Application to a High-performance Lapping Plate of Stainless Steel

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***Abstract*—The lapping plate is imperative because it influences the material removal rate and the surface quality of a workpiece. The cast-iron plate is a conventional lapping tool for machining hard and brittle material substrates, but it has poor lapping performance and bad rust resistance in the lapping process. To resolve these problems, our group has applied stainless steel as a lapping tool. The hardness of the lapping tool can be controlled using thermal treatment. The surface roughness of the lapping plate can be altered using mechanical conditioning or chemical etching. Because the rust resistance of stainless steel is very strong, the stable lapping performance of the lapping plate is easy to obtain. Furthermore, a great increase in the material removal rate and equal surface roughness of the workpiece can be achieved simply by changing the cast-iron lapping plate to a stainless-steel one.**

***Index Terms*—lapping, stainless steel, lapping plate, surface roughness, removal rate**

I. Introduction

The rapid development of the semiconductor and optical glass industries presents a need for increasing the diameter of workpieces. This trend makes it more challenging to achieve high manufacturing efficiency and good surface quality of substrates. Sapphire has been adopted as a substrate for light-emitting diodes (LEDs) [1]. Silicon-carbide (SiC) is the next generation powered device substrate that will lead to the realization of an energy saving society [2]. These materials are very hard and difficult to machine, thereby increasing manufacturing costs and preventing widespread application. Thus, it is necessary to improve machining efficiency to reduce manufacturing costs.

For reducing machining costs, it is crucial to raise the material removal rate in the lapping and polishing processes. Many researchers have investigated the polishing process [3-5], but the studies on lapping technologies, particularly the loose abrasive lapping technology, are insufficient. Lapping is the process of removing material from a slider and controlling the surface properties of workpieces. The lapping process is a very old manufacturing process, but it is still an essential technology for manufacturing semiconductor substrates, aspheric lens and cover glasses [6].

Previous researches have been conducted on lapping and grinding processes. Kim et al. evaluated a fixed abrasive pad in double sided lapping for sapphire substrates [7]. Zhu et al. addressed the surface feature count size characterization in the lapping process [8]. Wang et al. estimated the thickness of an affected layer and studied the effect of lapping slurry on machining performance [9]. Parameters of the lapping process have been widely investigated, but the impact of the lapping tool was rarely involved. The cast-iron plate is conventionally used in the lapping process. It has problems of low lapping performance and bad rust resistance. To resolve such problems, the authors have developed a lapping tool of compressed short-metal fibers and resin, which can obtain a high material removal rate such that the wear resistance is not so good [10].

In this study, we attempted to use stainless steel as a new lapping tool for improving lapping performance in the lapping process. Stainless steels are known for having high toughness and good chemical resistance. Several stainless-steel plates of different crystalline structures were examined as lapping tools. The grain size and hardness of stainless steel were adjusted by heat treatment. The surface states were adjusted by mechanical conditioning or chemical etching. A further discussion approximates the factors affecting lapping performance.

II. Experimental Setup

As shown in Table I, four types of stainless steel were used in the experiments. The crystalline structure and hardness for each type of stainless steel were different. For evaluating the lapping performance of the stainless-steel plate, a spherical graphite cast-iron plate was used as a reference. Before the lapping tests started, the lapping plates were polished with sandpaper to a surface roughness approximately 0.3 μmRa. Lapping experiments were conducted on a one-sided lapping machine. The material removal rate was calculated based on the weight loss and the average surface roughness was measured

Manuscript received March 30, 2017; revised Agust 5 , 2017.

doi: 10.18178/ijmerr.6.5.343-347

using an optical interferometric microscope (NewView 7300, Zygo, USA). The surface state of the lapping plate was evaluated using a color confocal microscope (OPTELICS H1200, Lasertec Corporation, Japan). The hardness of lapping plate was evaluated using a micro-Vickers hardness tester (HN-200, Mitutoyo Corporation, Japan).

III. Result and Discussion

Fig. 1 shows the material removal rate and the surface roughness of workpieces lapped by various lapping plates. The removal rate for each stainless-steel plate was markedly higher than that for the cast-iron one, but the surface roughness was slightly worse. The cut depth of the abrasives depends on the hardness of the lapping plate in machining the brittle materials. The graphite grains contained in the cast iron drop out in a short machining time and fine concave regions are generated on the cast-iron plate. As a result, the abrasive grains easily remain on the plate and the number of working abrasive grains increases. With the decreasing pressure of the abrasive grains chamfering to the workpiece, the surface roughness of workpiece improves and the material removal rate decreases. In contrast, there were no concave regions on the stainless-steel plates, which indicated the greater pressure of the abrasive grains. The removal rate increases in accordance to the hardness of the stainless-steel plates. Per the experimental results, controlling the surface asperity and hardness of the stainless-steel plate is essential for improving the lapping performance.

