CHARACTERIZING EDGE-WEAR IN CERAMIC-ON-CERAMIC ACETABULAR CUPS

Kapadia, Darshil[1]; Racasan, Radu[1]; Al-Hajjar, Mazen[2]; Bills, Paul[1]

[1]EPSRC Centre for Innovative Manufacturing in Advanced Metrology, University of Huddersfield, UK

[2]Institute of Medical and Biological Engineering, University of Leeds, UK

The use of fourth generation ceramic as an orthopaedic biomaterial has proved to be a very efficient and has gained popularity for primary hip surgery in the last 8-10 years. Cumulative percentage probability of revision after 7 years for uncemented CoC is 3.09% and for hybrid CoC is 2.00%, this compares favourably with traditional metal-on-UHMWPE uncemented at 3.05% and hybrid at 2.35% (*12th Annual Report - NJR*, 2015).

Such ceramic-on-ceramic hip prostheses are being implanted in ever younger, more active patients, and yet very few long-term large cohort retrieval studies are yet to be carried out due to the survivorship of the implants.

It has been seen in previous studies that levels of wear in ceramic-on-ceramic bearing surface can be of the order of 0.2 mm^3/million cycles (Al-Hajjar, Fisher, Tipper, Williams, & Jennings, 2013). This is incredibly low when compared to studies that characterize wear in other bearing surface combinations. It has also been reported that an unusual stripe pattern of wear can occur in some *in-vivo* retrieved cups (Macdonald & Bankes, 2014) and it has further been postulated that this is caused by cup edge loading (Walter, Insley, Walter, & Tuke, 2004). The combined measurement challenge of stripe wear occurring at the edge of a low-wear ceramic-on-ceramic device is considerable, a solution to which is presented here.

Current literature on wear measurement of such cases has been confined to in-vitro simulator studies and use of gravimetric measurement which by definition has limitations due to the lack of spacial characterisation.

This paper details a novel method for measuring edge-wear in CoC acetabular liners. The method has been employed in an in-vitro study where it has been benchmarked against gravimetric measurements. These liners were measured on a CMM to determine the volume of material loss. The measurements were conducted as a blinded post-wear study akin to measurement of retrieved components.

The most challenging part of this novel method was to create a reference geometry that replicates the free form edge surface of the 'unworn' cup using the residual post-wear surface. This was especially challenging due to the uncontrolled geometry at the cup edge and intersection of geometric features at this point. To achieve this, the geometry surrounding the wear patch was used to create a localized reference feature that minimised the effect of global form errors caused by hand polishing in the edge area. Furthermore, the reference geometry is compared with the measured surface to determine the linear penetration and volumetric wear loss. Result of this novel method can be seen in Fig 1 and Fig 2. The findings have been compared to gravimetric results and a bar graph comparing two results can be seen in Fig 3.

Overall the accuracy of the method for this cohort was 0.03-0.2 mm^3 when compared to gravimetric reference measurements. This compares very favourably with previously published wear measurement methods and gives confidence in the ability to measure such small measurement volumes over complex geometry.

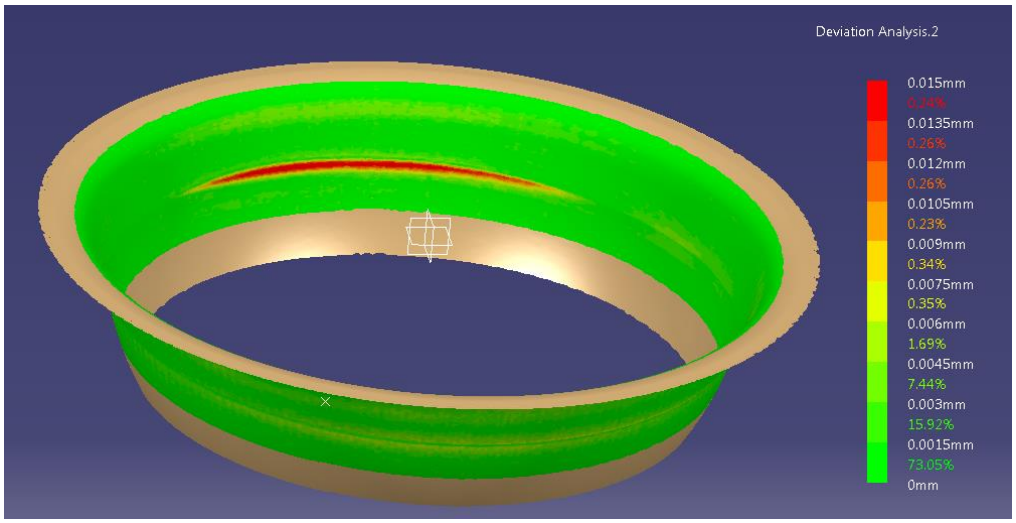

Figure 1: Result of the cup study displaying deviation between reference surface and worn surface.

