DIRECTION-DEPENDENCE OF UHMWPE WEAR FOR METAL COUNTERFACE SCRATCH TRAVERSE

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INTRODUCTION

Scratches on bearing surfaces of joint prostheses are known to appreciably accelerate wear. The dependence of polyethylene wear rates on counterface motion relative to scratch direction has heretofore not been explored.

METHODS

Arrays of parallel scratches (Fig. 1) were machined at 150 µm intervals on polished stainless steel plates. 25.4mm plugs were machined from conventional and highly-crosslinked UHMWPE.

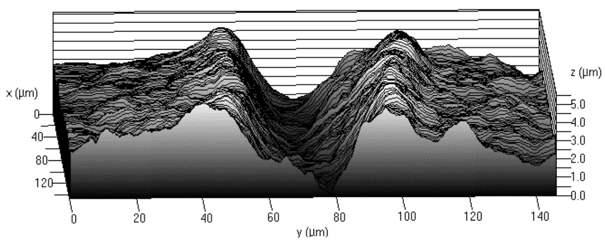


Figure 1. Laser scanning microscopy image of custom profile created on steel. Note axes scales

The scratched counterface plate was immersed in bovine serum and driven reciprocally against the polyethylene plug. The plug was made to traverse the plate at angles ranging from 0° to 90° relative to the scratch orientation, with wear being measured gravimetrically. Based on the scratch geometry of the experiment, a 3-D geometrically and materially nonlinear local finite element (FE) model (Fig. 2) of scratch sliding/ overpassage was developed, to explore continuum-level stress/strain parameters related to orientation-dependent scratch wear. A total of 1,027 candidate surrogate parameters were ranked according to goodness-of-fit to the experimental wear relationship.

RESULTS AND DISCUSSION

Experimentally, steady state wear for all angles was reached by approximately 60,000 cycles. Under this extremely abusive test regimen, in which scratches greatly dominate the surface engagement tribology, the absolute wear rates for both polyethylenes were nominally similar, Fig. 3. Maximum wear rates occurred at 15° for conventional and at 5° for highly-crosslinked UHMWPE. This suggests that at certain low angles, a slicing modality removed large amounts of material as the pin traveled across the scratch lips. The recovered debris was volumetrically dominated by strip/ribbon-like particles often hundreds of µm in length (Fig 4a) unlike the much smaller more bioreactive particles worn by a polished counterface (Fig 4b). In the FEA, computed maximum stress values exceeded polyethylene yield for all scratch orientations. The many FE metrics showed a spectrum of statistical fit with experimental direction-dependence, with (1) cumulative compressive total normal strain in the direction of loading and (2) maximum instantaneous compressive total normal strain transverse to the sliding direction.having best overall performance.

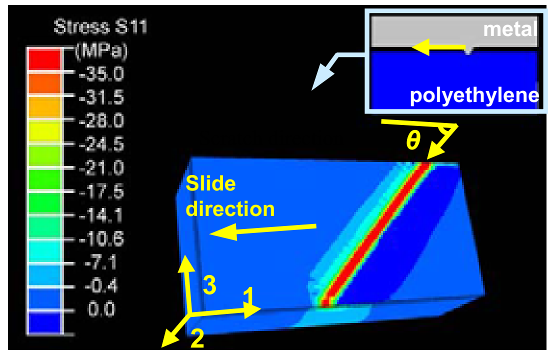


Figure 2. FE model depicting stress contours at θ=45˚.

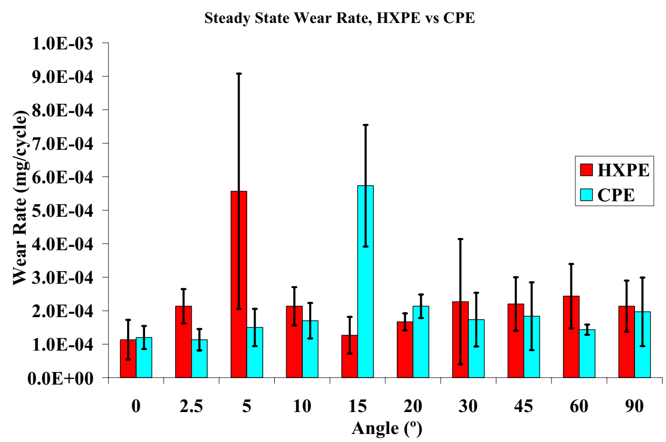
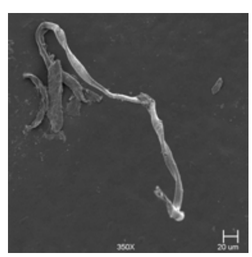


Figure 3. Experimental wear rates vs. scratch orientation.



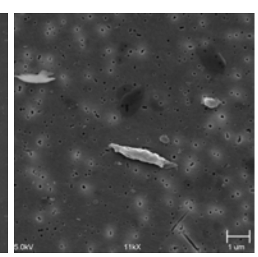


Figure 4a. **Figure 4b.** Polyethylene debris.

CONCLUSIONS

Conventional and highly-crosslinked UHMWPE both showed similar dependence on scratch vs. motion direction, and had comparable volumetric wear rates, in this very abusive regimen. However, the typical particle size was well above the most bioactive range.

ACKNOWLEDGEMENTS

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