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EXPERIMENTAL STUDIES OF TECHNOLOGICAL PARAMETERS OF ROLLING OF SAMPLES FROM ALUMINUM ALLOYS DURING ISOTHERMAL DEFORM

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Abstract

The developed method of conducting experimental research covers a wider range of tasks, which was necessary to determine the technological parameters of rolling of aluminum alloy blanks in the conditions of isothermal and approximate deformation. Deformation of the metal in such conditions is characterized by an increase in ductility compared to ductility when machined in a cold tool.

Keywords: hot deformation, rolling of workpieces, aluminum alloys.

Introduction. Deformation of metal in the conditions of isothermal deformation is characterized by increase in plasticity in comparison with plasticity at processing in the cold tool. This is due to the lower rate of deformation, the lower limit of which is limited only by the productivity of the process. As a result, the time of "filling defects" that occur during the deformation of the metal increases, the temperature stress in the volume of the workpiece decreases, the deformation becomes more uniform.

General conditions for conducting experiments to determine the optimal technological parameters of rolling workpieces under conditions of isothermal and approximate deformation are:

1. Brands of aluminum alloys used for experiments: AK6, AK4, AK4 - 1, AK8, AMg1, AMg2, AMg6, AMC with dimensions Ø 14, 18, 20, 25 mm and a length of 150 mm.

2. Use of methods of strain gauge, optical and electron microscopy, X-ray microanalysis, mathematical statistics.

3. At each point of dependence of technological parameters on various factors (heating temperatures of rolling dies t and workpieces t, speed and degree of deformation, there are three samples of the alloy under study, regardless of rolling in smooth rolls or calibers of different systems.

4. Before experimental researches to carry out calibration of the automatic potentiometer of the furnace. Decrease in temperature of a sample at transfer from the furnace to a condition, to compensate it by heating to 10 ° C above temperature of rolling.

5. Determine the coefficient of friction between the workpiece metal and the surface of the rolls in the conditions of experimental work.

6. Determine the optimal speed of the rolls for experiments. [1]

7. The absolute degree of deformation Δh is defined as the difference in height of the sample before and after rolling

$$\Delta h = h_0 - h_1,$$

where h_o - is the initial height of the sample, mm;

h_1 - height of the sample after rolling, mm

8. Expansion Δb is defined as the difference in width of the sample before and after rolling

$$\Delta b = b_1 - b_0$$

where b_0 is the width of the sample before rolling, mm;

b_1 - width of the sample after rolling, mm

9. Advancing S is determined by the formula

$$S = \frac{\ell_1 - \ell_2}{\ell_2} \cdot 100, \%,$$

where ℓ_1 is the distance between the imprints of the cores on the workpiece, mm

ℓ_2 - the distance between the imprints of the cores on the rolls, mm

To measure the distance between the cores, use a large microscope instrumental BMI - 1. The measurement error does not exceed $\pm$0.02 mm.

10. The pressure of the metal on the rolls is determined by the formula

$$P_{om} = 1 - \frac{P_0 - P_1}{P_0},$$

where P_{om} – the relative pressure;

P_0 – metal pressure on rolls having a temperature of 20 ° C, kg / mm^2;

P_1 - metal pressure on rolls having a temperature of 50 - 450 ° C, kg / mm^2.

11. According to the results of experimental studies, graphs of dependences of technological parameters on the degree of deformation, heating temperatures of rolling dies and workpieces, when rolling workpieces in smooth rolls and calibers of different systems:

11.1 Smooth rolls - Δb, S, P = f (ε, $t_в$, $t_з$),

where ε - the degree of deformation%;

$t_в$ - temperature of heating of rolls ° C;

$t_з$ - temperature of heating of preparations ° C.

a) Expansion and advancement of S are studied in:

- ε = 30, 40, 50 %;
- $t_{в}$ = 20, 50, 100, 150, 200, 250, 300, 350, 400, 450 °C;
- $t_{з}$ = 300, 350, 400, 450 °C.

b) The pressure of the metal on the rolls is measured using mesodes in the form of a force-measuring cup with a record of the oscilloscope H - 105 on light-sensitive paper type UV width of 120 mm and investigate when:

- ε = 30, 40, 50 %;
- $t_{в}$ = 20, 50, 100, 150, 200, 250, 300, 350, 400, 450 °C;
- $t_{з}$ = 450 °C.

11.2. Calibers - Δb, S, = f (ε, $t_{в}$, $t_{з}$):

a) Expansion and advancement of round blanks in oval calibers (table 4) to investigate depending on:

- ε = 30, 40, 50 %;
- $t_{в}$ = 20, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500 °C,;
- $t_{з}$ = 470 °C.

According to a similar method, in these calibers to study the expansion of the aluminum alloy D16, reinforced with filamentous SiC crystals.

b) Investigate the expansion and advancement of oval blanks, with the dimensions specified in table. 3.6, 3.7, when rolling in rhombic calibers with angles of 105 °, 110 °, 115 °, height 8.4 and 9.4 mm, depending on:

- ε = 30, 40,50 %;
- $t_{в}$ = 20, 50, 100, 150, 200, 250, 300, 350, 400, 450 °C,;
- $t_{з}$ = 470 °C.

Conduct similar studies to determine the expansion and advance in the systems of calibers: oval-square; oval-circle; rhombus-square; rhombus circle.

12. To carry out comprehensive researches of rolled preparations in the conditions of isothermal deformation and stamped forgings made of them (-macro, - micro, mechanical properties).

13. Determine the coefficients of extraction on the transitions for different systems of calibers.

14. The heating temperature of the rolling dies and workpieces to control the chromel - alumel thermocouple.

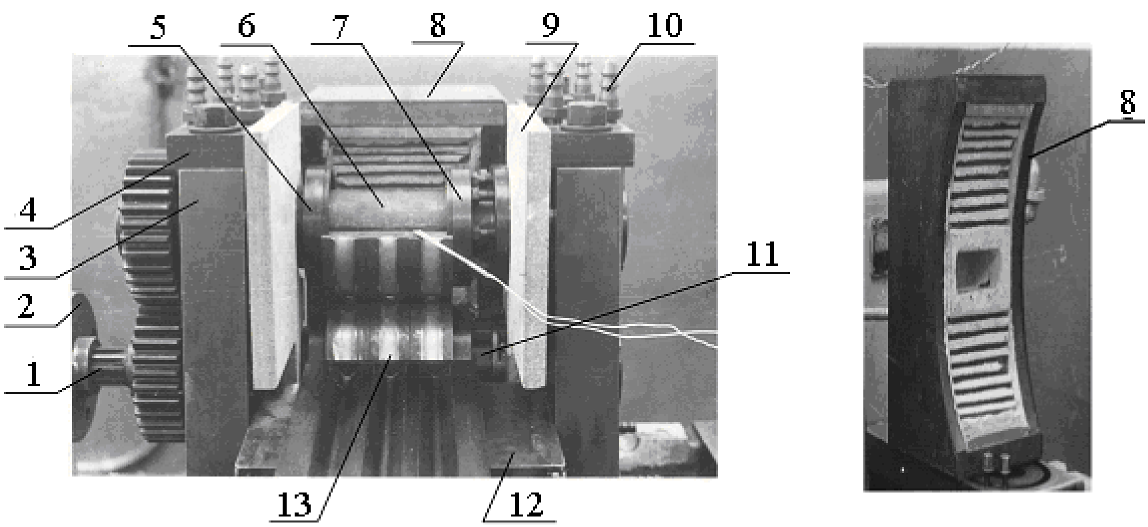
15. Control of the linear sizes of rolled preparations to carry out: a ruler of GOST 427 - 75; caliper, GOST 166 - 73, measurement error ± 0.05 mm; templates radii, GOST 4126 - 82; barbell, GOST 164 - 80, measurement error ± 0.05.

