Hydrodynamic Behavior of the Sliding Surface with Semicircular Pores: Theoretical and MATLAB Considerations

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ABSTRACT

A mathematical model, theoretical and numerical solutions are represented for non-contacting sliding surfaces with pores having a half-round form. The theoretically based expressions for the hydrodynamic pressure, the maximum positive pressure and the load capacity were obtained for a cell which includes the inside and outside of the pore areas. The cell and pore dimensions were studied in the range 7.5…100 and 5…20 micron respectively. The obtained expressions were validated with the MATLAB ODE-solver. It is shown that behavior of the sliding surfaces with semicircular pores can be achieved for the pores with pore radii-gap ratio about 0.5 … 2 and the control cell dimensions to pore radii ratios about 3 … 5. The rate of performance improvement becomes small above these values. In general, the optimum pore size decreases at higher pore cell-pore ratios and lower pore-gap ratio values.

KEYWORDS

Hydrodynamic Lubrication, Load Support, MATLAB, Maximal Pressure, Semicircle Pore Profile

1. INTRODUCTION

The texture of the sliding surface strongly influences the hydrodynamic pressure in the lubricating film separating the surfaces, this fact has been demonstrated theoretically in the numerous studies. The surface structure, in the investigations of this area, has been expressed by waves, grooves, or pores. Dimpled or waved surfaces have been studied by Salama, 1952, Etsion, 1980, and Burstein, 2007, 2008, 2009, 2010, 2015. Surfaces with microgrooves have been studied by Hamilton, Walwit, and Allen, 1969 and by Lai, 1994. Pored surfaces have been studied by Salama 1952, Anno, Walovitz and Allen, 1968, Etsion and Burstein, 1996, Burstein and Ingman, 1999, 2000. In these studies it has been demonstrated theoretically that the texture of the surfaces strongly influences the hydrodynamic pressure in the lubricating film separating the surfaces. Experimental studies in this direction have been reported by Etsion et al., 1999, 2004, 2004, Ryk et al., 2002, and Kligerman et al., 2005.

These studies all demonstrate the importance of understanding the behavior of pored surfaces in the design of rubbing mechanical parts: seals, pistons, piston rings and other items with surfaces separated by a lubricant and being in relative motion. In this connection, it is important to have theoretically grounded relations for calculating the hydrodynamic pressure in the lubricating film to reduce wear and increase machine service life. Etsion and Burstein (1996) studied surfaces with hemispherical pores and presented a numerical solution of two-dimensional Reynolds equations. Later Burstein (1998, 1999) theoretically solved two-dimensional Reynolds equations for cylindrical and exponential pores.

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Nevertheless, despite the fact that the pore having a semicircular cross section is the most significant case, there is still no theoretical solution of this problem. This paper intends to fill this gap.

2. MODEL AND BASIC EQUATIONS

Cross-section of the two opposite surfaces with hemispherical pores on the lower surface are shown in Fig.1; each pore has radius $r_0$ and the gap between surfaces equals $h_0$.

Assuming that the pores are arranged regularly and the distance $2r_1$ between pores (see Figure 1) is sufficiently large so that the interaction between the pores can be neglected, only one pore with the adjoining part, called the control cell, can be studied. The hydrodynamic lubrication is described by the Reynolds equation, which in its dimensionless form is

$$\frac{d}{dX} \left( H^3 \frac{dP}{dX} \right) = \frac{dH}{dX}$$

(1)

where

$X=\frac{x}{r_0}$,
$H=\frac{h}{h_0}$,
$P=\frac{p}{\Lambda}$,
$\Lambda=\frac{6\mu u r_0}{h_0^2}$.

Here and hereinafter:

$P = \frac{p}{\Lambda}$ - dimensionless hydrodynamic pressure;
$p$ - dimensional hydrodynamic pressure;
$u$ - dimensional velocity of sliding surface, along coordinate $x$;
$r_0$ - dimensional pore radii;
$r_1$ - control cell dimension;
$h_0$ - dimensional minimal clearance (gap) between surfaces;
$X=\frac{x}{r_0}$ - dimensionless coordinate;
$x$ - dimensional coordinate;
$H$ - dimensionless local film thickness;
$h$ - dimensional local film thickness;
$W=w/(\Lambda r_0)$ - dimensionless load support;
$\Lambda=\frac{6\mu u r_0}{h_0^2}$;
$\mu$ - dimensional dynamic viscosity of lubricating film;
w - dimensional load support along x-direction;

Figure 1. Semicircular pore cell geometry
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