IMPROVING THE QUALITY OF HOLLOW DRILL STEEL

Hollow drill steel rods are employed in the mining industry for drilling the blast holes in the rock. During operation the rods are subjected to impact loads which give rise to considerable alternating stresses in the metal. In addition, the rods are subjected to the corrosive effect of the water flowing through the channel. A high-quality metal surface and accurate geometrical dimensions of the rods are therefore necessary.

The following articles provide manufacturing experience with hollow drill steel at various metallurgical plants.

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Hammer and Sickle Plant

For rolling hollow drill steel a U7 carbon steel billet is employed with a square section, having a hole through the center taking an EI94 austenite steel core.

One of the main features of rolling this type of billet from the point of view of deformation of the metal is the appreciable difference in the strengths of the carbon and the austenite steels. With this difference in strength simultaneous deformation of the core (austenite steel) and the sheath (U7 steel) during hot rolling would be difficult to achieve if there were an insufficient force of friction between them in the process of deformation.

The bond between the core and the sheath, governed by this force of friction, strives to maintain equilibrium between the two elongations, that is to say, to reduce the elongation of the sheath and to increase the elongation of the core. In this way retardation of elongation of the sheath and the two-way pull of the core approximate their deformation resistance.

Another typical feature of rolling the billet is the absence of direct contact of the core with the rolls; deformation of the core is applied by the metal of the sheath. Hence, the nature of the core deformation is governed entirely by the quantity and directions of the displacements of the metal sheath at the seat of deformation of the given pass.

Large transverse displacements of the metal sheath at the seat of deformation are undesirable, since very slight asymmetry relative to the core gives rise to dislocation of distortion. It is very difficult, again, to achieve full symmetry of the transverse displacements of the metal in practice; to obtain this it would be necessary to provide completely uniform heating of the billet throughout the section, together with exact positioning of the rolls during reduction. It is therefore necessary during the rolling to limit the value of the relative reductions in the passes and to employ a system of passes for which sharp transverse displacements of the metal of the sheath do not occur at the seat of deformation.

An important part of rolling drill steel is the system of drawn rhomboid and square passes, in which there is the greatest possibility of sharp nonuniformities occurring in the distribution of the relative reductions at the seat of deformation.

Greatest reliability is afforded by rolling in a series of rhomboid and square passes with marked gaps in each pass. A disadvantage of this method is the necessity for limiting the reduction per pass; that is to say, for increasing the number of passes or reducing the cross-section of the billet.

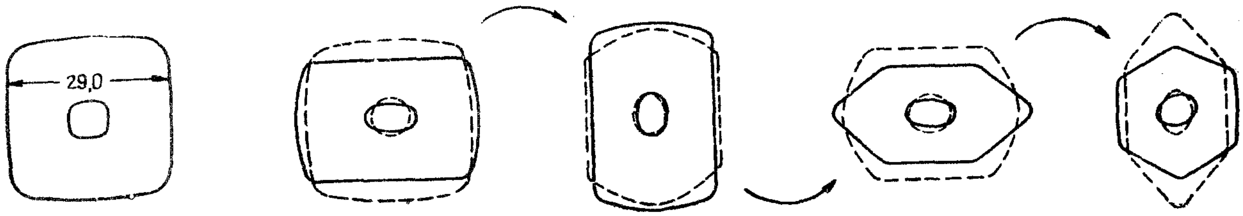

Fig. 1. Irrational shape of finsihing passes (rolling 22 mm hexagogonal).

In the roughing passes the distribution of the relative reductions at the seat of deformation does not give rise to such sharp forming of the core by the sheath metal as in the case of the rhomboid. This phenomenon may occur at the seat of deformation of the finishing pass when an unsuitable pre-finishing pass profile is employed (Fig. 1); this can be obviated by choosing a pre-finishing pass with sharp angles (Fig. 2) which provides uniform distribution of the relative reductions at the seat of deformation in the finishing pass.

