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INVESTIGATION OF METAL FLOW FROM AK6 ALUMINUM ALLOY ON A MODERNIZED HOT ROLLING INSTALLATION

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Wide use of aluminum alloys is determined by their technical, physical and mechanical properties. Aluminum and its various alloys are used in a wide range of heavy and light industry, both in machine building: tractors, cars and agricultural machinery, and in the aviation industry and shipbuilding. Especially during the war in Ukraine, the country's economy is in a critical state, the use of technologies that save the use of any materials is very expensive, including aluminum alloys, which is an expensive material. The coefficient of material use when using the technology we offer is 0,15...0,3, thanks to the use of a hot forming or rolling plant.

The application of the process of hot deformation of blanks makes it possible to use the effect on plasticity to the maximum. Since the deformation of heated workpieces is carried out by a tool heated to the same temperature or close to them. Such a scheme of hot deformation will reduce the effort due to the increase in the plasticity of the metal being processed. What happens due to the full flow of strengthening processes. Uniform deformation of the workpiece, in the absence of zones of difficult deformation and local overheating, ensures a good and comprehensive restoration of the structure. It was found that during hot deformation, the metal pressure on the rolls decreases by 1,8 or more times.

Currently, there are few works on researching the possibilities of hot rolling on small-sized installations, which are not inferior to the high-quality production of parts with strong characteristics and improved macro- and micro-structures and mechanical properties. Therefore, conducting research on the influence of heating temperatures of blanks and dies, the degree of deformation on the technological parameters of hot rolling of blanks in hot dies is an urgent task. The solution of which can lead to improvement of plasticity and reduction of deformation forces, improvement of the quality of blanks.

Key words: *billet, deformation, deformation rolling, plastic deformation, intensity of deformation, stress-strain state, plasticity, technological process, aluminum alloys, macro- and microstructure.*

Eq. 3. Fig. 16. Table. 3. Ref. 14.

1. Analysis of recent research and publications

For the production of any part, it is necessary to carry out deformation. Deformation is a change in the shape of a body without destruction under the action of external forces. Elastic deformation is restored, and plastic deformation remains after removal of the load.

Plastic deformation is carried out by means of numerous shifts along crystallographic planes, resulting in distortion and grinding of grains, which leads to an increase in the density of defects in the crystal lattice and an increase in the level of free energy. Grains are extracted and crushed. The structure becomes fibrous. The practical consequence of this is the strengthening of metals (slander).

As the degree of deformation increases, the strength of the metal increases, and plasticity decreases, and upon reaching certain (limiting) degrees of deformation, the riveted metal becomes brittle and cracks appear in it, which lead to destruction. [1-2]

The riveted metal is in an unstable state, and when heated to a temperature of about 0.4T of melting, the initial properties and structure are restored. This process is called recrystallization and is accompanied by a decrease in free energy through boundary movement. As a result, new equiaxed grains are formed instead of the fibrous structure of the deformed metal.

Deformation at temperatures above the recrystallization temperature is called hot pressure treatment, it is not accompanied by slander, since the resulting distortions of the structure are immediately restored in the process of deformation due to recrystallization. [3-5]

Deformation at temperatures below the recrystallization temperature is called cold pressure working and is accompanied by slander. To restore the structure and properties of the riveted metal (for example, if it is necessary to continue the cold pressure treatment), it must be heated above the recrystallization temperature. This treatment is called recrystallization annealing.

When developing a technological process of hot three-dimensional stamping, first of all, it is necessary to determine the method of stamping (in an open or closed die, with a depression in the end or a splash) and the surface of the separation of the stamp.

Forgings whose transverse dimensions are several times greater than their height are stamped by settling into the end face (at the same time, the axis of the workpiece is parallel to the direction of movement of the moving part of the stamp), and by splashing - forgings with an elongated axis. Hammer dies are usually open. Forgings that have the shape of bodies of rotation are usually produced by stamping in closed dies on presses. [6-7].

The following requirements should be taken into account when choosing a stamp release surface:

- the separation plane is chosen taking into account the possibility of free removal of the forging from the upper and lower parts of the die;
- it is desirable that the plane of separation coincides with the plane of the two largest overall dimensions of the part;
- filling of the final trough with sediment is easier than by extrusion;
- when stamping on hammers, deep cavities are placed in upper stamp, and on presses - in the lower one;
- it is desirable that the plane of separation when punching on hammers crossed the vertical surface of the forging.

For high-quality macro- and micro-structure and mechanical properties, hot processing of metals by pressure is used, for this it is necessary to make forgings in which the workpiece will be made, and then the part. [8-10].

The technological development of the forging manufacturing process includes the development of the forging drawing, the calculation of the workpiece, the selection of equipment, forging operations, the sequence of their execution, and the tool used. The main methods of manufacturing forgings are forging and hot three-dimensional stamping.

We offer the technology of manufacturing parts on modernized hot rolling equipment and offer to investigate it.

2. The purpose of the article

Existing technologies for the production of parts of an asymmetric appearance, with an elongated axis, and other complex configurations, are a very complex process, which are performed in three, four and five stages. We propose to apply the technology for the production of parts of any complexity in one or two stages, which will reduce the labor intensity of the work, the cost of the part by 2-3 times, and lead to the minimum coefficient of use of the material, namely aluminum alloy AK-6. And it will also lead to improvement of plasticity and reduction of deformation forces, improvement of the quality of blanks.

3. Results of the researches

To determine technological parameters and thermomechanical characteristics during rolling of blanks under conditions of isothermal deformation and close to it, the installation was used. Which was developed by scientists Professor Skryabin S.O. and associate professor Shvets L.V. rig. 1.

