JUNE 2004 / VOLUME 56 / NUMBER 6

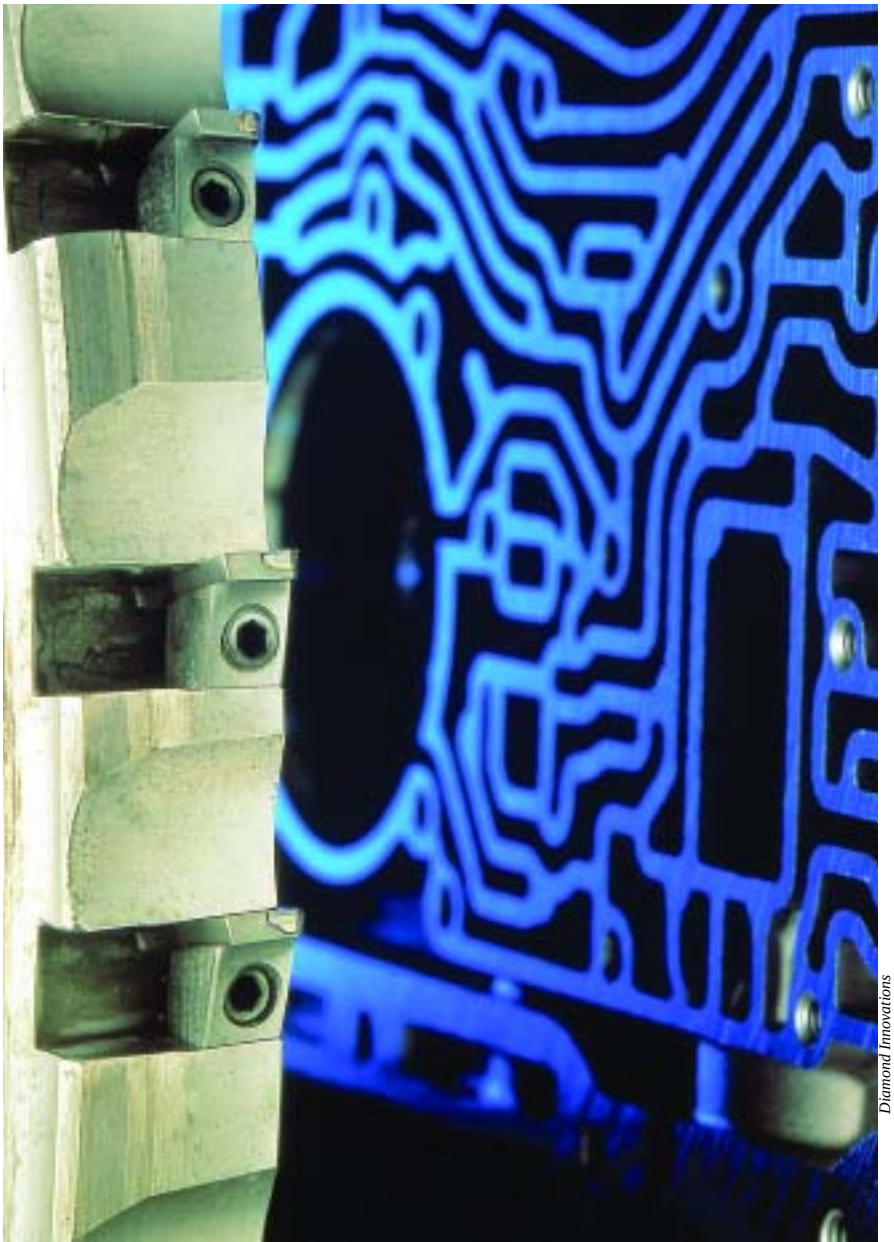
FOCUS: SUPERABRASIVES

Image depicting diamond crystal structure courtesy of American Superabrasives Corp.

▶BY ALAN RICHTER, MANAGING EDITOR

A Mixed Grade

The latest grades of polycrystalline diamond mix coarse and fine particles to increase packing density and yield a more continuous cutting edge.



Diamond Innovations

Imagine filling a large barrel with bowling balls and then mixing in golf balls to plug the gaps between the larger balls. That's sort of what PCD manufacturers do when producing their newer grades for cutting tools—except, of course, on a much smaller scale.

Bimodal PCD grades contain two distributions of diamond particles. One distribution is coarse particles measuring about 25µm to 30µm and the other is fine particles measuring about 2µm to 4µm.

Multimodal PCD grades are also available that have three (trimodal) or four (quadmodal) distributions of PCD particles. Each distribution follows a Gaussian curve, meaning a normal distribution. If, for example, a piece of quadmodal PCD contains 100 particles, 15 particles would measure 2µm, 15 would be 15µm, 15 would be 20µm and 15 would be 30µm, with an even distribution of the remaining 40 around those sizes.

