MODERN MATERIALS FOR CUTTING TOOLS

V. N. Glushkov

The All-Union Scientific Research and Planning Institute of Refractory Metals and Hard Alloys "VNIITS" was established in 1946. The scientific school founded at the VNIITS is unique in its approach in a number of disciplines, and the significant strides it has made in those areas are recognized both in Russia and abroad. For example, the Institute heads a subcommittee of the international standardization organization ISO; materials and technologies developed by the Institute are widely used in the defense industry, aviation, electrical engineering, machine construction, the recovery of oil, gas, and minerals, and several other industries.

The work of scientists at the VNIITS has been highly valued by the government: 15 employees have received the State Prize and the Prize of the Council of Ministers. Researchers at the Institute have written and published more than 70 monographs in physical metallurgy and the engineering of hard alloys and refractory metals.

The Institute has a permanent committee to oversee scientific and technical matters, a post-graduate program, a permanent academic council that reviews candidate dissertations. In 1999, the Institute won accreditation from the Ministry of Science and Technology as a scientific organization conforming to the Federal Law on Science and Governmental and Scientific-Technical Policy. More than 50 projects are under way in 1999 to improve various technologies and the quality of existing products and to develop competitive new types of products.

In 1997, the test center of the Institute was created on the basis of five research laboratories. In 1999, the center won the right to certify the quality of semifinished and finished products made of hard and heavy alloys and materials, facing materials, and mineral-ceramic alloys and materials. The center has also been accredited to certify products in ferrous and nonferrous metallurgy, which involves testing metals and alloys to determine their chemical composition, microstructure, physico-mechanical properties, and cutting properties.

The Institute has developed and successfully introduced more than 30 grades of hard alloys, including ultrafine-grained alloys based on high-temperature tungsten carbide and alloyed with tantalum, as well as ceramic and ultrahard synthetic materials. One of the most recent successes of the Institute was the development of hard alloys for treating wheel sets on rolling stock. The reconditioning of these wheels is becoming increasingly important.

The cutting tools that were in use until recently, made of domestic alloys, had service properties inferior to those of similar foreign makes made by such companies as Sandvik (in Sweden) and Vidia (Germany). New alloys T1 and T5, developed by the Institute, have an optimum combination of mechanical properties: good strength and good ductility and, thus, high resistance to impact loads and wear. The introduction of special alloying additions has made it possible to achieve high wear resistance and heat resistance in the alloys and alleviate fusion of the cutting edge when temperatures in the cutting zone are high.

Turning on wheel lathes is the operation performed to eliminate the main types of defects in wheel sets: undercutting of the flange and link bar and erosion of the rolling surface of the wheel. The turning is performed with the use of replaceable, non-resharpenable hard-alloy cutting tools of tangential form with a lateral hole (LNMX301940 and LNMX191940), a tangential cutting tool with a projection (BNMX201540), and cup-shaped cutters with diameters of 12 and 30.8 mm.

Commercial trials have shown that the average life of tangential cutting tools of alloys T1 and T5 corresponds to the average life of similar cutting tools made by leading foreign manufacturers, specifically: 6–9 machined wheel sets for one angle of the cutting edge of the tool. The average life of cup-shaped cutters made of these alloys exceeds the average life of cutting tools of alloy T1K8 by a factor of 2–4 [1]. Cutting tools equipped with tangential and cup-shaped cutting tools of hard alloys T1 and T5 are now being used by more than 100 railroad repair yards in Russia, the nations of the CIS, and the Baltic countries.

The Institute is conducting comprehensive studies directed toward improving the quality of hard alloys that are to be used to machine metals and alloys. These efforts are keyed on the development of technologies that can produce tungsten and tungsten-carbide powders with a uniform granulometric composition. Different approaches have been taken to achieve this. In particular, one technology yields powders ("NS" powders) of tungsten and tungsten carbide with particle sizes of 2–4 μm based on the Fisher criterion. These powders are characterized by a high degree of dimensional uniformity. Hard WC alloys VK6-NST and VK8-NST, which are obtained from these powders and are alloyed with tantalum carbide, have a high degree of structural uniformity (Fig. 1). The percentage of grains of the size 1–2 μm reaches 90%, while the percentage of 1-μm grains reaches 10%. There are almost no coarse grains of tungsten carbide larger than 5 μm. As a result, the alloys have superior mechanical properties (σₚₚ reaches 2200 N/mm² and hardness reaches 91 HRA).

The combination of high hardness and strength makes it possible to use these alloys in different applications. In connection with their high degree of homogeneity, it is best if they are used in the form of replaceable multiple-cornered cutting tools – including tools with wear-resistant coatings. The service life of alloys VK6-NST and VK8-NST is 1.5–2.0 times greater than that of standard grades of alloys.

Composites of the "hard-alloy substrate – coating" type constitute a special class of materials. These materials have found wide use in metalworking, where an appreciable number of replaceable multiple-cornered, nonresharpenable cutting tools are used with wear-resistant coatings. The application of such coatings sometimes makes it possible to obtain a layered material with radically new properties, combining the strength of the substrate with the high hardness of the coating. Some of the leading companies that specialize in this area have developed different types of coatings consisting mainly of carbides and nitrides of titanium and aluminum oxide. Different combinations of these layers and different methods of applying them are used, depending on the nature of the operation and the composition of the material being machined.

Hard alloys with wear-resistant coatings make it possible to reduce the number of types and grades of alloys used without coatings. The Institute has developed several grades of alloys specially designed for the application of wear-resistant coatings, a technology for applying the coatings, and compositions of many-layered and multi-layered coatings [2]. The organization now produces a wide range of hard alloys with wear-resistant coatings, including coatings for such large enterprises as the Volga Automobile Plant, Gorky Automobile Plant, and several machine factories. The coatings are successfully competing with similar products made by foreign companies.

Figure 2 shows certain types of replaceable nonresharpenable hard-alloy cutting tools made by VNIITS with multi-layered coatings.

The Institute has developed a technology for depositing combination coatings for certain applications. The technology combines chemical and physical vapor deposition and makes it possible to significantly improve the service characteristics of cutting tools with a coating [3]. Research is being done on optimizing the compositions of multi-layered coatings, determining the maximum effective thickness of the layers, studying the conditions of their formation and the required orientation of the grains of the material being deposited, and reducing the stresses that develop between the layers and the alloy-substrate.