In order to avoid jamming due to heating of the bearing units of the working rolls, the housings of the outer pairs are made with holes - channels to ensure the circulation of running water. The drive of the installation allows you to adjust the rotation frequency of the rolls, which ensures the removal of characteristics at different speed modes. [3]

But we went further and modernized the already existing installation.

The disadvantages of such an installation are the need to heat the billet in a furnace or furnace and to heat the forming rolls for a long time.

The invention is based on the task of increasing the heating speed of the forming rollers and the possibility of heating the billet in the device heating chamber, excluding auxiliary means.

The task is solved by the fact that the installation contains a chamber for heating the workpiece with a mixture of gas and oxygen, which is equipped with guide rollers and burners, and a system of internal heating of the forming rollers.

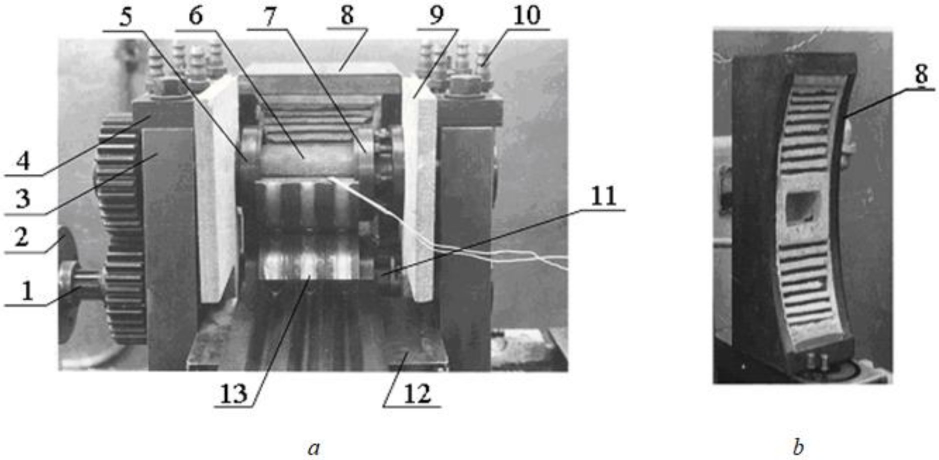


Fig. 1. Installation for rolling in hot conditions deformations (a); furnace heating device (b) [3]: 1 – slotted connection, 2 – coupling, 3 –body, 4 – tie bars 5 – fixed washer, 6 – upper rollers, 7 – movable washer, 8 – heating device, 9 – asbestos-cement plates, 10 – fitting, 11 – lower, drive rollers, 12 – guide bar, 13 – rolling dies.

Table 1

Technical characteristics of the installation during rolling of blanks under conditions of isothermal and near-isothermal deformation

Nominal effort, kN	20
Interaxial distance of rolls, mm	160
Frequency of rotation of rolls, min^{-1}	12 – 60
Diameter of the initial workpiece, mm	30
Landing dimensions, mm:	
diameter	80
length	135
Drive power, kW	7
Tool heating temperature °C	to 500
Type of heating device	Electrical resistance
Voltage, V	220
Heater power, kW	4
Wire diameter (nichrome)	0,6

The drawing (Fig. 2) shows the schematic diagram of the hot rolling plant.

The installation for hot rolling (Fig. 2) consists of: pressing rollers 5, on which dies for the manufacture of the part are installed, the body of the installation, guide rollers 1 for directing the blank to the dies, a heating chamber 2 for the blank and burners 3 for heating the blank.

The installation works as follows: the workpiece is inserted into the guide rollers 1 and fed to the pressing rollers 5, during feeding, the workpiece is heated in the heating chamber 2, the workpiece is captured by the dies and the configuration of the workpiece is squeezed out during pressing. The rollers are heated from the inside by a flame.

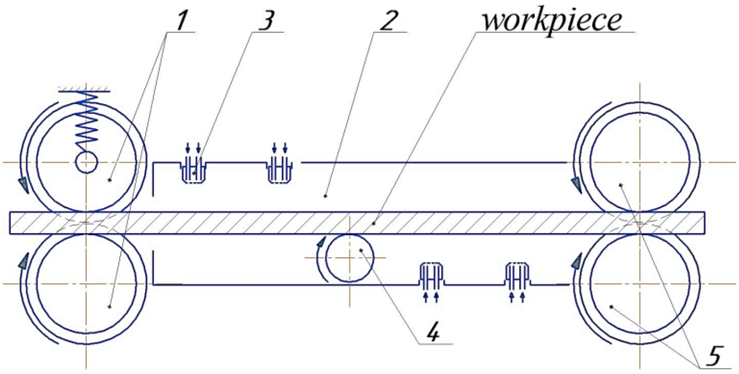


Fig. 2. Pressing rollers for rolling

Pressing rollers have their own design. Rollers 6 (Fig. 3) are attached to the body of the installation by bearing housings 8, in which sliding bearings 9 (inserts) are installed, stamps 7 are rigidly fixed on the rollers 6, which are the main working body of the installation, the rollers are made hollow from the middle to form a mixture combustion chamber gas with oxygen, through holes (Fig. 3, section A-A) exhaust gases enter chamber 2 (Fig. 2) where the workpiece is partially heated.

