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An Investigation of surface generation in swing precess bonnet polishing of 3D-structured surfaces possessing high wettability

Cheung Chi Fai[1,*], Cao Zhongchen[1] and Ho Lai Ting[1]

[1]Partner State Key Laboratory of Ultraprecision Machining Technology, Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong.

Corresponding Author: benny.cheung@polyu.edu.hk*

Abstract
This paper presents a study of the generation of complex 3D-structured surfaces possessing a high wettability by swing precess bonnet polishing (SPBP). A purposely built tool path generator (TPG) was developed for generating the CNC files for the SPBP. Hence, the factors affecting surface generation for the SPBP of different patterns of complex 3D-structured surfaces were investigated through a series of polishing experiments and functional tests. Experimental results show that the SPBP is able to generate complex 3D-structured surfaces possessing high wettability.

Keywords: wettability, structured surfaces, surface generation, tool path generator, swing precess bonnet polishing,

1. Introduction

Wettability is a property of a surface, which describes how easily the surface is covered by a fluid, most often water [1]. Many industrial applications like adhesion, anticorrosion, lubrication, friction, wear resistance, biocompatibility, catalysis, antifouling etc. involve wetting process that have been inspired by nature [2]. Surface texture or roughness plays a critical role in surface wettability and is most often altered permanently by structuring the surface. Three-dimensional structured surfaces (3D-structured surfaces) possessing high wettability can be potentially used for various functional applications such as wettability and lubrication.

In the past decades, the study of surface generation [3] and polishing mechanics [4,5] and in computer controlled polishing (CCP) has received a lot of research attention. Although the CCP is commonly used to reduce surface roughness [6] and polishing aspheric and freeform surfaces [7], the generation of complex 3D-structured surfaces with functional applications by CCP has received relatively little attention.

This paper attempts to study the technical feasibility of a swing precess bonnet polishing (SPBP) method for generating complex 3D-structured surfaces possessing a high wettability. The technological merits of the SPBP were realized through a series of polishing experiments and functional tests.

2. Swing precess bonnet polishing (SPBP)

As shown in Figure 1, the swing precess bonnet polishing (SPBP) method is a sub-aperture finishing process in which the polishing spindle is swung around the normal direction of the target surface within the scope of swing angle while moving around the center of the bonnet. The swing plane of the polishing spindle consists of the normal direction of the target surface and the feed direction of the polishing tool in SPBP. The generation of complex 3D-structured surfaces is affected by many factors which include point spacing, track spacing, swing speed, swing angle, head speed, tool pressure, tool radius, feed rate, polishing depth, polishing cloth, polishing strategies, polishing slurry, etc.

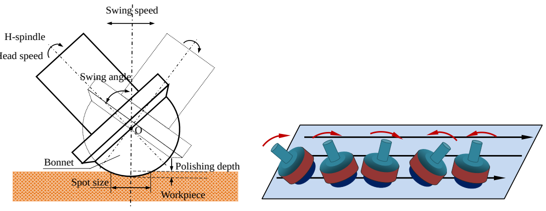


Figure 1. Schematic diagram of swing precess bonnet polishing

In the present study, a tool path generator (TPG) was purposely built for generating the CNC files for implementing the SPBP on a 7-axis polishing machine (i.e. Zeeko IRP200) through two kinds of motions which include feed motion (X,Y,Z,C-axis) and swing motion (A,B,H-axis), respectively.

3. Experimental Work

To study the surface generation of the SPBP, a series of polishing experiments were conducted on a Zeeko IRP 200 ultra-precision freeform polishing machine. Cylindrical Nickel copper samples with a diameter of 25.4 mm were machined by single-point diamond turning to ensure their consistent initial surface finish. The surface roughness and surface topography of the samples were measured by a Zygo Nexview 3D Optical Surface Profiler while the water contact angle of the 3D-structured surfaces were measured by a Sindatek Water Contact Goniometer with 5 ml water droplets. As shown in Figure 2, the surface roughness of the samples before polishing is 104 nm while the water contact angle is 85^{o}.

