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Making a Better Grade

Composite carbide substrates can improve the performance of rotary tools.

Rotary metalcutting tools such as drills and endmills are commonly made of cemented tungsten carbide (WC) substrates. The choice of cemented carbide as substrate material stems from the unique combination of strength, wear resistance and fracture toughness that this material offers.

Traditionally, solid-carbide rotary tools have had a "monolithic" construction, meaning the substrate is made from a single grade of carbide. Such tools have limitations with regard to their performance for a couple of reasons.

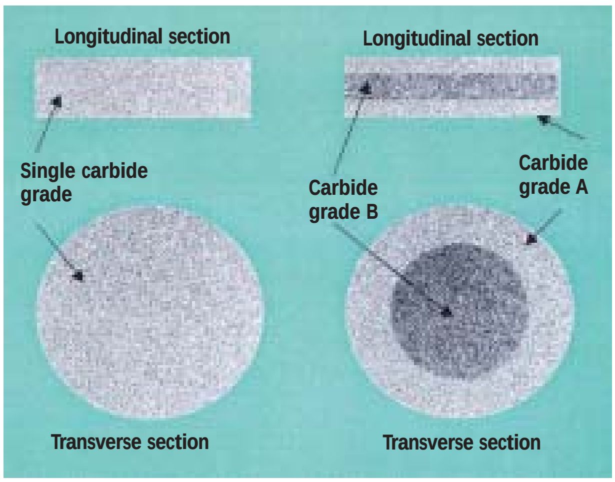

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Figure 1: Comparison between a conventional monolithic carbide grade and an advanced composite carbide grade.

In general, drilling operations are characterized by large differences in the cutting speed from the central tip region to the periphery, with the periphery rotating significantly faster than the central tip. This causes the central tip region of a monolithic drill to fail prematurely, usually because of microchipping, a result of the carbide grade being too hard. Or, the cutting edge at the periphery fails prematurely because the grade is too soft. Thus, the grade of carbide selected for monolithic drills invariably represents a compromise between these competing failure mechanisms.

Endmills are typically subject to high side-thrust forces. Because endmills are characterized by large length-to-diameter ratios, they exhibit some bending and flexing, with the degree of bending being related to the grade of the carbide substrate. The bending can limit the DOC and the dimensional accuracy of the workpiece. Similar to drills, the grade of carbide selected represents a compromise between two competing failure mechanisms. Namely, breakage when the grade is too hard or stiff, and premature wear when the grade is relatively soft.

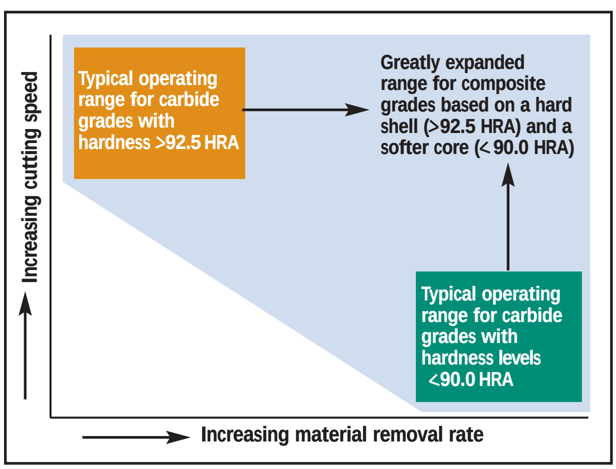

Figure 2: Expansion of the operating range when employing rotary tools based on composite-carbide grades.

Clearly, the performance of monolithic drills and endmills could be improved if they were constructed from carbide that incorporated variations in physical properties from one location to another within the tool. Wear life would be substantially longer, for example, if the carbide grade were somewhat softer and tougher in the core region to prevent premature microchipping of the central tip and harder in the peripheral shell region to prevent premature wear. Also, a carbide endmill's performance could be improved if the substrate had a stiffer core relative to the periphery to minimize bending and flexing.

Composite Substrates

A new generation of composite carbide grades has recently become available that have properties that vary from one location to another. These properties include the material's modulus of elasticity, hardness, wear resistance, fracture toughness, tensile strength, corrosion resistance, coefficient of thermal expansion and coefficient of thermal conductivity.