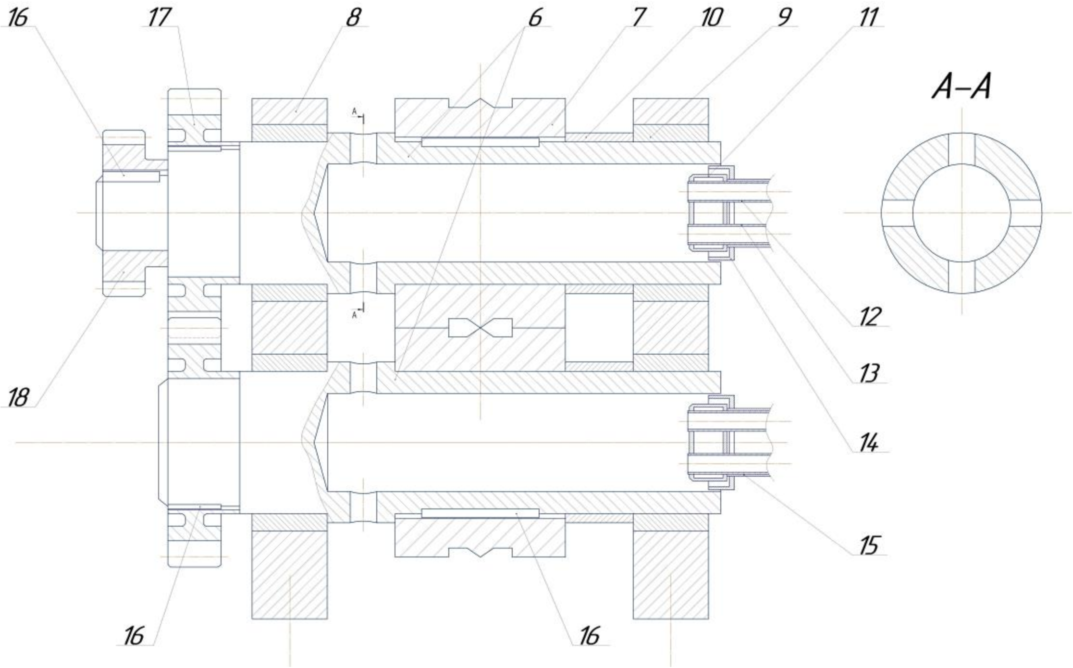


Fig. 3. Modernized installation for hot rolling

The burner for supplying the combustion mixture consists of a burner head 11 in which two tubes 12 and 13 are placed for the supply of oxygen and gas, the tubes are placed in the burner tube 15, which is attached to the cartridge 14. The drive of the two rollers is carried out from the gears 17, the drive of the installation from the gear 18 for rigid fastening of the seat parts, splines are used 16, spacer sleeves are installed to fix the stamps in a stationary position 10.

The novelty of the design consists in heating the rollers from the middle and heating the workpiece with a mixture of oxygen and gas.

In the process of rolling, together with the reduction of the height of the billet and its elongation (extraction), the movement of the metal also occurs in the transverse direction, which is called - expansion (Δb), which causes significant stress in the side edges of the rolled billet and reduces the overall elongation. [11-14]

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

$$\Delta b = b_1 - b_0, \quad (1)$$

where b_0 is the width of the sample before deformation, mm; b_1 – sample width after deformation, mm.

The advance of S is determined by the formula

$$S = \frac{\ell_1 - \ell_2}{\ell_2} \cdot 100, \%, \quad (2)$$

where ℓ_1 – the distance between the impressions of the cores on the workpiece mm; ℓ_2 – the distance between the impressions of the cores on the rolls, mm.

The metal pressure on the rolls was determined by the formula

$$P = 1 - \frac{P_0 - P_1}{P_0}, \quad (3)$$

where P – relative pressure; P_0 – metal pressure on rolls with a temperature of 20 °C, kg/mm^2; P_1 – metal pressure on rolls with a temperature of 50 – 450 °C, kg/mm^2. [3]

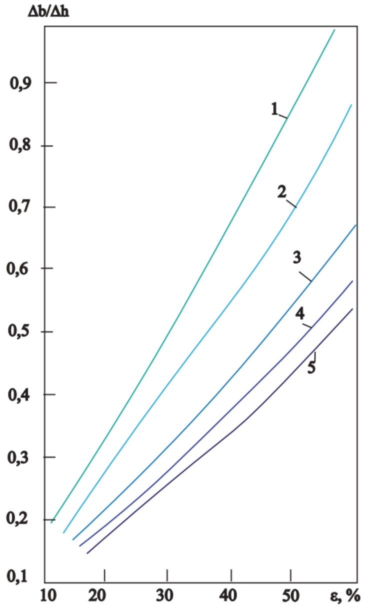


Fig. 4. Dependence of the indicator expansion Δb/Δh from the degree of crimping when rolling workpieces of different diameters in smooth rolls: mm; 1 – Ø20mm; 2 – Ø30 mm; 3 – Ø50 mm; 4 – Ø60mm; 5 – Ø65 mm

