Special Issue: Cutting Tools

— Trends of Functional Upgrading, Resource Saving Technologies and New Products —

Yoshihiro Minato
Executive Officer and General Manager
Advanced Materials R&D Laboratories

Of all the tools used for cutting ferrous metals and non-ferrous metals, about 90% are cemented carbide or coated cemented carbide tools. Cemented carbide (WC-Co) is a composite material of a tungsten carbide (WC) phase and a cobalt (Co) binder phase. It was invented in Germany in 1923 and put on the market in 1927 by the German corporation Krupp AG under the trade name "WIDIA." Subsequently, Sumitomo Electric Industries, Ltd. succeeded in its test manufacture of a cemented carbide wire-drawing die in 1928, and commercialized a cemented carbide tool in 1931. This tool has been marketed under the brand name of "IGETALLOY" ever since. In 2011, Sumitomo Electric celebrated 80 years of marketing this product. In the early 1900s, high-speed steel tools were used for steel cutting operations. The invention of cemented carbide tools have since enabled higher-speed cutting than high-speed steel tools. In the late 1970s, coated cemented carbide tools, which were made by coating cemented carbide with aluminum oxide and titanium carbonitride, were developed for use in even higher-speed cutting operations. Thus, 80 years after its invention, cemented carbide is the mainstream material for cutting tools. A cermet tool made from TiCN-Ni, a material originally developed for jet engine components, is suitable for finishing steel workpieces because of its low affinity with steel. Ceramic tools, whose principal components are aluminum oxide (Al_2O_3) and silicon nitride (Si_3N_4), are used for high-speed cutting of cast iron because of its high resistance to heat.

Sumitomo Electric has been working on developing ultra-high pressure technology that can generate the same levels of ultra-high pressure measured inside the earth. This pressure technology is to be used to create tool materials that are functionally superior to both cemented carbide and cermets. As a result of such efforts, Sumitomo Electric has developed a process for fabricating synthetic diamonds, the hardest material among existing materials, and Cubic boron nitride (CBN, cBN) characterized by hardness comparable to diamonds and low reactivity with ferrous metals. These new materials are indispensable for making tools used in high-speed finishing operations of non-ferrous metals and difficult-to-cut iron-based materials. One such tool developed was the world's first CBN sintered body, put on the market by Sumitomo Electric in 1977. With hardness and strength greater than that of traditional ceramics, this product was made by sintering CBN, using a specially prepared ceramic binder whose affinity with steel is extremely low. Subsequently, another type of CBN sintered body was developed by coating specially sintered CBN base material with a highly wear-resistant ceramic film. Coated CBN sintered body tools are widely used today to cut hardened steels that are extremely difficult to cut in place of grinding.

Metal cutting technology has progressed and developed in conjunction with three elements: tool materials, tool design/geometry, and machine tools. Among the above elements, Sumitomo Electric has promoted the development of advanced tool materials and tool design/geometry. In the very competitive market environment surrounding cutting operations, severe international competition has increased. In more developed countries, including Japan, there is a growing demand for high performance cutting tools that enable higher-efficiency, higher-accuracy, and higher-quality cutting. Meeting the requirements for agile manufacturing of machine parts, enhancing parts quality, and replacing parts with parts made from hard-to-cut materials, is critical.

In China and other emerging markets, tool users emphasize improving cutting efficiency and reducing cutting cost. Machine tools (spindle rigidity) and cutting conditions in developing countries also differ from those in advanced countries. In response to ongoing public concern about the environment and natural resources, Sumitomo Electric has also worked on developing new products that meet market demands. Emphasis has been placed on dry cutting and energy savings as well as environmental protection and secure supply of tungsten and other rare metals resources.

■ Recent Trends in Cutting Tool Material Development

For both steel cutting tools, which dominate the cutting tool market, and cast iron and ferrous powder metal cutting tools, tool manufacturers have focused mainly on the functional sophistication of film coating, such as refining the grain size of Al_2O_3 film coating. In particular, Sumitomo Electric has made every effort to control the stress of coated films and to increase their adhesion resistance. As a result, a series of new cast iron cutting tool materials with reduced abnormal wear and chipping have been developed. The

tools also achieve significantly higher cutting performance compared with traditional coated cemented carbide tool materials. Details of these tool materials are described in the section: "Development of New Coated Carbide Grade Ace Coat AC405K/415K for Cast Iron Turning."

The use of CBN sintered body tools is expanding to meet the needs for high-speed and high-accuracy cutting, especially for cast iron and ferrous powder metal alloys, which are significantly susceptive to thermal shock fractures and abrasive wear compared to hardened steel. To improve the performance of CBN sintered body tools, it is essential to increase the content of CBN that has superior thermal conductivity. Sumitomo Electric has developed a new technology for increasing the content of CBN in sintered bodies, thereby increasing the bonding strength between CBN particles. Using this technology, a cutting tool material displaying extremely high thermal crack resistance and wear resistance has been developed. A detailed description of this material is presented in the section: "Development of New Grade 'SUMIBORON BN7000' for Cast Iron and Ferrous Powder Metal Machining."

