Ball Cratering of Polymers for Biological Applications

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Abstract

Ball cratering, where a small (typically 25 mm diameter) ball is rotated on a surface to cause a conformal wear scar, is a method where a very small wear volume can be accurately measured. The wear can be confined to a thin surface layer and as such, the wear resistance of that layer, with little influence of the subsurface regions, can be examined.

This work examines the wear behaviour of polymers in the cratering system. It is shown that the effects of sterilisation and ageing of polymers on their wear rate can be detected with abrasive ball cratering and that the test provides suitable discrimination. However, it was found that the use of a polymer ball was necessary (rather than the more conventionally employed steel ball) and that results when wear experiments were performed with a steel ball did not provide any sensible sample discrimination.

Some polymers were modified to provide tailored biological activity. Only thin samples of this material were available and as such crater testing was a suitable method of assessing the mechanical behaviour of these materials. It was found that abrasive ball cratering was unable to provide discrimination between samples, but sliding wear testing (ball cratering with no abrasive) did provide measurable differences in the behaviour of the sample types.

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UHMWPE - Sterilisation

- Employed as cut component in hip and knee prostheses
- Sterilised by gamma irradiation
- Sterilisation and subsequent ageing leads to surface deterioration
- May promote wear, leading finally to implant loosening

Degradation by Gamma Irradiation

- Density - increases with crystallinity
- IR spectroscopy
- DSC
- Yield stress
- Stress at failure
- Strain to failure
- Wear behaviour

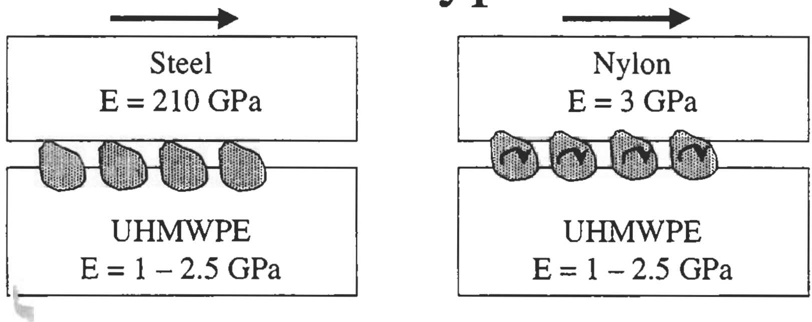
Test procedures

- UHMWPE
- Sterilised with 25 or 40 kGy
- Aged
  - O_2 (5 bar), 70°C, 4 and 8 days
  - Shelf (air) for 12 months
- Physical and mechanical properties of material measured

Wear test procedures

- Microabrasion
- 682 g l^{-1} SiC (C5, F1200) slurry
- 2 N load
- Between 20 and 200 m
- 3 repeats
- 52100 steel balls and nylon balls
- Steel balls run in against a mild steel specimen

