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MODELLING SYNOVIAL FLUID RHEOLOGY IN ELASTO-HYDRODYNAMIC LUBRICATION

Lee Nissim, Hamza A. Butt, Leiming Gao, Connor Myant, Robert Hewson

Imperial College London, United Kingdom
ln415@ic.ac.uk

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Summary: Joint replacements have been performed since the 1960s, the most common being hip and knee implants. Data collected from 2014 shows that, across the EU, on average 319 hip and knee replacements are carried out per 100 000 people. This equates to over 1.6 million surgeries annually. A number of factors including ageing populations, increasing life expectancy and improving joint designs mean that the number of replacement and revision procedures is only set to continue rising. Current computational models for hip and knee prostheses utilise the Elasto-Hydrodynamic Lubrication (EHL) equations to predict fluid pressure and lubricant film thickness within the joints. Experimental results, show that these models are not solving the problem in its entirety when used to describe synovial joints because of the complex and multi-component nature of the fluid. Synovial fluid is protein rich and these proteins induce complex rheological behaviour which appears to be geometry specific where the length scale of the protein is of the same order as the fluid film thickness. A number of approaches have been considered in the field to improve the accuracy of simulations such as including non-Newtonian behaviour, piezo-viscosity or fluid compressibility, however further improvements are still needed.

It can be seen in the experimental work of others that protein matter collects at the inlet of the lubricated contact area and this aggregated matter drives rheological changes locally within the fluid. In this work, to model this behaviour computationally, protein concentration is tracked using an advection-diffusion equation with modified terms to simulate aggregation. Concentration predictions are used to alter the local viscosity of the fluid via a number of rheological models, giving rise to observed rheopectic behaviour. This study captures the nature of Protein-Aggregation Lubrication (PAL) alongside EHL to obtain computational results that better agree with observed phenomenon.