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ELID GRINDING OF SIC ULTRA LIGHTWEIGHT MIRROR

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ABSTRUCT

Silicon carbide (SiC) is the most advantageous as the material of various telescope mirrors, because SiC has high stiffness, high thermal conductivity, low thermal expansion and low density and so on [1] [2]. However, since SiC is very hard, it is difficult to obtain the surfaces efficiently by using ordinary grinding method. Therefore, we developed the ultra lightweight mirror by ELID (ELectrolytic In-process Dressing) grinding method and ultra-precision grinding machine.

ELID grinding method is the new grinding technology which one of authors invented, produces the quality of the high surface efficiently, and is effective in processing of a very hard material, such as crystalline silicon and sapphire, ceramics, glasses, hard metals and so on. SiC mirror for space telescope is designed as regular polygon rib structures in the rear face for reducing weight, and both the optical face and the backside ribs are so thin that deformation of the mirror cannot disregard. Therefore, in order to feed back deformation of the mirror to the orbit of grinding wheel, it is necessary to analyze deformation.

In this research, we present the results which fabricated mirrors of sintered SiC by the ELID grinding method, the numerical calculation results of the profile deformations analyzed by FEM, and new jig for ϕ360mm a mirror.

1. INTRODUCTION

A large number of lightweight SiC mirrors are used for the space telescopes. For example, sandwich type SiC material is employed for the primary mirror of telescope onboard Japanese infrared astronomical satellite (Astro-F) is scheduled for launch in 2005. But, the effective diameter of its primary mirror was reduced down to 670mm from the designed value of 700mm since polish processing of SiC is difficult [3]. In order to solve such a problem, we studied in order to establish the manufacture technology of lightweight SiC mirrors which integrated ELID grinding technique which can produce efficiently high surface quality, ultra-precision rotary grinder and computational grinding simulation.

2. ELID GRINDING METHOD

The ELID grinding method that produces high surface quality was proposed by one of the authors [4] [5]. Fig. 1 shows that the ELID grinding system consists of a metal bonded diamond abrasive grinding wheel, electrode, electrolytic power supply and coolant. The grinding wheel serves as a positive pole through smooth contact of a brush, and the electrode serves as a negative pole. A clearance of approximately 0.3mm was kept between the grinding wheel and the electrode. This new grinding technique is not a complex machining method.

Fig. 2 shows the schematic illustration of the ELID grinding process. Initial electrolytic process removes metal matrix of the grinding wheel to form oxide layers to let the abrasive protrude from the grinding wheel surface. As the protruded abrasives wear during grinding process, the oxide layer also becomes thinner. The wear of the oxide layer increases the wheel's electric conductivity, oxidizing the metal bonded diamond wheel again. By this electrolytic process, the thickness of oxide layer is maintained to give stable abrasive protrusion.

We fabricated lightweight SiC mirrors by using an ultra-precision rotary grinder "RG-800" with rotary table of 800mm in diameter and 10 nm precision in control resolution (Fig. 3, 4). The grinding of the mirror by RG-800 is executed by tracing the grinding wheel from the outer to the center of the work piece.

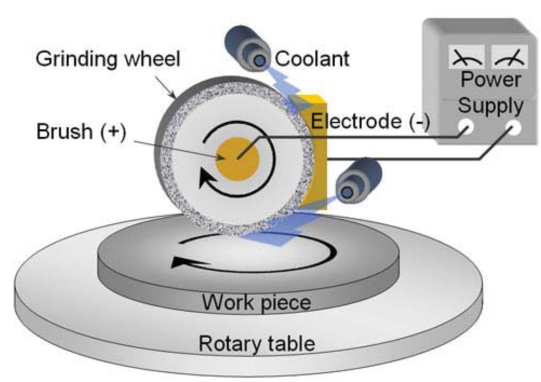

Fig. 1 Machine tool and work piece for ELID grinding

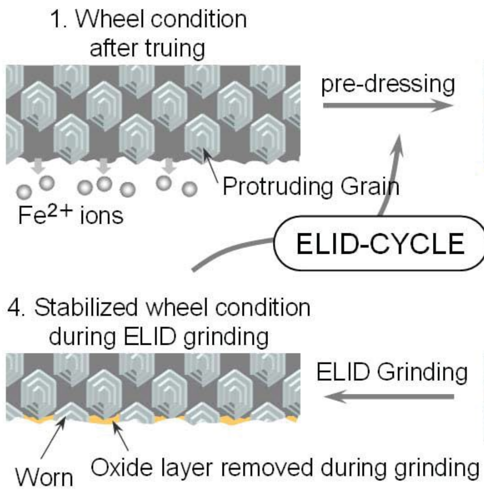

Fig. 2 ELID grinding process

Fig. 3 Ultra-precision rotary grinder “RG-800”