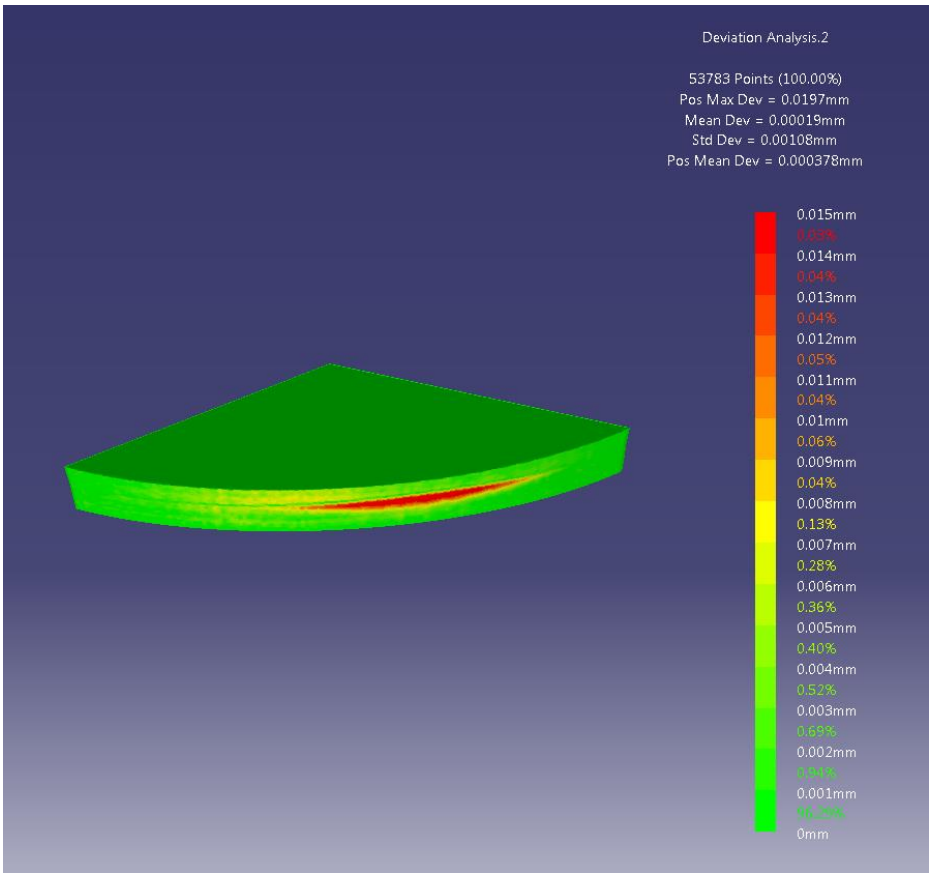

Figure 2: Result of the cup analysis for Localised Reference Geometry.

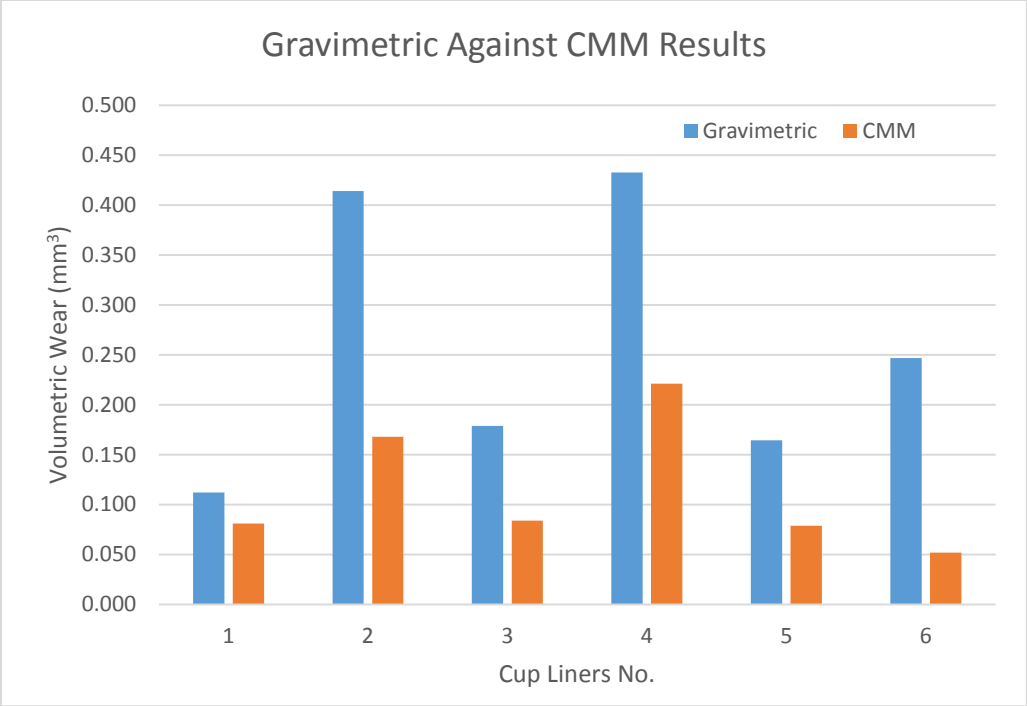

Figure 3: Bar graph comparing results from gravimetric and CMM method. (CMM method shows wear exclusively on the edge part, whereas gravimetric shows result on whole cup liner.)

Reference:

12th Annual Report - NJR. (2015).

Al-Hajjar, M., Fisher, J., Tipper, J. L., Williams, S., & Jennings, L. M. (2013). Wear of 36-mm BIOLOX(R) delta ceramic-on-ceramic bearing in total hip replacements under edge loading conditions. *Proceedings of the Institution of Mechanical Engineers.Part H, Journal of engineering in medicine, 227*(5), 535-542. doi: 10.1177/0954411912474613

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Walter, W. L., Insley, G. M., Walter, W. K., & Tuke, M. A. (2004). Edge loading in third generation alumina ceramic-on-ceramic bearings: Stripe wear1 1Benefits or funds were received in partial or total support of the research material described in this article from Stryker International, Newbury, United Kingdom and Finsbury Instruments, Surrey, United Kingdom. *The Journal of arthroplasty, 19*(4), 402-413.