Ball type

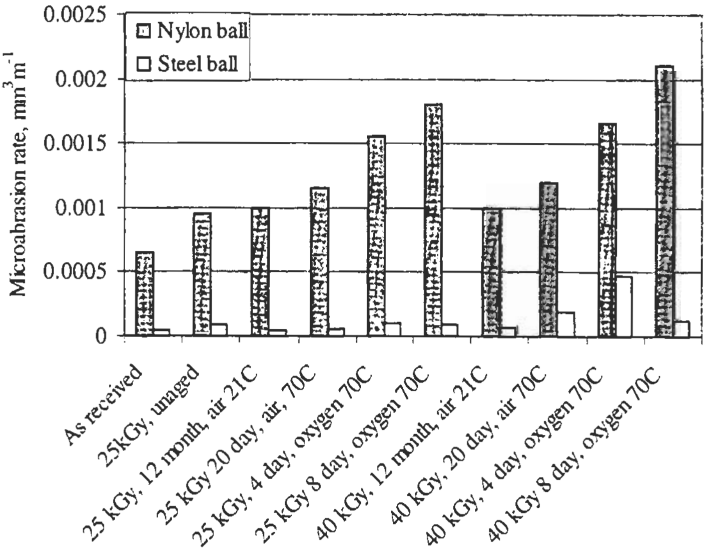


Steel wears
UHMWPE - little wear

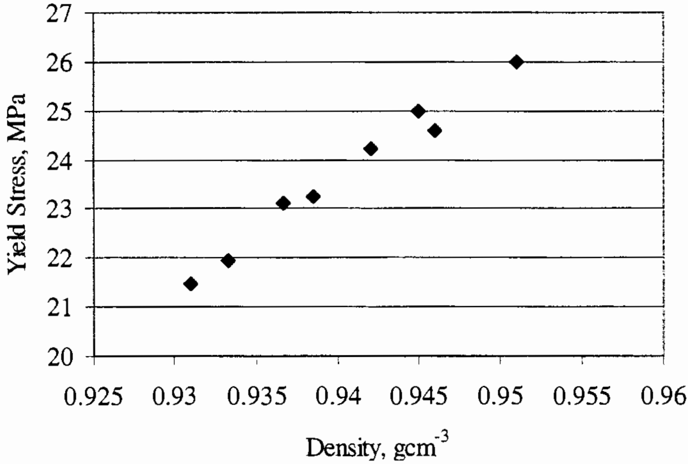
UHMWPE wears
Nylon - little wear

PP ball (E = 0.9 GPa) - low reproducibility and wear rates- wetability?