Basically, two experiments were conducted with experiment A1 focusing on the study of the effect of swing speed while experiment A2 focused on the study of the effect of spacing on the generation of complex 3D-structured surfaces and their wettability. Table 1 shows the process parameters for the two experiments. In experiment A1, two samples were polished under two different swing speeds which are 200 degrees per minute and 300 degrees per minute. The surface topography of the 3D-structured surfaces was studied under a spacing of the polishing tool path of 0.4 mm. In experiment A2, two samples were polished by using tool paths with spacings of 600 µm and 800 µm under a swing speed of 250 degrees per minute while another sample was polished by traditional single precess and raster bonnet polishing with a spacing of 600 µm and the same polishing parameters.

Table 1 Process parameters for Group A experiments

Polishing slurry	Silicon Carbide (1000 mesh)
Polishing cloth	Polyurethane loaded with cerium oxide
Bonnet radius	20 mm
Head speed	1500 rpm
Tool offset	0.287 mm
Tool pressure	1.2 bar
Feed rate	100 mm/min
Swing angle	10°

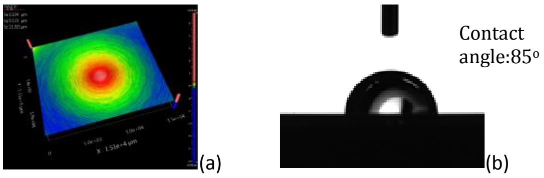
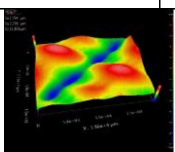
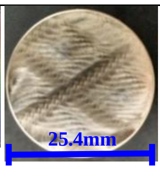
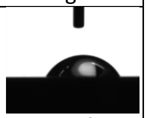
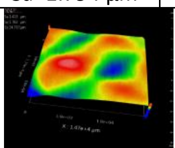
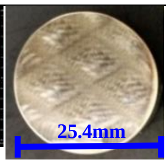


Figure 2. Surface of the samples before polishing (a) measured surface topography and (b) water contact angle of the surface

4. Results and discussion

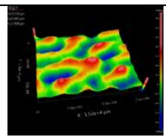
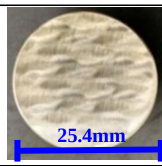
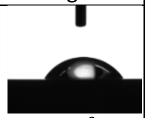
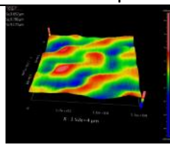
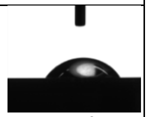
Table 2 shows the results of Experiment A1. It is interesting to note that complex 3D-structured patterns formed on the surfaces. The results in Experiment A2 show the effect of the spacing on the generation of the complex 3D-structured surfaces and their wettability (see Table 3). It is found that the topographies of the 3D-structured patterns generated on the surfaces are radically different from that in Experiment A1.

Table 2 Effect of swing speed on the generation of 3D-structured surfaces by SPBP and their wettability in Experiment A1

Swing speed	Surface topography	Photograph	Water contact angle
200 degrees per minute	 Sa=1.794 µm		 53.6°
300 degrees per minute	 Sa=1.413 µm		 49.5°

Water contact angles of the samples were compared so as to analyze the effect of SPBP on the wettability of the surfaces. Table 2 shows that the water contact angles of the complex 3D-structured surfaces generated after SPBP with the swing speeds of 200 degrees per minute and 300 degrees per minute were significantly reduced from 85° to 53.6° and 49.5°, respectively. Moreover, Table 3 shows that the water contact angles of the complex 3D-structured surfaces generated after SPBP with spacings of 600 µm and 800 µm were significantly reduced from 85° to 54.2° and 52.2°, respectively. The results indicate that the wettability of the surfaces is increased by using SPBP. The complex 3D-structured surfaces generated by SPBP enhance the functional effect of wettability of the engineered surfaces which make them become more adhesive

Table 3 The effect of spacing on the generation of 3D-structured surfaces by SPBP and their wettability in Experiment A2

Spacing (µm)	Surface topography	Photograph	Water contact angle
600	 Sa=0.538 µm		 54.2°
800	 Sa=0.657 µm		 52.2°

6. Conclusions

This paper presents a study of al swing precess bonnet polishing (SPBP) method for the generation of complex 3D-structured surfaces in which the polishing spindle is swung around the normal direction of the target surface within the scope of the swing angle while moving around the centre of the bonnet. Experimental results show that the complex 3D-structured surfaces generated by SPBP enhance the functional effect of wettability of the surfaces.

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