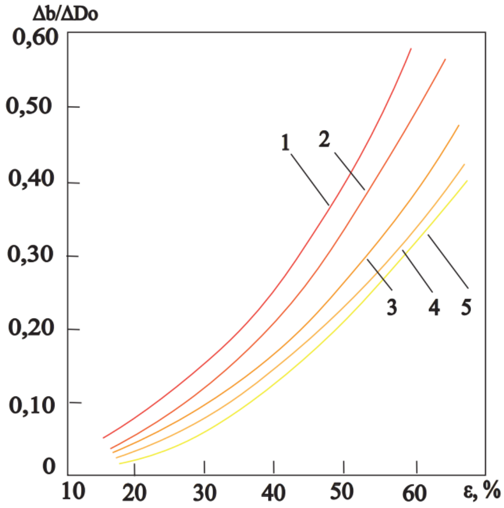
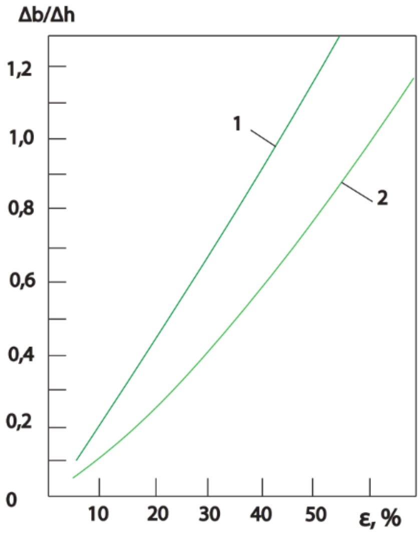


Fig. 5. Dependence of the relative expansion Δb/D0 on the degree of crimping when rolling blanks of different diameters in smooth rolls: mm; 1 – Ø 20 mm; 2 – Ø 30 mm; 3 – 50 mm; 4 – Ø 60 mm; 5 – Ø 65 mm

Analyzing the experimental data shown in fig. 4, 5, it can be concluded that with an increase in the degree of deformation, other things being equal, the expansion index and relative expansion increase. As the diameter of the rod decreases, the values of the expansion index and relative expansion increase. The decrease in expansion values with an increase in the diameter of the workpieces can be explained by the increase in frictional forces in the transverse direction, since the ratio of the width of the deformation center to its length increases.

The influence of the diameter of the rolls on expansion is presented in Fig. 6, from which it can be seen that the expansion increases with an increase in the diameter of the rolls. This is explained by the fact that with an increase in the diameter of the rolls, other things being equal, the length of the center of deformation increases and, as a result, the friction forces on the contact surfaces directed towards the neutral section increase. As a result, the resistance to the movement of the metal along the axis of the workpiece increases and the expansion increases.



Fiq. 6. The influence of the diameter of the rolls on the expansion index Δb/Δh when drawing blanks in smooth rolls: 1– the diameter of the rolls is 260 mm, the rotation frequency of the rolls is 26 min^{-1}; 2 – the diameter of the rolls is 103 mm, the rotation frequency of the rolls is 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 crimping ε = 38.5% is shown in Fig. 7.

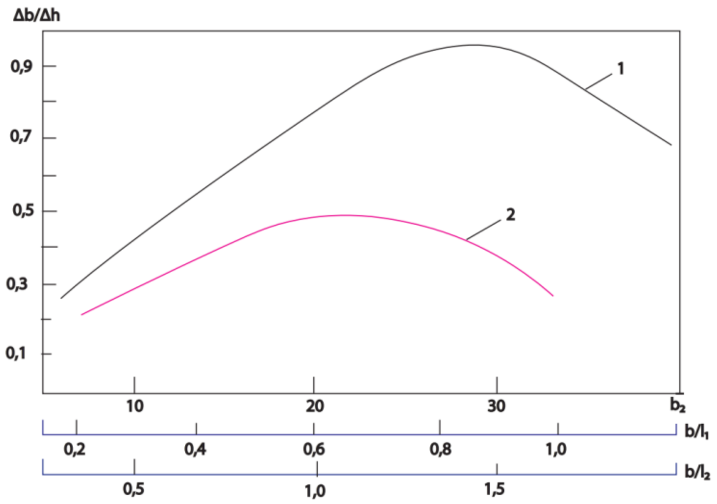


Fig. 7. Dependence of the expansion index on the width of the strip, rolls and the ratio of the initial width of the contact surface to its lengths b/l_1 and b/l_2 when drawing blanks in smooth rolls: 1 – the diameter of the rolls is 260 mm, the rotation frequency of the rolls is 26 min^{-1}; 2 – the diameter of the rolls is 103 mm, the rotation frequency of the rolls is 37 min $^{-1}$

The curves are constructed according to experimental data obtained in the process of rolling samples from the 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 a rotation frequency of 26 and 37 min^{-1}, respectively. Analyzing fig. 7 shows that with an increase in the width of the workpiece, the expansion index increases to a certain value (has a maximum) and with a further increase in the width of the workpiece, it begins to decrease. This is characteristic of expansion and is explained by the fact that the transverse frictional forces on the contact surfaces with increasing width of the workpiece increasingly restrain 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 mainly determined by the contact forces of friction.

In plane deformation, the value of linear expansion b at the maximum point stabilizes rather quickly and remains constant with further increase in width.

The dependence of the relative expansion on the degree of crimping during rolling of billets of different diameters from the AK6 alloy is presented in Fig. 8. The rolling of the blanks was carried out at a temperature of 450°C on forging rolls of the C162A model in smooth dies with a profile that provides increasing crimping.

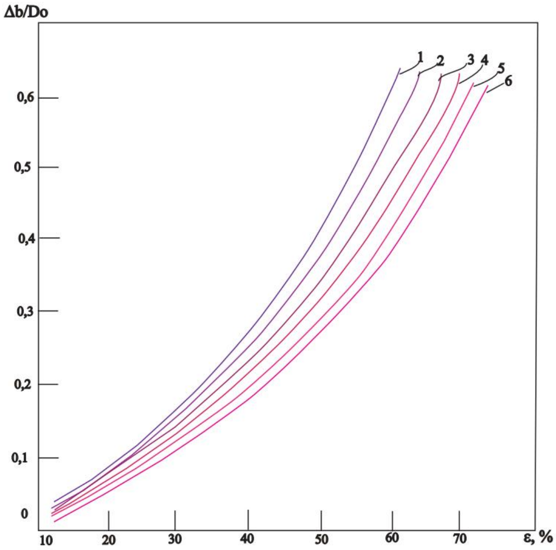


Fig. 8. Dependence of the relative expansion on the degree of crimping when rolling blanks of different diameters in smooth rolls:
1 – Ø25mm; 2 – Ø30 mm; 3 – Ø35 mm; 4 – Ø40mm; 5 – Ø45 mm; 6 – Ø50mm.

