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ANALYSIS OF TECHNOLOGICAL SCHEMES FOR OBTAINING RODS BY FORGING ON RADIAL-CRIMPING MACHINES

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Abstract. *This article discusses the analysis of technological schemes for the production of bars by forging on radial swaging machines that allows you to select the structural material and geometric dimensions of the workpiece and tool and technological parameters, the feed rate of the workpiece, the parameters of the compression cycle of the forging process of refractory metals on radial swaging machines that provide the production of bars good quality, sufficiently high plasticity.*

Keywords: *bar, billet, technological schemes, recrystallization, annealing, drawing.*

Introduction. Molybdenum rods are one of the most common types of molybdenum refractory metal products. In addition to their independent purpose, molybdenum rods can also serve as blanks for the manufacture of wire [1].

The technology for the production of molybdenum bars includes the following operations: ingot melting, its primary pressure treatment, annealing, subsequent deformation operations by various methods and heat treatment depending on the diameter of the final product [1].

Previous studies [6] showed that the primary deformation of molybdenum ingots and its alloys should be carried out by direct pressing, which makes it possible to obtain semi-finished products and products of a rational shape with large reductions in one pass.

Research method. Hot-pressed molybdenum rods of the MChVP and MCh grades with a diameter of 52-65 mm and a length of 350-400 mm, preliminarily annealed at a recrystallization temperature (Totf = 1000-11000C for 1 hour), are used as initial blanks for obtaining bars with a diameter of 12-16 mm. Forging of initial blanks is recommended to be carried out at a heating temperature of 900 ± 500 C, and with a diameter of 25-30 mm at 600 ± 500 C. Before forging at Tn = 600 ± 500 C, the bars should be subjected to recrystallization annealing in a hydrogen environment for 40-60 minutes. A schematic flow diagram for forging molybdenum bars with a diameter of 52-65 mm to bars with a diameter of 12-16 mm on a radial swaging machine (ROMe) is shown in Table 1.

Results of the study and their discussion. The authors proposed a technique and calculated the energy-power and deformation parameters of forging molybdenum blanks on a VV4032Ts radial swaging machine, the equipment of which is currently installed at the Moscow Plant of Refractory Metals and Hard Alloys [2, 3].

The total force P during radial compression is recommended to be determined by the formula:

$$P = q \cdot F \qquad (1)$$

where, $q-$ specific force, $F-$ is the contact area of the striker with the workpiece, and the specific force is q according to the following formula:

$$q = \sigma_s\left(1+\frac{2}{3}\mu\frac{l_0}{d_n}\right) \tag{2}$$

$\sigma_s -$ ultimate strength at compression temperature,

$\mu -$ coefficient of friction,

$l_o -$ length of the deforming part of the striker,

$d_n -$ forging diameter.

When forging with cut-out radius dies, there are two zones of contact areas of the forging with four dies:

