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Hybrid polishing system and basic process experiment using fluid jet and rotary pad device

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Abstract
In the conventional FJP(Fluid Jet Polishing) process, micro abrasive particles mixed with water discharged at high pressure and high speed collide with the surface of the workpiece to remove the material. This process is useful for polishing a high hardness or hard-brittle material. However, in the machining of a soft material by using FJP, the quality of mirror surface is deteriorated by abrasive particles stuck in the surface of the workpiece. Also, FJP process has the problem that pollutes the surrounding environment by scattered in all direction of the polishing liquid. In order to solve these problems, novel hybrid polishing system was designed that combines the FJP process and rotary pad polishing method. To confirm the efficacy of this hybrid polishing system, the machining experiments were conducted by using this system on the surface of the roll workpiece of brass material that was machined by lathe. The properties of the polished surface of the roll which were machined at one point and overlapped with regular interval were analyzed.

Hybrid polishing system, Fluid jet polishing, Pad polishing, Roll mold machining

1. Introduction

The ultra-precision cutting machining has been widely applied to fabricate of mirrors, lenses, and molds for optical components. In the cutting process, the fine feed marks are necessarily generated by the shape of a cutting tool, and these marks deteriorate the quality of the optical components. In order to remove the feed marks, a FJP(Fluid Jet Polishing) process of discharging liquid containing fine abrasive particles at a high speed on the surface of the workpiece is being widely studied.[1-4] This process is widely used for the high hardness and hard-brittle materials. However, when the low hardness materials such as Brass, Nickel, Aluminum, and etc were machined, the surface was damaged by impinging particles of high speed. And, the quality of the mirror surface depreciated because of stuck particles to the surface of the workpiece. Furthermore, the problem that surrounding environment is contaminated by rebounded and scattered polishing liquid because of the collision on the workpiece is generated.

As a means to solve this problem, the hybrid polishing system was designed that combines the FJP process and rotary pad polishing method. In this study, basic performance of designed hybrid polishing system was analysed.

2. Hybrid polishing system

Fig. 1 shows experimental set-up of the hybrid polishing system. This system is composed of the conventional FJP system and rotary polishing pad surrounding the nozzle. In the polishing method using this hybrid system, FJP system machining the shape of the spot at the center of machining area, and the rotary pad is polishing surrounding area of the spot.

The material of the polishing pad was PVA(Polyvinyl alcohol) which has characteristics such as high hygroscopic and very soft surface. The outer diameter of the pad is 30 mm, the inner diameter is 10 mm, and the thickness is 10 mm. The rotational speed of the pad can be controlled by the reduction gear ratio of the motor, and the maximum rotational speed is 1200 rpm.

The nozzle was located in the center of the PVA pad, and the maximum discharge pressure of the fluid jet is 70 bar. The distance from the surface of the workpiece to the nozzle can be controlled by using linear stage.

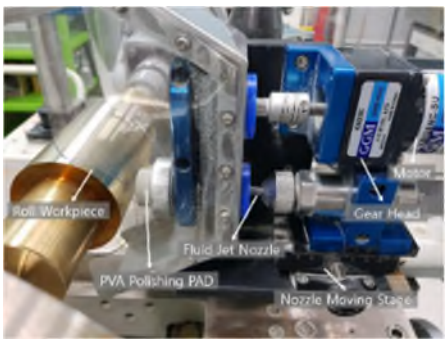

Figure 1. Experimental set-up of the hybrid polishing system

3. Experimental methods and conditions

The workpiece was 64 brass roll with a radius of 50 mm which was conducted in machined by lathe using PCD(Poly Crystal Diamond) cutting tool, and this workpiece was fabricated to surface roughness Ra of 0.2 μm and Rz of 1.1 μm.

The polishing experiments were conducted in two methods. The first method was that polishing liquid was discharged onto one point of the surface of the roll, and the rotational speed of the polishing pad was varied to 100, 500 rpm. Second, the

polishing system was moved at a constant interval of 500 µm for overlapping the machined surface by a hybrid polishing process. The rotational speed of the pad was controlled to 500 rpm. In these experiments, the nozzle with a diameter of 1 mm was used. The distance between nozzle and roll surface was 10 mm. The discharge pressure was 10 bar, and the polishing time was 3 min at each machining point. A polishing liquid that contained DI-water of 95 wt% and abrasive particles SiC(Silicon Carbide) #3000 of 5 wt% was used.

4. Experimental results

4.1. Hybrid polished suface at one point of the roll workpiece

Fig. 2 shows the machined surface of the roll by hybrid polishing when the rotational speeds were 100, 500 rpm and polishing time for 3 min. In the center of the machined area, there was a spot polished by FJP, and the shape of a polished surface with a width of 30 mm surrounds that. The spot commonly showed a 'ring' shape with an outer diameter of about 4.5 mm and an inner diameter of about 1 mm. The area polished by the PVA pad was elliptical shape along the surface of the roll. The machined surface showed the increase in gloss as the rotational speed of the pad increased.

