Technology course

Truing and Dressing

Techniques and mechanisms for creating a cutting edge that will maximize a grinding wheel's performance

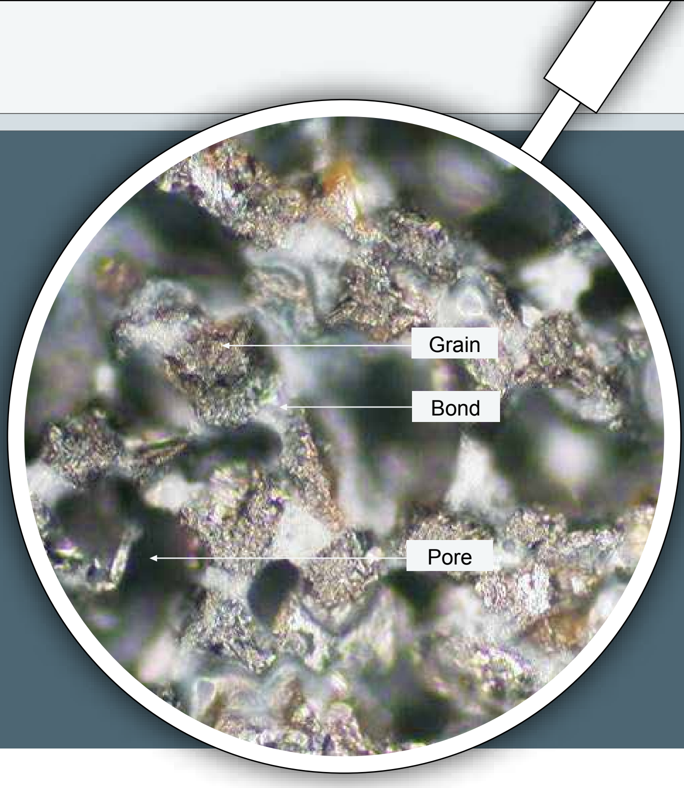


Fig. 1 Grinding Wheel (Vitrified CBN Wheel)

A Grinding Wheel's Cutting Edge Makes a Difference in Manufacturing

Grinding is a machining process in which a grinding wheel is used. This grinding wheel is composed of three essential components: grain, bond, and pores (Fig. 1). [1] Grain acts as the cutting edge of the grinding wheel, thus impacting workpiece accuracy and visual quality. Unlike other cutting tools, grinding wheels need to be initially shaped with a process called "truing" (described later) and have cutting edges formed through a "dressing" process. In order to improve workpiece accuracy and grinding efficiency, the creation of a good cutting edge is the key, in conjunction with selecting the appropriate grinding wheel specification.

Images Ⅰ and Ⅱ shown in Fig. 2 are the cutting edges of a single grain after dressing the same wheel under different dressing conditions. When comparing the two images, image Ⅰ shows smoother grain appearance. These test results demonsrate the fact that very different results can be obtained with the same grinding wheel (Fig. 3).

Fig. 2 Grain after Dressing

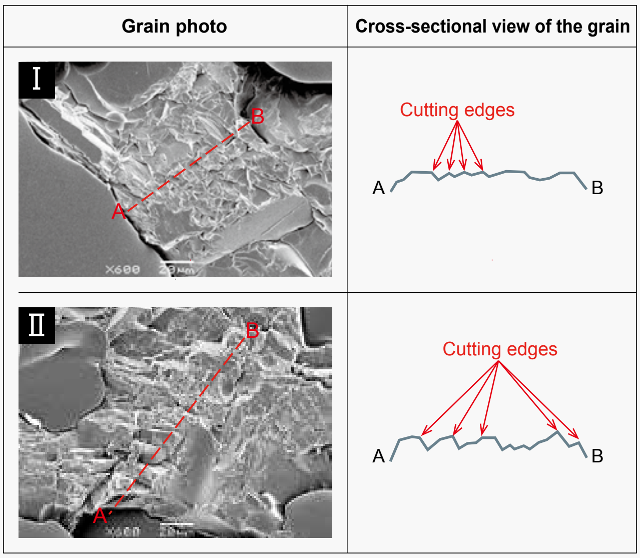
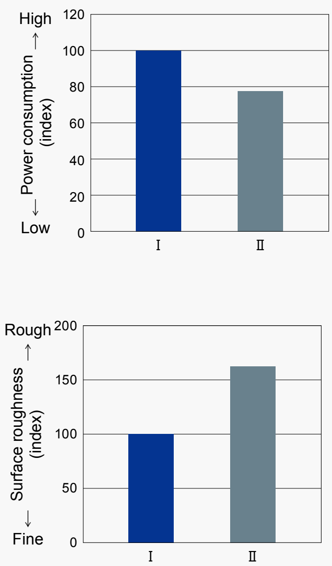


