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THE INFLUENCE OF TEXTURED SURFACES ON THE TRIBOLOGICAL BEHAVIOUR OF HIP REPLACEMENTS EMPLOYNG A MASS CONSERVING COMPLEMENTARITY ALGORITHM

TRACK OR CATEGORY

Biotribology

AUTHORS AND INSTITUTIONS

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INTRODUCTION

The tribological behaviour of Metal-on-Metal (MoM) hip prostheses is a key factor for their success. In particular, wear is recognized to have a crucial role in the failure of a prosthesis and can have severe consequences on the patient's health, *e.g.* pseudo-tumors in MoM implants, [1,2]. The lubrication of the coupling between the prosthetic head and the acetabular cup can affect both the contact behaviour and the wear of the prosthesis [3]. Different contributions exist in the pertinent literature addressing the elastohydrodynamic analysis of the head-acetabulum coupling, but rarely these analysis are performed taking into account the possible fluid cavitation in the contact area between the mating surfaces [4]. In order to improve the tribological performance of hip implants, the use of textured surfaces has been proposed in recent studies [5]. The present contribution focuses on the possible improvement that textured surfaces could give to the hip joint replacement tribological behaviour. Textured surfaces are widely used in mechanics in order to increase the carrying capacity of various kind of joints working in elastohydrodynamic condition [6-8]. Textured surfaces typically show a path of cavitated zones due to the presence of dimples in the contact surfaces. The effect of these cavitated zones can result in a global decreasing of friction and wear [9]. This preliminary contribution aims at studying, by means of preliminary simplified one-dimensional models, the influence of the geometrical parameters of the textures on the tribological behavior of a hip joint coupling. The analysis have been carried out employing a linear complementarity mass-conserving algorithm originally proposed in [10], capable of properly capturing the phenomenon of cavitation.

GOVERNING EQUATIONS

The HL complementarity formulation of the Reynolds equation in the presence of cavitation for compressible lubricants has been first proposed in [10] and it has been further improved in [11,12] to handle the elastic deflection of the contacting bodies and the mixed-lubrication regime. Being the pressure, *p*, and the void fraction, *r*, the complementary variables, the EHL complementarity problem can be written as:

$$\frac{\partial}{\partial x}\left(\frac{h^3}{6\mu}\frac{\partial p}{\partial x}\right) - 2\frac{\partial}{\partial t}(h) + 2\frac{\partial}{\partial t}(rh) - U\frac{\partial}{\partial x}(h) + U\frac{\partial}{\partial x}(rh) = 0$$

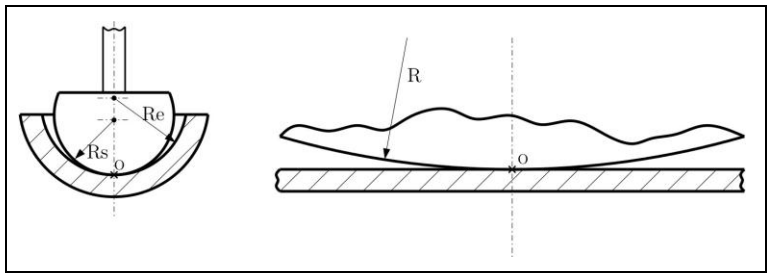
$$h = h_g + h_e = h_g + lp \tag{1}$$

$$p \geq 0$$
$$r \geq 0$$
$$p \cdot r = 0$$

where the total film thickness h is given by the sum of the geometric thickness h_g and the elastic deflection, h_e, and l is the linear integral operator that gives the elastic deflection of the solid surfaces as a function of the pressure p. Please refer to [10-12] for further details.