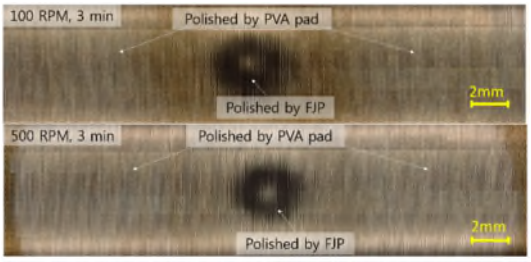

Figure 2. The polished surfaces of the roll by the hybrid polishing for 3 min when the rotational speeds of the pad were 100 rpm(up) and 500 rpm(down)

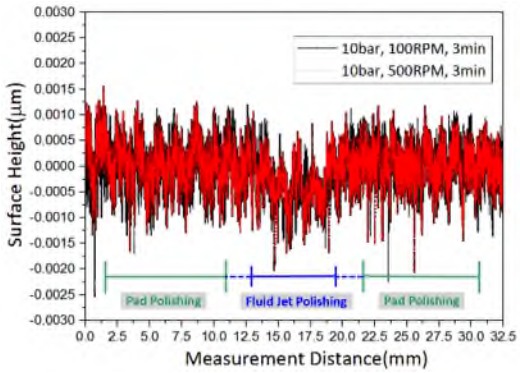

Figure 3. Profile of the polished surface of the roll by the hybrid polishing at 100 rpm (black) and 500 rpm (red) for 3min

Fig. 3 shows the surface profiles measured by surface roughness tester. In each polishing conditions, because the machined profile by FJP showed a typical 'W' shape, the process was normal. The polished depth by FJP was about 2.5 µm, the surface roughness Ra and Rz were about 0.16 µm and 0.8 µm. The polished depth by the pad showed a fine material removal rate of less than 0.2 µm. The surface roughness Ra and Rz were about 0.19 µm and 1.1 µm when the rotational speed of the pad was 100 rpm. And, Ra and Rz were about 0.18 µm and 1.09 µm when 500 rpm. From these experimental results, it was confirmed that FJP process showed a partial high material removal rate, but the surface of the soft workpiece was damaged by collision of abrasive particles. The pad polishing showed that it improves the surface roughness and the gloss effect over a large area compared to the low material removal rate of this process.

4.2. Overlap-polished surface of the roll workpiece

In order to confirm the overlap effect of the FJP and pad polishing, the machining experiment that the hybrid system was moved at an interval of 500 µm every 3 min was conducted. The rotational speed of polishing pad was 500 rpm.

Fig. 4 shows the micrograph and measured roughness of the overlap-polished surface of the brass roll. In the overlap-polished area, the removal of the feed marks by turning were confirmed, the polished surface roughness Ra and Rz were about 0.1 µm and 0.6 µm. This results showed a significant improvement compare to the basic workpiece.

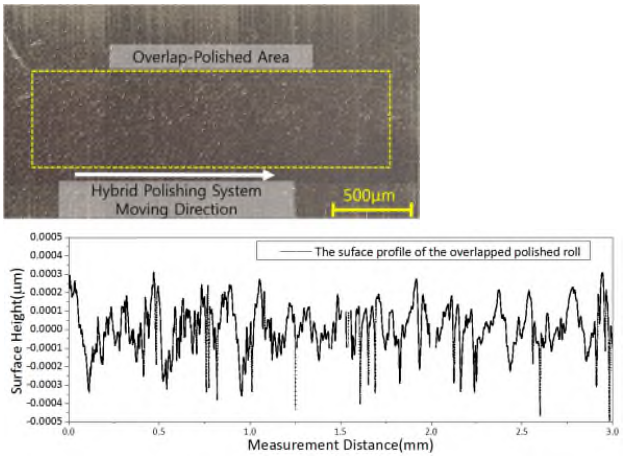

Figure 4. The micrograph of overlap-polished surface by hybrid polishing system moved at regular intervals of 500 µm (up) and this roughness profile (down)

5. Conclusion

1) In order to improve the problem of the conventional FJP process, the hybrid polishing system was design and constructed to eco-friendly combined with the pad polishing process. And, the effectiveness of this system was confirmed by the basic performance test.

2) The typical shape of 'w' was machined by FJP process. And, it was confirmed that improve the roughness and gloss of the surface machined by rotating polishing of PVA pad which absorbs the discharged polishing liquid.

3) The removal of the feed marks by cutting tool was confirmed when the surface of the workpiece was overlap-polished by hybrid polishing system moved at regular interval. And the surface roughness and gloss were more improved by this process.

4) In the future study, we will conduct the efficacy test of the hybrid polishing system on the entire surface of the roll by using the rotation and feed of the roll.

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