Fig. 3 Grinding Performance



The data from changing the dressing condition from Ⅰ to Ⅱ shows a decrease in power consumption. This means the cutting ability of the grinding wheel is improved and higher efficiency can be obtained by increasing the cutting rate. On the other hand, changing the dressing condition from Ⅱ to Ⅰ shows smoother surface roughness and improved workpiece accuracy. This shows that dressing is a critical technique that can affect the grinding wheel performance, and finding optimal dressing conditions can improve both the process efficiency and workpiece quality.

Improving Grinding Performance by Truing and Dressing Techniques.

Grinding wheels are designed to self-sharpen during grinding. Grains fracture and break under grinding forces, and cutting edges are renewed. However, excessive grain fracturing or breaking can cause workpiece inaccuracies and an inability to hold shape ("Soft Acting"). If the self-sharpening process is not carried out properly, the grains will dull rather than fracture and be unable to create new sharp edges ("Glazing"). This leads to a decrease in cutting ability. A similar situation occurs from excessive clogging of the wheel's pores with stock removal chips [2]. Fig. 4 shows various grinding conditions and images of grinding wheel surfaces with examples of possible issues.

To avoid these issues, it is essential to keep the grinding wheel in a normal (ideal) state by applying effective truing and dressing. The following discussion is focused on how to get the most out of the grinding wheel by applying proper truing and dressing techniques.

Fig. 4 Four Grinding Conditions

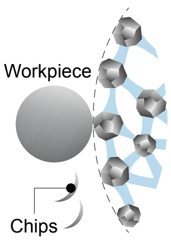
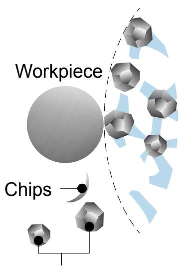
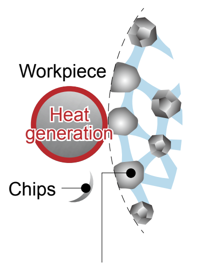
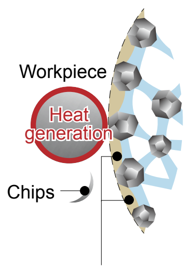
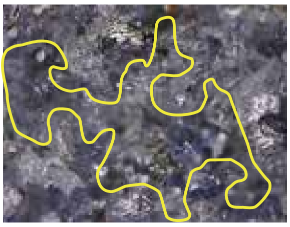
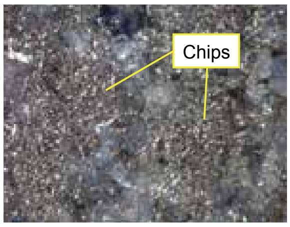
Normal (Ideal)	Soft acting	Glazing	Loading
			
			
Possible issues	Poor shape and surface accuracy	Grinding burn, Chatter	Grinding burn, Chatter

Fig. 5 Truing

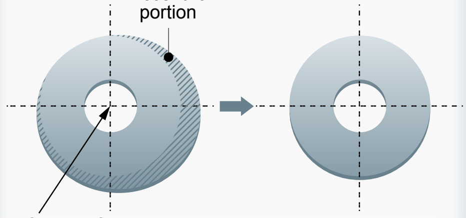
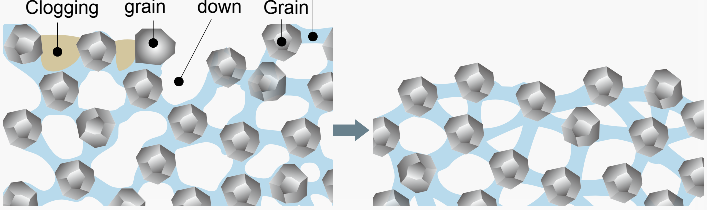


Fig. 6 Dressing



The specific purposes of these processes are described below.