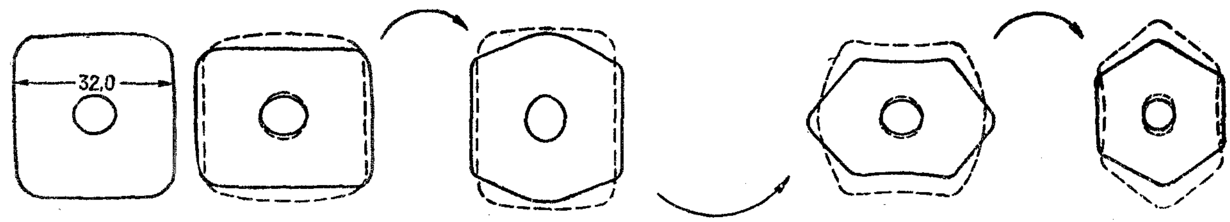

Fig. 2. Rational shape of finishing passes (rolling 25 mm hexagonal).

After a series of investigations the technology of rolling hollow drill steel was considerably improved at the Hammer and Sickle plant:

1) heating of the billet was improved by increasing the period in the holding furnace of the 300 mill from 1 hour 15 minutes to 1 hour 45 minutes and raising the initial rolling temperature from 1070 to 1100°;

2) the number of draw passes was increased from 7 to 9 in a number of rhomboid passes of the reducing stand by employing passes adjacent to the third and fifth passes. This was done for the purpose of avoiding overfilling of the passes, the over-all number of passes being increased from 14 to 16 for rolling 25 mm hexagon sections and from 16 to 18 for rolling 22 mm hexagon sections;

3) a pre-finishing profile was chosen providing uniform distribution of the relative reductions at the seat of deformation of the finishing pass, as a result of which no gap was formed between the core and the sheath;

4) a periodic check on the shape and position of the core in the rolled sections was introduced, occurring in the roughing, pre-finsihing and finishing passes. The check was carried out during the rolling process by cutting templets with a thin emery wheel. The templets from the roughing square sections (12th and 14th passes) provided an assessment of the quality of the setting in the draw pass system.

A disadvantage of the drill-steel rolling technology at the Hammer and Sickle plant was the considerable displacement of the core (hole) in the initial billet on account of "drift" of the drill during drilling and also as a result of bending of the billet.

The permissible variation in the sheath at the faces after drilling is not more than 6 mm and the permissible bending not more than 3 mm/lineal m. Obliquity of the billet face must not exceed 10 mm.

These tolerances cannot be regarded as sufficiently strict. It was soon found necessary to carry out straightening of the billet for the purpose of reducing the maximum curvature to 1.5 mm.

The billet must be well and uniformly heated. Nonuniform heating with a given setting of the mill produces an incorrectly shaped channel displaced from the axis of the billets.

Over-filling of the rolls in the first stand frequently leads to displacement and distortion of the core and is also the cause of slipping of the sheath from the core. This considerably complicates setting of the roughing, pre-finishing and finishing passes.

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During the last few years work has been carried out at the plant for improving the manufacturing technology of drill steel. The work was aimed at increasing the weight of the billet, varying the arrangement of the passes in the rolls of the reducing stand, increasing the length and improving the appearance of the finished product.

As a result of this work the percentage of standard product as compared with 1951 rose from 82.4 to 85.8% in 1955. The reject figure fell by a factor of 2.5.

For a long time, drill steel was rolled from a 115×115×900 mm billet weighing 80 kg. The billet arrived at the 850 mill after a large number of passes, which complicated the work of the large-batch factory. In order to raise the productivity of the rolling mill it was necessary to increase the weight of the billet.

To this end a 10-ton electric bridge crane was first erected on a new site together with three electric telpher lines each with a capacity of 0.25 tons.

A number of modifications were carried out in the design of the drilling machines: the spindles were fitted with specially prepared chucks at the rear stocks and self-centering chucks at the first stocks. This eliminated displacement of the holes in drilling and expedited fixing of the billet.

