Planarization of Long and Narrow Materials by Oscillation-Speed-Control Polishing

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Abstract

The planarization of long and narrow structural parts used in steppers and coaters has been required. This paper describes the flatness and end profiles of a long and narrow polished workpiece. It was clarified that the best flatness and the best end profile are obtained when the tool diameter is 120 mm and the overhang amount is 35 mm for a workpiece 80 mm wide. Although the simulation results generally agreed with the experimental results for a uniform oscillation speed, they did not agree well under oscillation-speed control. In the experiment, a flatness of less than ±1.5 µm was achieved by oscillation-speed control without dummy workpieces.

1. Introduction

Stepper and coater machines use long and narrow materials more than 5 m in length for the stages and nozzles, and their surfaces are machined to meet the stringent requirements of both flatness and smoothness. It is difficult to polish the surfaces of the workpieces without deterioration of the flatness after grinding, especially at both workpiece ends. Therefore, two dummy workpieces are usually pushed together at both workpiece ends. Previous simulation results clarified that the optimum tool radius is about 0.7 times the width of the workpiece [1], and a removal uniformity of ±6% and a flatness of less than 0.8 µm can be achieved by precise oscillation-speed control [2]. This paper describes the flatness and end profiles of a long and narrow polished workpiece, and the optimum tool diameter and overhang amount. The workpiece profiles were calculated to improve the flatness by using more precise oscillation-speed control. The experimental polished profiles under the overhanging condition were compared with the simulation results.

2. Influences of the tool diameter and the overhang amount on the flatness and end profiles of a long and narrow workpiece

The workpiece profiles were simulated under the polishing conditions listed in Table 1(a). The initial profiles of the tool and the workpiece were flat. The oscillation-speed distribution was adjusted to obtain better flatness. Figure 1 shows the workpiece profiles on the center line in the length direction for three tool diameters. The overhang amount is 35 mm. Each oscillation range changes for each tool diameter. The best flatness of less than 0.6 µm over the whole surface of the workpiece was obtained for a tool diameter of 120 mm.

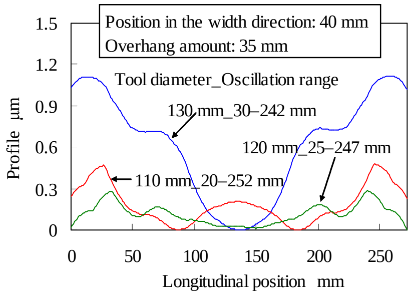


Figure 1: Influence of the tool diameter on the profiles in the length direction simulated under the oscillation-speed control.

The workpiece profiles were simulated to clarify the influences of overhanging on the flatness and end profiles under the oscillation-speed control. The optimum tool diameter of 120 mm was selected. Figure 2(a) shows the profiles on the center line in the length direction. The profile change is less than 0.4 µm at the overhang amounts of 33 mm and 35 mm. When the overhang amount is too large or too small, the inclination of the tool increases and the flatness significantly deteriorates. Figure 2(b) and (c) show section profiles in the width direction at the longitudinal positions of 0 mm and 140 mm. The end profile at the longitudinal position of 0 mm becomes concave at the overhang amount of 31 mm and becomes convex at 37 mm. The best profile of 0.12 µm is obtained for the overhang amount of 33 mm. In contrast, the section profile at the longitudinal position of 140 mm becomes concave at less than 0.4 µm. Accordingly, the optimum overhang amounts are 33 mm to obtain the best end profile and 35 mm to obtain the best flatness. The distributions of the oscillation speeds were adjusted as shown in Fig. 2(d). The speed in the central part was decreased with the increase of the overhang amount to improve the flatness.

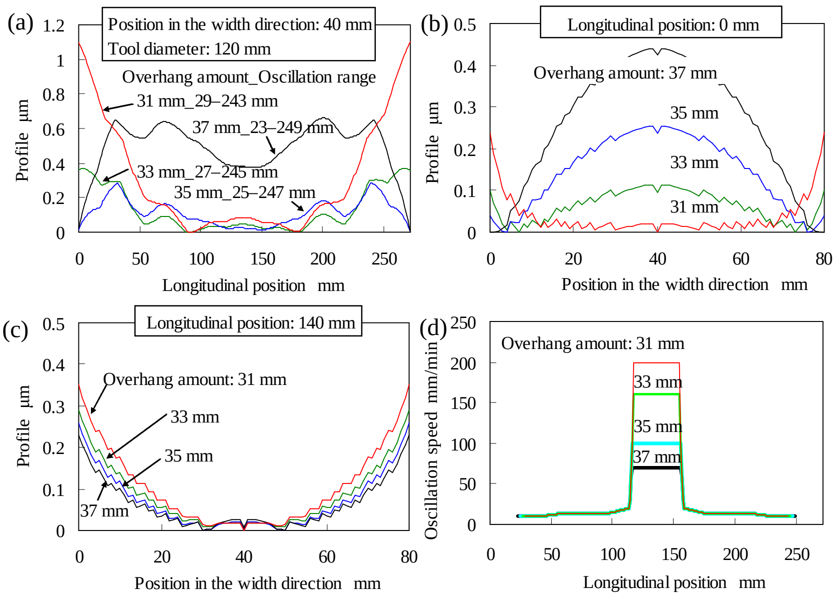


Figure 2: Influence of overhang amounts on the profiles: (a) in the length direction; (b), (c) in the width direction at the longitudinal positions of 0 mm and 140 mm, respectively, and (d) oscillation-speed distributions.

