Shape Adaptive Grinding of Silicon Carbide Aspheric Optic

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Abstract: Shape Adaptive Grinding (SAG) is a novel finishing process capable of achieving optical surface finish on silicon carbide. In this paper, we report on the application of SAG to grinding of an aspheric optic.
OCIS codes: (120.4610) Optical fabrication; (220.1920) Diamond machining.

1. Introduction

Last year we introduced a new freeform grinding technology called Shape Adaptive Grinding (SAG) [1,2], which is capable of finishing rough chemical vapor deposited (CVD) silicon carbide surfaces down to a surface roughness less than 0.5 nm Ra (using the finest grit size of diamond abrasives, which is approximately 3µm). The basic principle of SAG machining is shown in Fig. 1, and can be described as "semi-elasticity": through the use of an elastic tool, general compliance is maintained between the grinding tool and freeform surface over a sub-aperture contact area of the workpiece, while hard contact is simultaneously achieved at relatively smaller scale thanks to rigid pellets covering the surface of the elastic tool. In this paper, we report on the application of the SAG process to corrective grinding of a CVD SiC coated aspheric optic.

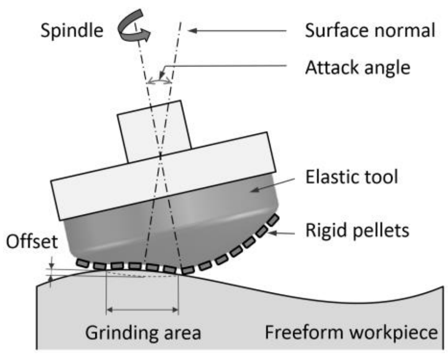

Fig. 1. Principle of Shape Adaptive Grinding (SAG) tool

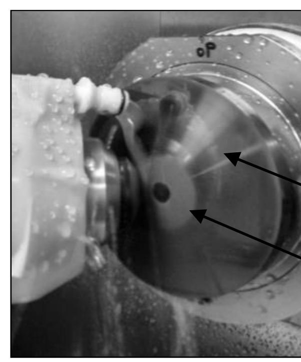

Fig. 2. SAG processing on Zeeko machine.

2. Shape Adaptive Grinding of Aspheric Optic

A 90 mm diameter convex asphere (with deviation from best fit sphere: ~50 µm) was generated in industry by rough grinding, and then coated with a 150 µm thick layer of silicon carbide by CVD. Using a contact profilometer, the aspheric from error of the CVD coated component was measured to be over 40 µm P-V of deviation from the exact prescription, while the surface roughness was measured at 4.3 µm Ra using a whitelight interferometer.

In order to improve the surface roughness and form error, the component was mounted inside a 7-axis Zeeko machine and ground by SAG using first 40 µm diamonds bonded in resin pellets, followed by 9 µm diamonds bonded in resin pellets. A spiral tool path was programmed in which the surface feed of the grinding tool was moderated against the form error of the component (i.e: slower at the high points and fasted at the low points). Figure 3 and 4 show the evolution of surface roughness (measured by whitelight interferometer) and form deviation (measured by contact profilometer) after each step of the process.

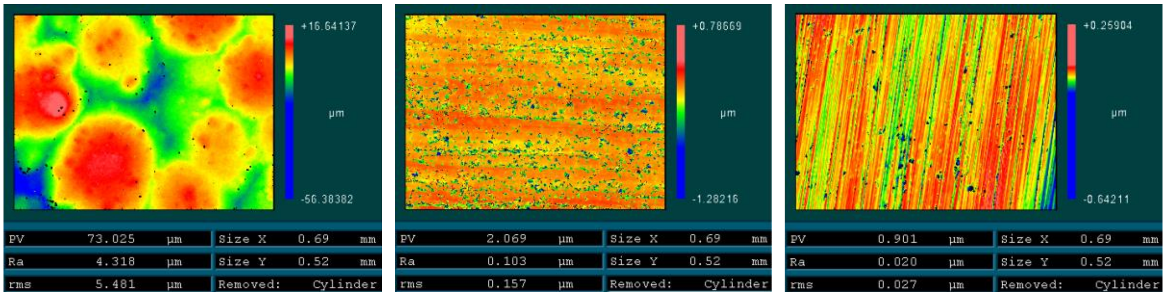

Fig. 3. Evolution of surface texture: As received (left), after SAG with 40 um (center), after SAG with 9 um (right).

As shown in Fig. 3, the CVD coating process generated a surface with grains of SiC grown to a nodular appearance. The 40 µm SAG tool was able to cut through these nodules, and leave a very noticeably smoother surface (103 nm Ra). Subsequent processing with the 9 µm SAG tool further reduced the surface roughness down to 20 nm Ra.

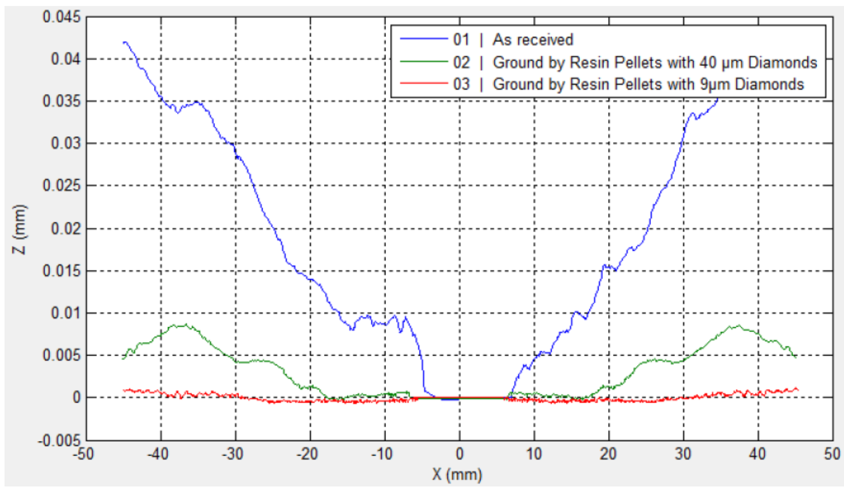

Fig. 4. Evolution of aspheric form deviation: As received (blue), after SAG with 40 um (green), after SAG with 9 um (red).

As shown in Fig.4, by moderation of the surface feed of the SAG tools, it was possible to iteratively improve the aspheric form error of the workpiece from over 40 µm P-V down to less than 2 µm P-V. This has brought the component into a state that is now good enough for finishing by deterministic polishing [3].

3. Conclusions

Using the SAG process, it was impossible to grind an aspheric silicon carbide optic. The surface roughness of the silicon carbide surface (produced by CVD coating method, which leaved a strongly nodular texture) was improved from 4.3 µm Ra down to 20 nm Ra using only two grinding tools with abrasives size 40 and 9 µm.

Simultaneously, the form error was improved from over 40 µm P-V down to less than 2 µm P-V. It is important to note that these results were achieved using a very low stiffness machine usually used for polishing (unlike the highly stiff and expensive machine tools usually used for precision grinding). The SAG method thus points towards a way to achieve lower costs in optical fabrication of aspheric and freeform ceramic components.

4. References

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