Truing:

- **Removing the peripheral runout portion of the grinding wheel to make the outer diameter concentric with respect to the center of the wheel spindle (Fig. 5).**
- **Adjusting the wheel's profile to the desired shape.**

Dressing:

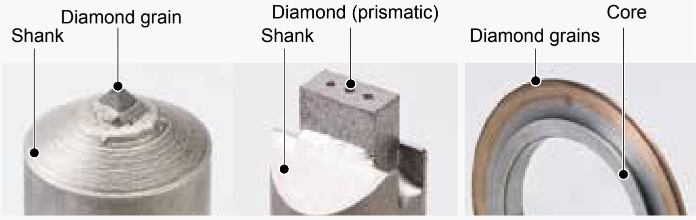
- **Fracturing or removing the worn grains and creating new sharp cutting edges (Fig. 6).**
- **Removing the bond to allow grain protrusion.**
- **Removing chips imbedded in the wheel's pores to create new pockets and continue chip discharging process.**

Two major factors significantly impact grinding wheel performance in truing or dressing: Type of dresser and parameters of use (cutting depth, feed rate, etc.). For this reason, the appropriate dresser and parameters must be selected based on the type of grinding wheel and required workpiece accuracy.

Choosing the Best Dresser

Although truing and dressing styles will vary depending on the type of grinding wheel, diamond dressers are used in most cases. A diamond dresser is a tool with diamond affixed to a metal base. Dresser types are divided into two categories: a stationary type, such as a single-point dresser (Fig. 7 (a)) or a multi-stone dresser (Fig. 7 (b)); and a rotating type, such as rotary dresser (Fig. 7 (c)).

Fig. 7 Diamond Dresser Types

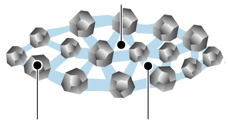
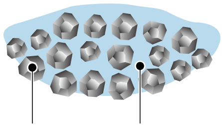


(a) Single-point dresser (G-Sharp) (b) Polystone dresser (LL blade dresser) (c) Rotary dresser

Noritake's G-Sharp dresser is recommended if a single-point dresser is desired with an emphasis on performance and long life [3]. Noritake's LL Dresser, whether it's the "single- point" (containing one diamond) or the "blade-type" (containing multiple diamonds), uses prismatic diamond rods. The surface area of the diamonds in contact with grinding wheel does not change, making dressing performance very stable. LL type dressers are available in both stationary and rotary configurations.

Grinding wheels have different properties and bond types [4]. In this article, we will discuss dresser selection guidelines, dressing methods, and grinding performance differences, among the following three types of grinding wheels: vitrified bond conventional wheels (referred to as "vitrified conventional wheels"), vitrified bond CBN wheels*

Fig. 8 Grinding Wheel Bond Types

Bond	Vitrified bond	Resin and metal bonds
Bonding Method	Chemical + Mechanical bonding (Bridge-Type)	Mechanical bonding (Matrix-Type)
Explanation	Bonds form a structure that bridge grain to grain, and are characterized by open pores (contiguous pores). This bond state is called "bond bridge-type" or "bridge-type".	The grain is held in place by caulking with bond, resulting in a "bond matrix-type" or "matrix structure".
Bond diagram		

(referred to as "vitrified CBN wheels"), and resinoid and metal bonded diamond/CBN wheels (referred to as "resin and metal diamond/CBN wheels") (Fig. 8). Other products include resin bonded conventional wheels and electroplated products. Based on the application, generally, the resin bonded conventional wheel is used for heavy duty grinding. Dressers are utilized for initial truing only, due to the wheel's self-sharpening ability. Electroplated products are made by affixing the grains to a metalic base by a plating process, which controls the grain protrusion. Truing and dressing are not required.

