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системы, то такой поиск будет выполняться точнее. Применяя CAD и PDM системы используя программные средства и определенный подходящий технологический процесс, мы значительно облегчаем процесс выбора оптимальных значений и оптимального выбора маршрутной карты или прецедента.

В рамках использования третьего фактора – применение паттернов, следует сказать, что в современных системах управления химических процессов электрохимического производства присутствует и аналитика средств производства по параметрам загрузки, но не техническим параметрам. Система планирования и подготовки производства и система управления электрохимического производства должны взаимодействовать между собой либо находиться в одном едином информационном пространстве. Постоянный обмен данными между системой планирования и подготовки производства и системой управления электрохимическим производством является обязательным условием, которая позволит использовать результаты проектирования в производстве и получать обратную связь в процессе изготовления от исполнителей. Зависимости работы систем проектирования сопроводительной документации от систем управления производством на сегодняшний день недостаточно известны, но попытки проводить анализ, например, загрузки оборудования, указывают на целесообразность объединения контура разработки сопроводительной документации с контуром управления производством предприятия.

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РОЗШИРЕННЯ ПРИ ВАЛЬЦЮВАННІ ЗАГОТОВОК В РІЗНИХ КАЛІБРАХ

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EXPANSION DURING ROLLING OF PREPARATIONS IN DIFFERENT CALIBERS

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Анотація

При експериментальному дослідженні вальцювання заготовок з алюмінієвих сплавів, встановлено, що в інтервалі температур нагріву вальцювальних штампів 250 – 350°C і постійному ступеню деформації, розширення і тиск металу на валки практично не міняються незалежно від того, де заготовки деформуються (гладкі валки, калібри різних систем). А зміна ступенів деформації міняє їх значення що пояснюється відсутністю| зміцнення металу за даних умов деформації.

Abstract

In an experimental study of rolling of billets of aluminum alloys, it was found that in the range of heating temperatures of rolling dies 250 - 350 ° C and a constant degree of deformation, expansion and pressure of metal on the rolls do not change regardless of where the workpieces are deformed (smooth rolls, calibers systems). And the change in the degree of deformation changes their value due to the lack of hardening of the metal under these conditions of deformation.

Ключові слова: гаряча деформація, вальцювання заготовок, алюмінієві сплави.

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

Introduction. The question of the correct approach to the definition of expansion - one of the main in the calculation of calibers. The accuracy of its determination determines the size (partly the shape of the gauges), the choice of the degree of deformation and the required coefficients of drawing, the number of transitions, the possibility of rolling in the subsequent stream, power parameters, surface quality of the rolled workpiece, and others.

Expansion when rolling blanks of round cross section in oval calibers.

Rolling in an oval stream both in intermediate, and in final is very widespread. When rolling blanks for stamping, the following caliber systems are most often used: circle - oval; circle - oval - square; circle - oval - rhombus - square; circle - oval - circle; circle - oval - rhombus - circle, etc.

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Note that the most significant factors influencing the expansion in the rolling process of workpieces in oval calibers are the degree of deformation and radius of curvature of the caliber in the plane perpendicular to the axis of rolling, as well as the ratio of geometric shapes of the gauge and the workpiece. caliber to the radius of the workpiece. In contrast to rolling in smooth rolls, the existing non-uniformity of deformation in width and height of the workpiece, caused by the curvature of the oval caliber in cross section, greatly complicates the problem of determining the movement of metal in the deformation center.

To determine the influence of the degree of deformation, the heating temperature of the rolling dies on the expansion, blanks of the above aluminum alloys with dimensions Ø14 x 150 mm heated to 470 ° C [1] were rolled in oval calibers (table 1) with degrees of deformation 30, 40 and 50%. Rolling dies were heated sequentially to a temperature of 20, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500 ° C. 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 optical and electron microscopy, X-ray microanalysis, and mathematical statistics were used in experimental studies.

The coefficient of friction between the metal of the workpiece and the surface of the rolling dies, determined by the method of maximum grip angle, without the use of lubricant and the roughness of the surface of the rolls is 0.3… 0.32.

Table 1

Dimensions of oval calibers for rolling blanks from aluminum alloys with the sizes Ø14x150 mm

The ratio of the axes, *a*	Height of caliber h, mm	Caliber width b, mm	Caliber radius R, mm	Extraction coefficient λ
2,0	9,3	18,65	11,70	1,45
2,4	8,3	19,9	11,95	1,55
2,8	7,1	20,1	12,00	1,65

Figure 1 shows the dependences of the change in expansion on the degree of deformation and heating temperature of the rolling dies when rolling blanks of round cross section with dimensions Ø14 x 150 mm of the above alloys in oval calibers. Analysis of experimental data presented in table. 2 and in fig. 1 shows that with increasing the heating temperature of the rolling dies to 250 ° C, the values of expansion decrease relative to the initial cross section of the workpiece during deformation in rolling dies having a temperature of 20 ° C, respectively, 17; 26 and 38%.