These measures made it possible to carry out drilling on a billet with dimensions of 125 × 125 × 1000 mm, as a result of which the productivity of the mills was raised by 16%.

On increasing the size of the billet it was necessary also to increase the diameter of the hole.

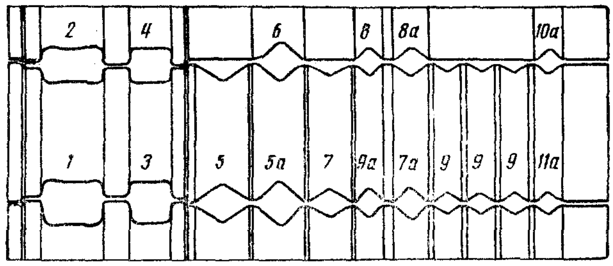
Calculation of the hole in a 125 × 125 mm billet was carried out according to the formula

$$d_1 = d_0 \sqrt{\lambda},$$

where d_1 is the diameter of the hole in the billet, mm;
d_0 is the diameter of the hole in the finished section, mm;
λ is the total reduction of the metal.

It was established by calculation that for a 125 × 125 mm billet the diameter of the hole must be within the range 38-40 mm. The accuracy of the calculation was confirmed by rolling an experimental batch of billets with a hole diameter 38.3 mm to 22 and 25 mm hexagon sections and 32 mm rounds.

a



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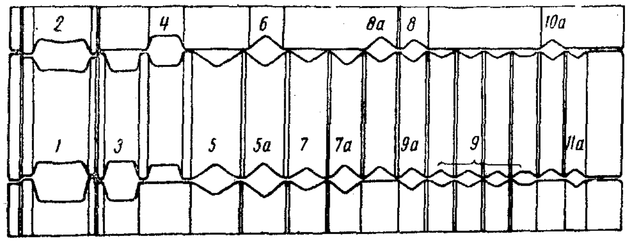

Fig. 1. Systems of passes in sinking rolls for rolling batch and drill steel:
a) old; b) new.

The high demands on shape and position of the hole in the finished section require an accurately worked-out setting of the rolls on the reducing and finishing passes.

Great difficulties are encountered in designing the rolls of the reducing stand, since according to the conditions of manufacture it is impossible to have an individual set of rolls for the reducing stand for rolling drill steel and therefore the reducing rolls must be set for simultaneous rolling of drill and light-alloy batch steel (Fig. 1, a).

In this case the batch steel is rolled in pases 1-9 and drill steel in passes 1,2,3,4,5a,6,7a,8a,9a,10a and 11a. Pases 1,2,3,4, and 6 are common. This is the old arrangement of passes. Its disadvantage is the large number of passes adjacent to each other and consequently it is necessary to roll the billet in rolls with widely different working diameters. This leads to distortion and displacement of the hole in the finished product.

A new pass arrangement has now been worked out for the rolls of the reducing stand. The length of the rolls was increased by 200 mm and some of the previously adjacent passes were arranged in zig-zag order (Fig. 1,b).

Experimental rolling of a billet with the new arrangement of passes in the rolls of the reducing stand showed satisfactory results.

In rolling hexagon sections the most common systems have the roll passes of the finishing train such that either the middle of the side of the section or the angle of the hexagon occur at the points of separation of the finishing passes.

Analysis of the elongation charts together with experience obtained indicate that the second system of passes in the rolling of drill steel yields better results. In operating this system, however, difficulties were encountered which could not be overcome at the plant. The bar twisted even when operating with forming wires and a small gap between the bar and the wire. The problem of setting the bar in the wires with minimum gap is difficult, leading to an increase in the idle time and substantial cooling of the metal.

Arising from this, rolling of hexagon sections in the finishing-mill passes is carried out at this plant according to the system shown in Fig. 2.

It was also established from the investigations that the following conditions have to be observed in order to obtain the correct shape of hole in the finished product:

1) correct shape of the finishing square section;

2) constant heating temperature of the rod and billet as well as degree of reduction and extension;

3) stability of the bar when passing through the roll;

4) difference between the diameters of the rod and hole in the billet not greater than 1 mm.