The influence of the temperature of rolled blanks on expansion is shown in Fig. 9. The dependence is constructed based on the results of experimental data obtained during the rolling of billets from the AK6 alloy measuring 20x30x250 mm in smooth rolls with a diameter of 103 mm and a rotation frequency of 37 min^{-1}. Rolling was carried out with a constant degree of crimping ε = 58.5% at different temperatures.

The graphs below, constructed based on experimental data on the influence of various factors on expansion during traditional rolling, will help to take them into account when developing the technological process of rolling blanks in smooth rolls and calculating gauges under hot deformation conditions.

It should be noted that knowledge of the features of the shape change of aluminum alloys and the exact method for calculating the expansion would make it possible to develop such crimping schemes during the rolling of blanks, which would make it possible to vary the width of the blank within wide limits.

The analysis of experimental data is presented in table. 2 and Fig. 10 obtained during the rolling of workpieces with dimensions of Ø14x150 mm shows that the expansion relative to the initial cross section of the workpiece during rolling in dies with a temperature of 20 °C and degrees of deformation of 30, 40 and 50% increases by 20.4, 30 and 42%, respectively. This is explained by the fact that with an increase in the degree of deformation, the volume of the metal in width and, therefore, the expansion, other things being equal, increase.

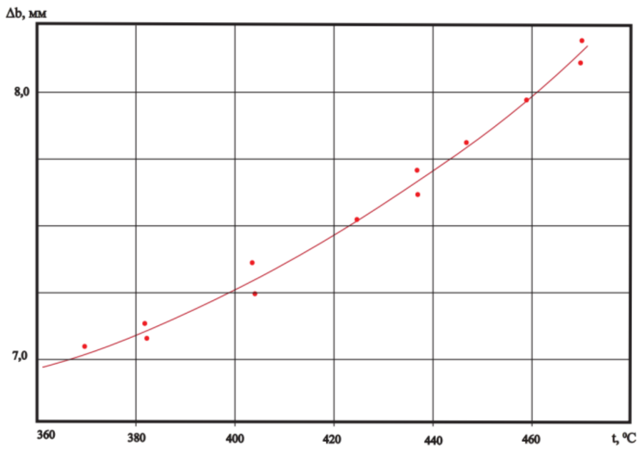


Fig. 9. Dependence of the expansion on the heating temperature of the blanks during rolling in smooth rolls

Table 2

The value of expansion Δb depending on the degree of deformation ε and the temperature of heating stamps $t_в$

degree of deformation ε	**temperature of heating stamps $t_в$**		
	20°C	250°C	450°C
ε = 30%	2,856	2,086	1,708
ε = 40%	4,2	3,64	3,3
ε = 50%	5,88	5,2	4,65

It will look like this on the diagram

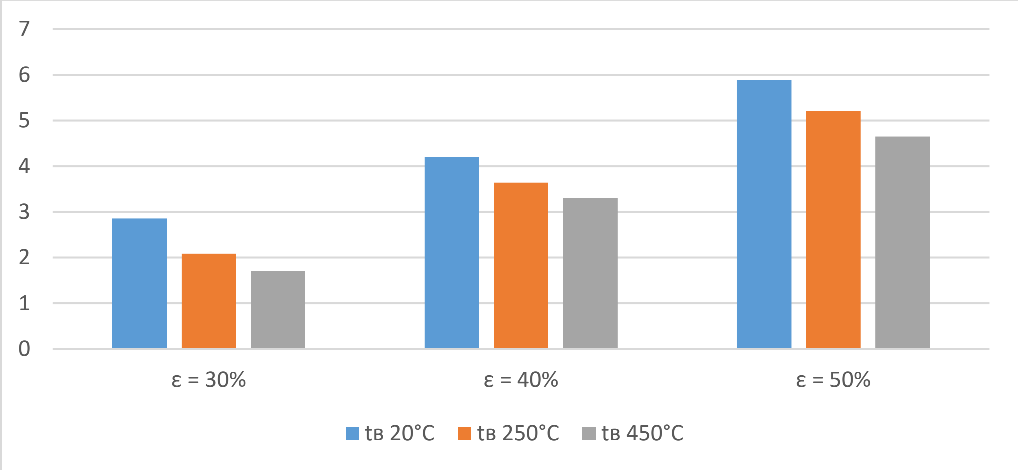


Fig. 10. Diagram of the dependence of the value of expansion Δb depending on the degree of deformation ε and the temperature of heating the stamps $t_в$

The nature of the dependence of the expansion on the temperature of heating the stamps in the range of 20-250°C (Fig. 11) can be explained as follows. At the temperature of the stamps of 20°C and degrees of deformation of 30, 40, 50%, the contact area of contact between the metal and the stamps is small, taking into account the rolling of a round workpiece Ø14mm. At the same time, the axial compressive stresses directed along the center of deformation are insignificant compared to the compressive stresses acting in the transverse direction, therefore, an increase in expansion is observed. A decrease in expansion with an increase in the heating temperature of the rolling dies occurs due to the flow of strengthening processes and an increase in the plasticity of the processed metal.

