Grinding Characteristic of Hard Disk Glass by ELID Grinding

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ABSTRACT

In this paper, we discuss the machining characteristics of HDD glass. Glass is now being used globally as a data storage device. Such glasses are usually machined by lapping. but this technique requires a long machining time, resulting in low productivity. For this reason, we examine the possibility of ELID grinding in HDD glass workpieces. A move to ELID grinding may result in substantial cost reduction. Our purpose is to investigate the grinding characteristics of HDD glass in ELID grinding. The bonding materials for fixing the abrasives of cast iron, cobalt and bronze are applied. and grinding conditions such as rotation speed and feeding are varied. Results show that with the use of ELID, mirror surfaces can be achieved with high efficiency.

Keywords : HDD glass, ELID grinding. P-V value, Pre – dressing, Metallic bond diamond wheel

1. Introduction

Our modern information based society shows rapid technological development, resulting in a demand for greater and greater amounts of data storage. The hard disk drive(HDD) is the most common form of permanent data storage. There are a number of different forms of HDD media currently in use among various countries. HDD glass is the most commonly employed in Japan (1, 2). Here we research the possibility of Electrolytic In-Process Dressing (ELID) grinding of HDD glass.

Generally a lapping technique is used to machine the glass. but the technique has some shortcomings. Lapping machining time is long, and the technique involves many short, separate processes. Also. reduction of slurry is a difficult process resulting in an environmental problem. However, if fixed abrasive grains are used instead of a slurry and machining precision is increased. the environmental and control problems associated with lapping will be eliminated. ELID grinding is a technique used to obtain high precision surfaces. If applied to the machining of HDD glass, when the resultant surface finish is of high quality, the productivity of the process will be increased due to reduction in the number of processes and the machining time required.

ELID is not a conventional dressing technique, but employs an electrolytic CBN or diamond wheel. In traditional grinding techniques, dressing is performed before machining. ELID is advantageous in allowing on-line dressing during machining. ELID grinding is a highly precise and efficient process employing Electrolytic In-Process Dressing in metal bond wheels.

An insulating layer is made, composed of oxidized bond material. During the grinding process. this insulating layer and its thickness in accordance with machining efficiency prevents excessive electrolysis. Specifically, the change of electric current stabilizes the protruding grains to be maintained during grinding operation. And also the metal bond wheels have a mechanical strength, it can achieves mirror surface and high precision surface Many kinds of material and shape can be machined using the above principle. Fig. 1 shows a schematic illustration of the mechanism of ELID grinding using metal bond wheels(3. 4).

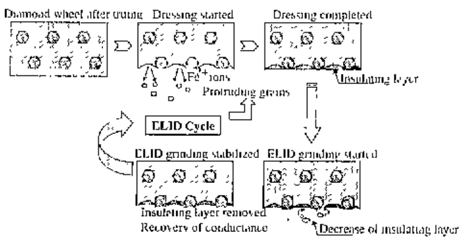


Fig. 1 Mechanism of ELID grinding

Experiments have shown the grinding characteristics of ELID rough and finish grinding of HDD glasses. To show the possibility of ELID finish grinding, experiments to test the ability of a rotary in-feed surface grinder to produce a surface roughness of 1 nm, were performed. The effects of changing three or four of the lapping process are investigated in this experiment.

2. Experimental system and method

2.1 Experimental system

The experimental equipment consists of a rotary in-feed surface grinder and a rotary surface grinder with ELID system. One is a HGS-10A (NACHI), equipped with air-bearings for the wheel and work spindle. The other is a conventional rotary surface grinder (SS-501, WASINO), that uses a hydraulic spindle. All have a feed-resolution of 0.1 micrometer for the wheel axis. The negative electrode employs a copper one, matched in the constant area of the wheel periphery. The experimental systems used in this work are shown in Table 1.

2.2 Experimental method

The material used in the experiments is HDD glass with outside and inside diameters of 66mm and 19mm respectively. Two types of materials are used. The grinding wheels used in the HGS-10A are cup type diamond wheels with concentrations of 100 and 75. The bond materials are cast iron, bronze and cobalt. The diameter of the grinding wheel is 143mm, the width 3mm. Table 2 shows the working conditions used in this experiment.