On changing over to rolling drill steel from a 125 × 125 mm billet the number of passes in the reducing stand and in the finishing train does not change.

By raising the weight of the billet from 80 to 110 kg it was possible to raise the productivity of the 320 mill when rolling drill steel by 11.4%.

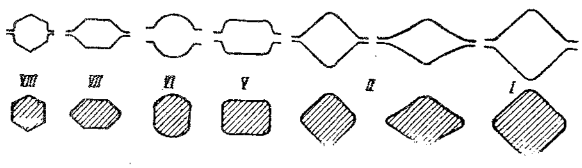

Fig. 2. System of rolling in the finishing tain for 22 mm hexagonal drill-steel.

Work was also undertaken for improving the quality of the finished product. In accordance with the requirements of the user, the length of drill steel was increased and, since the length of the rod was limited by the length of the draw bench on which the rod was drawn, the length of the draw bench was increased accordingly. At present, part of the drill steel is ordered by the users to a length up to 6.5 m.

Tests on the quality of the drills carried out by the users showed that several cases of drill breakage have occurred during operation recently. Since in the majority of cases a pobedit, tungsten carbide-titanium carbide alloy tip is welded onto the end of the drill and the drill steel is employed only in the capacity of a holder, the question arose as to the suitability of employing grade U7 steel, without annealing, for manufacturing the drill steel.

Tests were carried out on other grades of steel. For this purpose three test batches of drill steel of the 25 mm size were prepared from U7 steel (without annealing, and annealed) and grade 45 steel.

The finished drills were tested on the south Ural bauxite mines. It was found that the toughest drills were those manufactured from U7 steel with annealing (40.3 blast hole-meters to 1 drill failure).

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Hollow hexagon drill steel section manufactured from grades U7 and U8 steel is widely employed in the mining industry. According to the specification TU 2894-51 the internal diameter of the hexagon section must be in mm:

For the 22 mm hexagon section 5.8-7.7
For the 25 mm hexagon section 6.4-8.4

The core necessary for providing the hole in the hexagon section is prepared from grade EI94 steel.

The hexagon drill steel section is rolled on the 325 mill at the Red October factory.

In order to provide the correct dimensions and shape of the hole there must be a minimum gap between the core and the initial billet. In addition, uniform heating of the core throughout the section and along the length must be applied together with checking of the dimensions of the hole at the intermediate stands of the mill during rolling.

The old rolling technology for hexagonal drill-steel sections with the core inserted in the hot state did not justify itself since the correct shape of the hole could not be obtained on account of the sharp fluctuation in the heating temperature of the core and billet (instead of a round hole an oval or square hole was obtained). In addition, the rods frequently fractured on drawing out the core from the drill-steel sheath.

Investigations were carried out for improving the technology of manufacturing the hexagonal section.

The initial billet for rolling took the form of a 90 mm square section with a 27 mm diameter hole. The diameter of the core was 26 mm. The core was immersed in a milk-of-lime solution and then inserted in the cold state in the hole in the billet before setting in the furnace. The billet was heated for 3-5 hours to a temperature of 1100-1050° before rolling.

In rolling the first experimental batches of the drill steel according to this technology with cold insertion of the core, it was found that the core previously used, being 1000-1050 mm long for length of billet 900 mm, was excessively long.

In the first experiments a core of the same length was inserted in the hole in the billet in the cold state in such a way that it projected by 100-150 mm at the back end and was level with the billet at the front end. The projecting end of the core was bent slightly with a hammer before entering the first pass.

In the first two passes the billet over-ran the core, but did not completely cover it. At the third pass the core was pinched and the billet did not further over-run. The rear exposed end of the core frequently broke off, which gave rise to untimely wear of the surface of the finishing roll.

It is therefore necessary to have a core of limited length so that it is completely covered by the billet in the first passes in the reducing stand. At the same time the core temperature is held constant and is deformed together with the billet.