3. Comparison of simulated and experimental profiles

In the experiments, the workpiece is hard chrome plating coated on stainless steal. The slurry is alumina of diameter 0.3 μm. Figure 3(a) shows the profiles in the length direction when a workpiece was polished under the polishing conditions listed in Table 1(b). The overhang amounts at both workpiece ends are different. A large concave profile is formed because only a part of the tool passes over the ends. The flatness deteriorates to more than 10 μm, although the initial profile was less than 1 μm. The profile except the outer region of 240 mm agrees well with the simulation result. Figure 3(b) shows the profiles in the width direction at seven longitudinal positions. Most of the profiles become simply concave or convex, but the profile at the longitudinal position of 260 mm is concave at positions 10 mm and 70 mm. The profiles except near the right and left ends generally agree with the simulation results. Figure 4(a) shows the profiles in the length direction at the positions of 10 and 40 mm in the width direction when a workpiece was polished under the polishing conditions listed in Table 1(c).

Table 1: Polishing conditions

		(a)	(b)	(c)
Workpiece length (mm)		272	278	272
Tool	Outer diameter (mm)	110, 120, 130	120	
	Inner diameter (mm)	0	16	
Tool revolution speed (rpm)		100		
Pressure (kPa)		17.3		
Relative elastic coefficient (kPa/µm)		33		
Wear rate [µm/(km·kPa)]		0.8		
Stock removal rate [µm/(km·kPa)]		0.11		
Oscillation range (mm)		20–252	30–260	21–249
Overhang amount (mm)		31, 33, 35, 37	30, 42	39, 37
Number of oscillation		40		
Oscillation speed (mm/min)		15		
Total polishing time (min)		500–600	613	552

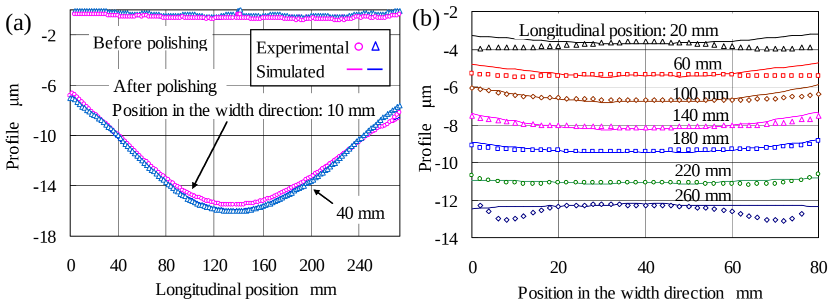
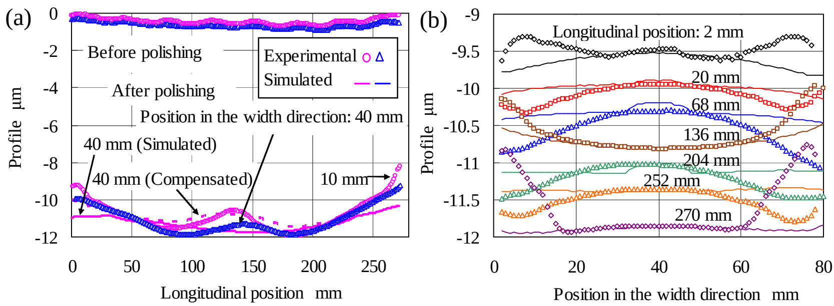


Figure 3: Workpiece profiles polished at a uniform oscillation speed: (a) in the length direction; and (b) in the width direction.

The flatness was improved to less than ±1.5 µm by precise oscillation-speed control. In a comparison of the experimental result at the position of 40 mm in the width direction with the simulated result, drawn as a heavy line, the inclinations of the profile at both ends and the convex profile in the central part are different. The compensated simulation result, drawn as a dashed heavy line, was calculated on the hypothesis that the tool diameter is smaller by only 6 mm. This compensated result shows better agreement with the experimental result, but it is difficult to say that they agree completely. Figure 4(b) shows the profiles in the width direction at seven longitudinal positions. The differences between the experimental results and the simulation results are large and become larger near both ends, because the wear and the viscous deformation of the pitch tool changes largely with the varying oscillation speeds, each of which is greater than the uniform oscillation speed.



4. Conclusions

Long and narrow structural parts are polished to a high degree of flatness and smoothness for use by steppers and coaters. The flatness and end profiles of such workpieces were clarified theoretically and experimentally. A flatness of less than ±1.5 µm over the whole surface of the workpiece was achieved by precise oscillation-speed control without dummy workpieces. In addition, the simulation results generally agreed with the experimental results at the uniform oscillation speed, but did not agree well under oscillation-speed control.

Acknowledgment:

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References:

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