Having more than one distribution of grain, or particle, size increases the PCD density, which results in a continuous cutting edge that can handle highly abrasive applications and interrupted cutting.

For PCD cutting tools, a neutral or slightly positive rake angle of 5° to 8° with a clearance angle of 10° to 13° is recommended for most applications. A high rake angle of 15° to 20° and a clearance angle of 20° to 25° are recommended for carbide cutters. These angles tend to cause cutting edge chipping when roughing and interrupted cutting with PCD tools.

Understanding Intergrowth

With the goal being a highly dense PCD, an obvious question arises: Why not pack even more, smaller particles together as is done when sintering submicron-grade carbide?

"PCD is not a sintered material," said Dr. Gabriel Dontu, technical support manager for Diamond Abrasives Corp. (DAC), New York. "It is a diamond compact, which means the diamond grains form bridges between themselves."

This physical growth process, known as intergrowth, occurs when the grains are subjected to high pressure and high temperature. The intense pressure and heat reorganizes the atoms to form bridges between the surfaces that are pressed together.

"The diamond itself is continuous," Dontu said. "There are no separate particles anymore."

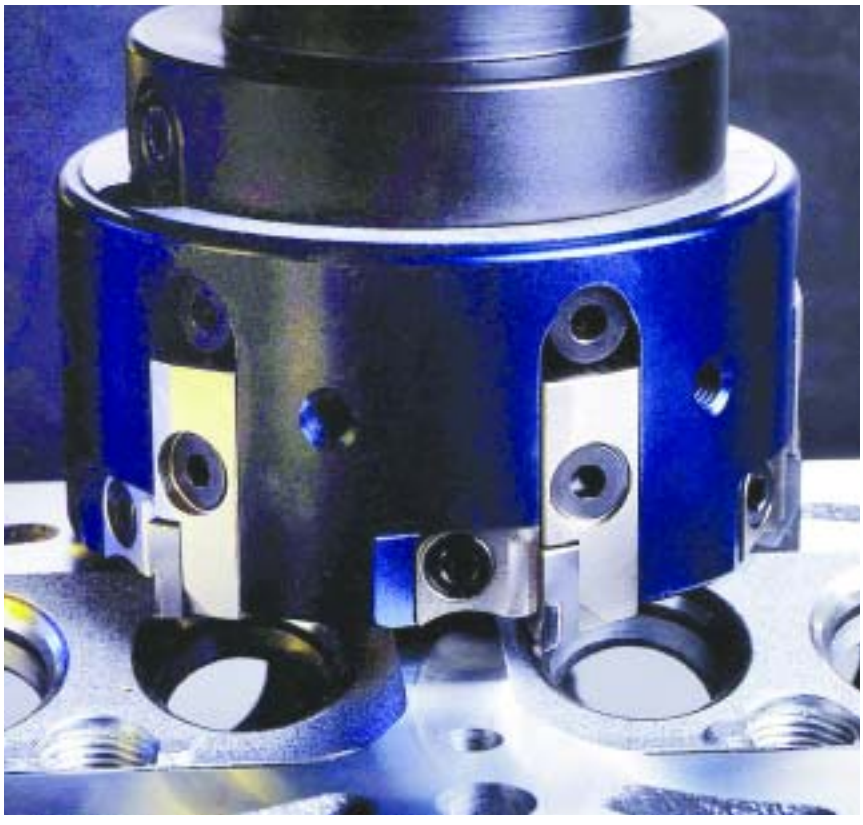
Dontu explained that although cobalt and other elements are added to the powder when producing PCD, they don't function as a binder that holds individual grains together. Rather, they serve as a catalyst for the reaction that produces the bridges between the particles.

Compared to fine-grain PCD grades, PCD grades with a coarse-grain structure, or crystal size, provide a higher level of wear resistance. But grinding that structure to create an effective cutting edge is easier said than done.

"When you need really good abrasion resistance or when you need a good surface finish on the workpiece, you're going to go with a ground edge, and when you have a coarse-grain structure, it's hard to get a good sharp edge," said Jim Graham, product manager for machining products at Diamond Innovations Inc. (formerly GE Superabrasives), Worthington, Ohio. "But when you have a bimodal structure, it helps you get a nice clean edge."

Dontu added that an even finer cutting edge is possible with a multimodal PCD grade. (DAC no longer offers bimodal grades to the metalcutting market.)

Tom Schumann, general manager of E.C. Kitzel and Sons Inc., a Cleveland-based manufacturer of superabrasive tools, agreed. "You get a cleaner cutting edge, and you don't lose the abrasion resistance," he said. "In fact, you probably enhance it because you've got a denser product."



Diamond Innovations

Whenever possible, a PCD tool with a sharp edge should be applied for most applications and a 0.025mm hone should be used for roughing and severely interrupted cutting.