16. Develop mathematical models and obtain formulas for determining the expansion and advancement in the rolling of billets of aluminum alloys in the calibers of different systems under conditions of isothermal and approximate deformation.

17. Based on the analysis of experimental research to determine the optimal technological parameters of rolling billets of aluminum alloys at variable temperatures, speeds, degrees of deformation and development of the technological process, develop technological recommendations for calculating calibers and specifications for industrial equipment for rolling billets in isothermal conditions. and approximate deformation, which allows you to work in a wide range of variable parameters, including work with traditional rolling (without heating the rolling dies).

Installation for rolling of blanks in the conditions of isothermal and close to it deformation

To determine the technological parameters and thermomechanical characteristics during rolling of workpieces in the conditions of isothermal and approximate deformation, an experimental installation was developed and manufactured, Fig.1. In order to ensure the rigidity of the rolls and maintain a constant center-to-center distance during deformation, the installation is made on the type of two-support forging rollers. To maintain the temperature of the workpiece and heat the working tool (rolling dies mounted directly on the rollers), the installation is equipped with a heating device mounted on the back.



a *b*

Fig. 1. Installation for rolling in isothermal conditions deformation (a); fragment of the furnace (b).

To avoid jamming due to heating of the bearing units of the work rolls, the outer steam housings are made with holes - channels to ensure the circulation of running water. The drive of installation allows to regulate frequency of rotation of rolls that provides removal of characteristics at various speed modes.

Technical characteristics of the installation are given below:

Nominal force, kN |	20
Wheelbase of rolls, mm	160
Frequency of rotation of rolls, min^{-1}	12 – 60
Diameter of the initial workpiece, mm	30
Seat dimensions, mm:	
diameter	80
length	135
Drive power, kW	7
The heating temperature of the deformer tool ° C	up to 500
Type of heating device	Electrical resistance
Voltage, V	220
Heater power, kW	4
The diameter of the wire (nichrome) is	0,6

Installation for rolling workpieces in the conditions of isothermal and approximate deformation (Fig. 1, a) consists of a welded housing 3, which includes a base and two vertical struts. The uprights have grooves for the installation of four sliding bearing housings, which are fastened with tie rods 4. In the bearings, as in the supports, rotate the upper 6 and lower drive 11 rollers. The latter through the splined connection 1 of the clutch 2 is connected to the drive, and through the gear (with a ratio of 1: 1) with the upper roller, which ensures their synchronous rotation. The wheelbase of the rolls is adjustable in the range of 0.5 - 2.0 mm with the help of calibrated gaskets. On the rolls between the fixed 5 and movable 7 washers fixed rolling dies 13. To insert the workpiece into the working area of the rolling dies strictly along the axis of the stream and its edge at 90 ° at transitions from stream to stream in the front part of the installation is provided with wiring 12 the housing of the installation is fixed to the heating device 8, which serves to heat and maintain the required surface temperatures of the rolling dies and workpieces. In addition, the heating device has a working chamber in which to maintain the temperature of the heated workpiece during its deformation in the rolling dies, there is always a rolled workpiece.

The heating device 8 is an electric resistance furnace with lining of the heating zone, a working tool that repeats the contour, regardless of the shape of the streams. The heating device is powered by an AC mains voltage of 220 V through a transformer RNO - 250 - 10. Heating of bearing housings is prevented by asbestos-cement plates 9. Fittings 10 are used to supply and drain cooling water. Control, regulation and registration of temperature of heating of preparation and rolling dies is provided by the recorder KSP - 4.

For introduction of preparations in calibers of rolling dies and edging at transitions from stream to stream, the installation has conducting. The workpieces are fed into the calibers with pliers, provided with a design of wiring that copies the relief, and which allows you to overturn the workpiece at 90 ° when moving from stream to stream.

Analysis of the results of experimental work to determine the optimal technological parameters, thermomechanical characteristics of rolling billets of aluminum alloys in isothermal and near-deformation, at variable temperatures, velocities and degrees of deformation, will be the basis for developing technical specifications for industrial design.

Expansion and pressure of metal on rolls when rolling blanks of round section in smooth rolls

In the process of rolling, along with the reduction of the workpiece height and its elongation (drawing), the metal moves and in the transverse direction - expansion Δb „ which causes significant tensile stress in the side edges of the rolled workpiece and reduces the overall drawing.

To determine the values of expansion in the rolling of billets of aluminum alloys by traditional technology (without heating the rolling dies), Ph.D. S.O. Scriabin conducted research to determine its dependence on the degree of deformation (compression), diameter of rolls, temperature of the workpiece, etc., which are recommended to be taken into account when rolling workpieces in smooth rolls and conditions of isothermal deformation. [2]

Thus, based on the analysis of experimental data presented in Fig. 2, 3, we can conclude that with increasing degree of deformation, other things being equal, the rate of expansion and relative expansion increases. As the diameter of the rod decreases, the values of the expansion index and the relative expansion increase. The decrease in the values of expansion with increasing diameter of the workpieces can be explained by the increase of friction forces in the transverse direction, as the ratio of the width of the deformation center to its length increases.

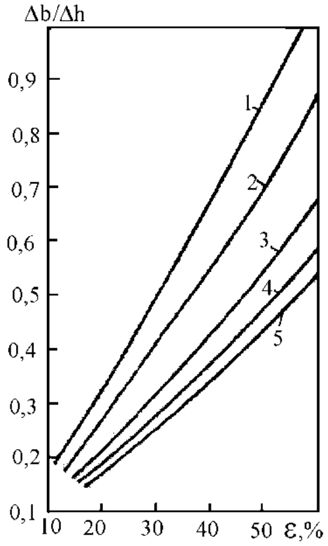


Fig. 2 Dependence of the indicator expansion Δb / Δh from the degree of compression when rolling workpieces of different diameters in smooth rolls: mm;
1- Ø20mm; 2- Ø30 mm; 3 - Ø50 mm;
4 - Ø60mm; 5 - Ø65 mm

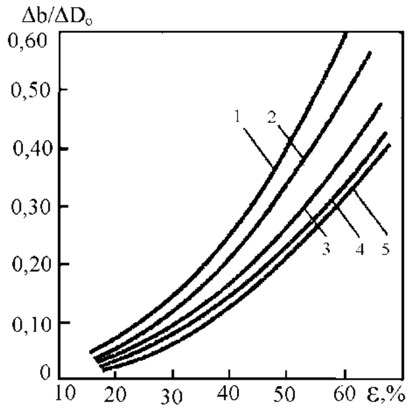


Fig. 3 Dependence of relative expansion $\Delta b / D_0$ *on the degree of compression when rolling workpieces of different diameters in smooth rolls: mm;*
1 - Ø 20 mm; 2 - Ø 30 mm; 3 - 50 mm;
4 - Ø 60 mm; 5 - Ø 65 mm

The influence of the diameter of the rolls on the expansion is presented in Fig. 4, which shows that the expansion increases with increasing diameter of the rolls. This is explained by the fact that with increasing diameter of the rolls, other things being equal, the length of the deformation center increases and, as a consequence, the friction forces on the contact surfaces directed to the neutral section increase.

