Institute of Medical & Biological Engineering

The Application of A CMM-based Technique On Retrieved Cups For Wear Assessment

UNIVERSITY OF LEEDS

Xijin Hua, Ling Wang, Zhongmin Jin, John Fisher
Institute of Medical and Biological Engineering, School of Mechanical Engineering, University of Leeds, UK
Contact email: x.hua@leeds.ac.uk

Background

- The accurate estimation of wear occurring at the bearing surface is an important step for identifying the cause of failure and improving the longevity of hip prostheses [1].
- In case of retrieved components, the gravimetric methods are not feasible due to the unknown pre-wear data.
- The coordinate measuring machine (CMM) technique was then used in this case recently, which required the determination of the unworn area in the components [2,3].
- The aims of this study was to present and apply a methodology for calculating wear on retrieved polyethylene cups in which no pre-wear data is available by using a combination of CMM data and Matlab (The Mathworks, Inc.) code.

Materials and Methods

Data collection:

- Two retrieved polyethylene cups, one had severe wear (severely worn cup) and another had mild wear (mildly worn cup), were scanned using a coordinate measuring machine (CMM, Legex 322, Mitutoyo, UK).
- The cups were scanned by taking 2304 points in the form of 36 traces with an interval of 10°.
- Each trace consisted of 64 points with a pitch of 0.5 mm starting at the pole and finishing at the rim.

Materials and Methods

Original surface prediction :

- All the coordinate data was imported in a two-dimensional coordinate system.
- The points that coincided with each other were selected for the first surface fitting.
- If the maximum deviation of the points was larger than 10 µm, a threshold value was set based on the maximum deviation of the points (Figure 1).
- Any point for which the calculated deviation was greater than the threshold value was discarded. The remaining points were used in the fitting of the second sphere.
- The process was repeated until the maximum deviation of the points was smaller than 10 µm.

Wear prediction:

- Once the original surface of the cups was determined, the deviation of each original point was calculated to determine the maximum penetration depth.
- To calculate the volumetric wear, adjacent points were connected to form gridsquares.
- A mean wear depth for each gridsquare was calculated by taking the mean of the depths at the four corners.
- The area of each gridsquare was then calculated and multiplied by the corresponding mean wear depth to give a wear volume. These individual volumes were then summed for the entire component to give an overall volumetric wear.

Results

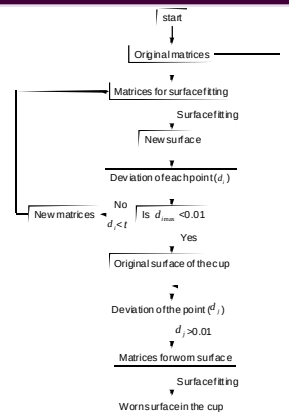

Figure 1: Flowchart for entire surface fitting process

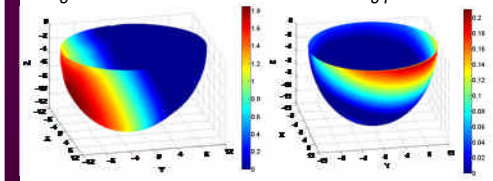

Figure 2: wear maps of bearing surface in retrieved PE cups for the severely worn cup (left) and mildly worn cup (right).

Table1: The predicted maximum penetration depth, wear angles and volumetric wear of the retrieved cups.

Components	Maximum penetration depths (mm)	Wear angle (°)	Volumetric wear (mm³)
Severely worn cup	1.85	32.5	432.7
Mildly worn cup	0.23	3.9	93.5

Results

- The severely worn cup had a liner penetration of approximately 1.85 mm while the mildly worn cup had a liner penetration depth of about 0.23 mm (Figure 2).
- The maximum penetration for the severely worn cup was offset at an angle of approximately 32.5° from the rim plane while for mildly worn cup, the maximum penetration was predicted at the rim of the cup (Figure 2).
- The volumetric wear for the two retrieved cups were predicted to be 432.7 mm^3 and 93.5 mm^3 respectively (Table 1).

Discussion

- The validation of the methodology was conducted in a previous study using polyethylene tibial knee inserts with physical volume removal [4].
- This study showed that the CMM-based technique can be used effectively and reliably for determining the wear volume and characterizing the wear patch by showing the shape, location, orientation and depth of retrieved components for hip prostheses with different degrees of wear in which no pre-wear data, CAD model and original design drawing were available.
- This technique can also be used to determine very low wear bearings such as metal-on-metal and ceramic-on-ceramic articulations.

References
[1] Ingham and Fisher. Biomaterials. 2005.
[2] Bills et al. Wear. 2007.
[3] Lord et al. Wear. 2011.
[4] Jiang et al. ORS 2013.

Acknowledgements
The authors would like to thank the University of Leeds, the Wellcome Trust and EPSRC (Grant no: WT088908/Z/09/Z) and the NIHR LMBRU, Leeds Musculoskeletal Biomedical Research Unit for providing financial support to this project. JF is an NIHR senior investigator.