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PREDICTION OF WEAR AND EVOLUTION OF ROUGHNESS IN TOTAL HIP REPLACEMENTS

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Summary: Wear plays a pivotal role in the performance of lubricated total hip replacements (THR), particularly in the boundary and mixed lubrication regimes where the surfaces come in the areas of direct solid contact. Minimum film thickness of the synovial fluid at these joints lies in the nanometer scale and is comparable to the local asperity dimensions. This requires solving the mechanics of fluid flow along with the contact mechanics to predict wear. Thus, the time of computation of wear, accompanied with the update of the evolved hip surface geometry becomes one of the challenges due to a deterministic definition of micro-scale roughness on a macro-scale geometry.
Researchers since 1970s, proposed solutions to mixed lubrication problems by conceptualizing a flow factor approach to consider the influence of roughness at the asperity scale on the fluid flow and adapted the Reynolds Equation. During the same time, asperity contact models based on the Hertzian contact of probabilistically described asperities were developed. The current approach builds on that concept and characterizes the wear of a simple pin-on-plate system and then extends it to hip replacements. The THR model considers the load and motions based on a human walking cycle. The model uses the cumulative distribution function (CDF) of roughness of the two surfaces in contact to solve the mixed lubricated problem.
The evolution of load partition ratio in the mixed lubrication regime indicates an increase in load sharing by the fluid as wear occurs, accompanied by a reduction in the contact area ratio. The evolution of the CDF of the wearing surface reflects gradual smoothening of the asperities and the transition from run-in to steady wear. A friction study is carried out to identify the regimes of lubrication of the total system which showed a friction drop from the solid friction coefficient by 96% , followed by a little increase due to the viscous shear of the fluid. A numerical study on a CoCrMo(cup) - CoCrMo(head) reports comparable wear volume results up to five million walking cycles with experimental findings, the slight overestimate may be attributed to neglecting the asperity deformation and viscosity effects.