The investigation of material removal in bonnet polishing of CoCr alloy artificial joints

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Abstract

In the process of form control using bonnet polishing an influence function is of vital importance for establishing material removal rates. However, the effects of polishing cloth, workpiece hardness and polishing parameters (such as precess angle, head speed, tool pressure and tool offset) on influence function when polishing CoCr alloys are not yet established and these factors affect the deterministic polishing process. In order to obtain a controlled polishing process, this study has further investigated the effects of polishing parameters on the influence function, including geometric size and volumetric material removal rates (MRRs).

1 Introduction

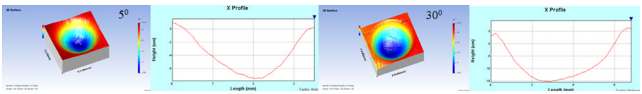
In bonnet polishing the material is removed by an inflated rubber tool which is covered by a polishing cloth and actuated against the part surface [1]. The slurry is introduced or the polishing cloth is coated in a polishing paste. The characteristic of material removal is termed as influence function. The influence function is closely related to the material removal characteristics of the polishing tool and is critical in defining the polishing dwell time for form control on the part surface[2]. This investigation seeks to find the relationship between influence function and the above process parameters when polishing medical grade CoCr alloy. Increasingly complex of hip and knee implant now call for specific non-spherical hip surfaces optimised for sinovial lubrication and better controlled free forms for knee bearings. Improved surface roughness and form both aid in the reduction of wear debris and ultimate implant failure. The samples used in the investigation are CoCr alloy commonly used in artificial implants (knee and hip). The polishing mediums are polyurethane GR-35 cloth with 3µm Al_2O_3 slurry whose specific gravity is 1.025. All experiments were carried out on a Zeeko IRP200 polishing machine. The machine settings are shown in table 1. After influence function spots were polished, the 3D maps of influence functions were measured by a contacting stylus (Somicronic 3D) instrument. The volumetric material removal rates (MRRs) were calculated by Precession software as developed by the Zeeko Company.

Table 1: Machine settings

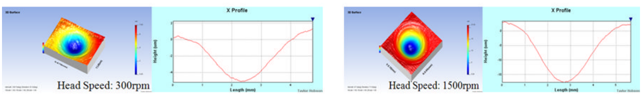
Factors	Precess angle	Head speed	Tool offset	Tool pressure
Value	15degs	1200rpm	0.15mm	1bar

2 The effects of precess angle

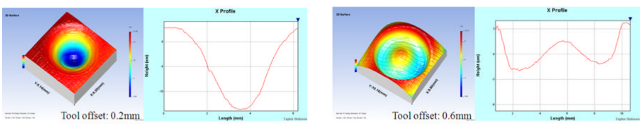
The experimental conditions for the effects of precess angle are given in table 1. The precess angle which is defined as the angle of inclination of the bonnet axis of rotation to the specimen surface increased from 5^0 to 30^0 at increments of 5^0. Other parameters were kept constant. The influence functions measurements are shown in Figure 1. As can be seen all influence functions are circular and precess angle clearly affects the geometric size of influence functions. The figure also shows that all influence functions are approximately Gaussian in shape and are uniform except for precess angle is 30^0. The calculation for MRR indicates that MRR increases with the increase of precess angle non-linearly (Figure 2).



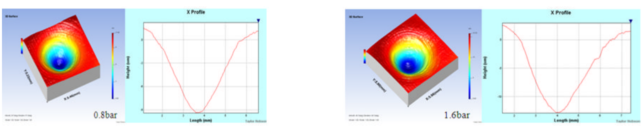
Measurements of influence functions vs. Precess angle



Measurements of influence functions vs. Head speed



Measurements of influence functions vs. Tool offset



Measurements of influence functions vs. Tool Pressure

Figure 1 Measurement of influence functions VS polishing parameters

3 The effects of head speed

The effect of head speed on influence function/ MRR for CoCr was investigated. The polishing speeds varied from 300rpm to 1800rpm with an increment of 300rpm while other parameters were set as in table 1. Figure 1 shows the influence function changes with the increasing polishing speed. The geometric size of influence function with increasing speeds from 300rpm to 1800rpm shows little change and all influence functions are approximately Gaussian in shape. It appears that polishing speed has little significant influence on the basic influence function. In this investigation, MRR increases linearly with the increase of head speed (Figure 2).

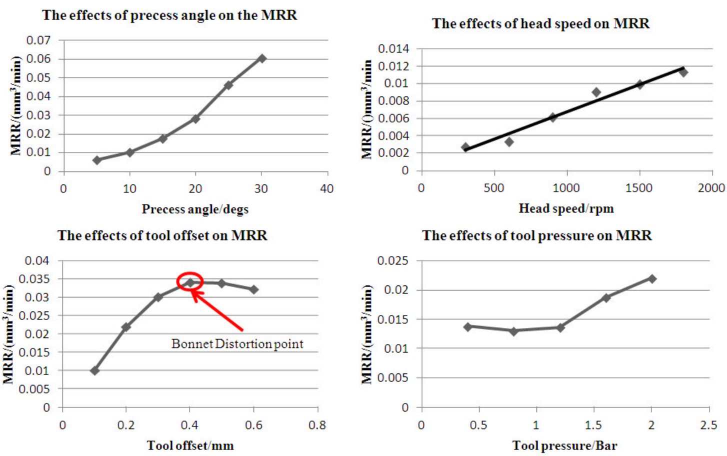


Figure 2: The effects of polishing parameters on MRR

4 The effects of tool offset

In this set of experiments, the tool offset was increased from 0.1mm to 0.6mm with an increment of 0.1mm while the other parameters are given in table 1. Figure 1 shows the influence function measurements when the tool offsets are changed from 0.1mm to 0.6mm. As shown the geometric size of influence function increases significantly with the increase of tool offset. However at higher offsets from 0.4mm to 0.6mm, the influence functions are not Gaussian shape and are related to the distortion of the bonnet tool (Figure 2). This phenomenon is harmful for deterministic corrective polishing and indicates that there is a limit to increasing MRR via tool offset for a given tool. The MRR increases greatly with the increase of tool offset from 0.1mm to 0.4mm, from 0.4mm to 0.6mm, the MRR decreases slightly due to the tool distortion (Figure 2).

5 The effects of tool pressure

The tool pressure was changed from 0.4bar to 2.0bar with an increment of 0.4bar whilst other polishing parameters were as given in table 1. Figure 1 shows the geometric size of influence function varies with the change of tool pressure. It can be seen that the geometric size of influence function shows little change with the increase of tool pressure. When the tool pressure increases, the influence function always remains approximately Gaussian in shape. The MRR increases with the increase of tool pressure only slightly (Figure 2). This indicates that if precess angle, head speed and tool offset are kept constant, tool pressure has little effect on MRR or that for this material combination the stiffness of the tool is sufficient to remove material.

6 Conclusions

The results indicate that the MRR increases with the increase of precess angle non-linearly, increases with the increase of tool speed linearly increases firstly and then decreases with the increase of tool offset and increases slightly with the increase of tool pressure. The geometric size of influence function increases with the increase of precess angle and tool offset but head speed and tool pressure nearly does not change the geometric size of influence function.

References:

[1] S.Zeng, et al., The application of Taguchi approach to optimise the processing conditions on bonnet polishing of CoCr, Key Engineering Materials, Vol. 496 (2012) : p. 235-240

[2] Schinhaerl, M., et al., Mathematical modelling of influence fuctions in computer-controlled polishing: part *I*. Applied Mathematical Modelling, 2008. 32 (12): p. 2888-2906.