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

With an increase in the heating temperature of the stamps to 450°C and blanks with degrees of deformation of 30, 40 and 50%, the value of expansion relative to the initial cross-section of the blank decreases and amounts to 12.2, 23.6, 33%, respectively. The decrease in expansion occurs due to an increase in axial compressive stress directed along the center of deformation, a more complete flow of strengthening processes, and the absence of zones of difficult deformation.

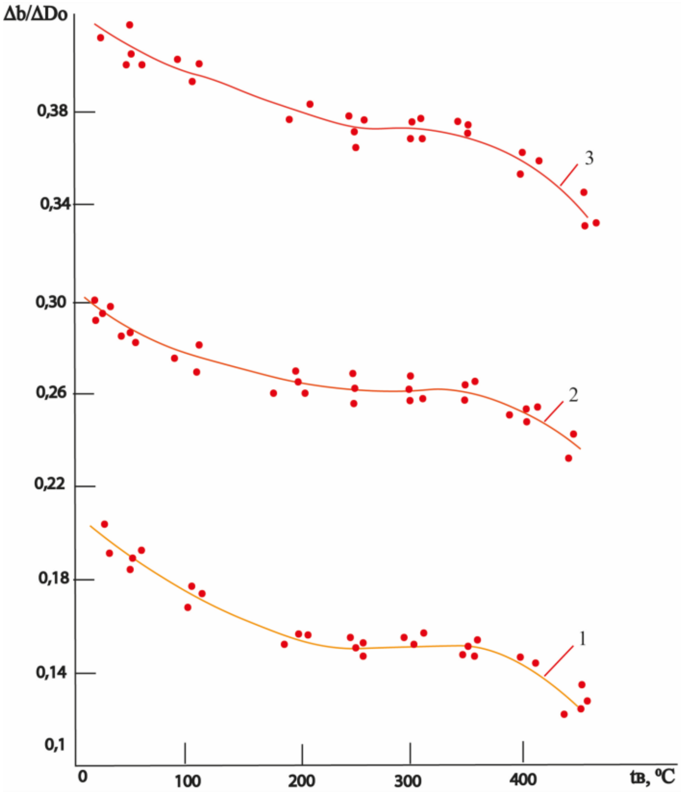
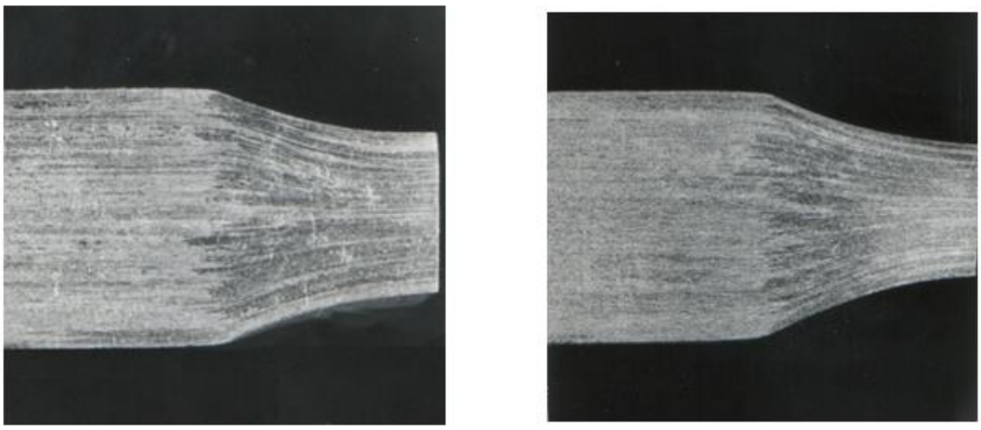


Fig. 11. Dependence of expansion on the degree of deformation and heating temperature of rolling dies (degree of deformation: 1–30%; 2–40%; 3–50%; heating temperature of blanks 450°C)

The analysis of expansion changes showed that with an increase in the heating temperature of the stamps, the expansion values decrease. Thus, the values of expansion obtained at the temperature of heating the dies to $t_в$ = 250 and 450°C at deformation ε = 30% decrease in relation to the expansion obtained during rolling of blanks in dies with a temperature of 20°C by 37 and 67,2%, respectively. The decrease in expansion at t_v = 450°C relative to t_v = 250°C is 22%.

Similarly, the analysis of the change in expansion values during rolling of blanks 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%).



a *b*

Fig. 12. Macrostructure of longitudinal sections of rolled blanks in smooth rolls. Alloy AK6, Ø14x150mm. Temperature of blanks and stamps 470°C: a – degree of deformation 40%; b – degree of deformation 50%

Analyzing fig. 11, it can be seen that the change in the degree of deformation from 30 to 50% increases the value of the expansion, without changing the nature of their dependence on the temperature of heating the dies. It was noted above that with an increase in the degree of deformation, the volume of the metal in width and, therefore, the expansion, other things being equal, increase.

In fig. 12 shows the macrostructure of the longitudinal cross-section of billets made of AK6 alloy in smooth dies in one pass at a temperature of billets and dies of 470°C, degrees of deformation 40 and 50%. Conducted comprehensive studies (macro-, micro-structures and mechanical properties) of the quality of rolled blanks, in hot conditions, met the requirements of the technical documentation.

Analyzing the table. 3 and fig. 13, it can be seen that when rolling workpieces with dimensions Ø14x150 mm at a temperature of 450 °C, the relative pressure of the metal on the Rv rolls decreases with an increase in the heating temperature of the dies, and, most intensely, with an increase in the degree of deformation.