◆Vitrified Conventional Wheel Truing and Dressing Methods

Conventional grinding wheel dressing typically calls for static forms such as single-point dressers or LL dressers. When dressing with a dresser, there are two essential metrics: (1) cutting depth, and (2) dressing lead. Below is a closer look at each parameter.

(1) Cutting Depth

The dresser's cutting depth affects the grain's fracturing and changes grinding wheel performance. Reducing cutting depth results in more refined workpiece surface roughness. Fig. 9 shows results of different dresser cut depths. A shallow depth will result in smoother grain surfaces and smoother workpiece surface texture. As a result, the cutting ability of the grinding wheel is also reduced as seen by the increase of power consumption (Fig. 10).

To improve grinding wheel cutting ability, the dresser cutting depth should be increased. Increasing dresser cutting depth will create large cutting edges and add stress to the bond. This results in further grinding wheel breakdown and

Fig. 9 Dressing Diagrams and Difference of Cutting Depth Photos

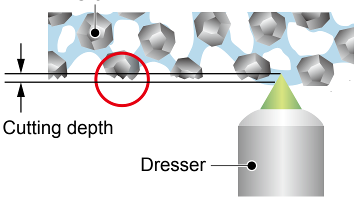
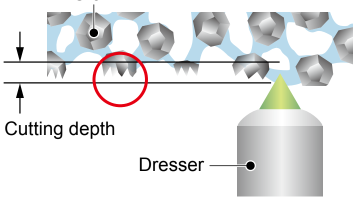
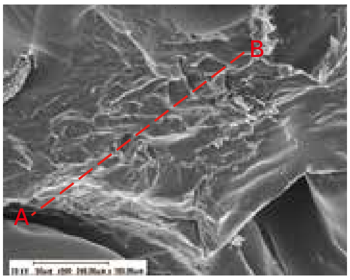
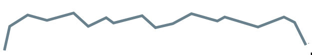
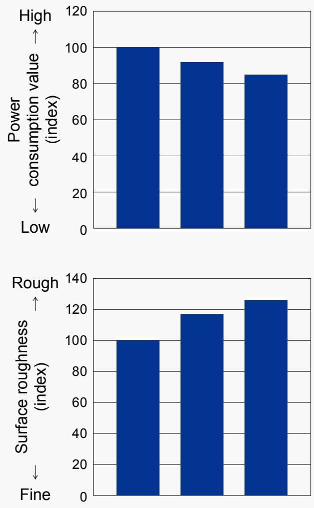
	Cutting depth: shallow	Cutting depth : deep
Dressing diagram		
Grain photo		
Cross-sectional diagram of one grain		

Fig. 10 Grinding Performance Results from Various Dressing Conditions



Dressing lead (mm/r.o.w.)	0.05	0.05	0.1
Cutting depth (mm)	0.01	0.02	0.01

Fig. 11 Dressing Lead

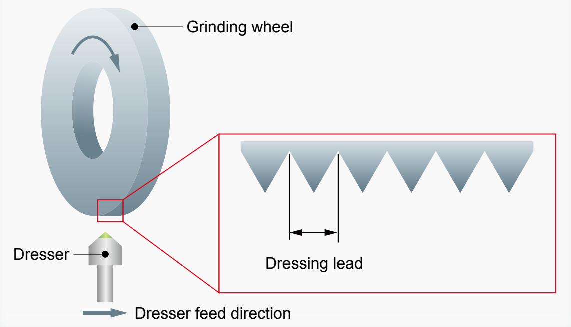


Fig. 12 Wheel Life with Various Dressing Leads

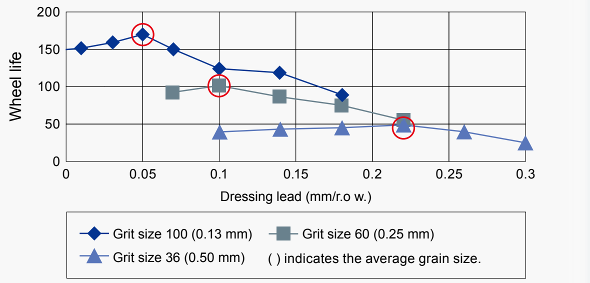
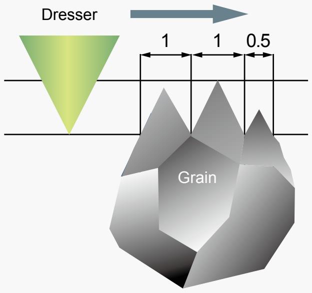