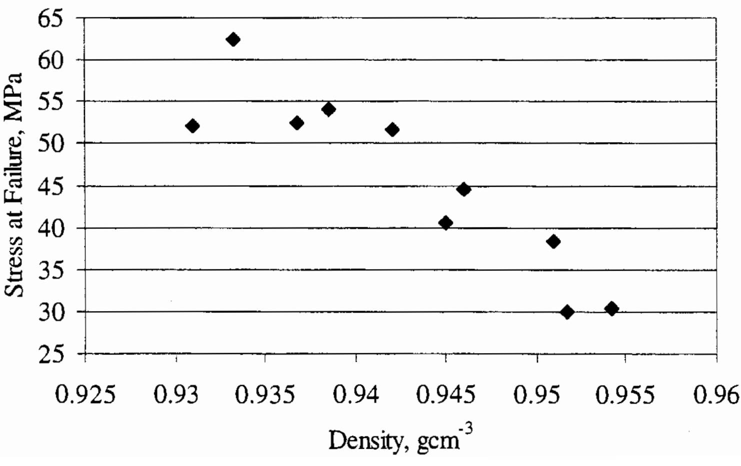
Microabrasion Rate



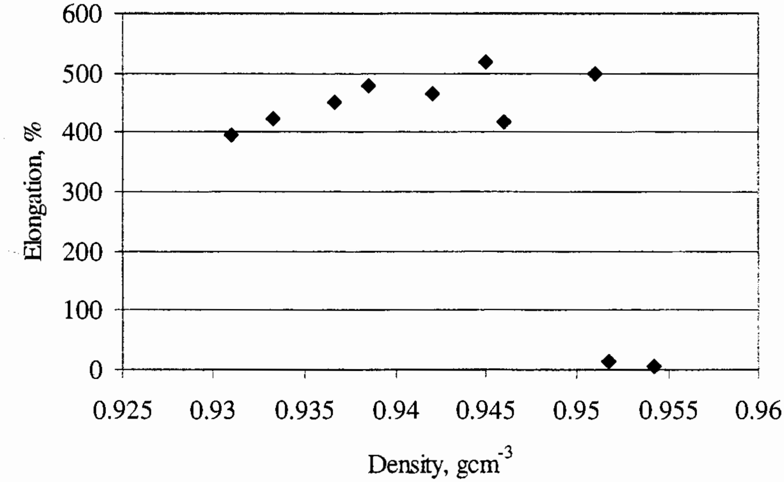
Yield stress vs density



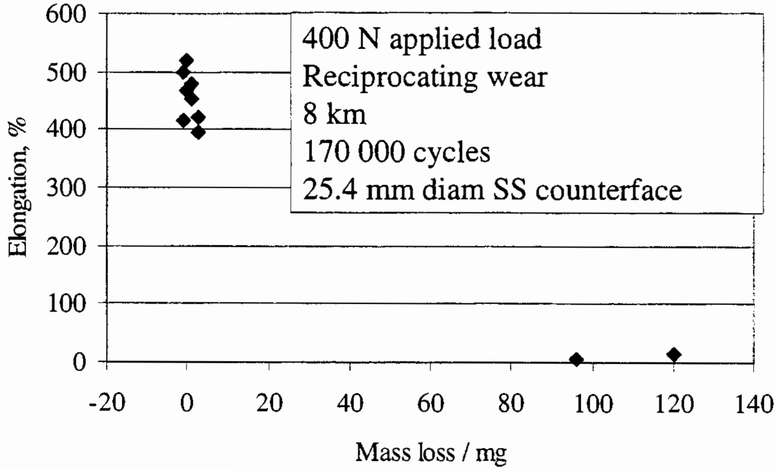
Stress at failure vs density



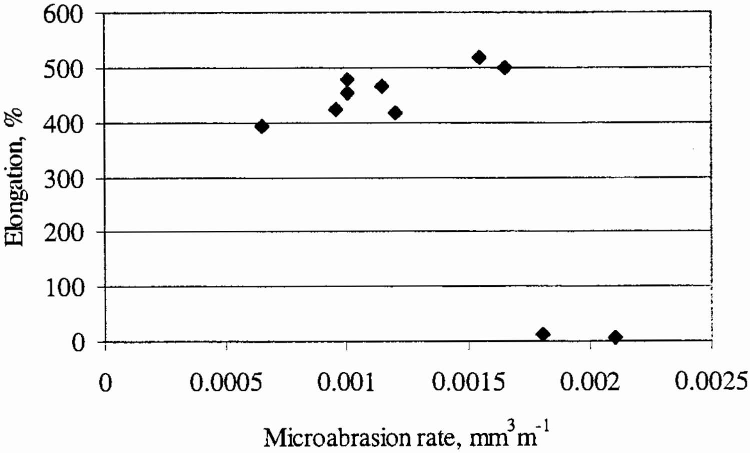
Elongation vs density



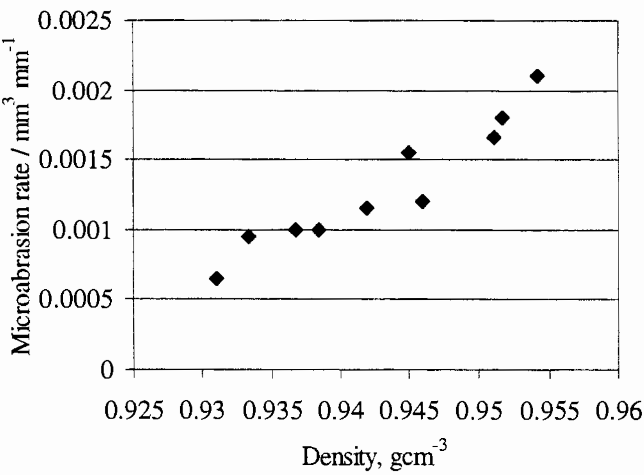
Elongation vs sliding wear rate



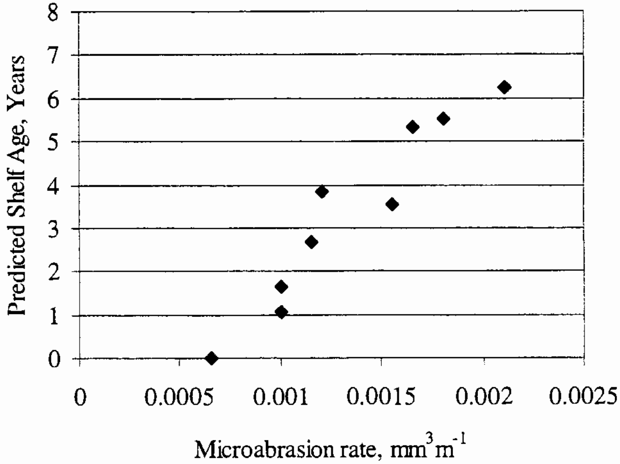
Elongation vs microabrasion rate



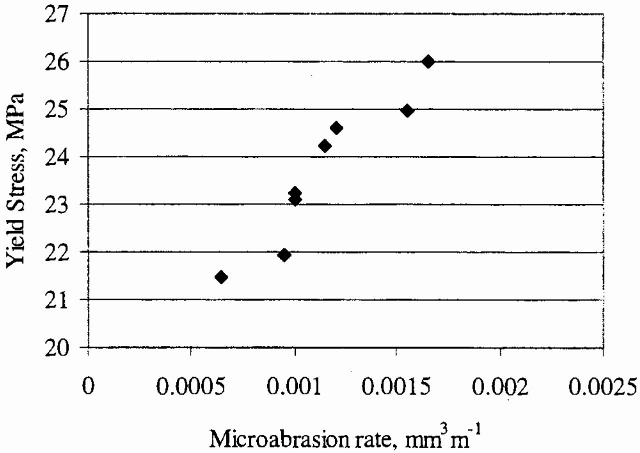
