THE POWDER METALLURGY INDUSTRY, ECONOMICS,
AND ORGANIZATION OF PRODUCTION

DISK-TYPE MILLING CUTTERS WITH WORKING ELEMENTS
MADE OF POWDER HIGH-SPEED STEEL.
I. TECHNOLOGY FOR MAKING SEMIFINISHED
PRODUCTS FOR THE CUTTERS

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A technology is developed for making monometallic and bimetallic compacts for the production of disk-type milling cutters based on powder high-speed steel. The main operation in the technology is the hot upsetting of porous ring-shaped semifinished products, with the material flowing toward the center of the product. The article describes the methods used to fabricate the compacts from powder high-speed steel and protect against oxidation during heating, as well as the design of a disk-type milling cutter with a replaceable bimetallic ring. The requirements of the main manufacturing operations are presented.

The expediency of making semifinished products for disk-type milling cutters (DCSPs) with working elements made of high-speed steel stems from the fact that it lowers the total production cost and makes the parts of the cutter more durable. Although such cutters are in great demand, there is no centralized distribution center for the machine factories that need them. Due to the high cost of high-speed steel, it is used only to make the working elements of the cutter, and the body parts are made of structural steel. Certain aspects of the cutters' configuration and the inferior processing properties of powder high-speed steel have made it necessary to develop a special technology for making the semifinished products. This study was commissioned by the Novocherkassk Electric Locomotive Factory.

Proceeding on the basis of the requirements of the client and the capabilities of the manufacturing facility, we restricted the diameter of the DCSPs that were made for the study to 80 mm. The thickness of the cutters, determined by their service conditions, was 3 mm. Semifinished products for the production of disk cutters are made from rolled products by free upsetting or butt-end rolling. Preliminary tests in which porous semifinished products obtained from powder high-speed steel were upset in a rigid die, with no flow of the material in the transverse direction, showed that it is impossible to achieve the minimum porosity [1] or even produce elements with the required radial texture. In freely (without a die) upset semifinished products, density continuously decreases from the center to the periphery, and peripheral radial cracks are formed. In this case, the material has the density of hot-rolled steel only in the central region [2]. In these cases and all of the instances described below, the initial materials were powder high-speed steels of grades R5M5K5 (produced by the Zaporozh'e Special Steels Plant) and R5M5 (made by "Tulachermet," GOST 19265-73). No corrections were made to the chemical or granulometric composition of the powder. It had an apparent density of 5.54 g/cm³ before shaking and 5.88 g/cm³ after shaking. Its pycnometric density was 8.11 g/cm³.

The preliminary tests showed that it was necessary to devise a method of forming DCSPs that would not only allow radial flow of the material during upsetting, but would also ensure formation of the desired texture by providing for adequate "support" of the peripheral zones in order to prevent crack formation. Free hot upsetting of poured powder in thin-walled shells (D_out = 26 mm, H = 38 mm, δ = 2-3 mm) did not ensure sufficient consolidation and led to cracking of the shells and distortion of the semifinished products.

The second stage of the experiments involved the hot upsetting of R5M5K5 powder poured into thick-walled shells. The degree of deformation in the upsetting operation $\varepsilon = 87\%$. The semifinished products were heated in dissociated ammonia at $1190 \pm 10^\circ C$. The resulting disks were cut to reveal the macrostructure (Fig. 1). After removal of the shell, we determined the density of the high-speed steel: it increased with a decrease in the thickness of the shell, reaching $8.05 \text{ g/cm}^3$ at $D_{\text{out}}/D_{\text{in}} = 2.25$. The macrostructure had two distinct zones: a dark core and a contour region, formed by the interaction between the powder and the protective medium during heating. The contour region was distorted due to the nonuniformity of the deformation, but the high density of the steel testifies to the effectiveness of sometimes using a thick-walled shell as a "support" during upsetting.

The data that were obtained made it possible to formulate requirements for a technology to make DCSPs and for the corresponding equipment. It is best if the upsetting operation is performed in a closed cylindrical die, which makes it possible to obtain a DCSP with a cylindrical contour and avoid the loss of powder due to its "equalizing." The radial flow of the powder should be directed toward the center of the DCSP. To ensure such flow, the semifinished product is formed with a hole. Support is provided during upsetting by using a thick-walled bushing. The bushing can later be used as the body of the cutter.

Additional problems are encountered in making large-diameter bimetallic DCSPs with a body made of structural steel, since its phase-transformation temperatures and thermophysical properties differ significantly from the corresponding characteristics of the high-speed steel. Shaping and heat treatment of the DCSP creates appreciable stresses, which in turn makes it necessary to fabricate replaceable rings with mechanical fastening the relatively narrow rim to the body of the cutter (see Fig. 2). The working part of the ring is wider, stronger, and more rigid than the rim, which serves as the "support" during hot upsetting of the DCSP and thus prevents fracture of the semifinished product during heat treatment. The stresses in the rim are relieved during tempering. Several designs and configurations of DCSPs were developed.

The initial semifinished products were monometallic and bimetallic and had the form of a ring. The monometallic semifinished products were obtained by pouring powder into the space between two shells made of dense paper. The shells were placed in concentric grooves in the bottom plate. The powder was impregnated with paraffin. The cooled compacts were removed from the bottom plate, the shells were removed from the compacts, and the compacts were sintered in a bed of a dispersed refractory in a medium of dissociated ammonia at $1050^\circ C$ for 1.5 h, $1100^\circ C$ for 1 h, or $1150^\circ C$ for 40 min. The radial shrinkage in these cases was 1.5, 3.5, and 6.5%, respectively. The paraffin volatilized during the initial heating.