Fig. 13 Grain Cutting Edge Image



$$f=\frac{F}{N}=\frac{d}{2.5}$$ ······Equation 1

f: Dressing lead (mm/r.o.w.)
F: Dresser feed rate (mm/min)
N: Grinding wheel RPM (min^{-1})
d: The average grain size (mm)

Table 1 Grit Size and Recommended Dressing Leads

Grit size	60	80	100	120	180	220
The average grain size (mm)	0.25	0.18	0.13	0.10	0.06	0.05
Dressing lead (mm/r.o.w.)	0.1	0.08	0.05	0.04	0.02	0.02

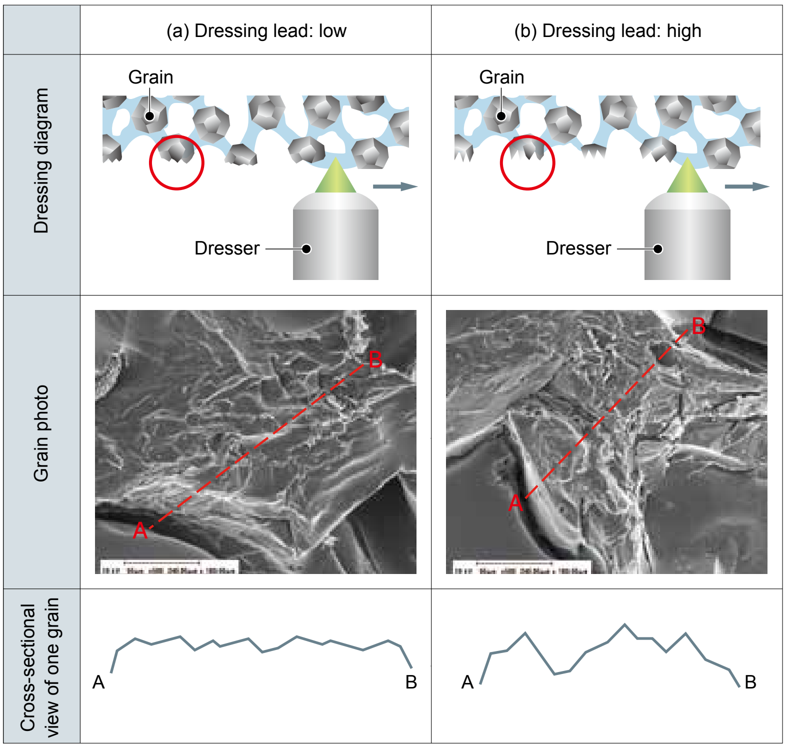
rougher workpiece surface most likely to occur. Generally, a cutting depth of about 1/10 of the average grain size is standard (φ0.03 mm or less) ,or 1/20 of the average grain size when dressing ceramic grinding wheels, due to the ceramic wheel grain toughness.

(2) Dressing Lead

The dressing lead indicates the amount of dresser feed per grinding wheel revolution (Fig. 11).

According to the experimental trial, it was determened that the best grinding wheel life was obtained with 0.05 mm/r.o.w.* dressing lead for #100 grit size, 0.01 mm/r.o.w. for #60 grit size and 0.22 mm/r.o.w. for #36 grit size (red circle in Fig. 12). As shown in Fig. 13, the dresser formed 2.5 cutting edges on the surface of the grain, circled in Fig. 12. Based on these results, the equation shown in Fig. 13 is established for initial dress lead recommendations (Table 1).