Microabrasion rate vs density



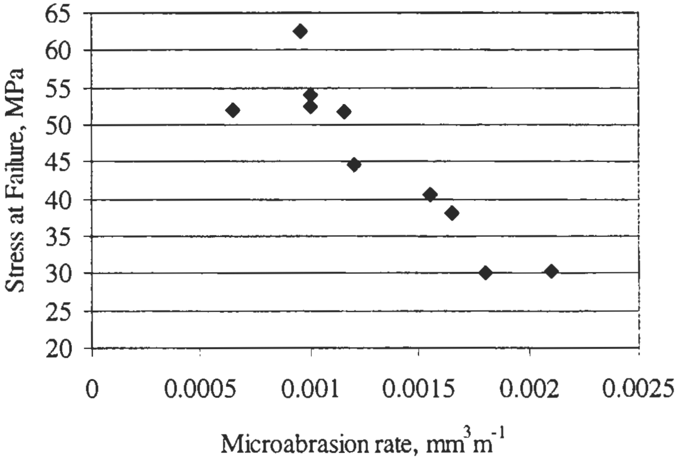
Wear rate vs shelf age



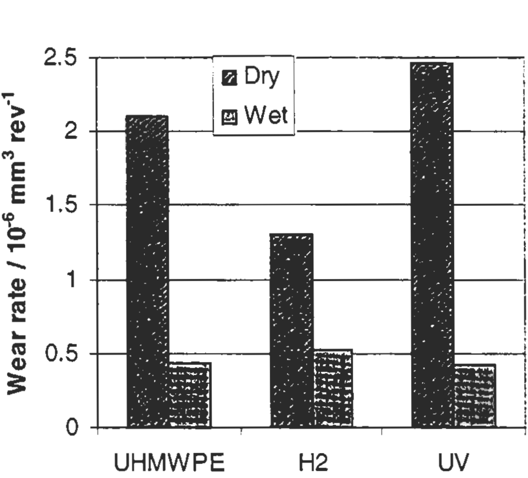
Yield stress vs microabrasion rate



Stress at failure vs microabrasion rate



Ball cratering - sliding wear



Summary

- Abrasive ball cratering
  - choice of ball
  - can discriminate effectively
- Sliding ball cratering
  - for physically small samples
  - has shown some sensitivity