Pre-experiment truing was performed using a bronze bond #325 wheel. Before the experiment, grinding wheels were dressed to protrude abrasive grains from 20 to 30 min. During the initial electrolytic dressing, the change of voltage and current is shown in Fig. 2. This figure shows the case where the maximum values of 90V and 20A are used for a DB6000M100. The value of current stability is 5A - a high value. This may be due to the higher values of voltage and current required and the effects of consolidation of grinding wheel. In fact, the initial grinding experiment, current value is 4A. Grinding fluid flows through the clearance between grinding wheel and electrode in the direction of revolution of grinding wheel.

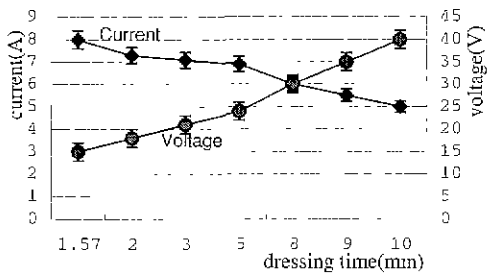


Fig. 2 Behavior of electrolytic pre - dressing

The grinding fluid becomes electrolytic between electrode and grinding wheel and causes protrusion of abrasive grains. The total grinding quantity was selected from between 20 and 200 micrometers determined by the status of the specimens. In Table 2, the grinding and electrolytic conditions are summarized, measured using a surface roughness measurement. Ground surface defects were checked using a microscope. Schematic illustration

Table 1 specification of ELID grinding system

rotary in-feed surface grinder(HGS-10A)		rotary surface grinder(SS-501)	
grinding wheel	workpiece	grinding wheel	workpiece
SD200N100M-cast iron SD270N100M-cobalt SD325N100M-bronze SD325N100M-cobalt SD325N75M-cast iron SD400N100M-cast iron SD600N100M-bronze SD800N100M-bronze SD1200J100FX3-cast iron	crystallized glass (ohara) chemically reinforced glass (hoya, before reinforced)	SD2000N100M-cast iron DB6000N100M- cast iron SD8000N100M- cast iron	crystallized glass (ohara) chemically reinforced glass (hoya, before reinforced)
power source	ELID power supply(EPD-10A)		
coolant	chemical solution type grinding fluid(CEM 2% diluted to water)		
measuring instrument	surftest-701(mitutoyo)		

Table 2 Grinding and electrolytic conditions

grinding condition	machine		HGS - 10A	SS - 501
	revolution of wheel		2500(1500),3600 rpm	870, 1190 rpm
	revolution of workpiece		300, 400 rpm	150 m/min
	spark - out		30 sec	3 times
	wheel feed	first	2 ~ 1600 μm/min	120 m/min
		second	2 ~ 1600 μm/min	
electrolytic condition	maximum voltage		60 V	90 V
	peak current		10 A	20 A
	wave form		pulse	pulse
	on - off time		2/2 μs	2/2(4/4) μs

of the experimental equipment and the ELID system is shown in Fig. 3.

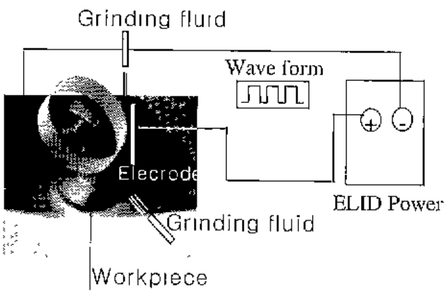


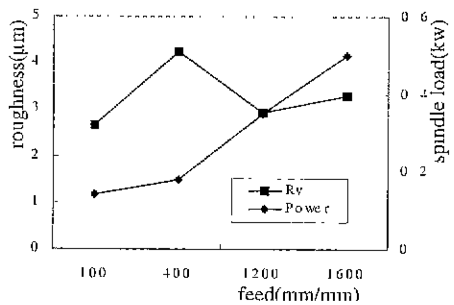
Fig. 3 Mechanism of ELID grinding

3. Experimental results and discussion

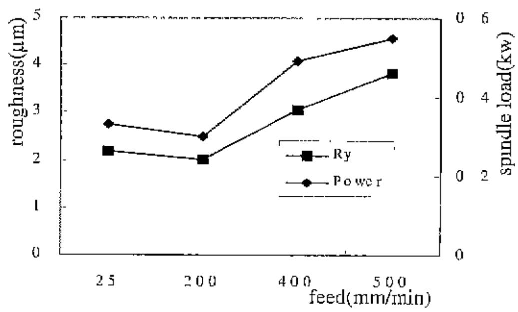
3.1 Experiment with the rotary in-feed surface grinder

