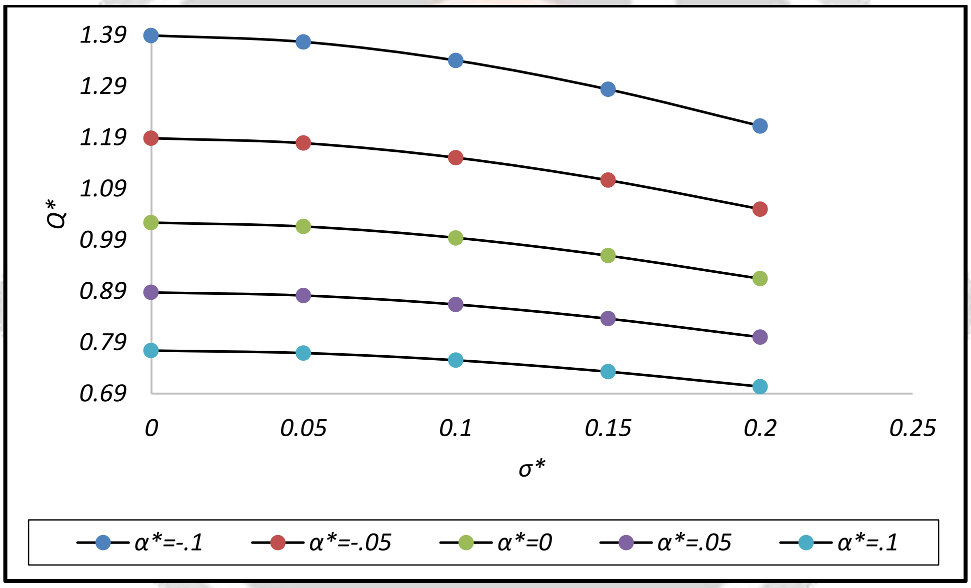
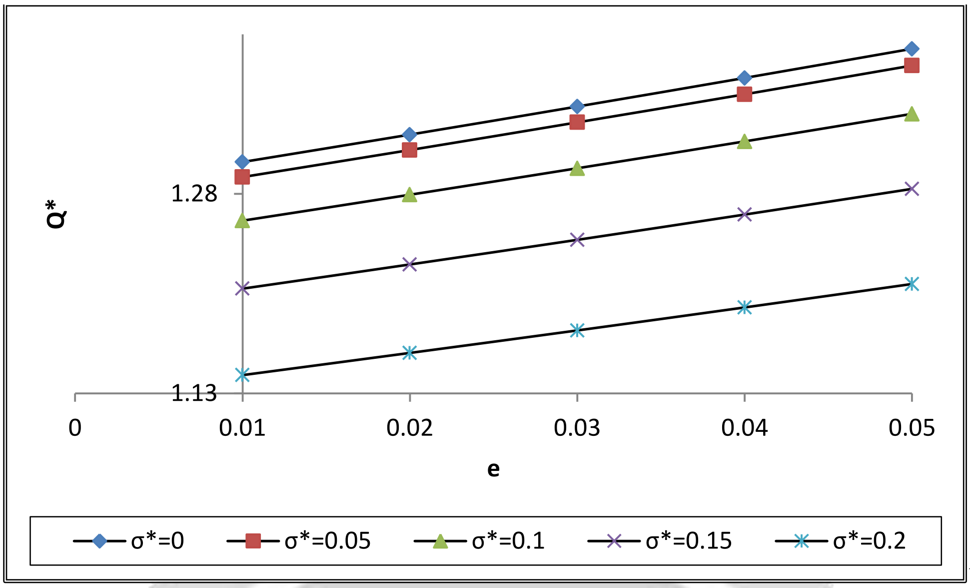


Fig.3.The variation of flow rate with σ^* and α^*

One can examine the variation of non-dimensional axial flow rate with respect to eccentricity ratio from Fig.4-6 and Table-2. From this it make clear that α^*(+ve) decreases theaxial flow. It is seen that α^*(-ve) induces an increase in the axial flow. One can easily find that the effect of eccentricity ratio is sharper which can be seen from Fig. 4. The skewedness follows the same trends of variance. Furthermore, one can visualize that the combined effect of negatively skewed roughness and negative variance is significantly positive in most of the situations.