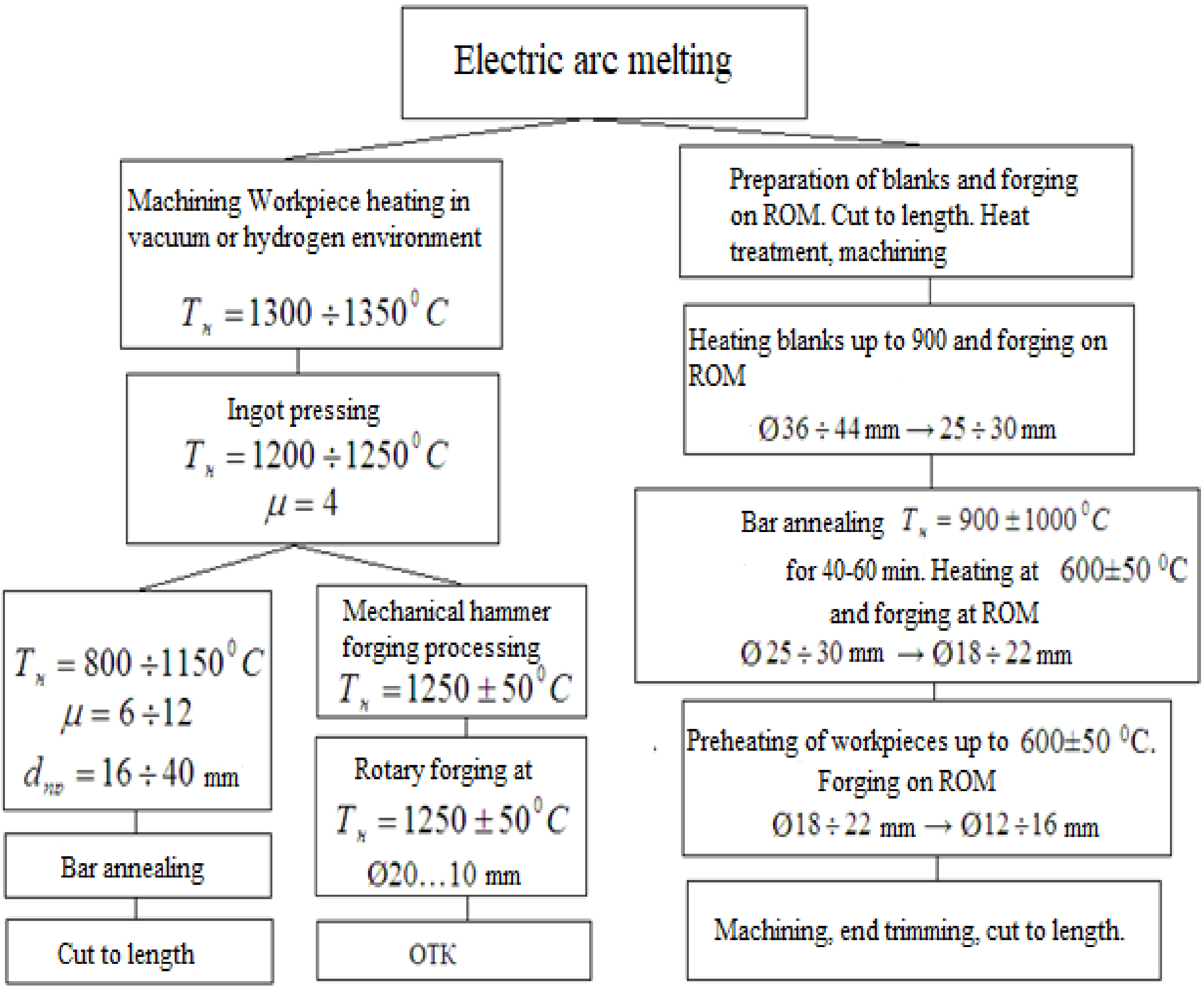
a) for the conical deforming zone of the striker

$$F_o = \frac{1}{4}\left(D_3^2 - d_n^2\right)\frac{\sin\frac{\theta}{2}}{tg\beta} \tag{3}$$

where: angle /coverage/ of the working radius surface of the striker from the workpiece;

Table 1.

Technological scheme for the production of bars from cast molybdenum using the forging process at ROM.



b) for the calibrating cylindrical zone of the striker

$$F_{\kappa} = d_n l_k \sin\frac{\theta}{2} \tag{4}$$

The specific force is determined by:

- for the conical deforming zone of the striker

$$q = \sigma_s\left(1-\frac{2}{3}\mu\frac{D_3-d_n}{2tg\beta}\cdot\frac{\sqrt{2}}{\sqrt{D_3^2-d_n^2}}\right) \tag{5}$$

- for the calibrating cylindrical zone of the striker

$$q_k = \sigma_s\left(1+\frac{2}{3}\mu\frac{l_k}{d_k}\right) \tag{6}$$

The total force during radial compression of molybdenum by four strikers is determined from the expression:

$$P = q_{Д}\cdot F_{Д} + q_K\cdot F_K \tag{7}$$

At the specified heating temperatures of the workpieces (molybdenum at Tn=9000C and Tp=6000C equal to 90-110 kN and single reductions from 30% to 75%, the total force is 1000-1600 kN) [4, 5].

In order to ensure that the specific loads on the strikers do not exceed the limit values (80-85 kN), it is advisable to forge molybdenum bars at 3000C in two passes with hoods, and at a heating temperature of 600 ± 500C - with hoods.

Peredelno admissible feed rate of the workpiece into the strikers is calculated by the formula:

$$V_n = \frac{\pi\cdot n\cdot H\cdot(1-\cos\varphi_0)}{60\cdot(2\pi-\varphi_0)tg\beta} \tag{8}$$

where: n-is the frequency of striker strokes per minute, n=800 rpm

H-value of the full stroke of the striker, mm; H=6mm

$\varphi_0 -$ loading angle of the crankshaft, the limit value of which is 30-40^0, $\varphi_0 = 40^0$.

$\beta -$ the angle of the entry cone of the striker, which is equal to 120.