Tough Stuff

Diamond, being the hardness known substance and, therefore, quite brittle, isn't regarded as a tough cutting tool material. Because of its lack of fracture toughness compared to other cutting tool materials, "toughness is kind of a relative term with diamond," Schumann said, but he added that a bimodal grade's ability to better handle severe machining is expanding the use of PCD. "It does toughen the cutting edge."

Dontu concurred that the denser grades are increasing the base of application for PCD cutting tools. Prior to the 8-year-old bimodal PCD and the multimodal concept, which was introduced to the cutting tool market about 2 years ago, he said five or more grades were targeted toward specific applications, such as roughing and finishing. "The goal now is to have one or two grades of PCD that cover multiple applications."

Dontu cited DAC's CTM 302 as an example of a multimodal PCD grade that is helping to accomplish that goal. "Based on the tests we performed in-house, it's the most wear-resistant species by far," he claimed. "But at the same time, it can give you an edge-prep

The following companies contributed to this report:

American Superabrasives Corp.
(732) 389-8066
www.diamond-abrasives.com

Diamond Abrasives Corp.
(212) 869-5155
www.diamondabrasives.com

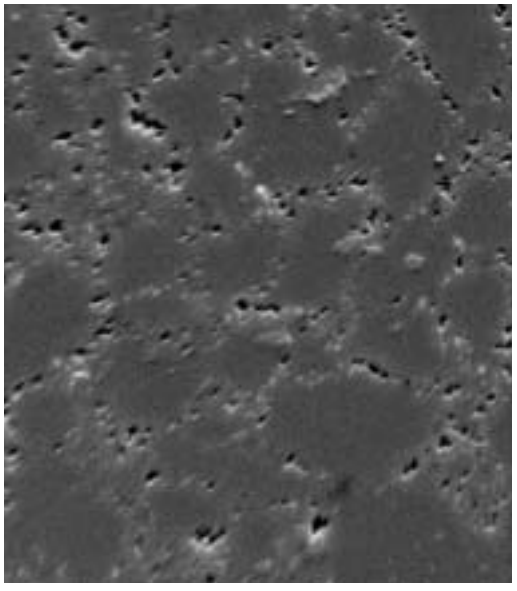
Diamond Innovations Inc.
(800) 443-1955
www.abrasivesnet.com

E.C. Kitzel & Sons Inc.
(800) 227-0431
www.kitzel.com

Diamond Abrasives Corp.

The newer multimodal PCD grades increase productivity because their tougher cutting edges allow tools to be run at higher speeds and feeds.

quality equivalent to a medium-size grain, like a 10µm grade." He said this means CTM 302 replaces at least three or four grades of PCD.



Diamond Innovations

The Compax 1800 consists of polycrystalline Man Made diamond with a bimodal distribution of 25µm and 4µm particles. The extremely dense PCD structure of the electrically conductive grade provides a high level of abrasion resistance when machining nonferrous and nonmetallic materials.

Best of Both Worlds

Some PCD grades are selected to impart a fine surface finish while others are selected for their long life. With a bimodal or multimodal grade, which experiences less chipping than a unimodal grade, longer tool life and a finer surface finish can be achieved with a single grade, said Tom Corcoran, president of American Superabrasives Corp., Shrewsbury, N.J.

"There's more one-pass machining now and no changing of tool tips," Corcoran said.

An obvious benefit of one-pass machining and no changing of tool tips is reduced cycle time. DAC's Dontu said that the newer PCD grades also increase productivity because their tougher cutting edges allow them to be run at higher speeds. "Analyzing the case studies I have access to, in 99 percent of the cases, the quad-modal material improved tool performance over medium and coarse grains."

The denser and tougher structure is also going to allow a more positive tool geometry and a smaller included angle for machining soft materials, Dontu said. And a strong edge allows a higher feed, especially if the tool has a wiper flap for finishing.

Cool Down

As with other types of cutting tools, temperature control is critical when cutting with PCD tools. Generally, no coolant is required with PCD tools, except for aiding chip removal from the cutting zone, so the tool material has to help remove heat from the cut. Because diamond has the highest level of thermal conductivity, the more diamond a tool contains, the more heat it removes from the workpiece, Dontu said. "Multimodal is always going to have more diamond than a single-modal type of diamond," he explained. "It's more compact, so it's going to absorb more [heat], giving you the opportunity to work at higher speeds and feeds."

And as more workpiece materials are alloyed to increase their strength-to-weight ratio, more bimodal and multimodal PCD tools will be applied. "Milling is big for multimodal tools, especially the machining of pistons," said Corcoran.

Nonetheless, bimodal and multimodal PCD grades aren't going to eliminate single-modal varieties entirely. "For some applications, a regular coarse grade works better," Corcoran said.

These newer PCD grades don't represent the end of the line. Efforts to develop newer, even better grades continues. "If you would have called me in 3 to 4 months, I would have fantastic news for you," Dontu told CUTTING TOOL ENGINEERING. "I can't disclose it now, because the products have not been commercially launched."