# Modeling the Effect of Coating on the Contact in Artificial Hip Joints

Yuchuan Liu[1], Markus A. Wimmer[2], Joshua J. Jacobs[2], Q. Jane Wang[1], A. Martini[1]
[1]Department of Mechanical Engineering, Northwestern University, Evanston, IL 60202
[2]Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL 60612

**Introduction:** Effective reduction of wear debris is a key to extending the longevity of artificial hip joints. Coating is a potential technique for reducing the volumetric wear. It may also provide a protection against friction shear and motion impact. This research is devoted to the development of a 3D mixed elastohydrodynamic lubrication (EHL) model for coated surfaces in artificial hip joints for the prediction of the effect of coatings or surface layers on joint interface lubrication behavior.

**Methods:** Experiments indicate that contemporary artificial joints function in the mixed or boundary lubrication regimes. A 3D mixed EHL model for the interaction of coated surfaces [1] is extended to evaluate the effect of a surface layer on the lubrication behavior of joint replacement components. The model is based on two novel sub-models. The first is a mixed EHL model that can simulate EHL of engineered rough surfaces in point contact from full film lubrication to boundary lubrication or even dry contact [2]. The second is an efficient elastic deformation model for coated surfaces using the discrete convolution and fast Fourier transform (DC-FFT) algorithm [3]. The newly developed coating EHL model for circular contacts is verified by comparison to available simulation results in dry contact [4].

**Results:** Simulations were conducted based on a metal-on-metal hip prosthesis with an uncoated femoral head against a coated acetabular component. The ball-and-socket configuration is simplified into a ball-on-flat model as a first approximation, where the ball radius equals the equivalent radius of curvature of the contacting geometry. The Young's modulus of the coating varies from 1/4 to 4 times that of the substrate. The coating thickness increases gradually form 0.1 to 3 times the contact radius found in the contact of uncoated surfaces. All results presented here are only for smooth surfaces. Figures 1 and 2 show the effects of the coating thickness and Young's modulus on pressure and film thickness profiles, where "a" refers to the contact radius for uncoated surfaces. It is found that lowering Young's modulus of the coating tends to increase the contact area, central film thickness and minimum film thickness while reducing the maximum contact pressure. The inverse is true for coatings with high Young's modulus. As the coating thickness approaches 3 times the contact radius for uncoated surfaces, the contact behaviors are controlled almost entirely by the coating.

**Discussion:** Real joint surfaces are rough. Therefore, the real lubrication behavior is affected by the ratio between deformed asperity height and minimum film thickness. Improving the lubricating film and controlling roughness may be effective means of reducing friction and wear in artificial hip joints. A highly elastic coating may be an approach to try along this direction through introducing an appreciable deformation and surface compliance. The application of a thick and highly elastic coating may result in an improvement in film thickness up to about 50%, and thus greatly reduce the friction and wear. However, the strength of such coatings may be a concern, which requires further study.

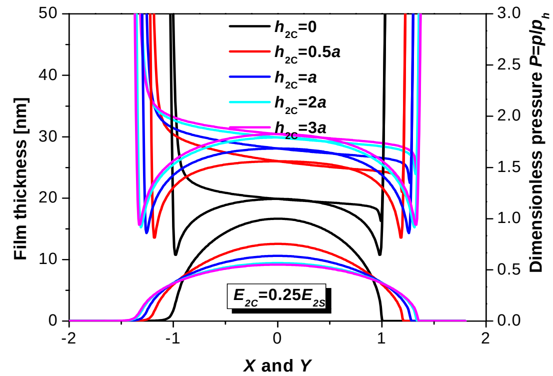


Figure 1. Effects of coating thickness on pressure and film thickness

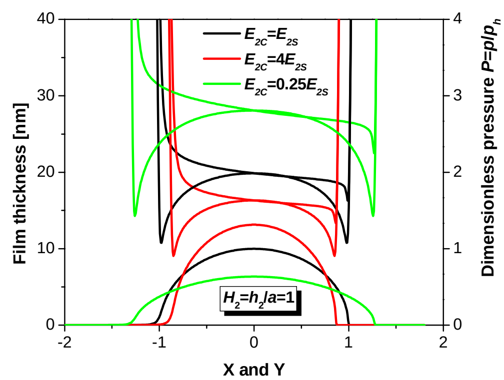


Figure 2. Effects of Young's modulus of the coating on pressure and film thicknesses

**Conclusions:** A 3D mixed EHL model for the interaction of coated surfaces is extended to evaluate the effect of a surface layer on the lubrication behavior of joint replacements using a ball-on-disk approximation. Coatings with a low Young's modulus demonstrate the desirable attributes of a large contact area, thick central film thickness and minimum film thickness at two lobes with low maximum contact pressure.

**References:**

[1] Liu, Y., Chen, W., and et al., Submitted to ASME J. Tribol., 2006.
[2] Hu, Y. and Zhu, D., ASME J. Tribol., 2000, 122(1), pp. 1–9.
[3] Liu, S., Wang, Q. and Liu, G., Wear, 2000, 243(1-2), pp. 101–110.
[4] O'Sullivan, T. C. and King, R. B., ASME J. Tribol., 1988, 110(2), pp. 235-240.