The structure of conventional monolithic carbide grades commonly employed for rotary tools vs. the structure of the advanced composite grades is shown in Figure 1. The new composite grades consist of at least two distinct conventional carbide grades arranged in a coaxial fashion. In this manner, it is possible to fabricate carbide substrates with distinctly different properties in the core region compared to the shell region.

The theoretical performance ranges (cutting speed vs. material-removal rate) of rotary tools can be greatly expanded if they are made from a composite material. As shown in Figure 2, monolithic grades with a hardness greater than 92.5 HRA are typically applied at relatively high cutting speeds and low material-removal rates, such as when finishing, while softer grades (less than 90.0 HRA) are typically applied at lower cutting speeds and a higher mrr, such as when roughing. It is generally difficult to extend the operating range of either type of monolithic grade without the risk of premature tool failure. For example, roughing with a tool made from a high-hardness grade is likely to fail prematurely by breaking. On the other hand, a softer grade run at a high cutting speed will experience deformation and excessive wear.

Composite construction helps to overcome the inherent limitations of monolithic grades. For example, a tool made of a composite grade with a high-hardness shell and a softer core can cut at speeds characteristic of high-hardness grades while removing material at rates usually seen with softer grades. Obviously, the size of the operating range depends on the choice of the individual grades that make up the composite grade.

In many drilling and endmilling applications, it's advantageous to machine with tools made from a new class of cemented carbide grades called "ultrafine." They have an average WC grain size of about 0.5µm. Tools made of these grades possess extremely high hardness and strength levels, along with the ability to retain sharp cutting edges for an extended life. Unfortunately, such grades are also characterized by relatively low fracture-toughness levels. This enhanced brittleness has limited their use in monolithic drills and endmills because even low levels of vibration can cause rotary tools made of ultrafine grades to break prematurely.

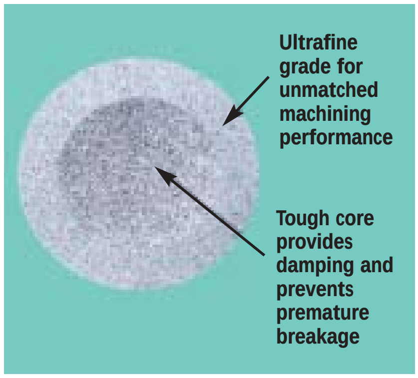

Figure 3: Composite construction widens the operating range for ultrafine grades.

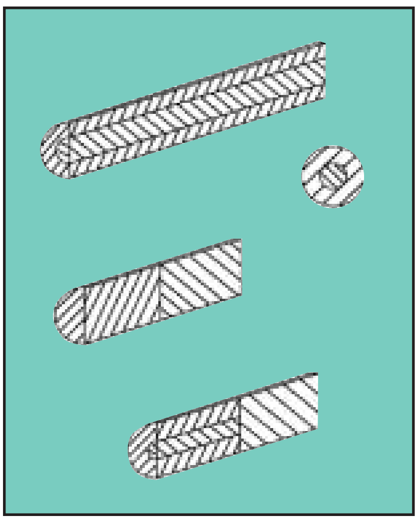

Figure 4: Examples of possible composite carbide configurations.

Composite construction can overcome the risk of premature breakage in ultrafine grades when vibration is present. Figure 3 illustrates a composite carbide grade based on an ultrafine carbide shell and a tougher conventional submicron carbide grade.

Composite Applications

The versatility of the process for fabricating composite grades allows an unlimited variety of combinations to suit specific applications. In addition, the composite construction can enable cemented carbide grades to be used in applications often reserved for softer and tougher HSS. For example, composite carbide step drills could have a softer and tougher nose region to match the properties of HSS, and a hard shell region to extend tool life. Thus, composite carbide substrates provide new options for fabricating combination drills—tools capable of roughing and finishing in one step.

Besides the coaxial configuration, composite grades are also available in other configurations to provide flexibility when designing high-performance rotary tools (Figure 4).

Composite-carbide grades offer unique opportunities for designing high-performance drills and endmills that are characterized by much wider operating ranges (cutting speed vs. mrr) compared to monolithic carbide grades. This, in turn, allows users to dramatically increase the productivity of their drilling and endmilling operations.

About the Author

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