As a result, the resistance to movement of the metal along the axis of the workpiece increases and increases the expansion.

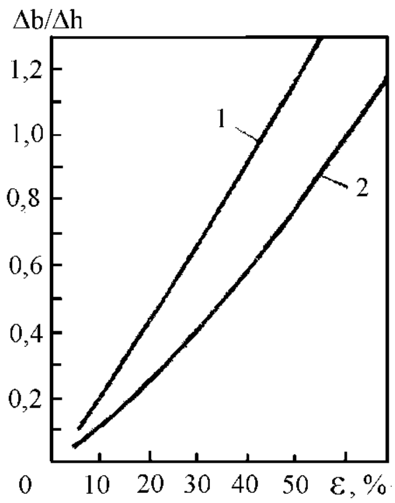


Fig. 4
The influence of the diameter of the rolls on the rate of expansion Δb / Δh when rolling workpieces in smooth rolls:
1- diameter of rolls 260 mm, frequency of rotation of rolls 26 min^{-1};
2 - diameter of rolls 103 mm, frequency of rotation of rolls 37 min^{-1};

The dependence of the expansion on the width of the strip, the diameter of the rolls and the ratio of the initial width of the contact surface to its length during rolling with constant compression ε = 38.5% is shown in Fig. 5.

The curves were constructed according to experimental data obtained in the process of rolling samples of AK6 alloy (height 22 mm, width 5, 10, 22, 30, 40 and 50 mm) in smooth steel rolls with diameters of 260 and 103 mm and speed of 26 and 37 min-1, respectively. From the analysis of fig. 5 shows that with increasing width of the workpiece, the expansion rate increases to a certain value (has a maximum) and with further increase in the width of the workpiece begins to decrease. This is characteristic of the expansion and is explained by the fact that the transverse forces of friction on the contact surfaces with increasing width of the workpiece are increasingly restraining it. Therefore, the nature of the dependence of the expansion index on the width of the workpiece to the right of the maximum point is determined mainly by the contact forces of friction. [4]

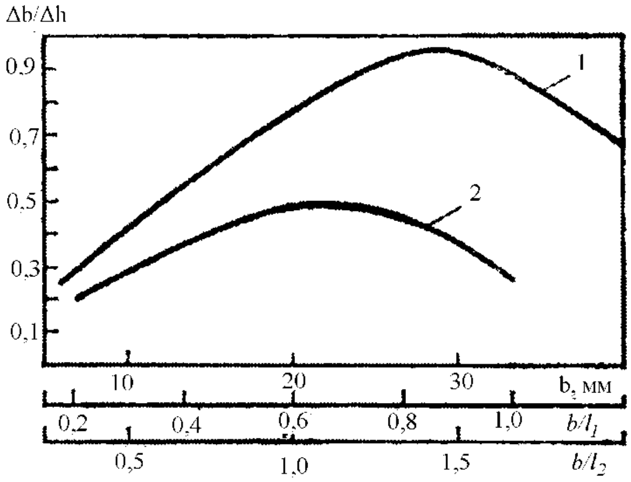


Fig. 5 Dependence of the expansion rate on the width of the strip, the diameter of the rolls and the ratio of the initial width of the contact surface to its length b / l_1 and b / l_2 when rolling workpieces in smooth rolls:
1 - diameter of rolls 260 mm, frequency of rotation of rolls 26 min^{-1};
2 - diameter of rolls 103 mm, frequency of rotation of rolls 37 min^{-1}

At flat deformation, the value of the linear expansion b at the point of maximum stabilizes fairly quickly and remains constant with a further increase in width.

The dependence of the relative expansion on the degree of compression during rolling of workpieces of different diameters of AK6 alloy is presented in Fig. 6 Rolling of workpieces was performed at a temperature of 450 ° C on forging rollers model C162A in smooth rolling dies with a profile that provides increasing compression. [5]

The effect of temperature of rolled workpieces on the expansion is shown in Fig.7. The dependence is based on the results of experimental data obtained during the rolling of blanks made of AK6 alloy with a size of 20x30x250 mm in smooth rolls with a diameter of 103 mm and a speed of 37 min-1. Rolling was performed with a constant degree of compression ε = 58.5% at different temperatures.

The following graphs, based on experimental data on the influence of various factors on the expansion of traditional rolling, will help to take them into account when developing the technological process of rolling workpieces in smooth rolls and calculating calibers in isothermal deformation.

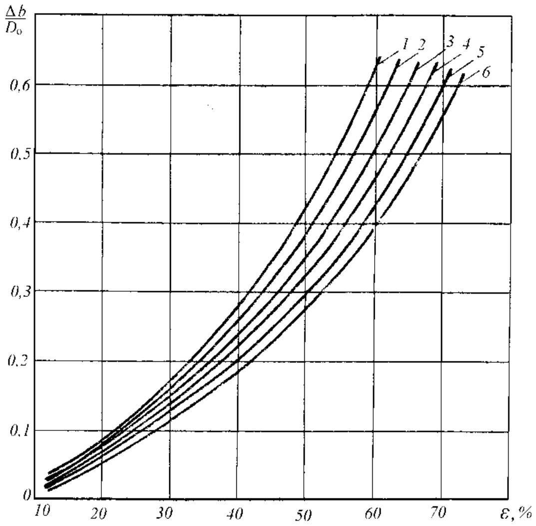


Fig. 6 Dependence of relative expansion on the degree of compression when rolling workpieces of different diameters in smooth rolls:
1 - Ø25mm; 2 - Ø30 mm; 3 - Ø35 mm; 4 - Ø40mm; 5 - Ø45 mm; 6 - Ø50mm.

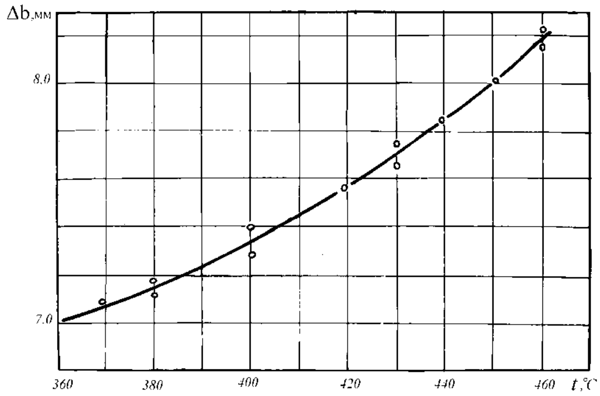


Fig. 7 Dependence of expansion on the heating temperature of the workpieces during rolling in smooth rolls

The literature describes several theories of the development of expansion and gives numerous formulas for calculating the expansion of the strip with a rectangular cross section in smooth rolls on the results obtained by rolling steel billets.