In order to determine the optimum core length seven experimental billets were rolled (90 mm square section) with cores up to 950 mm long inserted in the cold state. After rolling the billets to 25 mm hexagonal sections, samples 1 m long were cut from both ends of each bar, and washers were cut at every 100 mm for checking the diameter of the hole in the hexagonal section.

Analysis of the samples showed that the neck of the core was drawn out at both ends of each bar to 400-700 mm. In the remainder, the diameter and configuration of the hole were normal throughout the entire length of the bar.

It was established on the basis of the experiments that the optimum core length at which the billet completely covers the rear end must be 930-940 mm. In this case deformation in the finishing rolls will proceed without fracture of the end. Smaller cores would result in voids at the ends of the hexagonal section and would seriously distort the shape of the hole.

For stability in rolling 22 mm hexagonal sections it was necessary to slightly increase the diameter of the hole in the billet.

It was established by calculation that a 6.35 mm diameter hole could be obtained in the finished 22 mm hexagonal section (minimum according to specification TU 5.8 mm). With this diameter several difficulties in rolling were removed.

Accuracy of shape of the hole and limitation of core breakages in drawing out also depend on the process of drilling the billet on the horizontal drilling machines. The absence of collar plates (taking up the thrusts) on the machines gives rise to heavy vibration of the drill itself, resulting in a nonuniform hole-diameter along the length of the billet and sometimes to displacement of the hole from the center.

An axial section of a drilled billet demonstrated that on using a drill which had been previously used (diameter approximately 27 mm), the front ends of the billets had a hole diameter 27.3-27.8 mm and the back ends (at the end where the drill leaves the billet) 26.9-27.5 mm. In addition it was established that the internal diameter in the billet at a distance $^1/_3$ of the length from the end where the drill project, had a minimum size of 26.7 mm.

Hence, the diameter of the core inserted into the billet hole must be slightly less than 26.7 mm. Otherwise, the core seizes. To check the minimum diameter a calibrated rod with diameter 26 mm +0.2 mm was inserted in the billet hole.

In order to reduce vibration of the drill and to obtain a hole uniform throughout the length of the billet, collar plates were set up on the horizontal drilling machine (taking the thrusts) for guiding the drill. This considerably improved the quality of the rolled hexagonal drill-steel section.

The minimum diameter of the hole in the billet when employing a drill previously used has to be measured by means of a reference core; the gap between the billet and the reference core must not exceed 1.0 mm.

As a result of the experiments the drilling technology was improved, the core length was established for the 90 mm square billet, the optimum heating temperature was found for the drill-steel billet (1100-1050°), and the correct diameter and shape of the hole in the hexagonal section were found, conforming to the requirements of the TU specification.

On the basis of these investigations a new technology was developed and introduced for the manufacture of hexagonal drill-steel sections.

On this basis it was possible to raise the productivity of the 325 mill by 15-20% and to turn out hollow hexagonal drill-steel sections in complete conformity to the requirements of the TU technical specification.

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One of the conditions for obtaining high-strength drill rods is accuracy of the geometrical dimensions of the cross sections.

It is particularly important that the channel in the rod should have a geometrically-circular cross section, since only under these conditions is a uniform distribution of the stresses throughout the whole cross section of the profile achieved. If the channel does not have a true round section and particularly if the axis of the channel is displaced with respect to the axis of the rod, then at points where the active section is reduced, excessive stresses occur giving rise to untimely wear of the rod.

In recent years hollow drill-steel has been rolled in practically the same way as ordinary hexagonal steel (disregarding specific characteristics), employing the same setting of the rolls. The quality was checked only after rolling in the last stand. Adjustment of the profile for correct shape of the channel was not carried out.