EXAMPLES

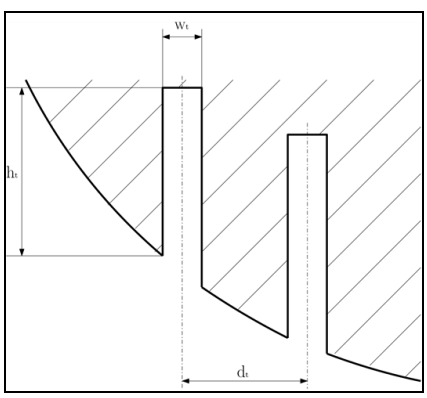
The aim of this analysis is to evaluate the influence of a textured profile on the tribological behaviour of the ball-in-socket like problem of a hip joint. The same equivalent ball-on-plain model proposed in [13] has been considered, see Figure 1. In particular, preliminary simplified one dimensional analysis have been performed. The one dimensional domain length has been chosen equal to πRs/2. The domain length is about 22mm and it has been discretized with 880 elements of 0.025mm length. It is important to underline that these one dimensional and static simulations aim at analysing the influence of the texture geometric parameters. Therefore, all the results, compared in terms of friction force, have to be considered as trend indicators with no quantitative aims.



Rs (head radius)	14	[mm]
c (radial clearance)	0.03	[mm]
E_{head}	210	[GPa]
E_{cup}	210	[GPa]
ν_{head}	0.3	
ν_{cup}	0.3	

Figure 1: Geometrical and phisical parameters of the problem.

A constant load of 1500N and a sliding speed of 2rad/s have been considered. The lubricant has been modelled as isoviscous and incompressible with a viscosity value of 0.0009Pas, consistently with [13]. The texture geometrical parameters investigated are the pocket width, w_t, the pocket height, h_t, and the distance between two pockets, d_t, see Figure 2. These parameters have been varied following data in Figure 2, on a total of 90 configurations.



d_t	4	2	1	-	-	-	[mm]
w_t	0.5	0.4	0.3	0.2	0.1	-	[mm]
h_t	0.1	0.05	0.01	0.005	0.001	0.0005	[mm]

Figure 2: Geometrical parameters of the texture pattern.

As an example of the obtained results, Figure 3 shows the friction force trend for a centre-to-centre distance, d_t, equal to 4mm as a function of the texture width, w_t, and texture height, h_t. The trend of the friction force with respect to width and height is different: on one side, the friction force decreases almost linearly with the texture width; on the othe side, its decreasing as a function of the texture height is more accentuated where the height is small, while it reaches almost a constant plateaux for high values of the texture heigh. Nevertheless, at least for this particular centre-to-centre distance, d_t, equal to 4mm, increasing both the pocket width and the pocket height, an improvement of the tribological behaviour of the joint is obtained.

Considering different values of the centre-to-centre distance, dt, namely 2mm and 1mm, a different trend is observed thus showing that a deeper investigation of the problem has to be performed.

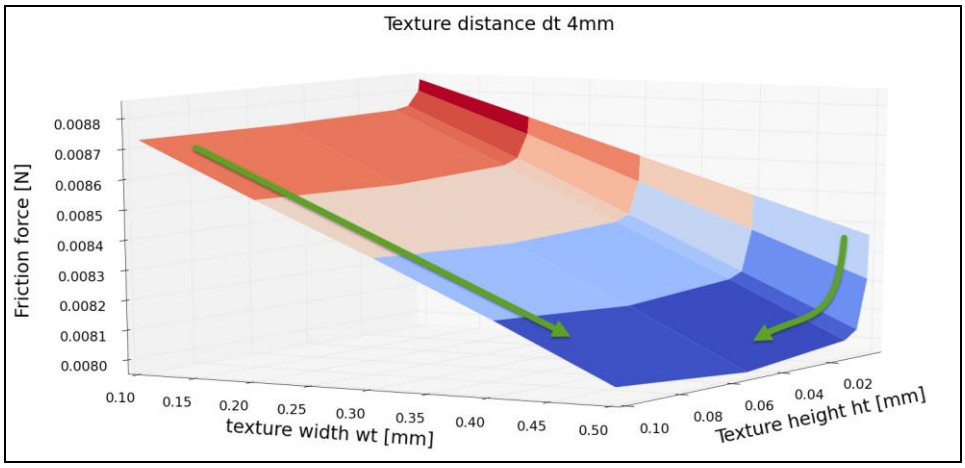


Figure 3: Friction force trend for a centre-to-centre distance of 4mm as a function the texture width and texture height.

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KEYWORDS

Applied Tribology:Biotribology, Computation:Fluid Mechanics Methods, EHL:EHL (General).