Thus, with an increase in the heating temperature of the stamps to 250, 350 and 450°C, the pressure on the rolls decreases in comparison with the pressure values during the deformation of the blanks in the stamps with a temperature of 20°C and a degree of deformation of 30, 40, 50%, respectively, by: 250 °C – 62,45%, 54%, 45%; 350°C – 55,8%, 47,5%, 38,73%; 450 °C – 53,3%, 46,5%, 38,2%.

In the temperature range of 350–450°C, the metal pressure on the rolls at different degrees of deformation changes slightly, and when the dies reach temperatures of 400°C and above, it almost stabilizes, and an increase in the degree of deformation affects only the absolute values of the relative pressure Pv, fig. 13.

Table 3

The value of the relative pressure Pv depending on the temperature heating of stamps $t_в$ and degree of deformation ε

Item №	ε = 30%		ε = 40%		ε = 50%	
	$t_в$,°C	*Pv*	$t_в$,°C	*Pv*	$t_в$,°C	*Pv*
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

Analysis of the experimental data presented in fig. 13 shows that during the rolling of blanks on forging rolls, in hot conditions, the metal pressure on the rolls decreases with the increase in the heating temperature of the dies, most intensively in the temperature range of 20–350°C. Further heating of the stamps does not lead to a significant decrease in pressure and is impractical, because it leads to additional energy consumption. In addition, the appearance of scale on the surface of the stamps is observed.

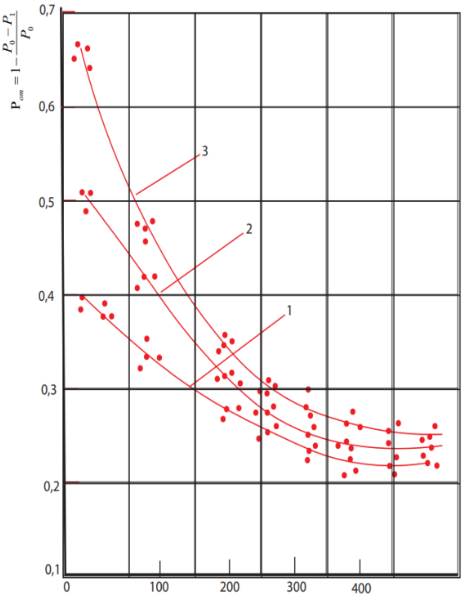


Fig. 13. Addiction the relative pressure of the metal for rolling from the temperature of heating the dies and the degree of deformation: 1 – 30%; 2 – 40%; 3 – 50%. The heating temperature of the blanks is 450°C

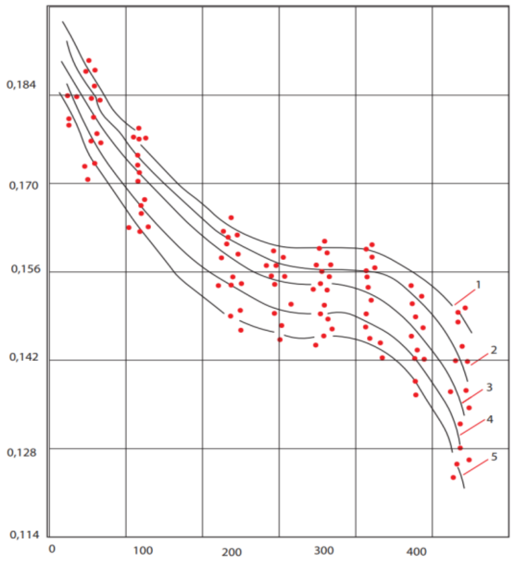


Fig. 14. Dependence of expansion on the heating temperature of blanks and stamps at a degree of deformation of 30% workpiece heating temperature: 1 – 300°C; 2 – 350°C; 3 – 400°C; 4 – 450°C; 5 – 470°C.

In another series of experiments, workpieces from the above-mentioned alloys with dimensions of Ø14, 18, 20, 25 x 150 mm, electric resistance heated in a chamber furnace to temperatures of 300, 350, 400, 450, 470+10 °C were rolled in smooth dies, which were heated sequentially to temperatures of 20, 50, 100, 150, 200, 250, 300, 350, 400, 470°C. The blanks were rolled with degrees of deformation of 30 and 40%. The results of the experimental data are presented in fig. 14, 15.

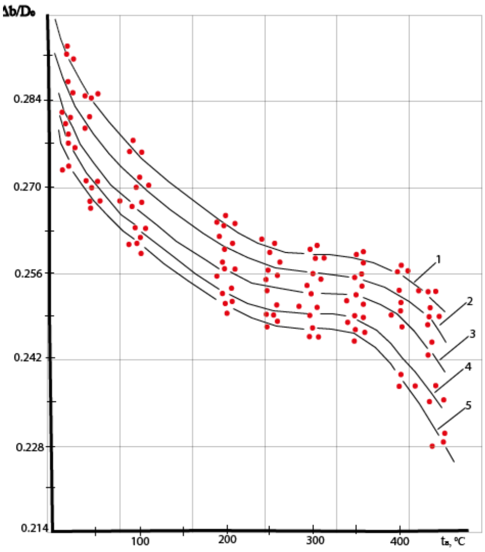
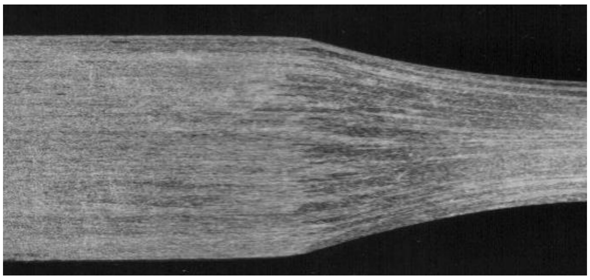
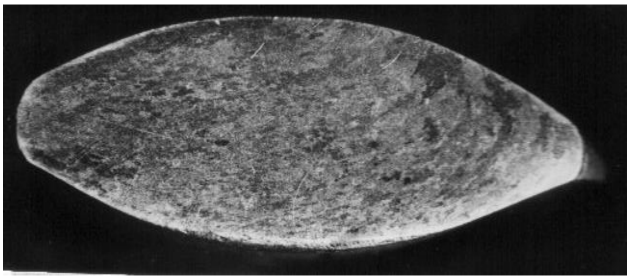