Fig.14 Grain after Dressing with Different Dressing Leads

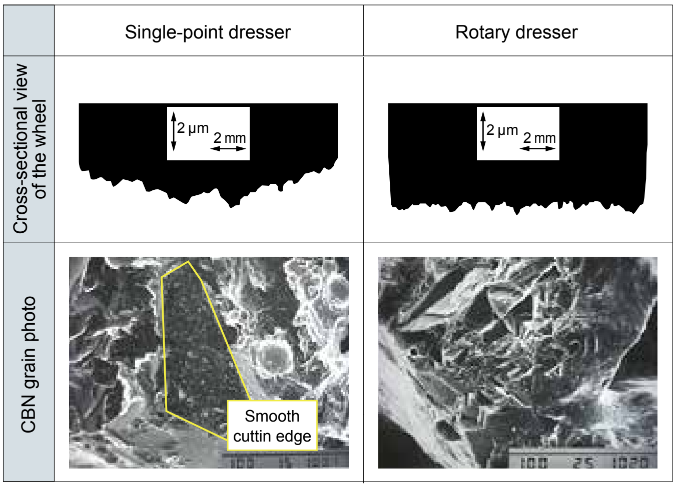


Lowering the dresser feed rate ("Dress Lead") will further refine the workpiece surface roughness. This ensures a larger amount of smaller cutting edges created on each grain resulting in a smother grinding wheel surface (Fig. 14(a)). Workpiece surface roughness improves, however the grinding force will increase which could result in loading or burning.

To improve grinding wheel cutting ability, the dressing lead should be increased. By doing so, larger cutting edges are formed on the grains and the grinding wheel surface becomes rougher. If some degree of workpiece surface roughness can be tolerated, increasing the dressing lead is an effective measure for reducing the grinding force (Fig. 14 (b)).

Overall, adjusting the dressing lead has a great impact on grinding wheel performance and in most cases is better than adjusting the dressing depth. The most effective way to improve workpiece accuracy is to adjust the dressing lead first.

Fig. 15 Grain and Cross-Sectional Wheel Shape View after Dressing by Various Dressers



◆Vitrified CBN Wheel Truing and Dressing Methods

Since CBN grains are especially hard, rotary dressers are recommended to form cutting edges with high precision (Fig. 7(c)). Using single-point dressers can cause the wheel profile to collapse significantly and generate dull cutting edges which will inhibit grinding performance (Fig. 15). Rotary dressers require dedicated devices to provide rotation. To eliminate additional dressing which wastes CBN, Noritake recommends the use of an AE sensor system which accurately detects the initial contact point.

Dressing vitrified CBN wheels also requires appropriate ① cutting depth and ② dressing lead, just like vitrified conventional wheels. The setting values are different, but it shows the same trends as vitrified conventional wheels. However, because of the hardness of the CBN grains, the recommended parameters for cutting depth and dressing lead differ from vitrified conventional wheels. For vitrified CBN, the standard is φ1-7 μm cut depth and 0.01-0.2 mm/r.o.w. lead.

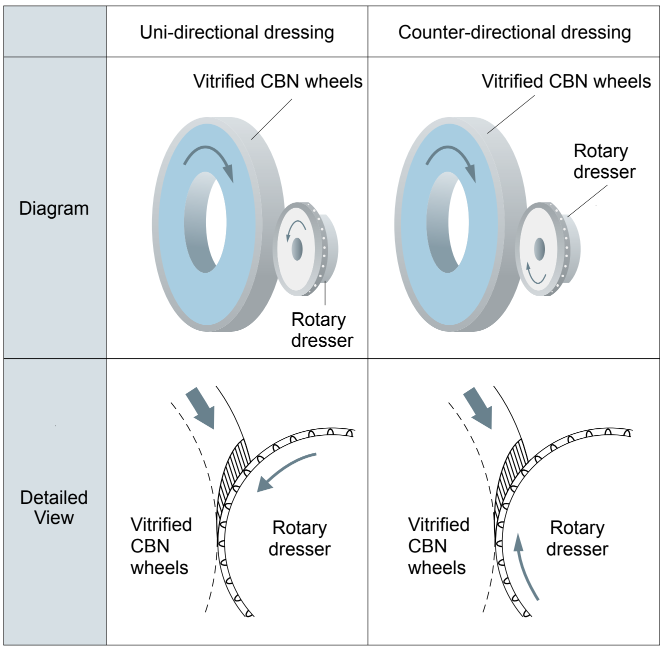
Since rotary dressers rotate, ③ the dresser's rotation direction and ④ the peripheral speed ratio have a significant impact on grinding performance in addition to the previously discussed cut depth and dressing lead.