In recent years the quality of hollow drill-steel has been considerably improved. The changeover, to simultaneous heating of the billet and insertion of the core in the cold state was first introduced at the Hammer and Sickle plant. This provided a substantial improvement in the shape of the channel. The setting of the profile according to the shape of the channel was first organized at the Red October plant, for this purpose setting up the emery cutting wheel directly near the mill. At all plants heating of the billet before rolling was improved, providing uniform heating of the metal. A substantial improvement was brought about in drilling the billet and so on. At the same time, insufficient attention was turned to setting the rolls.

The investigations carried out by the Central Iron and Steel Scientific Research Institute in conjunction with the workers of the Hammer and Sickle plant indicated a predominant influence on the setting of the rolls on the quality of the hollow drill-steel, particularly with regard to the rolls of the roughing and finishing stands. In the course of the investigations an attempt was made to obtain a hollow drill-steel corresponding to the best samples in regard to the quality of the section. The size tolerances were reduced to less than half: oval shape of the channel from plus 1.2-minus 0.8 to plus 0.5-minus 0.3 mm, that is to say the over-all oval tolerance of the channel was reduced from 2.0 to 0.8 mm and displacement of the center from 1.5 to 0.75 mm.

The investigations showed that hollow drill-steel with these tolerances could be obtained by introducing essential changes in the roll setting. Uniform deformation of the metal must be provided in each pass and conditions set up which would render difficult or reduce the tendency for the metal of the billet (sheath) to leave the core. For this purpose it was necessary to employ a rhomboid groove as far as possible with similar angles at the top. The finishing square section must have equal diagonals and this can be achieved by double rolling of the bar in similar grooves. The core in the finishing square section must be round and occupy the center of the cross section. The last three or four shaping grooves in which the profile is shaped are particularly important.

The investigations also showed that the best results are obtained on rolling in the grooves illustrated in Fig. 1. The conditions of deformation in these grooves are so favorable that on rolling in these grooves it is possible to obtain a hollow drill steel of almost ideal quality not only from the middle but from the front and back ends of the bar section also.

This setting has not so far been adopted in our factory. It requires a higher level of production, more careful setting of the profile, a better condition of the roughing and finishing stands, higher quality fittings and so on.

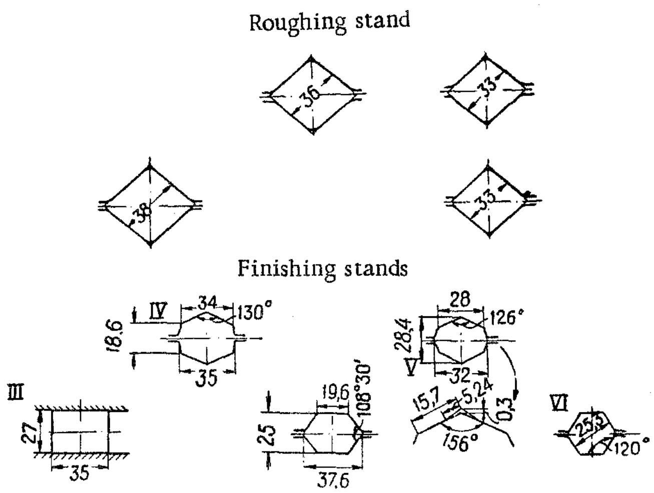

Fig. 1. Adjustment of rolls on the 300 mill for rolling high-quality hollow drill steel: III, IV, etc Number of stand.

The quality of hollow drill-steel was considerably improved at the Hammer and Sickle plant after introducing the pass sequence as recommended by the Central Iron and Steel Scientific Research Institute (Fig. 2, a) in place of that earlier employed (Fig. 2, b). One important feature of this sequence is that pressing out is considerably reduced particularly in the finishing pass. Instead of the finishing square section of 36 mm, a finishing square section of 32 mm was introduced, thus reducing the total elongation in the four passes from 2.7 to 2.15; the round upset pass was changed for a hexagonal and the pre-finishing pass was substantially modified: the width (height) was reduced by increasing the slope of the walls. In order to carry out better the finishing pass, the thickness of the pre-finishing pass was increased.