v

Fig.4.The variation of flow rate with $e$and σ^*

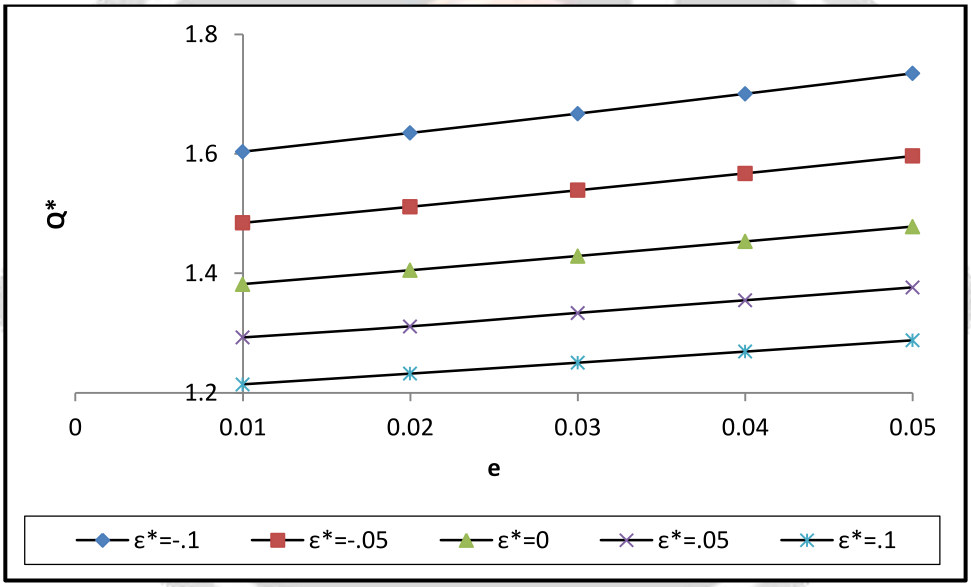


Fig.5.The variation of flow rate with e and ε^*

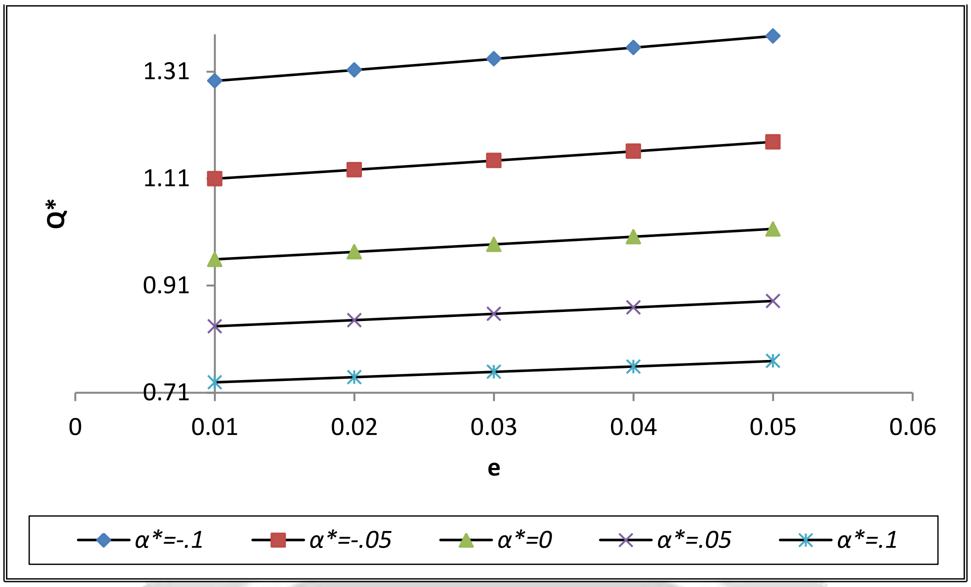


Fig.6.The variation of flow rate with e and α^*

Non-dimensional flow rate Q^*	$e = 0.01$	$e = 0.02$	$e = 0.03$	$e = 0.04$	$e = 0.05$
	Characteristics Performance with Standard Deviation				
$\sigma^* = 0$	1.3039	1.2926	1.2598	1.2087	1.1437
$\sigma^* = 0.05$	1.3245	1.3129	1.2793	1.2269	1.1604
$\sigma^* = 0.1$	1.3456	1.3337	1.2992	1.2454	1.1773
$\sigma^* = 0.15$	1.3671	1.3548	1.3194	1.2644	1.1946
$\sigma^* = 0.2$	1.3890	1.3764	1.3401	1.2837	1.2122
	Characteristics Performance with Skewness Roughness				
$\varepsilon^* = -0.1$	1.6035	1.4844	1.3819	1.2926	1.2141
$\varepsilon^* = -0.05$	1.6349	1.5113	1.4051	1.3112	1.2320
$\varepsilon^* = 0$	1.6672	1.5389	1.4289	1.3337	1.2503
$\varepsilon^* = 0.05$	1.7004	1.5672	1.4533	1.3548	1.2689
$\varepsilon^* = 0.1$	1.7346	1.5962	1.4782	1.3764	1.2878
	Characteristics Performance with Mean Roughness				
$\alpha^* = -0.1$	1.2926	1.1098	0.9591	0.8340	0.7293
$\alpha^* = -0.05$	1.3129	1.1265	0.9730	0.8455	0.7389
$\alpha^* = 0$	1.3337	1.1436	0.9871	0.8572	0.7488
$\alpha^* = 0.05$	1.3548	1.1609	1.0014	0.8692	0.7588
$\alpha^* = 0.1$	1.3764	1.1787	1.0160	0.8813	0.7690

Table-2: The variation of e with roughness parameters

4. CONCLUSION

This investigation strongly suggests that the roughness must be addressed while designing the bearing system. From this investigation, the following conclusions can be drawn:

- The eccentricity ratio offers some help in reducing the adverse effect of standard deviation in the case of negatively skewed roughness. Further, this effect enhances when variance (-ve) occurs.

- Although, there are many factors reducing the axial flow rate, the standard deviation is at considerably low level.

4.1 Nomenclature

c	radial clearance
e	eccentricity ratio $\left(e = \frac{e_1}{c}\right)$
h	oil film thickness
e_1	eccentricity
p_0	Oil feed pressure
D	Diameter of the hole
L	axial length
P	lubricant pressure
R	radius of the hole
U	shaft surface speed
σ	standard deviation
ε	Skewness
α	variance
θ	circumferential co-ordinate
η	dynamic viscosity of fluid
σ^*	non-dimensional standard deviation
ε^*	non-dimensional skewness
α^*	non-dimensional variance
$\frac{dp}{dx}$	Pressure gradient

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