The nature of the behavior of the dependences of the expansion on the degree of deformation and the heating temperature of the rolling dies in the range of 20 - 250 ° C (Fig. 1) 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 increase in the plasticity of the treated metal and the flow of softening processes.

Table 2

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

	Temperature, t_v |			
	20 °C	250 °C	450 °C	500 °C
	ε = 30%			
Expansion Δb, mm	2,38	2,11	1,96	1,5
	ε = 40%			
	3,64	3,33	3,2	2,74
	ε = 50%			
	5,32	4,9	4,76	4,34

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 11.3; 9.3 and 8.6% relative to the initial cross section of the deformable workpieces, respectively, with degrees of deformation of 30, 40 and 50%. This is due to the course of softening processes, achieving equality of axial compressive stress directed along and across the center of deformation, as well as the equality of displaced volumes in these directions and the absence of areas of difficult deformation.

With increasing temperature of heating of rolling dies to 450, 500 ° C and rolling of workpieces with degrees of deformation of 30, 40 and 50%, the values of expansion relative to the initial cross section of the workpiece decrease by 21,4; 13,7 i 11,8 % (450°C), 58,7, 32,8 i 22,6 % (500°C). The reduction of expansion is due to the increase of axial compressive stresses directed along the center of deformation, the fuller course of the softening processes, the absence of zones of difficult deformation.

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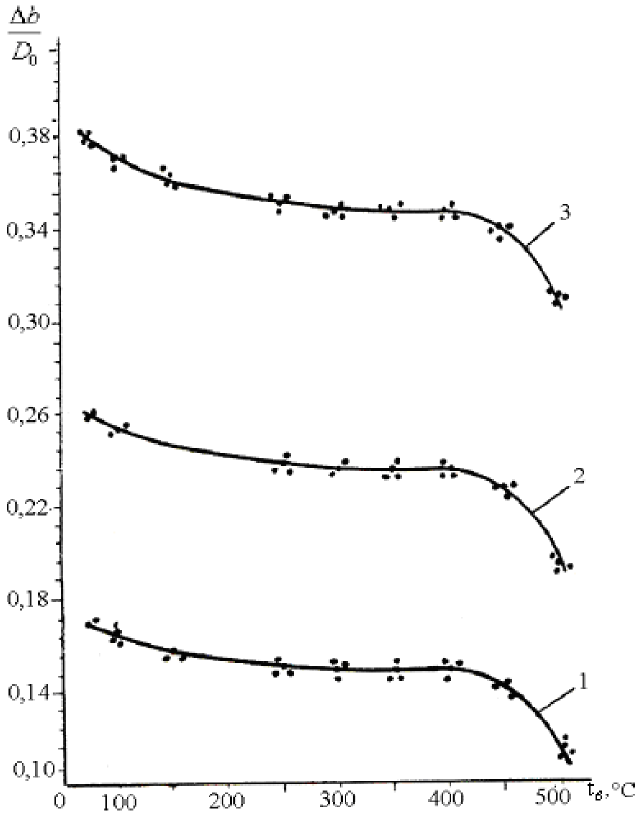


Fig. 1.

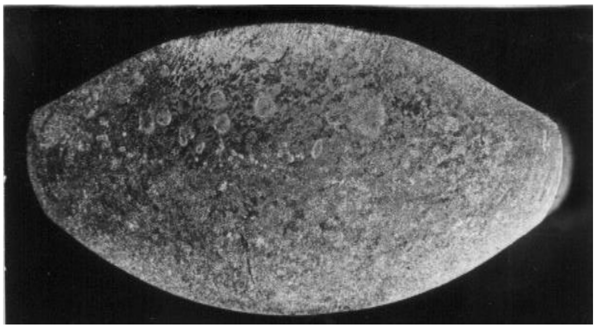
Dependence of expansion on heating temperature of rolling dies at rolling of preparations of round section in oval calibers (degree of deformation: 1 - 30%; 2 - 40%; 3 - 50%; the heating temperature of the workpieces 470 ° C)

The analysis of the change in expansion showed that with increasing heating temperature of the rolling dies, the values of expansion decrease. Thus, the reduction of expansion at heating temperatures of rolling dies to 450, 500 ° C relative to t_b = 250 - 350 ° C is at degrees of deformation: 30 % - 7,1; 40% - 4,0 and 21,5 %; 50 % - 3,0 and 12,9 % respectively. The decrease in expansion at t_b = 500 ° C relative to t_b = 450 ° C at degrees of deformation of 30, 40 and 50% is 30,7; 16,8 and 9,8%.