In Fig. 4, the surface roughness and spindle load are shown for the grinding of chemically reinforced and crystallized glasses, each of 200 and 50 micrometer depth. using a BB-SD325N100M. Revolution speeds of the grinding wheel and workpieces are 3600 and 300 rpm, respectively

For the case of chemically reinforced glass, the grinding can be performed under all conditions. However, the gradients of surface roughness and spindle load were large. In Fig. 4(a). spindle load increases linearly with the feed. The surface roughness quickly changes at 400μm/min. The averaged working current is about 0.8A, corresponding to a stable condition. The surface roughness is also stable without depending upon spindle load. In Fig. 4(b), through spindle load increases linearly with increasing feed rate, and the surface roughness also increases. the feed rate of grinding possibly becoming shorter than that in Fig. 4(a). For above 550μm/min , the ground surface becomes unacceptable and the machining job can not be continuous due to increase spindle load.



(a) chemically reinforced glass

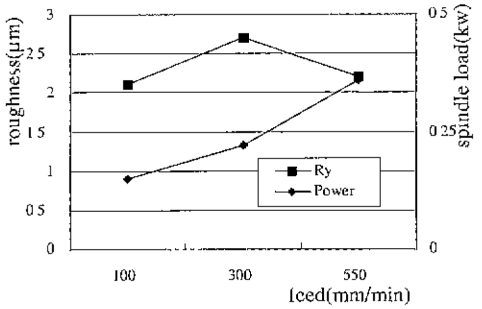


(b) crystallized glass

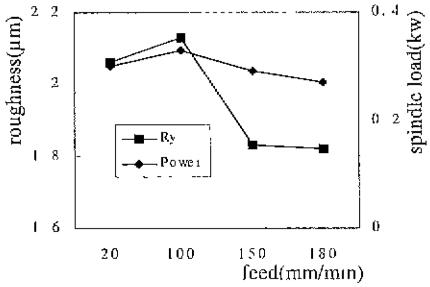
Fig. 4 Influence of feed rate for BB – SD325

For the chemically reinforced HDD glass, spindle load increases continuously with feed. This may be due to plastic deformation or brittle fractures occurring due to the temporary destruction of abrasives. For crystallized HDD glass, the trends of the surface roughness and spindle load are the same with increasing feed rate because the rate of wear of abrasive grains increases when the highly brittle crystallized HDD glass is ground.

The grinding is unstable because of the destruction of insulating layers of electrolytic nonconductor.



(a) chemical reinforced glass



(b) crystallized glass

Fig. 5 Influence of feed rate for BB – SD325

Fig. 5 shows the results of grinding using BB-SD600N100M wheel. Revolution speed of the grinding wheel and workpiece are 3600 and 300 rpm, respectively. In Fig. 5(a), the change of maximum surface roughness and spindle load are shown when 100μm of chemically reinforced HDD glass is ground. For rough grinding, it can be ground at the crucial rate of 500μm/min due to the possibility of high efficiency grinding However the spindle load rapidly increases. The maximum surface roughness at 550μm/min is less than at 300μm/min. This may not be due to the lack of balance between the rate of protrusions of diamond and rate of wear in the condition of which the averaged working current is about 1A, but the grinding pressure may be acted on workpiece. In Fig. 5(b), the change of surface roughness and spindle load is shown when the total grinding quantity is 50μm. For increasing feed rate, the averaged roundness at the centerline is 0.27 ~ 0.33μm – a stable surface roughness. The feed rate for which it is possible to grind is significantly reduced. At 180μm/min, the ground surface was unacceptable.

In Fig. 6, the results of 100μm of grinding. using the BB-SD800N100M wheel, are shown. For the #800 wheel with the same bronze bond material, feed rates above 200μm/min can not be employed due to spindle load Spindle load increases linearly with increasing feed rate, but the surface roughness decreases to 150μm/min. Because the stable working current is 1A. the surface roughness may be good even though the feed is increased a little due to the flatness of the wheel surface.