When studying expansion, researchers set the task of determining the largest number of factors influencing expansion. For example, AI Tselikov notes four main stages in the development of the theory of expansion:

- expansion proportional to linear compression (L. Zheza's formula);

- expansion is proportional not only to the compression, but also to the length of the arc of capture (formulas of SN Petrov and E. Siebel);

- expansion is proportional not to the entire length of the arc of capture, but only to the zone of advance (formulas of BP Bakhtinov and SI Gubkin);

- expansion depends on the length of the advance zone, the logarithm of the deformation, the width and tension of the strip (formulas of AI Tselikov and AI Grishkov).

It should be noted that knowledge of the peculiarities of the shape change of aluminum alloys and the exact method for calculating the expansion would allow to develop such compression schemes when rolling blanks, which would allow to vary the width of the workpiece within wide limits.

After rolling blanks of aluminum alloys, the values of the obtained expansion differ significantly from the calculated ones according to the formulas given in the literature.

The purpose of these experiments is to, based on the results, based on already known, to choose a formula that would give values close to experimental. In this paper, we used the formulas of the last two stages of development of the theory of calculation of expansion, because these formulas take into account the largest number of factors influencing the expansion. Analysis of the nature of changes in the calculated and experimental dependences showed that the curve calculated according to the formula of AI Tselikov (1) equidistantly repeats the experimental one. Therefore, AI Tselikov's formula was taken as a basis for developing a mathematical model of the studied dependence and presented in the form (2).

$$\frac{\Delta b}{\Delta h} = C_{\text{вн}}\left(2\sqrt{\frac{R}{\Delta h}} - \frac{1}{f}\right)\left[0,138\left(\frac{\Delta h}{h_0}\right)^2 + 0,323\frac{\Delta h}{h_0}\right], \qquad (1)$$

where $C_{\text{вн}} = 1,34\left(\frac{b_o}{\sqrt{R\Delta h}} - 0,15\right)\ell^{0,15-\frac{b_o}{\sqrt{R\Delta h}}}$;

ℓ - довжина осередку|осередку| деформації.

$$\frac{\frac{\Delta b}{\Delta h}}{C_{вн}\left(2\sqrt{\frac{R}{\Delta h}} - \frac{1}{f}\right)} = a_1\left(\frac{\Delta h}{h_0}\right)^2 + a_2\left(\frac{\Delta h}{h_0}\right) + a_3. \qquad (2)$$

Processing of experimental data by the method of least squares with averaged coefficients a_i|,gave the following results: a_1 = 5,64, a_2 = 3,31; a_3 = 0,7.| The general equation for determining the expansion during rolling of billets of aluminum alloys is as follows.

$$\Delta b/\Delta h = C_{вн}\sqrt{R/\Delta h} - 1/f\left[5,64\left(\Delta h/h_0\right)^2 - 3,31\left(\Delta h/h\right) + 0,7\right] \qquad (3)$$

where $C_{вн} = 1,34\left(\frac{b_0}{\sqrt{R\Delta h}} - 0,15\right)\ell^{0,15-\frac{b_o}{\sqrt{R\Delta h}}}$.

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After performing a test calculation according to formula (3), it was found that the discrepancy between the calculated and experimental values of relative expansion depending on the compression for workpieces, round section of aluminum alloy AK6 with diameters 20 - 40mm does not exceed 4%. The error of measurement and calculation of expansion after rolling of billets of aluminum alloys AK4, AK4 - 1, AK8, AMg1, AMg2, AMg6, AMC did not exceed 4%, so formula (3.3) is recommended to use to determine the expansion of rolling blanks of aluminum alloys in aluminum alloys .

To determine the influence of the degree of deformation, heating temperatures of rolling dies on the expansion and pressure of metal on felting, blanks of aluminum alloys AK6, AK4, AK4 - 1, AK8, AMg1, AMg2, AMg6, AMC with dimensions Ø14, 18, 20, 25x1m temperature of 450 ° C was rolled in smooth felting with degrees of deformation of 30, 40 and 50%. Rolling dies were heated sequentially to temperatures of 20, 50, 100, 150, 200, 250, 300, 350, 400, 450 ° C, at which the experiments were performed. The temperature was measured with a chromel-alumel thermocouple and regulated using a KSP recorder. The rotation frequency of the rolls was 12 min^{-1}. Methods of strain gauge, optical and electron microscopy, X-ray microanalysis, and mathematical statistics were used in experimental studies.

Table 1

The value of the expansion $\triangle b$ relative to the initial cross section of the workpiece depending on the degree of deformation ε and the heating temperature of the rolling dies t_v

	Temperature, t_v		
	20°C	250°C	450°C
	ε = 30%		
Expansion Δb	2,856	2,086	1,708
	ε = 40%		
	4,2	3,64	3,3
	ε = 50%		
	5,88	5,2	4,65

Analysis of experimental data is presented in table. 1 and in fig. 8, obtained by rolling workpieces with dimensions Ø14x150 mm shows that the expansion relative to the initial cross section of the workpiece when rolling in dies having a temperature of 20 ° C and degrees of deformation 30, 40 and 50% increases by 20.4, 30 and 42% . This is explained by the fact that with increasing degree of deformation, the volume of the metal in width and, consequently, expansion, other things being equal, increases.

The nature of the behavior of the dependences of the expansion on the heating temperature of the rolling dies in the range of 20 - 250 ° C (Fig. 8) can be explained as follows. At a stamp temperature of 20 ° C and degrees of deformation of 30, 40, 50%, the contact area of contact of metal with rolling dies is small, considering hire of round preparation of Ø14 mm. In this case, the axial compressive stresses directed along the deformation center are insignificant in comparison with the compressive stresses acting in the transverse direction, so there is an increase in expansion. The decrease in expansion with increasing heating temperature of the rolling dies is due to the flow of softening processes and increase the ductility of the treated metal.

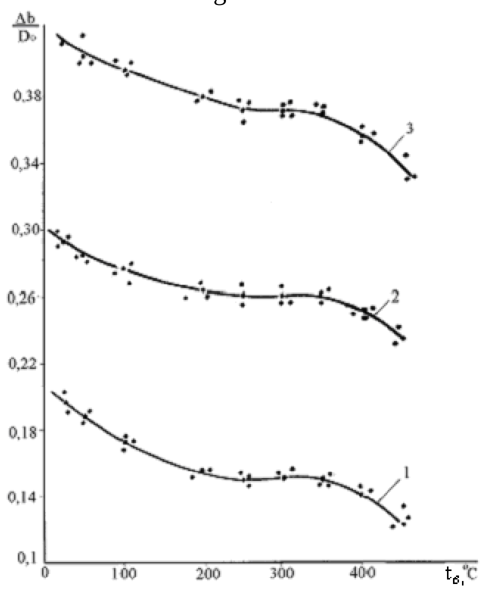


Fig. 8. Dependence of expansion on the degree of deformation and heating temperature of rolling dies (degree of deformation: 1-30%; 2-40%; 3-50%; heating temperature of workpieces 450 ° C)