TABLE I. Material of Lapping Plate

Meterial	Type	Vickers hardness(HV)
Cast iron	FCD450 (Spherical graphite)	170
Stainless steel	SUS430 (Ferrite phase)	172
	SUS420 (Martensite phase)	232
	SUS304 (Austenite phase)	193
	SUS329 (Austenite/ Ferrite, two-phase alloy)	304

TABLE II. Lapping Conditions

Machine	Single side lapping machine (FACT-200, Nano Factor Co., Ltd)
Lapping plate	Cast-iron plate, Stainless-steel plate
Workpiece	Soda-lime glass: Initial surface roughness 0.6μmRa ϕ 20mm ×t10mm × 3pieces
Lapping pressure	20kPa
Rotation speed	Lapping plate/Work-holder: 90rpm
Slurry	GC#2000, 3wt% in pure water Supply rate (throw-away type): 25mL/min
Lapping time	30min

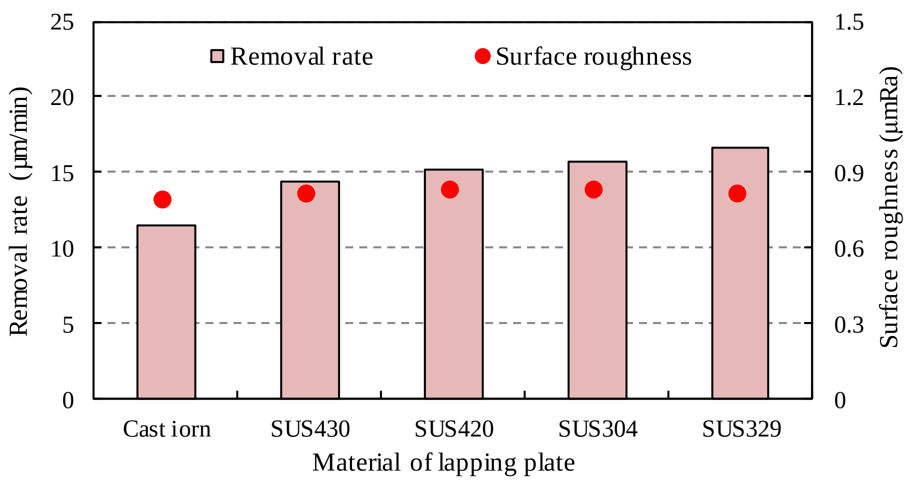
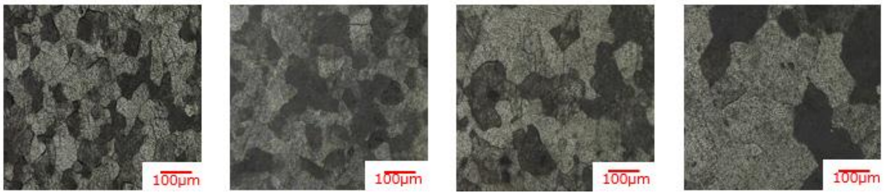