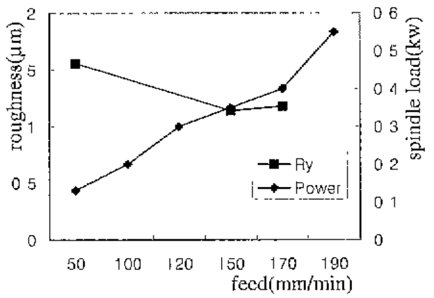


Fig. 6 Influence of feed rate for BB – SD800

For the case of chemically reinforced HDD glass, the lower the grain size, the larger the possible feed rate. It is possible to grind stably at higher efficiency without a change in the averaged surface roughness at the centerline, with increased feed. Unfortunately, grinding marks, which remain in the grinding scar, appear in the ground surface for 1600μm/min. For crystallized HDD glass, workpiece revolution speed is 300rpm with the same feed rate and the grinding wheel speed has changed from 2500 to 3600rpm. We find that the surface roughness does not change, meaning that the grinding characteristics of HDD glass are mainly dependent on feed rate

It is impossible to grind crystallized HDD glass using #200 and #325 cast iron bond wheels. In such cases, the revolution of grinding wheel is 1500 ~ 3600 rpm, that of workpiece 200 ~ 400 rpm and the feed 5 ~ 20μm/min. This may be due to slip phenomena occurring. as it does not protrude abrasives and produces a straight of insulating layer. Also the specimen removes the insulating layers during grinding, because the cast iron bond material is stronger than bronze and cobalt.

For the #400 wheel, the revolution of the grinding wheel is 3600 rpm, that of workpiece 300 ~ 400 rpm, and the feed 10 ~ 20μm/min. Under such conditions. the surface roughness becomes better than that of the bond materials except for cast iron, but the ground surface is poor for almost all conditions For the #1200 cast iron bond wheel, crystallized HDD glass grinding, is possible below 10μm/min and the surface roughness is about 25nm. The rough grinding of cast iron bond wheel is impossible but the semi-finish grinding is possible. When the crystallized HDD glass is ground using a #325 cobalt bond wheel, many scars of machining on the ground surface are observed. The bronze bond wheel which give the best result for rough grinding cannot be machined with the #1200 wheel under any conditions. The etching phenomenon is repeated.

3.2 Experiments with the rotary surface grinder

In Fig. 7, when #2000, #6000 and #8000 wheels were used under the given conditions, the surface roughness of crystallized and chemically reinforced HDD glass were as shown. From experiment, the machining of glass is acutely influenced by the feed, but not by the revolution of the wheel. The figure shows the influence of grain size on the change of surface roughness.

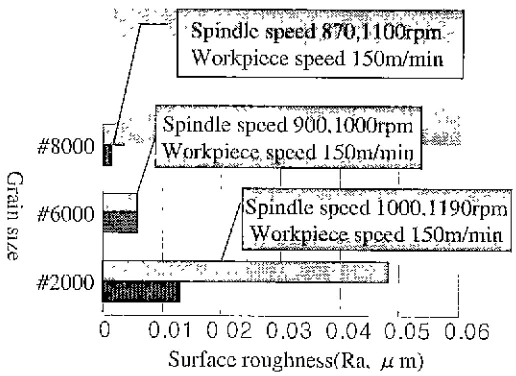
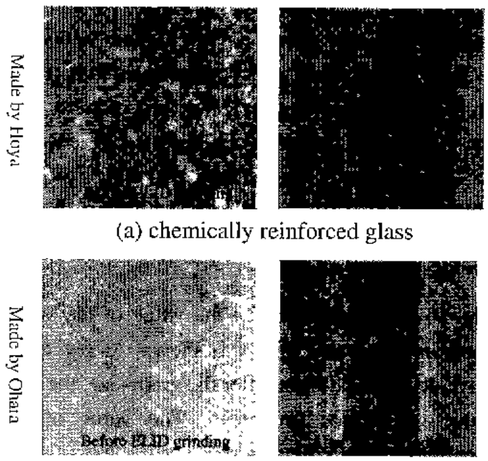


Fig. 7 Resulte of surface roughness in finishing grinding

When the ELID grinding is performed using the #8000 wheel, the dressing conditions are the maximum current of 20A and the maximum voltage of 90V. The revolution of the wheel is also 300 rpm. The current value converges to 4A, respectively, as in Fig. 2.

When ELID grinding is performed with a wheel revolution of 1100 rpm and a workpiece velocity of 150 m/min, the initial current value is inside the range of stable values.