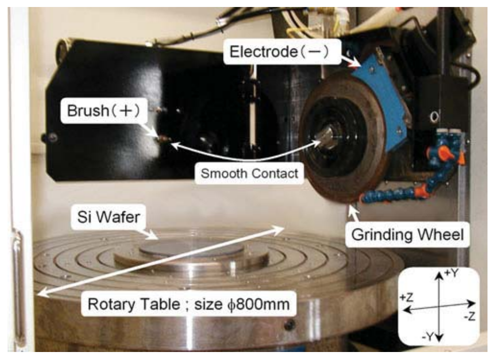

Fig. 4 ELID grinding system of RG-800

Fig. 5 Finished ϕ80mm sintered SiC mirror by ELID grinding

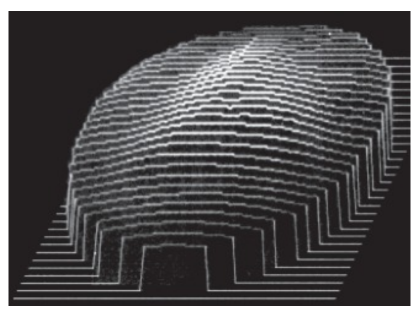

Fig. 6 Surface profile of finished ϕ80mm sintered SiC mirror

ϕ80mm sintered SiC mirror with one triangular rib structure in the rear face in order to reduce weight was finished using cast iron bond diamond wheel with grain size of #4000 (Fig. 5). The thickness of the backside ribs and mirror surface is determined to be 3mm. The roughness of this mirror surface was found to be Ry = 87nm and Ra = 11nm by SURFTEST-701 [Mitsutoyo Co. Ltd].

By the ELID grinding method, since the sharpness of diamond abrasive grinding wheel is good, grinding force is below the half of the ordinary grinding method. However, owing to the very thin mirror, profile deformation occurred in the central part of the triangle without rib structures. Fig. 6 shows the measured surface profile of the ground surface, and maximum deformation is approximately 330nm at the center of the mirror. It is thought that this deformation occurred since the mirror was pressed by grinding wheel.

3. NUMERICAL CALCULATION

Fig. 7 shows the illustration of the necessity for numerical calculation. If a mirror is grinded with orbit of wheel by ordinary processing, profile deformation is occurred at the parts without rib structures. Therefore, the profile deformation is calculated beforehand. The obtained calculation result is fed back to orbit of wheel, and realizes grinding of efficient ideal accuracy.

In order to measure the grinding force which is required for computational grinding simulation by FEM, we performed test fabrication by ELID grinding method. The result is shown in Fig. 8. Naturally, grinding force also increases with the increase in depth of cut and feed rate of rotational speed. By this measurement results, profile deformation of the mirror was analyzed according to the same conditions as experiment (mesh size of grinding wheel; #4000, depth of cut; 1mm, feed rate of rotational speed; 7500mm/min). Maximum deformation at the center of the mirror is 316nm (Fig. 9), and it agreed the experiment result well. Then, it is thought that this simulation is very effective in ELID grinding.

4. JIG FOR ϕ360MM MIRROR

As the next research subject, we will fabricate a lightweight mirror. The design shape of the mirror is shown in Fig. 10. The mirror is 360mm in diameter, the radius of curvature is 2380mm, and the material is sintered SiC. The mirror has equilateral triangle rib structures in the rear face for reducing weight, and the thickness of a optical face and rib structures are 5mm.

As shown by the result of a grinding experiment, deformation of the mirror by grinding force cannot be disregarded. We developed special jig for suppressing deformation of the mirror. External view of the jig is shown in Fig. 11. The jig carries nine supports for suppressing deformation and three supports for eliminating vibration. When the mirror is set on this jig, the supports for suppressing deformation are lifted by air pressure and contact a mirror lightly. After that, the supports hold the position by oil pressure. Therefore, if the mirror is strongly pressed by grinding wheel, they support the mirror and deformation does not occur. Fig. 12 expresses the state where the supports are in contact with the mirror.

Although the ϕ360mm mirror is manufactured using this jig, if the mirror face and rib structures are going to become thinner in the future, we can add thirty six supports on this jig for directly holding a optical face.

5. CONCLUSION

The following contents were reported:

1. ELID grinding of sintered SiC mirror is successfully carried out using ultra-precision rotary grinder, and high surface quality was obtained. But, Due to the very thin mirror, profile deformation occurred.
2. The numerical calculation results by FEM agree with the results by ELID grinding experiment.
3. The jig developed in order to carry out the grinding of ϕ360mm mirror was introduced.

Our next work is actually fabrication of ϕ360mm sintered SiC lightweight mirror using a proposed fabrication method (combination of ELID grinding and simulation) and developed new jig. We plan to finish it by this autumn.