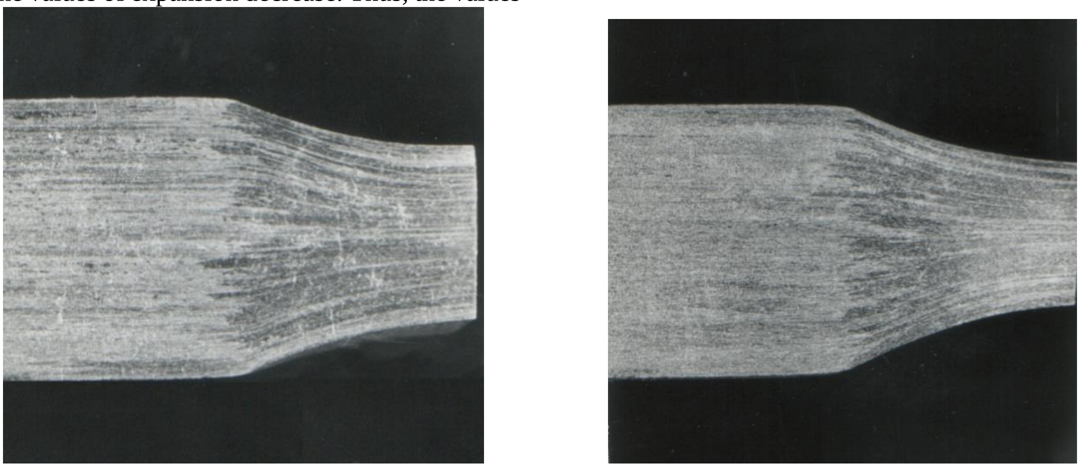
In the range of heating temperatures of rolling dies 250–350 ° C at a constant degree of deformation, the expansion practically does not change, and the change of degrees of deformation changes the absolute values of expansion by 15, 26, 37% relative to the initial cross section of deformed workpieces 30, 40 and 50%. This is due to the equality of the axial compressive stress directed along and across the center of deformation, as well as the equality of the displaced volumes in these directions.

With increasing temperature of heating of rolling dies to 450 ° C and rolling of workpieces with degrees of deformation of 30, 40 and 50%, the value of expansion relative to the initial cross section of the workpiece decreases and is 12,2, 23,6, 33%, respectively. The reduction of expansion is due to the increase of the axial compressive stress directed along the center of deformation, the fuller course of the softening processes, the absence of zones of difficult deformation. [6].

The analysis of the change in expansion showed that with increasing heating temperature of the rolling dies, the values of expansion decrease. Thus, the values of expansion obtained at the heating temperature of the rolling dies to t_v = 250 and 450 ° C at a deformation of ε = 30% decrease relative to the expansion obtained by rolling blanks in rolling dies having a temperature of 20 ° C at 37 and 67,2 %. The reduction in expansion at t_v = 450 ° C relative to t_v = 250 ° C is 22%.

Similarly, the analysis of changes in the values of expansion during rolling of workpieces at degrees of deformation of 40, 50% and other equal conditions showed that the expansion decreases by 15,4 and 27,3% (ε = 40%), 13 and 26, 45% (50%)). The decrease in expansion at t_v = 450 ° C relative to t_v = 250 ° C is 10,3% (ε = 40%), 11,8% (ε = 50%).

From the analysis of fig. 8 shows that changing the degree of deformation from 30 to 50% increases the value of expansion, without changing the nature of their dependence on the heating temperature of the rolling dies. It was noted above that with increasing degree of deformation, the volume of the metal in width and, consequently, expansion, other things being equal, increases.



a b

Fig. 9. Macrostructure of longitudinal sections of rolled workpieces in smooth rolls. Alloy AK6, Ø14x150mm. The temperature of the workpieces and rolling dies 470 ° C:
a - the degree of deformation of 40%; b - degree of deformation 50%

In fig. 9 shows the macrostructure of the longitudinal section of rolled blanks of alloy AK6 in smooth rolling dies for one transition at a temperature of billets and rolling dies of 470 ° C, degrees of deformation of 40 and 50%. Conducted comprehensive studies (-macro, - micro, mechanical properties) of the quality of rolled workpieces, under conditions of isothermal deformation and close to it, met the requirements of technical documentation.

From the analysis of table. 2 and fig. 10 shows that when rolling workpieces with dimensions Ø14x150 mm, having a temperature of 450 ° C, the relative pressure of the metal on the rolls $P_{om} = 1 - \frac{P_0 - P_1}{P_0}$ decreases with increasing heating temperature of the rolling dies, and, most intensively with increasing degree of deformation.

Thus, with increasing heating temperature of rolling dies to 250, 350 and 450 °C, the pressure on the rolls decreases compared to the pressure values during deformation of the workpieces in rolling dies having a temperature of 20 °C and strain levels of 30, 40, 50%, respectively. : 250°C – 62,45 %, 54 %, 45 %; 350°C – 55,8 %, 47,5 %, 38,73 %; 450 °C - 53,3%, 46,5 %, 38,2 %.

In the range of heating temperatures of rolling dies 350–450 ° C the metal pressure on the rolls at different degrees of deformation changes slightly, and when the rolling dies reach temperatures of 400 ° C and above almost stabilizes, and increasing the degree of deformation affects only the absolute values of relative pressure P_{om}, fig.10.

Table 2

The value of the relative pressure of the mouth depending on the temperature heating of rolling dies t_v and the degree of deformation ε

№	ε = 30%		ε = 40%		ε = 50%	
	t_v,°C	P_{om}	t_v,°C	P_{om}	t_v,°C	P_{om}
1	20	0,4	20	0,5083	20	0,6664
2	250	0,2498	250	0,2747	250	0,3
3	300	0,2365	300	0,2498	300	0,2664
4	350	0,2232	350	0,2415	350	0,2581
5	400	0,2166	400	0,2365	400	0,2548
6	450	0,2133	450	0,2365	450	0,2548

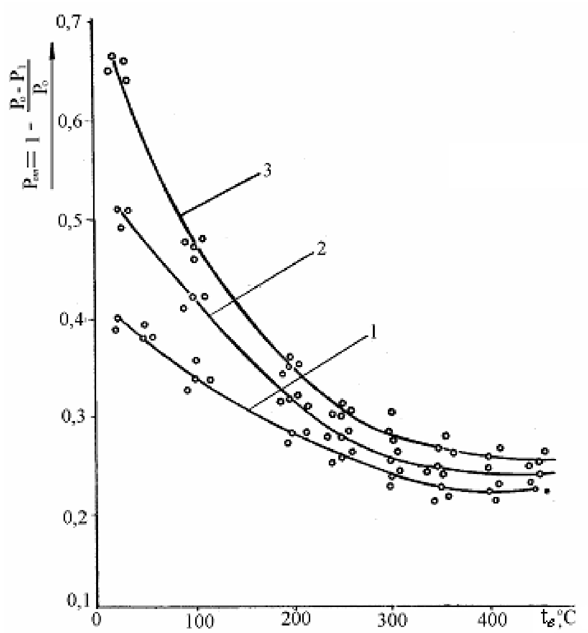


Fig. 10 Dependence
the relative pressure of the metal on the felting from the heating temperature of the rolling dies and the degree of deformation: 1 - 30%; 2 - 40%; 3 - 50%.
The heating temperature of the workpieces is 450 ° C