However, excessive protrusion of abrasives occurs during the grinding process. Stimulated scars on the surface are observed. The surface roughness may become unacceptable due to excessive protrusion caused by the grinding wheel under these conditions. The maximum voltage of 70V and the maximum current of 20A are changed and dressing is performed again with all other parameters the same. The current value is converges to a stable value of 2.5A and then the ELID grinding is performed. The surface roughness shows improvement from 24nm to 14nm. As revealed in the above discussion, the surface roughness is strongly dependent on the maximum voltage and the input energy, under the same conditions. Fig. 8 shows the surfaces of HDD glass before grinding and after grinding. The surface is investigated at 1000 times magnification.



(a) chemically reinforced glass

(b) crystallized glass

Fig. 8 Surface quality of HDD glass

For crystallized glass, the surface roughness has a value between 1~5nm. However the surface roughness of chemically reinforced glass has a value between 3 ~7nm. In the real world, the value of the surface roughness for the HD media has a single digit nm, thus the result may be satisfactions. However, Japanese companies require 1nm, so values of surface roughness less than this is required. The surface roughness is limited with the rotary method and so an ELID equipped lap-grinding system is required to achieve such results.

Since the hardness and brittleness of crystallized glass is high, The surf ace is better than that of chemically reinforced glass. However, the scratch phenomena on the center part occur This may be due to low speed at the center that is a characteristic of the rotary surface grinder. Grains of diamond are removed causing scratching on the surface. For the chemically reinforced glass, although there is no scratching, some dents are present. This is because of the difference between materials.

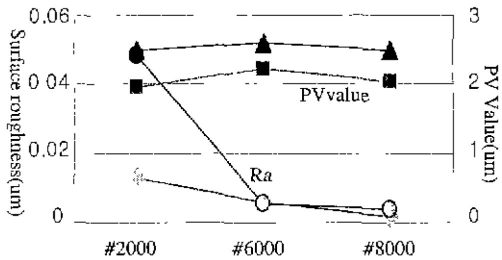


Fig. 9 Effect of grain size on roughness and p - v value

For the crystallized glass, a smooth and less sloped surface is produced. The surface roughness of chemically reinforced glass has a steep and sharp slope due to back-transfer. Also there are dents beneath the surface due to plastic deformation when the diamond grain is machining. It is known as the crystallized glass is a denser and stronger material than chemical reinforced glass.

In Fig. 9, The comparison of the value of the surface roughness and the value of P-V is shown. As revealed in the above discussion, the smaller the grain size, the better the value of surface roughness. The value of P-V, however, independent of grain size.

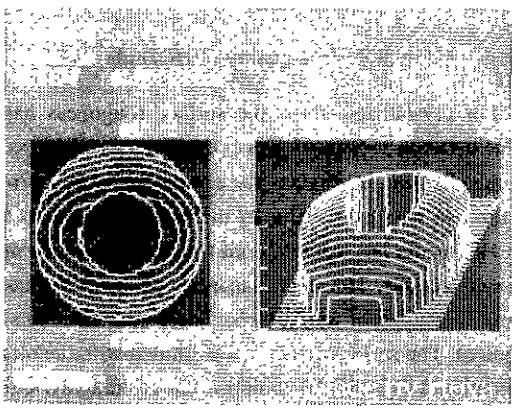


Fig. 10 Flatness of ground HDD glass

Fig. 10 shows the status of P-V for a ground media glass. Both crystallized glass and chemically reinforced glass show the same shape in which a convex forms of the center of the three dimensional surface. This is due to the velocity of the grinding wheel which changes according to the position of wheel, even though the revolution of the table is constant at the rotary surface grinder. Because the velocity of the center part is much lower, the machining does not work well and the shore-shape is formed. This problem influences the flatness of the media. Thus as changes of mechanical characteristics are made, the problem will be solved.

4. Conclusions

The purpose of this research was to examine the characteristics of ELID grinding, when applied to HDD glass. Since the applied material is in the first stage, the experiments are made under many different grinding conditions, which focus on grinding by different kinds of grinding wheel, feed rate, machinability and bond material. From the results using bronze bond wheels, we find that ELID grinding of glass is possible. For the same grinding wheel, chemically reinforced glass is ground at higher efficiency than crystallized glass. Bronze bond wheels above #1200 can not be employed under these grinding conditions. However, mirror-surface is obtained for the case of #8000 wheel. Thus the use of the traverse method becomes much more effective than that of the in-feed one for ELID grinding of HDD glasses.

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