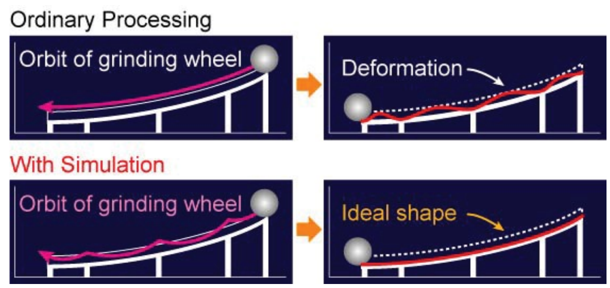

Fig. 7 Necessity for numerical computation

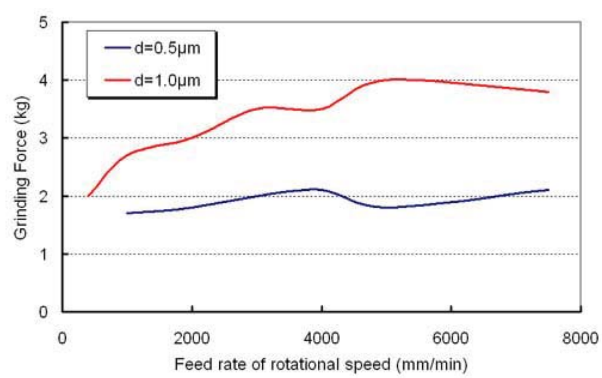

Fig. 8 Grinding force (#4000)
depth of cut (d)

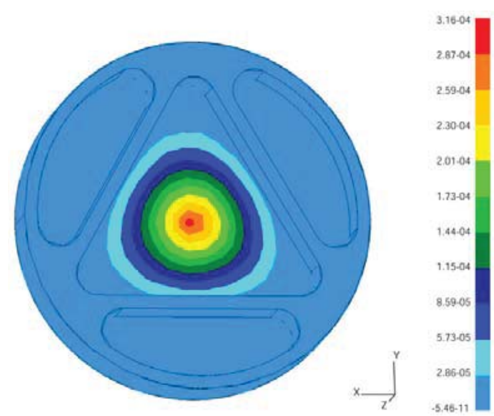

Fig. 9 Deformation distribution by FEM

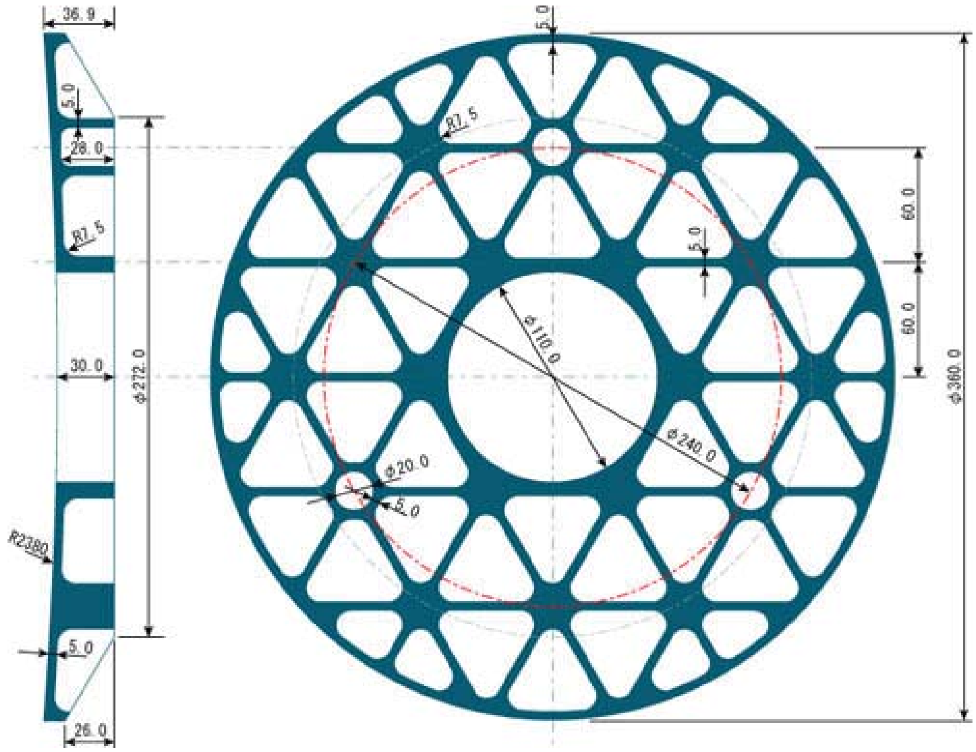

Fig. 10 Design shape of the ϕ360mm sintered SiC mirror

Fig. 11 External view of jig for ϕ360mm sintered SiC mirror

Fig. 12 The state where supports are in contact with f360mm sintered SiC mirror

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