For forging bars from molybdenum, the feed rate of the workpiece into the strikers should not exceed the following values:

$$V_n = \frac{\pi\cdot n\cdot H\cdot(1-\cos\varphi_0)}{60\cdot(2\pi-\varphi_0)tg\beta} = \frac{3{,}14\cdot 800\cdot 6(1-\cos 40^0)}{60\cdot(2\cdot 3{,}14-40^0)tg12^0} = \frac{15072(1\cdot 0{,}8)}{60\cdot 6{,}2\cdot tg12^0} = \frac{3014{,}4}{74{,}4} = 40{,}52\,{}^{мм}\!/_{c};$$

The working speed of approach of the strikers is determined by the formula:

$$V_c = \frac{\pi\cdot n\cdot H(1-\cos\varphi_0)}{60(2\pi-\varphi_0)} \tag{9}$$

When forging molybdenum, the working speed of approach of the strikers is 8.1 mm/s, and the maximum allowable speeds and for ROM VV4032Ts at and will be equal;

$$V_n = \frac{n\cdot H\cdot(1-\cos\varphi_0)}{60\cdot\left(2-\frac{\varphi_0}{\pi}\right)tg\beta} = \frac{800\cdot 6(1-\cos 40^0)}{60\left(2-\frac{40}{\pi}\right)tg12^0} = \frac{4800\cdot 0{,}2}{60\left(2\cdot\frac{0{,}8}{3{,}14}\right)\cdot 02} = 49{,}52\,{}^{мм}\!/_{c};$$

and

$$V_c = \frac{n \cdot H \cdot (1-\cos\varphi_0)}{60 \cdot \left(2 - \frac{\varphi_0}{\pi}\right)} = \frac{800 \cdot 6(1-\cos 40^0)}{60\left(2 - \frac{40^0}{3{,}14}\right)} = 10{,}53 \,мм/с;$$

the average speed of approach of the strikers must always be less than the average speed of the striker $V_\delta = \frac{n \cdot H}{60}$ because. forging of the workpiece is carried out by the flywheel drive-stroke of the striker, and not by its convergence.

$$V_\delta = \frac{n \cdot H}{60} = \frac{800 \cdot 6}{60} = 80 \,мм/с \qquad V_\delta \rangle V_c$$

The choice of the angular speed of the workpiece.

In the general case, the angular velocity of the workpiece during its processing is determined by the dependence

$$W = \frac{\theta}{t_ц} = \frac{\pi \cdot n_3}{30} \tag{10}$$

$$\text{где } n_3 = \frac{n \cdot \theta}{2\pi} \text{ или } n_3 = C \cdot \Pi \frac{n \cdot \theta}{2\pi}$$

$\theta -$ the angle of coverage by the striker of the workpiece at the end of the stroke, $n_3 -$ the number of revolutions of the workpiece. C is the overlap coefficient of the deformed surface, which is taken equal to 0.1-0.6.

$$\theta \le \frac{360}{Z} = \frac{360}{4} = 90 \qquad \text{C- accepts=0,2.}$$

where: $Z -$ is the number of strikers in the machine. $Z = 4$

$$n_3 = \frac{800 \cdot 90}{2 \cdot 3{,}14} = \frac{72000}{6{,}28} = 11465 \,об/мин.$$

$$W = \frac{\pi \cdot n_3}{30} \cdot C = \frac{3{,}14 \cdot 11465 \cdot 0{,}2}{30} = \frac{7200}{30} = 240 c^{-1}.$$

The number of revolutions of the workpiece when processing in a hot state is taken within the limits nz.g = (0.125 ... 0.05) rpm, nz.g = 0.1x11465 = 1146.5 rpm.

This technology for the production of molybdenum bars and the method for calculating the forging forces, as well as the thermomechanical parameters for forging molybdenum blanks, are accepted for implementation at the Moscow Plant of Refractory Metals and Hard Alloys and will be implemented with the commissioning of the radial crimping machine model VV4032Ts.

Conclusions:

1. A new highly efficient process and thermomechanical forging modes have been developed on a radial swaging machine for producing small-diameter bars from refractory metals, which improves product quality, increases equipment productivity and improves working conditions.

2. A highly efficient technology for the production of rods from molybdenum ingots has been created, which includes hot pressing, high-temperature hydraulic pressing and forging on a radial swaging machine, provides for the production of small-diameter rods with a well-developed structure, improved quality and with an increased (by 15-20%) level of mechanical properties.

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