BIPHASIC LUBRICATION OF CARTILAGE MODELLED USING A FRICTION COEFFICIENT DEPENDENT ON THE INSTANTANEOUS FLUID LOAD SUPPORT

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Introduction

Hip hemiarthroplasty, whereby the femoral head is replaced, operates within multiple lubrication regimes. These biotribological interactions prove indicative of longevity, as wear determines implant durability. Recently, studies have shown higher contact stresses lead to higher friction and wear in cartilage when the natural material articulates against metal bearings [1]. Thus, quantifying accurate contact stress levels is paramount.

Methodology

The following methodology aimed to predict accurate contact stresses by implementing a biphasic lubrication scheme in a finite element simulation. Assuming the effective coefficient of friction μ_{eff}, is linearly related to the fluid load support [2], μ_{eff} can be described as

$$\mu_{eff} = \mu_{eq}\left[1-(1-\varphi)\left(\frac{F_p}{F_n}\right)\right] \qquad (1)$$

where μ_{eq} is the equivalent coefficient of friction when interstitial fluid pressure has subsided (0.45), φ is the solid-to-solid contact area fraction (0.1) [1-3] and F_p/F_n represents the fraction of interstitial fluid load support at any given time.

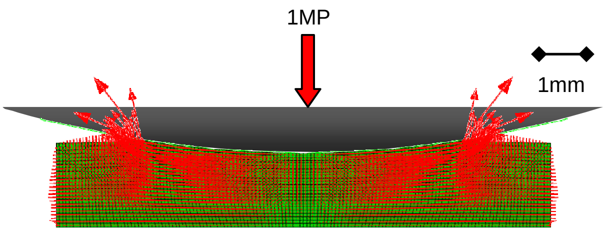

Figure 1. Illustration of model solution with fluid velocity vectors

A 2D finite element model implemented equation (1) via user subroutines in ABAQUS v6.9. The contact interface between the instantaneous cartilage-metal bearing (radius, $\phi = 50mm$) [4], and the entire cartilage-bone boundary were impermeable. Regional elastic anisotropy [5], regional permeability [1,2] and a metal-bearing pressure of 1MPa (0.0166MPa/sec ramp and hold) were applied to the model (Figure 1).

Results

While F_p/F_n decreased with time, μ_{eff} increased (Figure 2). Compared to likewise models with fixed friction coefficients ($\mu_{eff} = 0; \mu_{eff} = 0.109$), the peripheral contact areas demonstrated higher stresses and higher fluid velocities exuding the cartilage (8% and 6% higher stresses respectively; 18% and 17% higher fluid velocities respectively).

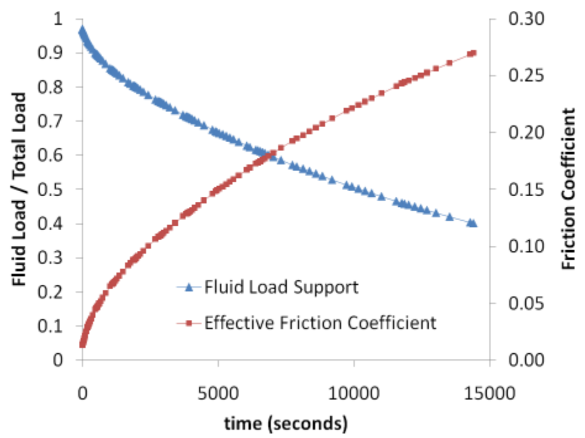

Figure 2. Plot of μ_{eff} and F_p/F_n against time

Discussion

The computational methodology presented here has proven successful in simulating biphasic lubrication; transient frictional behaviour is required to capture realistic contact mechanics. Consequently, future work intends to experimentally validate and then subsequently implement the above modelling techniques to assess contact stresses in a complete joint hemiarthroplasty. Acknowledgement: EPSRC

References

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