49th Leeds-Lyon Symposium on Tribology – September 2-4, 2024, Lyon, France
50 years of Leeds-Lyon

PREDICTING FRICTION IN TOTAL HIP REPLACEMENT BEARINGS: A MULTISCALE APPROACH

Robin Furze [a*], Michael Bryant [b], Peter Jimack [c], Mazen Al Hajjar [d], Gregory de Boer [b]
*py07rf@leeds.ac.uk
[a] EPSRC CDT in Fluid Dynamics, University of Leeds, LS2 9JT, United Kingdom
[b] School of Mechanical Engineering, University of Leeds, LS2 PJT, United Kingdom
[c] School of Computing, University of Leeds, LS2 PJT, United Kingdom
[d] DePuy Synthes Joint Reconstruction, Johnson and Johnson MedTech, Leeds, LS11 8DT, United Kingdom

KEYWORDS KEYWORDS
Mixed Lubrication; Friction; Modelling in tribology; Total Joint Replacements

ABSTRACT
The tribological performance of total hip replacements (THRs) significantly influences their longevity and success and, consequently, are subject to extensive preclinical tribological tests, which are time-consuming and difficult to predict the outcome of in silico. One such test, ASTM F3143-20 [1], prescribes the measurement of frictional torque in a THR when subject to a reciprocating motion in one degree of freedom coupled with a dynamic loading profile.

THRs predominantly operate in the mixed lubrication regime, where the accurate prediction of friction is challenging due to the complex interactions between solid and fluid domains across disparate scales. A simplified cross-section of the tribological contact for THRs with idealised spherical geometry is shown in Figure 1. Deterministic models have been developed to predict friction of THRs under ASTM F3143-20 operating conditions, dividing the bearing into contact and lubricated regions [2]. Such models do not capture the microscale fluid and contact phenomena due to the asperity interactions and, as a result, do not accurately replicate in vitro friction per ASTM F3143-20.

This work examines the limitations of a finite-element flow factor model for predicting friction in the mixed lubrication regime, applied to idealised and measured THR bearing geometries under ASTM F3143-20 operating conditions. Flow factor methods initially developed by Patir and Cheng [3] have been implemented in mixed lubrication models away from the application to THRs. The method modifies the Reynolds equation to account for stochastic surface roughness in solutions for the lubricant pressure. Although the flow factor model offers greater insight into friction in THRs in the mixed lubrication regime than existing models, they do not capture microscale phenomena accurately for real surface roughness profiles in dynamic systems.

Subsequently, the application of heterogeneous multiscale methods in the context of THRs and mixed lubrication are

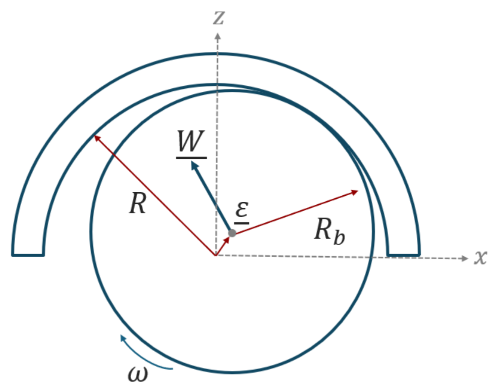

Fig.1 A simplified cross-sectional schematic of the tribological contact in THRs. A ball of radius R_b, offset from the origin by a vector $\underline{\varepsilon}$, subject to an applied load $\underline{W}$ articulates with an angular velocity ω against a cup of radius R.

discussed and contrasted with the flow factor model. These methods have been successfully applied in elastohydrodynamic lubrication problems [4] but have yet to be developed for mixed lubrication. The methods provide a framework for coupling macro and microscale models, which can capture complex microscale phenomena and offer an alternative to established flow factor approaches.

ACKNOWLEDGEMENTS
This research is financially supported by the EPSRC (Grant No. EP/S022732/1) and DePuy Synthes J&J MedTech.

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