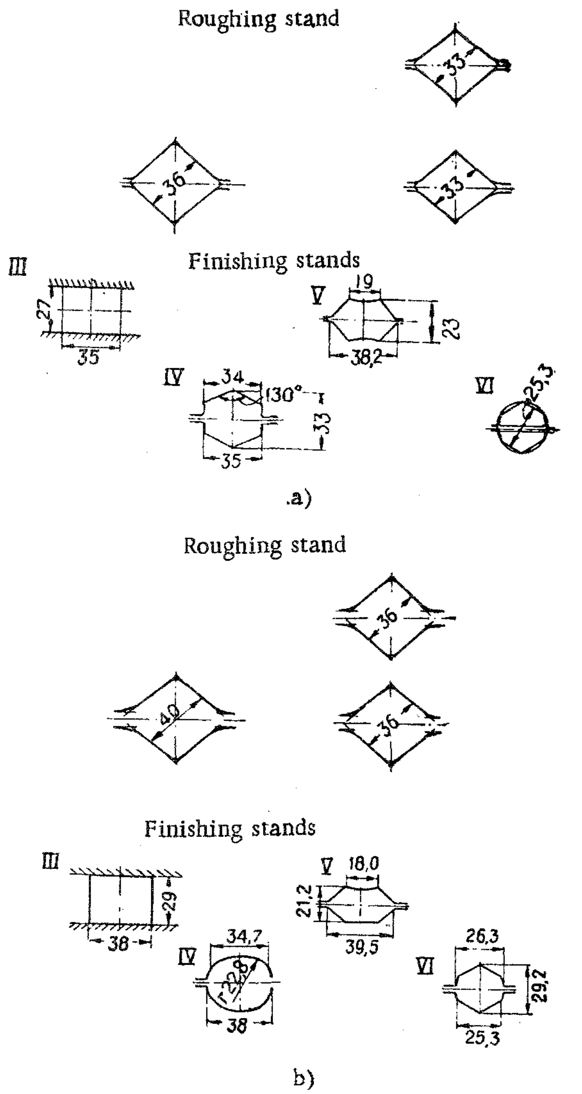

Fig. 2. Setting of rolls for rolling hollow drill-steel: a) improved; b) old; III, IV, etc.) number of stand.

Practice showed that rolling in the finishing pass provided conditions for which the metal of the sheath did not leave the core and the channel was not deflected following reduction in the squeezing and broadening process.

The investigations also showed that in order to obtain a high-quality hollow drill-steel it was necessary to apply more rigid specifications with regard to the preparation of the billet for rolling. The billet had to be straightened before drilling; the deflection of the billet must not exceed 1.0 mm; the center displacement of the hole in the raw billet during drilling must not exceed 0.75 mm.

It is important to provide a hollow drill-steel with a good surface. This is provided by cleaning the billet. In order to obtain a channel with a good quality surface it is necessary to apply a new method for removing the core from the rolled rods. At the present time, in all the Russian factories, the cores are removed by the extraction method. This method is as follows. The cores are drawn out through the rod on chain draw-machines. By reason of the fact that the cross section of the back end of the core is scarcely diminished, on drawing out, along the inner surface of the channel there are formed scratches and score marks and the metal adheres. This all has an injurious effect on the quality of the channel surface, since in the operation of the rods the stresses are concentrated at the faulty locations and fracture occurs.

The method of preliminary stretching is a much more advanced method for removing the core. The core is initially stretched at both ends. By reason of the characteristics of the austenite steel from which the core is made, it diminishes uniformly in cross section along the length during elongation without forming necks. As this proceeds the metal of the core leaves the billet (sheath). After preliminary elongation by 20-30% the core readily leaves the rolled bar. The channel surface is clean and without defects.

In the course of experiment it was established that after preliminary stretching of the core by 25% it can readily be extracted from a bar 15-17 m long, even manually.

Removal of the core by the method of preliminary stretching provides not only an improved quality of the internal channel surface but also an increase in the acceptance level, since spoilage through end-cropping is reduced.