NEW DESIGN OF DRILLING BIT WITH CENTRIFUGALLY THROUGH-HARDENED CUTTER STRUCTURE, FOR JET-TURBINE DRILLING

V. A. Yasashin, N. G. Makarov, A. M. Nazarov, and D. Yu. Serikov

In various industries in recent years, there is an increasing demand for large-diameter wells (from 0.5 to 5 m) with depths of 1000 m or more. Such wells are needed for water systems in flooded deposits of minerals, for ventilation and other purposes in coal and hard-rock mines, for drilling below the surface casing string in super-deep oil/gas and exploratory wells, for the construction of oil mines, and for other purposes.

The All-Union Scientific-Research Institute of Drilling Technology (VNIIBT) has developed a method for drilling these wells based on the use of a turbodrill; this technique has been termed the "jet-turbine drilling (JTD) method."

JTD is accomplished by means of a downhole assembly consisting of two, three, or four turbodrills with bits, operating in parallel with a rigid interconnection. In the operation of this assembly, the only elements that come into contact with the rock are the peripheral rows of bit teeth. Thus it becomes possible, with a limited total axial load, to create contact stresses that would require extreme loads when turbodrilling conventional wells [1].

VNIIBT has developed drill bits that are specially designed for the JTD method: Sh490TZ-TsVR and Sh490S-TsVR. The distinctive feature of these bits is that the cutting structure is confined to the periphery of the rollers. Bits of these types are in regular production at the joint stock company Sarapul'skii Mashzavod [Sarapul Machinery Plant], which specializes in the manufacture of large-diameter bits [2].

The process used in manufacturing the Sh490S-TsVR bit differs from those for intermediate-size bits (215.9-295.3 mm) with milled teeth, in that a different method is used to obtain the roller-cutter blanks. In the manufacture of roller-cutters for intermediate-size bits, forged blanks are used; in contrast, roller-cutter blanks are manufactured at the Sarapul Machinery Plant by investment casting.

In order to increase the wear resistance of the toothed cutters of the bits in regular production, a process of surface hardening by "relite" is used; this is accomplished by mixing granular relite with the molten surface layer of metal. The teeth are heated by an oxyacetylene torch or by induction heating. The hardened layer that is obtained is brittle and nonuniform; and as a consequence, when the surfaces are subjected to any significant alternating loads, microcracks appear [3], followed by brittle spalling. The surface hardening of the cutting structure of the bit is of particularly low quality in the case of cast teeth, since the layer of relite is melted onto the surface of teeth coated with skin from the casting operation, which contains various nonmetallic inclusions.

The surface-hardened cutters have a very low resistance to shock and fatigue [4] owing to the presence of internal stresses caused by nonuniformity of metal bonding and the concentration of hard alloy in the hardened zone; therefore, in the course of service, the hardened layer will peel and scale, resulting in premature wear of the cutter. Still another shortcoming of surface deposition by heating with a gas torch is the significant distortion of geometry of the toothed elements of the cutter, which lowers the efficiency of the drilling bit cutting structure quite significantly. Furthermore, the use of a cast blank in obtaining drilling bit cutters has an adverse effect on not only the quality of the toothed cutting structure, but also (to a significantly greater degree) on the life of the bearing unit.

On the basis of an analysis of the shortcomings of the regularly manufactured Sh490S-TsVR drilling bits, and with due consideration for the most advanced processes for the manufacture of composite materials, the scientific-production firm Mayana, together with the Sarapul Machinery Plant, has developed a new design of a JTD bit with a centrifugally through-hardened cutting structure.

Translated from Khimicheskoe i Neftyanoe Mashinostroenie, No. 2, pp. 16-18, March-April, 1996.
The main feature of the new bit design is that it is equipped with cutters fabricated as an assembly consisting of a centrifugally through-hardened row (CTHR) and a forged hub, joined by two annular welds (Fig. 1).

The tooth rows are manufactured by the use of a centrifugally through-hardening technology developed at Mayana, in which the processes of centrifugal casting, through-hardening, and investment casting are combined. The technology of centrifugal through-hardening is based on the injection of a hard alloy into a rotating casting mold at the same time the molten metal is introduced. Under the action of centrifugal force, the hard alloy, which has a higher density than the base metal, migrates to the peripheral part of the mold and fills the volume of the roller-cutter structure. As a result of processes of crystallization of metal and optimal alloying of the metal bond with tungsten, a CTHR is formed. The process of manufacturing large-diameter CTHRs with a wide cutter structure (60-80 mm) has a number of significant differences from manufacturing processes of this type that had been developed previously.

Experience in drilling with JTD units equipped with Sh490S-TsVR and Sh490S-TsV bits, in sinking mine shafts at the production association Spetsshakhtoburenie, has shown that in soft or moderately hard rock, the main cause of tool failure is catastrophic wear of the bearing units of the bit. For example, according to data reported by Spetsshakhtoburenie, the Sh490S-TsVR and Sh490S-TsV bits, after 18-22 h of downhole operation, had 100% wear of the bearing units (the lock bearing was worn so much that in some cases it could no longer perform its function), with 50-70% wear of the cutting structure.

In order to increase the life of the bearing units of the experimental bits Sh490S-TsVR-1 and Sh490S-TsVR-1M, it was very important to ensure that the CTHR would be mounted on the cutter hubs in a reliable manner. Electric arc welding was selected as the method of attachment.

It is known that the reliability of a welded joint depends on such factors as the weldability of the materials being joined, the electrode material, the weld geometry, the subsequent heat-treatment, and other factors [4].

In the design of welded structures, one of the primary problems is the calculation of weld geometry; these calculations are performed on the basis of assumed stresses that arise under the influence of some particular load. In the cutter assembly, the welds must bear loads acting from the side of the hole wall, since in the design of the cutter assembly,