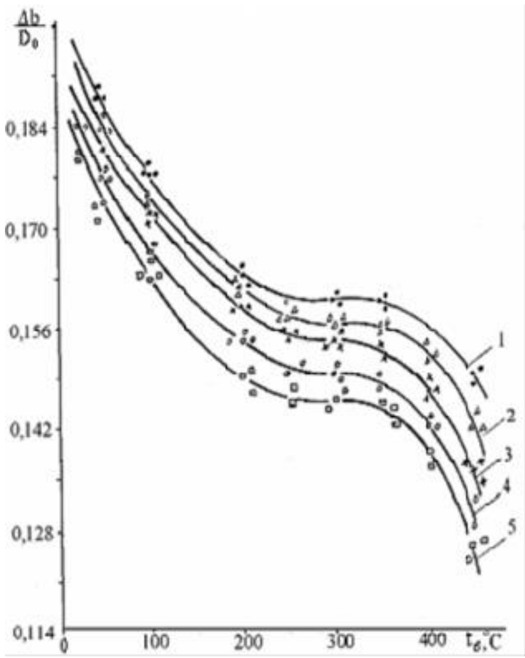


Fig. 11 Dependence of expansion on the heating temperature of the workpieces and rolling dies at a degree of deformation of 30% (heating temperature of the workpieces:
1-300 ° C; 2-350 ° C; 3 - 400 ° C; 4- 450 ° C; 5 - 470 ° C)

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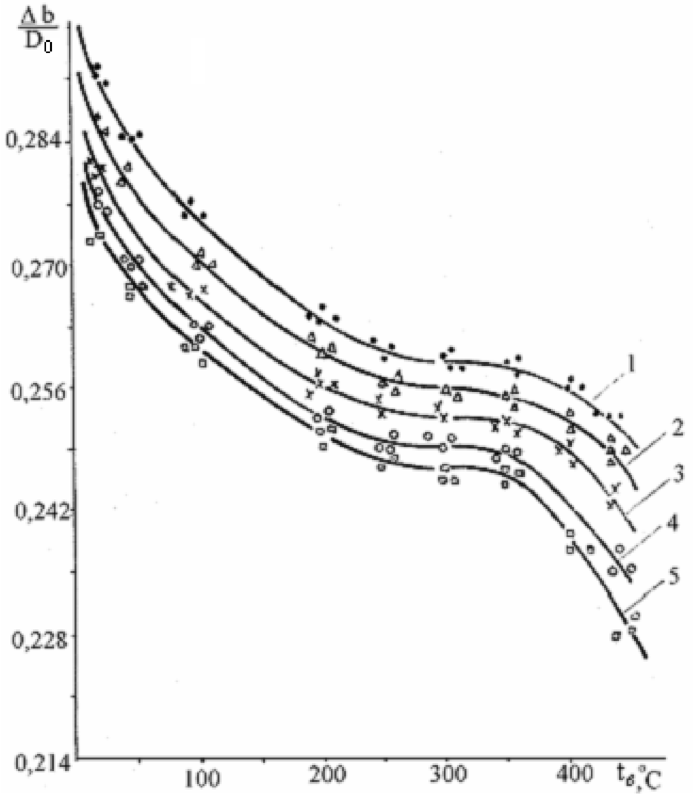

Fig. 12. Dependence of expansion on temperature of heating of preparations and rolling dies at degree of deformation of 40% (temperature of heating of preparations: 1 - 300 ° C; 2 - 350 ° C; 3 - 400 ° C; 4 - 450 ° C; 5 - 470 ° C)

Analysis of experimental data presented in Fig. 10 shows that when rolling workpieces on forging rollers, under conditions of isothermal deformation and close to them, the metal pressure on the rolls decreases with increasing heating temperature of rolling dies most intensely in the temperature range 20–350 ° C. Further heating of the rolling dies does not lead to a significant reduction in pressure and is impractical because it leads to additional energy consumption. In addition, there is the appearance of scale on the surface of the rolling dies.

In another series of experiments, blanks of the above alloys with dimensions Ø14, 18, 20, 25 x 150 mm, heated in a chamber furnace electrical resistance to temperatures of 300, 350, 400, 450, 470 $^{+10}$ ° C were rolled in smooth rolling dies, which were heated consistently to temperatures of 20, 50, 100, 150, 200, 250, 300, 350, 400, 470 ° C. Rolling of workpieces was carried out with degrees of deformation of 30 and 40%. The results of experimental data are presented in fig. 11, 12.

Analysis of experimental data presented in fig. 11, 12 shows that with increasing heating temperature of the workpieces and rolling dies, the expansion decreases due to the course of softening processes. In addition, it should be noted that in the range of heating temperatures of rolling dies 250 - 350 ° C, expansion at a constant degree of deformation (similar to that shown in fig. 8) is practically unchanged, and changing the degree of deformation leads to changes in its absolute values.

Advances in rolling blanks of round cross section in smooth rolls

Anticipation is a speed characteristic of the rolling process. One of the reasons for the advance is the addition of the speed of movement of the metal from the neutral section towards the exit of the rolls when compressed with the translational speed of the entire strip. Another is the presence of zones of difficult deformation or zones of hardening during hot rolling at the contact surfaces. These zones seem to increase the diameter of the rolls, telling the deeper layers of the rolled metal the speed of movement is greater than the circumferential speed of the rolls. Third, near the plane of exit of the metal from the rolls, in the absence of significant development of expansion, the speed of movement of elementary parts of the metal along the axis of rolling increases, while the circumferential speed of the rolls remains constant.

When calculating the length of the deformed section has a variable cross-section along the axis, the accuracy of determining the lead is extremely necessary, because in addition to determining the size of cross-sections you need to calculate the length of its individual sections. In case of incorrect determination of the lead, the length of the workpiece after rolling in the previous section may be more or less estimated and does not correspond to the length of the subsequent section, which may lead to a lack of rolled workpiece.

To determine the values of advance in the rolling of workpieces by traditional technology, Ph.D. Sokryabin conducted research to determine its dependence on the degree of deformation, temperature, width and final height of the workpiece. [2]

Thus, based on the analysis of experimental data presented in fig.13 shows that with increasing degree of deformation the lead increases, and with increasing rolling temperature it decreases. The increase in the values of advance with increasing degree of deformation under these rolling conditions is explained by the fact that with increasing deformation increases the volume of metal shifted in the direction of rolling in the zone of advance, resulting in increasing advance. The decrease in the advance with increasing rolling temperature is associated with a decrease in the coefficient of friction during rolling in this temperature range, which is easy to see if we turn to the known formulas of advance Pavlov, Fink, Ekelund, Dresden-Golovin. From these formulas it follows that the lead increases with increasing neutral angle, diameter of the rolls and decreasing the height of the strip. [7]

In fig. 14 presents a graph obtained from the results of rolling samples of AK6 alloy of different widths and the same degree of deformation (19,5%). From the graph data it is seen that the advance with increasing width increases first rectilinearly to B / H = 3,7 and B / H = 4,3 (B and H - width and height of the sample before rolling), respectively, and then the intensity of its growth begins decrease and the dependence becomes curvilinear. This change in the intensity of advance growth can be explained by a gradual decrease in expansion, which reduces the advance with increasing bandwidth and its practical stabilization at B / H > 5. This relationship is a consequence of the constant volume during rolling.