Figure 1. Influence to lapping performance of material of lapping plate



(a) Non-heat treatment (b) 700 ℃ (c) 800 ℃ (d) 900 ℃

Figure 2. Crystal grain images of heat-treated SUS430

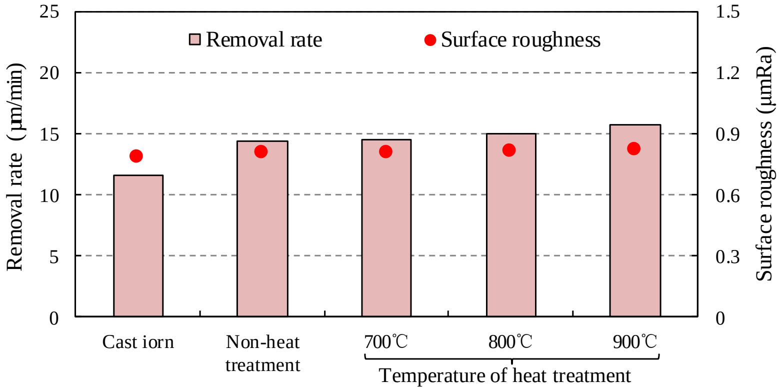


Figure 3. Influence on lapping characteristics of heat-treated SUS430 plate

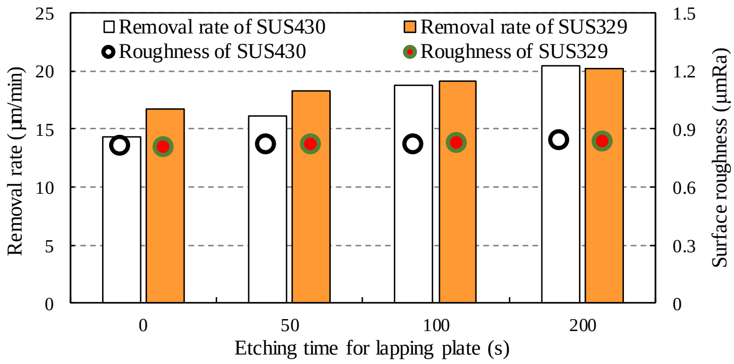


Figure 4. Influence on lapping characteristics of etched stainless plate

It is conceivable that the crystal structure of stainless steel was utilized to change the surface state of the lapping plates. For altering the grain size, the stainless-steel plates were heat-treated. Fig. 2 shows the crystal grain images of the heat-treated ferrite stainless steel (SUS430) at different temperatures. The images confirm that the crystal grains increase in size as the heat treatment temperature increases, the smaller the crystal grain size, the harder the material. The hardness of the heat-treated plates was measured at 172 HV, 173 HV, 190 HV and 240 HV. The Vickers hardness values show that the hardness of stainless-steel plate increases as the heat treatment temperature rises. It was assumed that the structural-phase transformation in the SUS430 was generated in the heat-treated process and the percentage of the hard pearlite-phase increased. The lapping characteristics of the heat-treated SUS430 plates are shown in Fig. 3. The material removal rate increases as the temperatures of the heat treatment rise. This result shows that the lapping performance of a stainless-steel plate can be improved by heat treatment.

TABLE III. SURFACE ROUGHNESS OF LAPPING PLATE BEFORE/AFTER LAPPING TEST

	SUS430		SUS329	
Etching time(s)	Before	After	Before	After
0	0.3	0.6	0.3	0.6
50	1.4	0.9	1.0	0.8
100	2.7	1.4	1.2	0.8
200	4.4	1.9	1.2	0.9

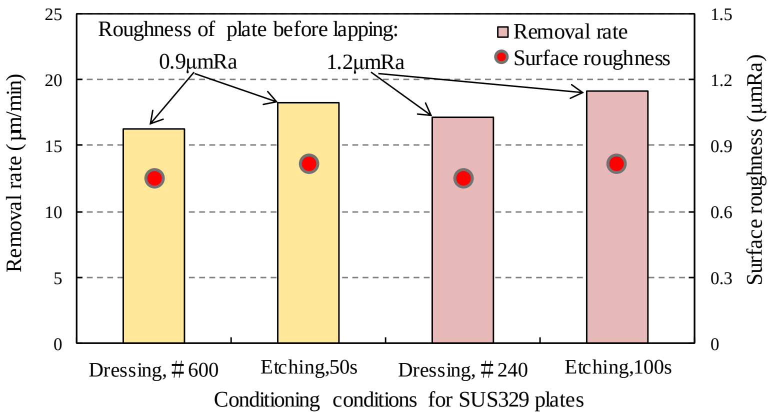


Figure 5. Effect of conditioning method on lapping characteristics

It is known that the surface etching process can be applied to change the surface state of components. For changing the surface roughness of the stainless-steel plates before the lapping test, SUS430 and austenitic stainless steel (SUS329) were etched by aqua regal for different etching times. Fig. 4 shows the lapping characteristics of the stainless-steel plates at the different etching times. The material removal rate, when any lapping plate was used, increased along with the etching time. While the rate of the SUS430 plate rose rapidly, the rate of the SUS329 plate grew slowly. The difference occurs because the acid resistance of the austenitic stainless steel (SUS329) is superior to that of the ferrite stainless steel (SUS430), which generated shallow concave portions on the plate. Table III confirms that the surface roughness change of the SUS430 plate was more evident than that of SUS329, between before and after lapping tests. It's true at the same etching times.

A stainless-steel plate can typically be conditioned by mechanical dressing or chemical etching. In the study, the surface roughness of the SUS329 plate was conditioned to the same degree by dressing or etching. The high material removal rate and bad surface roughness of the workpiece in the case of the etched plate are shown in Fig. 5. The soft ferrite phase is believed to have been etched preferentially, and the lapping characteristics of the stainless-steel plate were dominated by the hard austenite phase.

IV. Conclusion

In this work, stainless steels were applied to a lapping tool to improve the machining performance of a cast-iron plate. The machining properties of the stainless steels were investigated. The crystal structure of the stainless steel was converted by heat treatment. It was found that the stainless-steel plates have a higher lapping performance than the cast-iron plate. The heat treatment was useful for improving the lapping performance of the stainless-steel plates. The stainless-steel lapping plates were conditioned by mechanical conditioning or chemical etching. It was confirmed that the conditioning method affects the lapping performance. The chemical etching can remove the crystal phase selectively and greatly influences the lapping performance of the stainless-steel plates.

Acknowledgment

This work was partially supported by JSPS KAKENHI Grant Number 17K06096 and the Mitutoyo Association for Science and Technology. The authors wish to thank the financial support of this research from the Nippon Steel & Sumitomo Metal Corporation. The authors also thank Mr. S. Masui for his help with the lapping experiments.

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