(3) Dresser Rotation Direction

When the dresser and wheel rotate in different directions (one clockwise, and the other counterclockwise), this is called "uni-directional" dressing rotation. This dressing rotation method is best for improving the grinding wheel's cutting ability. Choosing the "counter-directional" rotation method, in which dresser and wheel rotation direction is the same, will result in improved workpiece surface roughness (Fig. 16).

"Uni-directional" contact crushes grains more effectively than "Counter-directional". Dressing speed ratio, which is described below, is also a necessary factor to achieve good cutting ability.

Fig. 16 Dresser Rotation Direction



(4) Dressing Speed Ratio

Selecting a speed ratio closer to 1 will improve grinding wheel cutting ability when using "Uni-directional" dressing rotation. Surface roughness will be higher due to effectively fractured grains, but the grinding force will be significantly reduced (Fig. 17 and 18).

On the other hand, in the case of "Counter-directional" dressing rotation, no significant effect on the grinding wheel performance is observed. This is because the area of contact with the dresser is smaller, making the grain more difficult to fracture and resulting in a smoother surface.

The dressing speed ratio depends on the required workpiece surface finish. In "Uni-directional" dressing rotation, the dressing speed ratio is usualy between 0.4 and 0.9. For more emphasis on the grinding wheel cutting ability, 0.75 or higher.

Fig. 17 Dressing Speed Ratio and Grinding Performance

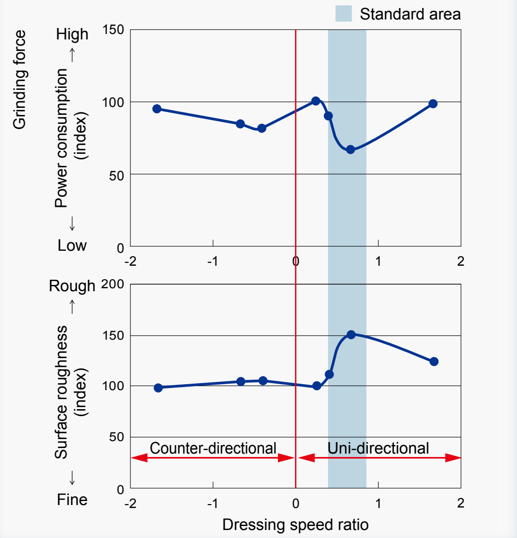
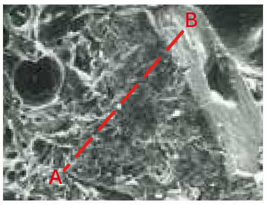
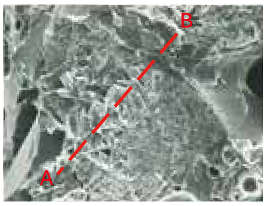
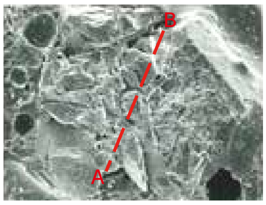
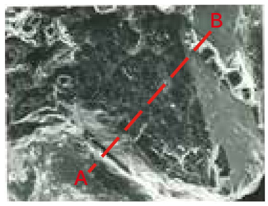
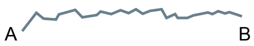


Fig. 18 Grains after Dressing for Each Dressing Speed Ratios

Speed ratio	0.25	0.4	0.67	Counter-direction 0.67
Grain photo				
Cross-sectional view of the grain				

◆Truing and Dressing for Resin and Metal Bonded Diamond/CBN Grinding Wheels

In "Matrix-type" wheels, dressing is done by removing bond and allowing grains to protrude. Higher protrusion improves grinding wheel cutting ability as shown in Fig. 19. During a dynamometer-measured test shown in Fig. 20, the grinding force decreased when grain protrusion increased.

Generally, resin and metal Diamond/CBN wheels are difficult to true and dress. Because of this, separate vitrified bond conventional grinding wheels and soft metals are used for truing and dressing. In this process, 2-3 times finer grain stones or vitrified conventional wheels are utilized to remove the bond as shown in Table 2.