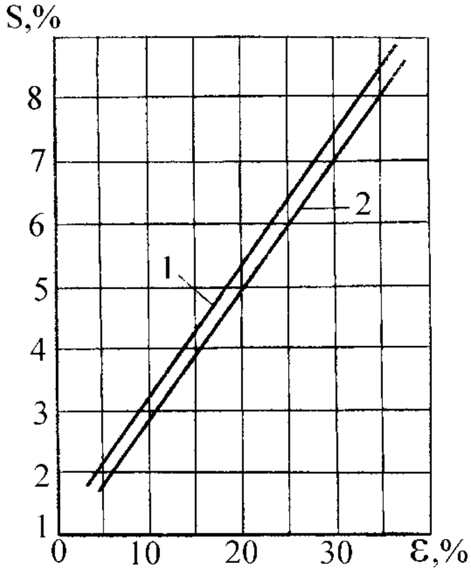

Fig. 13. Dependence of advance on the degree of compression and rolling temperature of the workpieces in smooth rolls: 1 - 350 ° C; 450 ° C

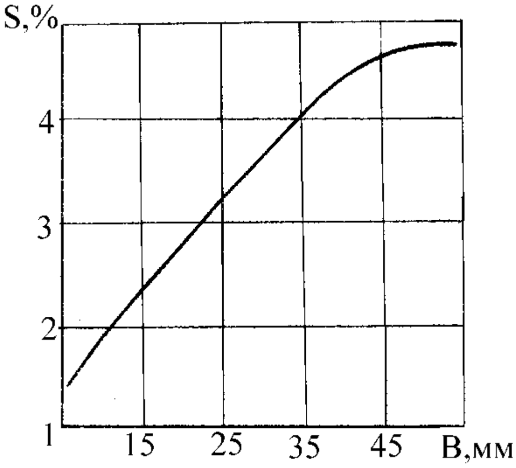

Fig. 14. Dependence of advance on the width of the workpiece.

The degree of deformation is 19.5%.

The analysis of the presented data (fig. 15) shows that with increasing the height of the rolled workpiece at the same degree of deformation, the value of the advance decreases due to the decrease in the displaced length of the workpiece volume relative to the total volume in the advance zone.

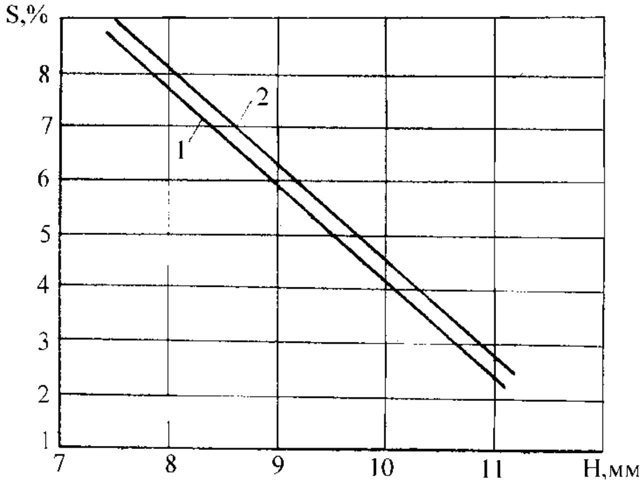

Fig. 15 Dependence of advance on the final height of the workpiece at rolling temperatures: 1 - 350; 2 - 450 ° C.

To determine the effect of the degree of deformation, heating temperatures of workpieces and rolling dies on the lead, workpieces of aluminum alloys AK6, AK4, AK; - 1, AK8, AMg1, AMg2, AMg6, AMC with dimensions Ø 14, 18, 20, 25 x 150 mm heated to 450 ° C were rolled in smooth rolls with degrees of deformation of 30, 40 and 50%. Rolling dies were heated sequentially to a temperature of 20, 50, 100, 150, 200, 250, 300, 350, 400, 450 ° C. The temperature was measured with a chromel-alumel thermocouple and regulated using a recorder KSP. The rotation frequency of the rolls was 12 min-1.

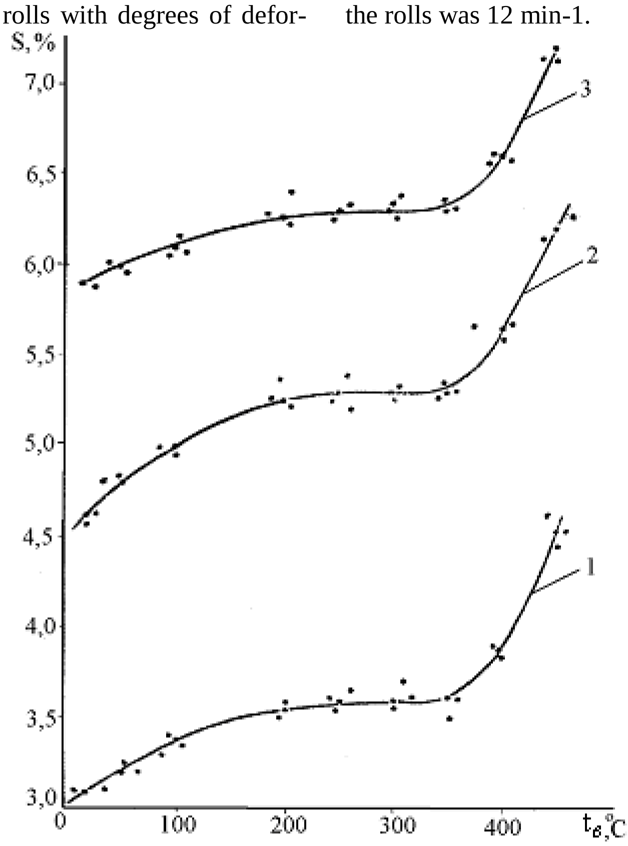

Fig. 16. Dependence of advance on the degree of deformation and heating temperature of rolling dies (degree of deformation: 1 - 30%; 2 - 40%; 3 - 50%; the heating temperature of the workpieces 450 ° C).

Table 3

The value of the advance S depending on the degree of deformation ε and the heating temperature of the rolling dies t_v

	Temperature, t_v		
	20°C	250°C	450°C
	ε = 30%		
Advance S,%	3,1	3,54	4,55
	ε = 40%		
	4,55	5,3	6,2
	ε = 50%		
	5,59	6,29	7,2

In fig. 16 shows the dependences of the change in advance on the degree of deformation and heating temperature of the dies during rolling of blanks made of AK6 alloy with dimensions Ø 14 x 150 mm. Analysis of experimental data presented in table 3 and Fig.16 shows that with increasing heating temperature of rolling dies to 250 ° C, the values of advance increase compared to the values of advance in deformation in rolling dies having a temperature of 20 ° C by 14, 2; 16.48 and 12.52% with degrees of deformation of 30, 40 and 50%, respectively.