Diamond tools are widely used for both nonferrous metal and non-metallic material cutting operations. However, conventional diamond tools are ineffective for cutting some difficult-to-cut materials that have recently started to be used. Cemented carbides used for high-precision dies, for example, require super-hard, higher-strength, and ultimate abrasive wear-resistant cutting tool materials that can work from grinding to cutting. To meet such requirements, the world's first nano-polycrystalline diamond has been commercialized, having greater hardness than mono-crystalline diamonds and greater strength than traditional diamond-sintered bodies. This new material, which is synthesized under unprecedentedly high pressures, is a super-hard, binder-free polycrystalline body with an ultra-microscopic texture. As discussed in the section: "Application of Nano-Polycrystalline Diamond to Cutting Tools," this material is highly promising as a next-generation cutting tool material and is expected to be used for various cutting operations.

■ Recent Trends in Tool Geometry Development

In the field of tool geometry design, applications are expanding for rapidly progressing 3D design and modeling technologies of intricately shaped objects. In particular, intricately shaped, high-performance, and extremely sharp tools are mainly used in milling operations. Tools with a cutting edge on both faces are becoming more popular because of their effectiveness in cost cutting. In response to such changes in customer demands and new technology development, Sumitomo Electric has developed a new indexable insert and milling cutter with sharp cutting edges on both faces. This product minimizes deformation caused by sintering and enables accurate and economically efficient machining. The newly developed insert and milling cutter is described in detail in the section: "Development of SEC-Dual Mill DGC Series for General-Purpose Face Milling." Sumitomo Electric has also developed a high-efficiency chip breaker and vibration-proof grooving tool by making full use of leading-edge simulation technology. These products are introduced in the section titled "Development of Grooving Tools 'SEC-GND' Series." Sumitomo Electric has also been working on the development of a new CBN sintered body tool with improved design flexibility of a CBN sintered body itself, as well as other new products by applying coating technologies to our conventional products. Examples of such new products are the small-diameter CBN endmill and the "AURORA COAT" endmill. The small-diameter endmill is suitable for high-speed, high-accuracy cutting of hardened steel, cast iron dies, and copper electrodes. The AURORA COAT endmill is made by specially coating the cutting edge to enhance sharpness and improve chip-removing performance with a high-lubricity diamond like carbon (DLC) film.

The AURORA COAT endmill is suitable for cutting copper electrodes. These endmills can satisfy customer needs for new endmills that can achieve high-accuracy and high-efficiency cutting of high hardness steel dies. The new endmills can replace traditional endmills that have customarily been used for directly engraving general dies and copper electrodes for die fabrication. Detailed description of these products is presented in the section: "Development of Endmills for Milling Hardened Steel Molds and Copper Electrodes."

■ Efforts for Solving Resource Problems

Tungsten, an important material for cemented carbide tools, is a natural resource concentrated in China. Tungsten production in China alone accounts for about 80% of the global production. The price of tungsten has continued to soar since 2005 because of the Chinese government's tightened control of tungsten mining and export. The current tungsten price is about 10 times higher than that of 10 years ago. To cope with problems associated with skyrocketing tungsten price, cemented carbide tool manufacturers have launched R&D programs to establish the so-called 3R (Reduce, Reuse, Recycle) system. Since early times, Sumitomo Electric has recycled tungsten using a zinc treatment system. However, the system is unfavorable because its treatment capacity is small and can treat only limited grades of tungsten scrap. Aiming to develop a process that can recycle used tungsten from cemented carbide with less constraints, Sumitomo Electric participated in a national project sponsored by Japan Oil, Gas and Metals National Corporation (JOGMEC). As part of the project, a new process that recycles even small lots of cemented carbide scrap with less energy and chemical consumption was developed. Sumitomo Electric has also participated in a national project sponsored by the Ministry of Economy, Trade and Industry (METI) and New Energy and Industrial Technology Development Organization (NEDO). In this project, strenuous efforts were made to develop the tool industry's first technology for compounding powdered raw materials at the time when the materials are pressed into shapes. This technology reduces tungsten use in cemented carbide by 30% without deteriorating cutting performance. Details of the new technology are described in the section: "Development of Technologies for Recycling Cemented Carbide Scrap and Reducing Tungsten Use in Cemented Carbide Tools."

Cutting tools are basic products that are indispensable in almost every manufacturing industry. The tools must always be improved to enhance their performance, thereby helping to address energy, environment, and resource issues, which are of growing public concern today. Sumitomo Electric will continue to promote its R&D to swiftly market new products with innovative tool materials and tool geometries.