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Multitask Diamond Wheel

Milling and grinding with a single-layer, metal-bond diamond wheel.

Common aluminum machining typically involves milling. To achieve fine surface finishes, grinding is performed as a secondary operation. However, a single-layer, metal-bond diamond wheel has been developed to effectively mill and grind on the same setup at the same time. This wheel is capable of quick cycle times while imparting a precision finish. This product consists of a "planted field" of diamond grain with a specific size, location and grain exposure, giving it the ability to efficiently mill and grind.

There has always been a requirement in the manufacturing market for high efficiency, productivity enhancement, lower cost and high precision. This includes the cutting and grinding of aluminum parts. Lightweight cast aluminum has recently been in much greater demand as fuel costs rise. Consequently, the manufacturing market can use a specialized tool able to provide both heavy material removal and the accuracy common to grinding practices.

When grinding a part after milling it, the goal is to efficiently provide a suitable finish while achieving dimensional accuracy. There have been several case studies conducted with EP (electroplated) CBN grinding wheels run at variable wheel speeds and with the CBN grain conditioned by microtruing, but we aren't aware of a specific case study with metal-bond diamond wheels.

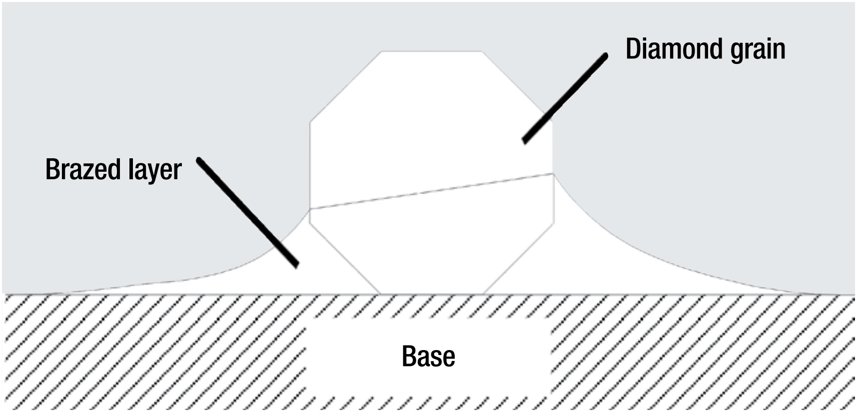

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Figure 1: Illustrated cross section of diamond grain and brazed layer.

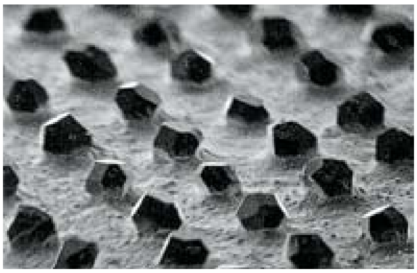

Figure 2: Diamond grain grit rows.

This article discusses the structure, features and truing condition of a single-layer, metal-bond diamond wheel. This wheel was specifically designed to grind die-cast aluminum, though diamond grain can also be applied to machining and grinding many composite materials and some cast irons. The wheel's performance results and how the truing and grinding conditions affect the grinding force and workpiece surface roughness are discussed in detail.

Basic Structure

The top of the diamond grain protrudes well above the brazed base layer. At the interface of the diamond grain and brazing material, there is a strong chemical and mechanical bond (Figure 1).

The amount of diamond grain diameter that's encapsulated, or wetted, by the bronze bond is about 50 percent. However, due to the strong chemical attraction between the bronze bond and the diamond, the effective protrusion height of the diamond grain is about 70 percent. Therefore, high-efficiency grinding can be achieved with a deep cutting depth and high grinding speed without fear of the diamonds being pulled out of the bronze bond.

The single-layer, metal-bond diamond wheel has diamond grains, or grit rows, specifically placed on the core material (Figure 2). The grit placement results in grinding chips being efficiently ejected and heat being quickly discharged from the grinding zone.

Truing Conditions

The goal when grinding is to efficiently produce a workpiece surface that is highly accurate and stable. Microtruing of the diamond wheel

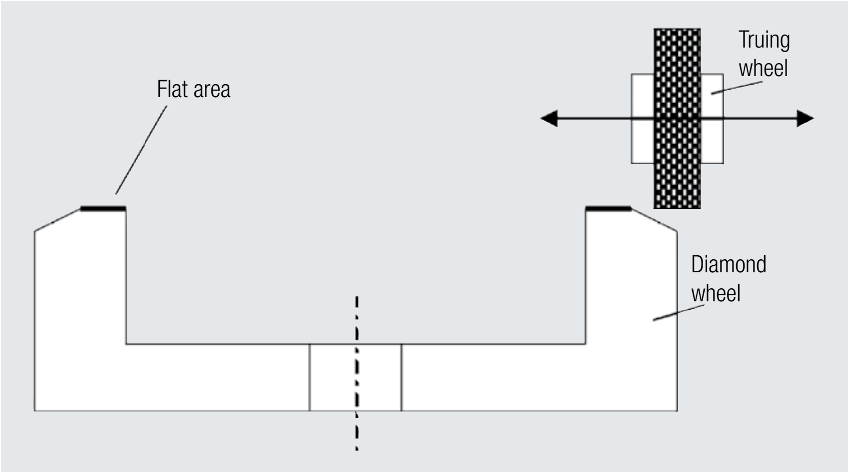

Figure 3: Truing diagram.