Fig. 15. Dependence of expansion on the heating temperature of blanks and stamps at a degree of deformation of 40% workpiece heating temperature: 1 – 300°C; 2 – 350°C; 3 – 400°C; 4 – 450°C; 5 – 470°C.

Analysis of the experimental data presented in fig. 14, 15 shows that with an increase in the heating temperature of the blanks and stamps, the expansion decreases due to the strengthening processes. In addition, it should be noted that in the temperature range of heating stamps 250 – 350°C, the expansion at a constant degree of deformation (similarly presented in Fig. 15) practically does not change, and a change in the degree of deformation leads to a change in its absolute values.

In fig. 16 shows the macrostructure of the longitudinal and transverse sections of rolled blanks made of AK6 alloy with dimensions Ø14 × 150 mm, corresponding to the requirements of the technical documentation. Rolling was carried out at temperatures of blanks and dies equal to 450 °C with a degree of deformation of 50%.





a ***b***

Fig. **16. Macrostructure of the longitudinal (a) and transverse (*b*) cross-sections of the rolled blank in oval gauge: AK6 alloy, Ø14×150; degree of deformation 50%; the temperature of blanks and stamps is 450°C**

4. Conclusions

Aluminum and its various alloys are used in a wide range of heavy and light industry, both in machine building: tractors, cars and agricultural machinery, and in the aviation industry and shipbuilding. Especially during the war in Ukraine, the economy of the country is in a critical state, the use of technologies that save the use of any materials is very expensive, including aluminum alloys, which is an expensive material. The coefficient of material use when using the technology we offer is 0,15...0,3, thanks to the use of a hot forming or rolling plant.

Having studied the flow processes of aluminum alloy AK-6, during the production of blanks on modernized equipment for hot deformation, we can see that the structure of the metal has only improved, it has become more densely grained with small crystals. In addition, we invented a temperature for heating metal and dies at which the expansion of metal is the same in the range of 250 – 350°C, which makes it possible not to increase the energy consumption effort for heating dies and aluminum alloy, and it is possible to use the specified range for the manufacture of high-quality blanks. At the same time, use small-sized, cheaper and more efficient equipment.

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ДОСЛІДЖЕННЯ ТЕЧІЇ МЕТАЛУ ІЗ АЛЮМІНІЄВОГО СПЛАВУ АК6 НА МОДЕРНІЗОВАНІЙ УСТАНОВЦІ ДЛЯ ГАРЯЧОГО ПРОКАТУВАННЯ

Широке використання алюмінієвих сплавів визначається їх технічними, фізичними і механічними властивостями. Алюміній та його різноманітні сплави застосовуються у широкому спектрі важкої та легкої промисловості, як в машинобудуванні: тракторів, автомобілів і сільськогосподарської техніки , так і в авіаційній промисловості і кораблебудуванні. Особливо у час війни в Україні, економіка країни в критичному стані, застосування технологій, які заощаджують використання любих матеріалів, дуже ціно, в тому числі і алюмінієвих сплавів, який є дороговартісним матеріалом. Коефіцієнт використання матеріалу при застосування технології, яку ми пропонуємо становить 0,15…0,3, завдячуючи застосування установки для гарячого деформування або прокатування.

Застосування процесу гарячого деформування заготовок дає можливість максимально використовувати ефект над пластичності. Оскільки деформація нагрітих заготовок проводиться інструментом нагрітим до тієї ж температури або близької до них. Така схема гарячої деформації дозволить знизити зусилля за рахунок підвищення пластичності металу, який обробляється. Що відбувається із-за повного протікання розміцнюючих процесів. Рівномірна деформація заготовки, за відсутності зон утрудненої деформації і локального перегріву, забезпечує хороше і всебічне відновлення структури. Встановлено, що при гарячій деформації знижується тиск металу на вальки в 1,8 і більше разів.

В даний час мало робіт по дослідженню можливостей гарячого прокатування на малогабаритних установках, що не поступаються якісним виготовленням деталей з міцними характеристиками та покращеними макро- і мікро- структурами та механічними властивостями. Тому проведення досліджень по впливу температур нагріву заготовок і штампів, ступеня деформації на технологічні параметри гарячого прокату заготовок в гарячих штампах є актуальним завданням. Вирішення якого може привести до покращання пластичності і зниження зусиль деформації, підвищення якості заготовок.

Ключові слова: *заготовка, деформація, деформаційне протягування, пластична деформація, інтенсивність деформацій, напружено-деформований стан, пластичність, технологічний процес, деформаційне протягування, алюмінієві сплави, макро- і мікроструктура.*

Ф. 3. Рис. 16. Табл. 3. Літ. 14.

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