The Application of Optics Polishing to Free form Knee Implants

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Abstract

Free form surfaces have for some time played a part in the latest developments in the exploitation of new products in optics, from micro lenses up to ELT telescopes. The demands of the required tolerance on these "new" optics have led to significant improvements in manufacturing and metrology, as the capability to produce form in the tens of nanometre range coupled with nanometre surface roughness have become the critical enabler the their use. Free form surfaces are not limited to optics, and other product developments such as bio-implant surfaces in the prosthetics industry are utilising free form surfaces to make significant strides implant life. The prosthetic industry, have for some time, known from research into hip replacements, that significant reductions in the production of biologically damaging wear debris could be achieved by implementing hard on hard bearing couples rather than the traditional metal on polymer bearing couples. In these "new" knee joints the bearing couples comprise free form alumina on alumina or CoCr alloy on CoCr alloy surfaces. Unfortunately the application of these new materials for knee implants has been largely halted by the inability of manufacturers to polish their knee surfaces to the more demanding tolerances placed on free form hard on hard bearings of both form and roughness. These tolerances require micron level form deviation combined with nanometre surface finish in order to maintain full fluid film lubrication during in vivo functioning of the joint. This paper discusses the development of the capability to machine biomaterials for use as hard on hard knee joints. The surfaces are machined utilising a 7 axis CNC optics polishing machine, the Zeeko IRP200. The machine uses a novel precision technique to correctively polish components [1].

1 Introduction

The aging population has put demands on modern healthcare deliverers in particular in terms of replacement of diseased joints such as knees and hips. The emergence and success of long life hard metal bearing couples for hips has meant that the focus has now turned to knee joints. A limiting factor in hard on hard bearing couples for knees has been the inability to manufacture these free form “saddle like” surfaces to sufficient accuracy of form and finish. The Zeeko precessions technology has offered the possibility of realistically achieving this for hard on hard knee manufacture. This paper demonstrates the ability of the Zeeko precessions technology to accomplish this task in times comparable to standardised lower precision conventional polishing techniques. It also presents preliminary pin on plate wear results for standard hand polished test surfaces compared to Zeeko polished surfaces. Massively free form surfaces such as those needed for highly conforming hard on hard total knee implants (TKR’s) require the development of a multi stage processing route consisting of roughing form correction and final polishing. In addition these processes should be achieved in process times at least as good as the current 45mins used for conventional machining and polishing methods which relise poorer conformance joints. The process route developed as a result of the project is outlined below.

2.0 Roughing Bio Metals

For bio-materials, optimising process time or finish was achieved using “Tagucci” methods; and resulted in a process time of 28 minutes with the best result of Sa = 27nm whereas a results of 35nm was achieved in an accelerated “grolishing” time of 11.5 minutes. These optimal conditions were used throughout for the bio metals as a base surface preparation prior to final polishing.

2.1 Form Correction for Bio Metals;

The main difficulty in form correction of CoCr and 316 stainless steel is to achieve stable material removal. During the project it was discovered that bonded diamond is susceptible to graphitisation at ideal conditions for the Zeeko IRP machine. Stable material removal for correction was achieved by the novel application of non-woven mats of polymer with SiC bonded abrasives fig 1a.[2] Form correction was achieved to 10um using by this technique compared to 25um+ for conventional manufacturing.

2.2 Polishing Bio Metals

This method was optimised using diamond pastes and surface roughness values of Sa= 1.5-2nm were routinely produced using only 2 precessions this process takes approximately 15mins. Conventionally 5nm texture values are considered high quality fig 1b and c.

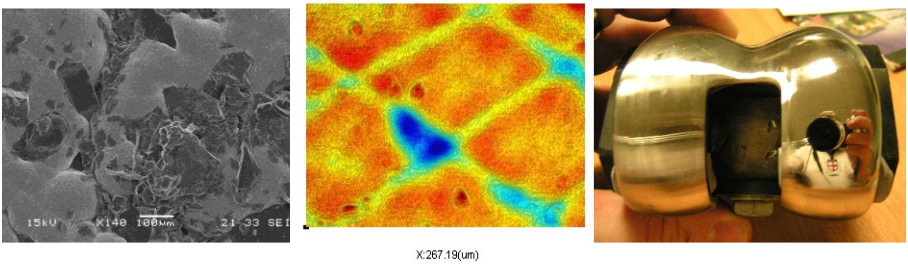

Figure 1a Graphitised bonded diamond b) polished knee surface c) polished and roughed knee condiles

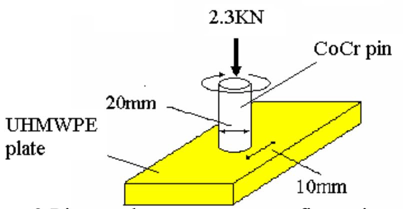

Figure 2 Pin on plate wear test configuration

In order to compare the Zeeko polished surfaces(referred to as super polished on the figure) with conventional "hand" polished surfaces pin on plate wear tests were carried out under standard conditions. The pins were made of the polished metal and the platess of conventional UHMWPE polymer. The pin-on-disc test used a constant load of 2.3kN (equivalent to three times body weight). A constant load was applied to the pins and the plates were reciprocated 10mm of total travel and a radial motion of +/- 5°. The articulation was lubricated with 30% bovine serum. At every million cycles the test was broken down and the pins measured. Pin on plate wear results are shown in Figure 3. The results show on average that under these conditions, the precessions polished specimens show lower wear against the UHMWPE than the conventional "hand polished" specimens.

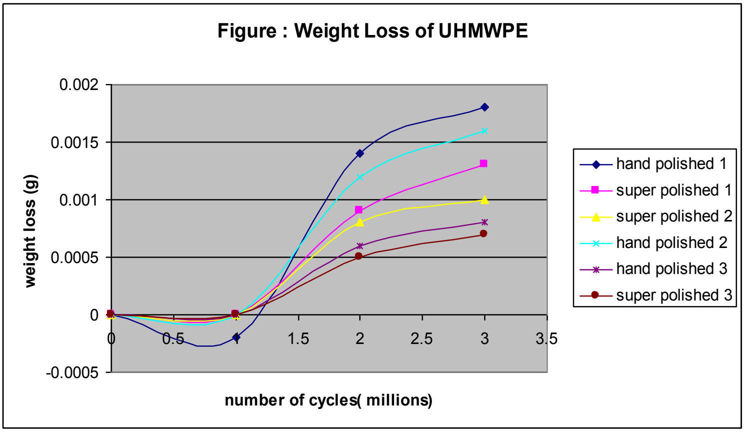

Figure 3 Wear tests results for Zeeko polished and hand polished pins

3.0 Conclusions

The precissions CNC polishing process is effective in reproducing the ideal surface geometry and improving texture as measured against samples of complex 3D form, especially knee replacements made using contemporary techniques. Moreover, the CNC process is cost-effective in terms of process-time and more importantly process-flexibility c.f. contemporary craft techniques, allowing small batch manufacture and bespoke surface geometries. Pin-on-disc wear-tests show statistically significant improvements in performance over conventional polishing. Knee simulator tests have now been initiated to allow a better comparison over conventionally polished knees the results of these tests be reported in the literature shortly.

4.0 References

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