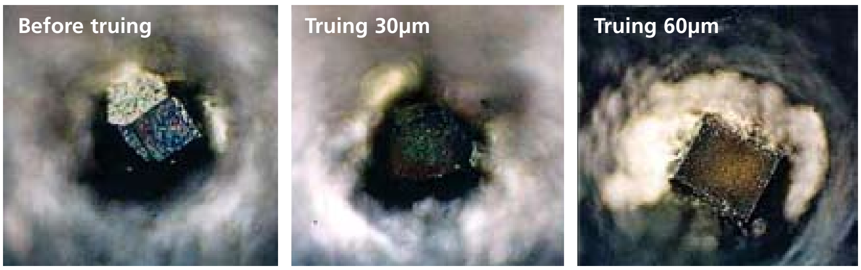

Figure 4: Diamond grains before and after truing to depths of 30μm and 60μm.

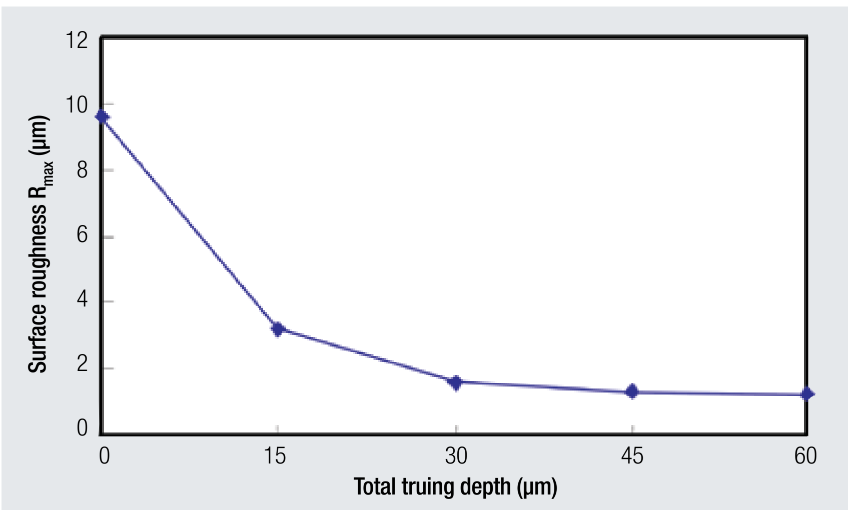

Figure 5: Relationship between total truing depth and surface roughness.

Table 2: Grinding parameters for test to show relationship between truing depth and workpiece surface roughness.

Grit size	#40/50
Grain spacing (mm)	0.9
Wheel speed (rpm)	1,760
Feed (mm/min.)	800
DOC (mm)	0.3
Workpiece material	ADC-14
Total truing depth (μm)	15, 30, 45 and 60

enables the workpiece to have contact with most of the available diamond grains during the first cut instead of contact with only the highest protruding diamonds. This enables a precise and stable process from the start.

A case study shows the diamond wheel is able to perform high-efficiency grinding without sacrificing work surface integrity. Microtruing was performed only on the "flat" finishing area of the single-layer, metal-bond diamond wheel, not the lead angle.

Table 1: Truing Conditions.

Grit size	#40/50
Truing wheel	SD140
Depth of truing (μm)	5
Total truing depth (μm)	15, 30, 45 and 60

The truing conditions are shown in Table 1, and the truing schematic diagram is shown in Figure 3. Truing depth was created by taking a total DOC of 60μm via three passes of 5μm each and repeating that four times (Figure 4). As the DOC was increased, the flat portion of the diamond "grain face" was formed and the surface area increased.

A grinding test was performed to show the relationship between truing depth and workpiece surface roughness (Figure 5). Grinding conditions are shown in Table 2.

When the truing depth was increased, the workpiece surface finish improved. Also, the surface finish did not change greatly after truing to a total depth of more than 30μm, so a truing depth of 30μm was created for the following test.

Grinding Ability and Evaluation

The high-speed precision grinding of die-cast aluminum was performed using a single-layer, metal-bond diamond wheel (Figure 6). The wheel had a diameter of 116mm, a hole diameter of 31.75mm and a rim width of 12mm. The test investigated how the main spindle rotation speed affects the grinding force and workpiece surface roughness. The grinding parameters are shown in Table 3.

A relationship exists between spindle rotation speeds and grinding force.

The test results are shown in Figure 7. It was found that tangential and normal grinding force components were reduced when infeed per revolution was effectively reduced by increasing spindle rotation speed.

