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Study of footprint variations of CCP considering machine kinematics

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Abstract. This paper investigates the differentiation between machine's static and dynamic footprint (FP). The results have shown progressing footprint variation related to tool's tilt angle. Continuous tilt angle compensation has been applied to offset this effect.

1 Introduction

Computer controlled polishing (CCP) has been adopted as main optical figuring technology due to its many merits, such as high repeatability, accuracy and efficiency. Today, there are many kinds of CCP machines on the market that based on different material removal mechanism [1, 2, 3]. The consideration of certain technology may base on the processing material, dimension, material removal rate and achievable accuracy.
One important factor to achieve a successful form correction is to maintain consistency of the polishing tool's FPs. It has been observed that Ion beam figuring and fluid jet polishing can reach form accuracies that using fewer iteration steps than those of chemical mechanical polishing (CMP) [4]. The slow converging in form correction are normally caused by the variation of FPs during the polishing process. In our previous publication [5], we have reported second derivative footprint recording (SECondo) of the difference between static and dynamic FP and its compensation. In this paper, we will investigate the trend of SECondo effect with respect to different tool tilt angle. This will provide us with quantitative information to facilitate compensation.

2 Experimental approach

There are many factors that can affect the depth, shape and position of a polishing tool's FP. The dominating first-order factors are head speed, pressure on the part and slurry specific gravity. Factors of second order such as machine runout, temperature, slurry PH have been considered and monitored/controlled. The effect that arises from polishing tool/machine's elasticity and its dynamic behavior has not been studied thoroughly. It has been demonstrated that when the polishing machine is accelerated at very large speed around a small circle, there will be a change of shape between static and dynamic FPs and the amount of shift varies with the tilt angle. This is due to the change of machine dynamics thus the redistribution of tool mass with different tilt angle. In the following experiment, the polishing machine was set to polish circular FPs with continuously-varying tilt angle. The FPs will be analyzed to find an offset value of tilt angle so that the dynamic FPs can be compensated to match the static FP of the same tilt angle.

The static footprint was obtained by keeping tool still whilst the part moves to achieve 3000mm/min relative speed. In contrary, the dynamic footprints were obtained by keeping the part still and the tool moves at 3000mm/min so that dynamic characteristic would be present. The footprint was then measured with interferometer and cross-sections were taken for analysis. Note that in this experiment, the polishing parameters were set to the machine's extreme accelerating allowance so that the dynamic FPs' variation can be observed. To observe a trend in the FPs variation, tilt angle will change continuously. The nominal tilt angle was set to be 20 degrees. When polishing the circular FP, the starting tilt angle was offset by -2 degree and increased to 22 degrees (offset value = 2 degrees) at +Y axis and reduced to 18 degrees at –X axis.

3 Results and analysis

Fig. 1 shows different FPs been plotted together which shows variations of the FPs. The Full Width at Half Maximum (FWHM) of the FPs' center has been calculated. As shown in Fig. 2.

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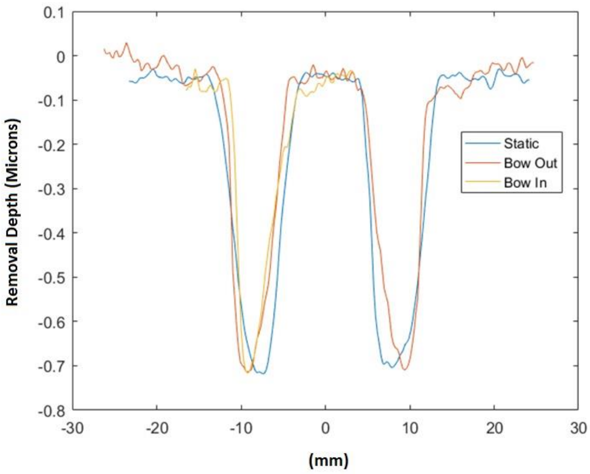

Fig. 1. Dynamic FPs and static FPs showing shape change.

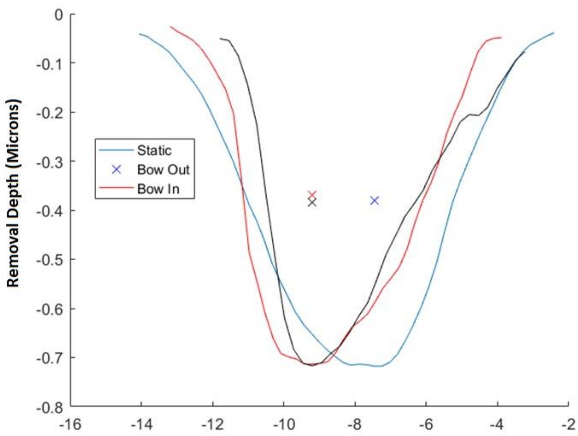

Fig. 2. FWHM analysis of FPs

The X axis cross-section of the circular FP has been used. The tool's tilt angle is 20 degrees. The tool was bowing out so that the tool mass was placed outwards. The coordinates of the centers of the static and dynamic FPs are: X = -7.4651 and -9.2 mm, Y = -0.37954 and -0.36985 µm. The central line of the dynamic and static FPs have been shifted in the X direction by 1.73mm, which will lead to erroneous form correction even if the metrology data has been aligned precisely.

Fig. 3. Experimental setup of tilt angle.

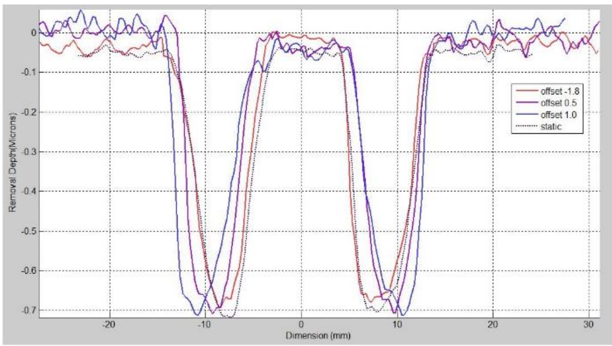

Fig. 4. Dynamic FPs with different tilt angle offsets showing shape change and compensated dynamic FP with static FP (dotted line).

In the experiment, the tilt angle offset setup is shown in Fig.3. From the cross-sections of the FPs (shown in Fig. 4), it can be calculated that the FWHM center of the FPs varies with the change of tilt angle and the best fit of the cross-section is obtained when the tilt angle is 18.2 degrees which are offset the nominal value by -1.8 degrees.

4. Conclusions

We have investigated the shape change of dynamic FPs and found that this can be compensated by tilt angle variation. This is largely because of the change of machine's dynamic distribution. In addition, the combined effect of FP's speed profile and tool run-out have contributed a certain level of compensation.

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