The increase in advance with increasing heating temperature of the rolling dies is due to the reduction of the coefficient of friction, increasing the ductility of the treated metal and the flow of softening processes.

In the range of heating temperatures of rolling dies 220–350 ° C and constant degree of deformation, the advance is practically unchanged, and the change of degrees of deformation changes the absolute values of advance. Thus, increasing the degree of deformation to 40% leads to an increase in lead relative to 30% by 49,7%. Increasing the degree of deformation to 50% leads to an increase in lead relative to 30% by 77.68% and relative to 40% by 18.68%.

The behavior of advance dependences on the degree of deformation and heating temperatures of rolling dies in the range of 220–350 ° C is explained by the achievement of equality of axial compressive stresses directed along and across the deformation center, as well as equality of displaced metal volumes in these directions.

A further increase in the heating temperature of the rolling dies to 450 ° C leads to an increase in the values of the advance in comparison with the values of the advance in deformation in the rolling dies of those having: a temperature of 20°C by 46,8; 36,26 and 28,8%, temperature 250°C at 28,53; 17 and 14,47%, respectively, at degrees of deformation of 30, 40 and 50%.

Changing the degree of deformation from 30 to 50% increases the value of the lead, without changing the nature of their dependence on the heating temperature of the rolling dies.In another series of experiments, blanks of the above aluminum alloys with dimensions Ø14, 18, 20, 25x150 mm, heated in a chamber furnace electrical resistance to temperatures of 300, 350, 400, 450, 470 +10°C were rolled in smooth rolling dies, which were heated consistently to temperatures of 20, 50, 100, 150, 200, 250, 300, 350, 400, 470 ° C. Rolling was performed with degrees of deformation of 30 and 40%. The results of experimental data are presented in fig. 17, 18.

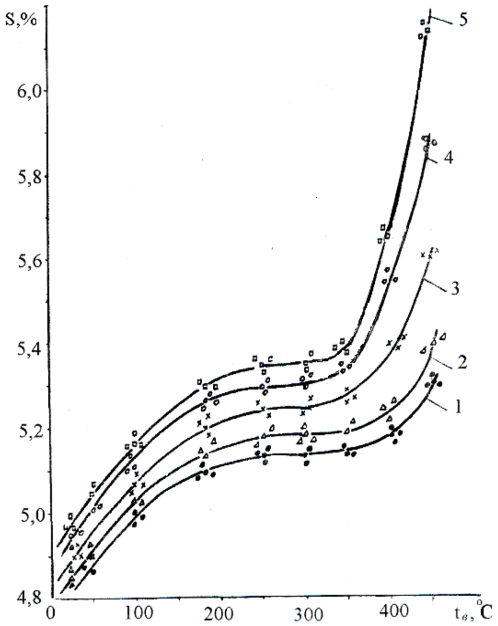

Fig. 17. Dependence of advance on the heating temperature of the dies at a degree of deformation of 30% (heating temperature of the workpieces:
1-300 ° C; 2-350 ° C; 3 - 400 ° C; 4-450 ° C; 5 - 470 ° C)

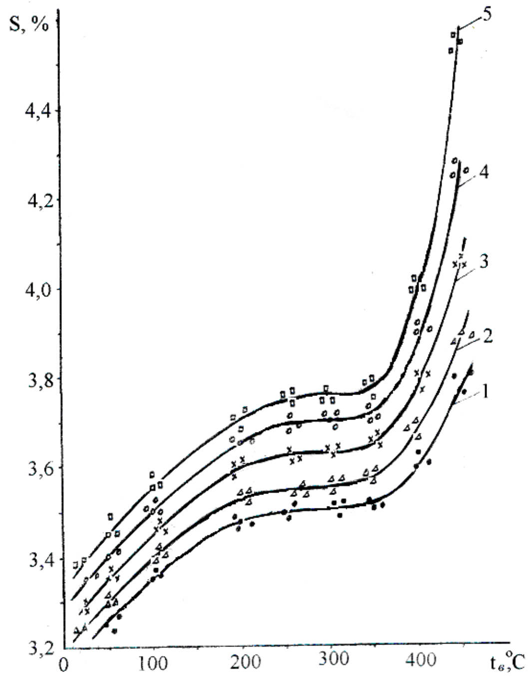

Fig. 18. Dependence of advance on the heating temperature of rolling dies at a degree of deformation of 40% (heating temperature of workpieces: 1 - 300 ° C; 2 - 350 ° C; 3 - 400 ° C; 4 - 450 ° C; 5 - 470 ° C) S,%

Analysis of experimental data presented in Fig. 17, 18 shows that with increasing degree of deformation, heating temperatures of workpieces and rolling dies advance is increased by reducing the coefficient of friction, increasing the plasticity of the treated metal and the flow of softening processes. In addition, it should be noted that in the heating temperature range of rolling dies 220–350 ° C, the advance at a constant degree of deformation (similar to that shown in fig. 16) practically does not change, and the change in degrees of deformation changes its absolute values.

Conclusions

Analyzing the advantages of isothermal deformation compared to metal deformation under normal conditions, a method was developed and experimental studies of basic technological parameters (expansion, metal pressure on rolls, advance, friction) of the process of rolling aluminum alloy billets in isothermal and similar deformation. Their dependences on the degree of deformation, heating temperatures of rolling dies and workpieces, extraction coefficients during rolling of workpieces in smooth rolls and calibers of different systems are determined. It is established that the nature of the behavior of dependencies during rolling in smooth rolls and calibers of different systems is similar.

The analysis of the conducted experiments showed that the course of the metal, the degree of filling of the engraving of the rolling stamp, the resistance of the metal to deformation, friction significantly depend on the heating temperature of the stamps.

The coefficient of friction is determined from the conditions of the maximum angle of capture. It is established that when rolling billets from aluminum alloys without the use of lubricant at the roughness of the rolls Rz = 20–1.25, the coefficient of friction is equal to 0.32 - 0.3.

The coefficients of extraction on the transitions for rolling workpieces in smooth rolls and calibers of different systems are determined.Based on the obtained experimental data, it was found that in the range of heating temperatures of rolling dies 250 - 350 ° C and a constant degree of deformation, expansion, pressure of metal on felting, advancement in rolling aluminum alloy blanks do not change regardless of where the workpieces are deformed (smooth rolls, calibers of different systems), and changing the degree of deformation changes their value. This is due to the lack of hardening of the metal under these conditions of deformation. Therefore, rolling of aluminum alloy blanks, under conditions of hot deformation, is recommended to be carried out in dies heated to temperatures of 250 - 350 ° C, at which the values of the above technological parameters are constant and the pressure is minimal.

Analysis of experimental data shows that rolling workpieces under conditions of isothermal deformation reduces the pressure of the metal on the rolls by 1.8 times or more. This is a confirmation of the improvement of the ductility of the metal during its deformation in isothermal conditions and the use of equipment with much less effort.

Comprehensive research (-macro, -micro, mechanical properties) of the quality of rolled blanks made in the conditions of isothermal and approximate deformation, meet the requirements of technical documentation.

Mathematical models are developed and formulas for determination of expansion and advancement at rolling of preparations, in the conditions of isothermal and close to it deformation are received.

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