Figure 6: Cup design of single-layer, metal-bond diamond wheel.

Workpiece surface roughness was measured for each wheel speed. The results are shown in Figure 8. The single-layer, metal-bond diamond wheel imparted a surface finish of less than 3µm in all conditions tested. Feed marks appeared, though, when the main spindle rotation speed was too low. However, as the main spindle rotation speed was increased, feed marks were reduced, and workpiece surface finish improved.

The microtruing procedure set at about 30µm significantly improved the surface finish. In addition, grinding force decreased as the spindle rotational speed increased. △

About the Authors

N. Tohge possesses more than 20 years of experience in the technical department of Noritake Super Abrasive Co. Ltd., Kurume City, Fukuoka, Japan. His experience includes metal-bond development. D. Ide worked for 10 years as an engineer and lab assistant on the project to develop single-layer, metal-bond diamond wheels. Y. Inoue served for 8 years as the project's manager. H. Funahashi worked as a metal-bond development project manager for Noritake Co. Inc. USA, Cincinnati. Questions can be directed to Funahashi's successor, Dan Hadate, at (800) 688-8234 or by e-mail: hadate.abr@noritake.com. For more information about the company's products, visit www.noritake.co.jp/eng.

Table 3: Grinding parameters for test to investigate how main spindle rotation speed affects grinding force and workpiece surface roughness.

Grit size	#40/50
Grain spacing (mm)	0.9
Wheel speed (rpm)	1760, 3500 and 5500
Feed (mm/min.)	800
DOC (mm)	0.3
Workpiece material	ADC-14
Total truing depth (µm)	30

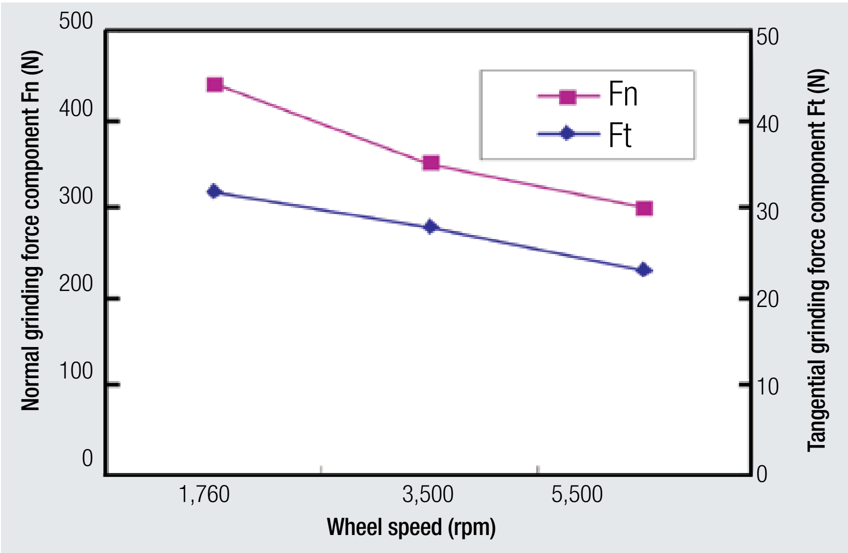

Figure 7: Relationship between wheel speed and grinding force.

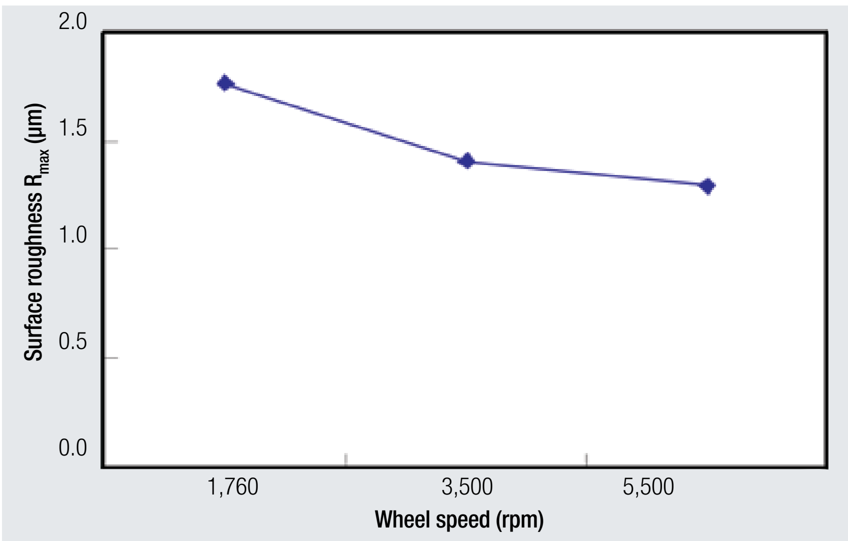

Figure 8: Relationship between workpiece surface roughness and wheel speed.