Fig. 19 Grain Protrusion

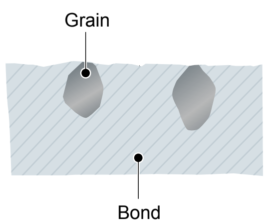
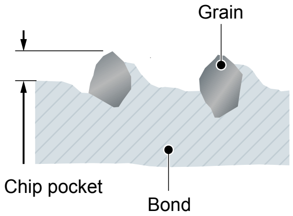
Grain protrusion height	Small	Large
Cutting ability of grinding wheel	Inferior	Superior
Image		

Fig. 20 Protrusion and Grinding Force Relation

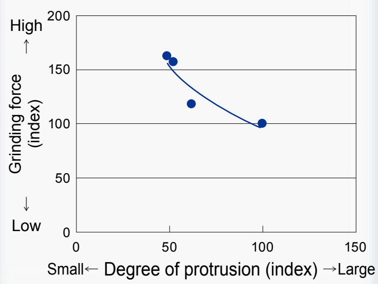


Table 2 Truing and Dressing Methods

	Wheel / Dresser	Resin CBN	Resin DIA	Metal CBN	Metal DIA
Truing	Impregnated diamond dresser	△	×	×	×
	Rotary dresser	△	×	×	×
	Soft metal	○	○	○	○
	vitrified conventional grinding wheel	○	○	○	○
	Brake control	○	○	○	○
	electro-discharge dressing	×	×	○	○
Dressing	Conventional stone sticks	○	○	○	○
	Vitrified conventional grinding wheel	○	○	○	○
	Loose grain method	○	○	○	○
	Discharge and electrolysis method	×	×	○	○
	Shot blast method	○	○	○	○

Metal wheels can be trued and dressed in the same way as resin bond wheels, but due to bond strength, dressing time is increased. To improve dressing time for metal and resin bond wheels, electrical methods such as electrolitic dressing* and electro-discharge dressing* are offen utilized. Due to the electro-conductive properties of the bond, it can be melted to acheve desired grain protrusion.

Summary: It is important to choose the optimal truing and dressing methods based on the grinding wheel bond and grain (Table 2).

Troubleshooting

Consider reviewing the dressing conditions when dealing with grinding issues such as: grinding burn, cracking, chatter, form accuracy and surface finish.

For example, grinding burn may be attributed to heat generation during grinding due to loading and glazing of the grinding wheel. To avoid this, improve grinding wheel cutting ability by increasing dressing lead.

On the other hand, if the precision of the finished surface deteriorates or grinding wheel breaks down, decreasing dressing lead and dressing cut depth will allow for better precision grinding.

The relation between the dressing conditions and the grinding wheel performance is summarized in Table 3.

This concludes truing and dressing methods. Noritake hopes this information will help you get the best performance out of your grinding wheel.

Table 3 Dressing Conditions and Grinding Wheel Performances

Performance	Cutting ability of grinding wheel	Good	Poor
	Workpiece surface roughness	Rough	Fine
	Dressing force	Weak	Strong
Condition	Dressing cutting depth	Deep	Shallow
	Dressing lead	High	Low
	Dresser rotation direction (rotary dresser)	Uni-directional	Counter-directional
	Dressing speed ratio (uni-direction)	Close to 1	Far from 1
	Degree of protrusion	Large	Small

[Notes]
* r.o.w.: revolution of the grinding wheel
* Electro-discharge dressing: A method of using pre-formed electrodes to melt or erode bond by high current electricity.
* Whitestone: A grinding stone for the dressing of diamond-CBN wheels using WA grain

[Literature]
[1] Masayuki Yamamoto: Structure of Grinding Wheels (Structure and Concentration), NORITAKE TECHNICAL JOURNAL 2018, (2017)4
[2] Satoshi Isogimi: Choosing A Grinding Wheel, Mechanical Engineering, Vol. 65, No. 4 (2017) 31
[3] Shuhei Matsuo: G Sharp, NORITAKE TECHNICAL JOURNAL 2018, (2017) 46
[4] Satoshi Isogimi: Grinding Wheel Basics, Mechanical Engineering, Vol. 65, No. 4 (2017) 26

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