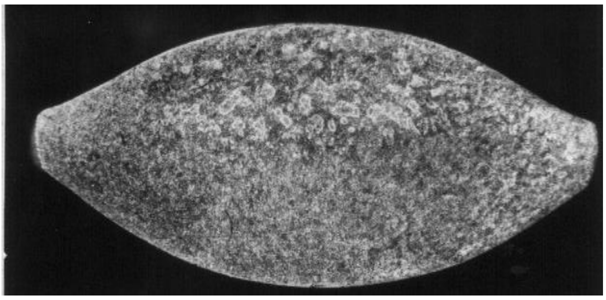
From the analysis of fig. 1 shows that changing the degree of deformation from 30 to 50% increases the value of expansion, without changing the nature of their dependence on the heating temperature of the rolling dies. It was noted above that with increasing degree of deformation, the volume of the metal in width, and, consequently, expansion, other things being equal, increases.

Experiments have shown that the best coefficients of extraction and expansion without the formation of burrs in the rolling of billets of aluminum alloys are provided with the ratio of the axes of the oval caliber *a* = 2,6 ÷ 4,0.

Figures 2–1 and 2–2 show the macrostructure of cross sections of rolled billets (AK6 alloy, degree of deformation 50%) at a temperature of 470 ° C in oval calibers and different heating temperatures of rolling dies.

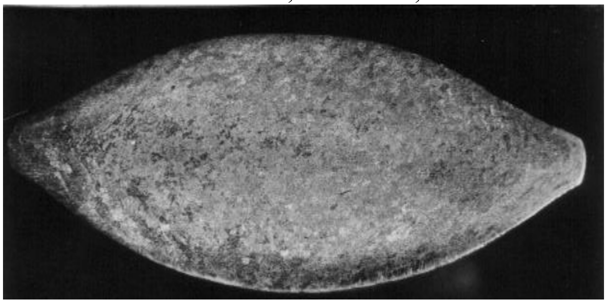


a

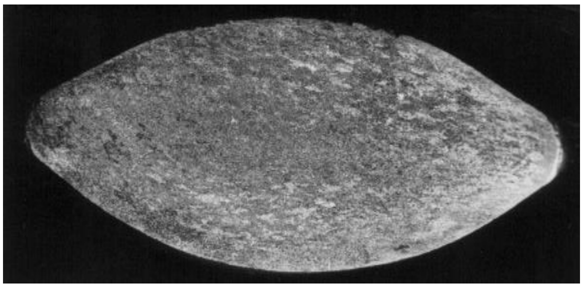


b

Fig. 2 - 1. Macrostructure of the cross section of rolled workpieces (alloy AK6, t = 470 ° C, ε = 50%) at different temperatures of the rolls:
a - 20 ° C, *b* - 150 ° C,



c



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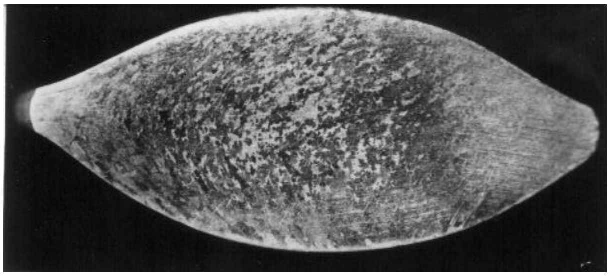

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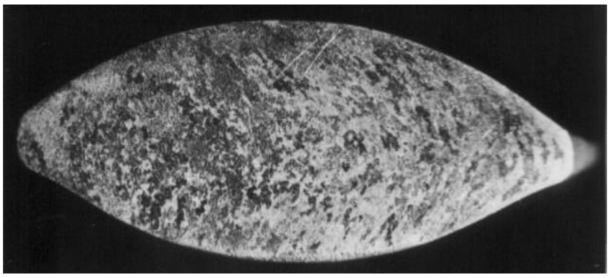

f

Fig. 2 - 2. Macrostructure of the cross section of rolled workpieces (alloy AK6, t = 470 ° C, ε = 50%) at different temperatures of the rolls:
c - 200 ° C, *d* - 250 ° C, *e* - 300 ° C, *f* - 370 ° C

Comprehensive studies (- macro, - micro, mechanical properties) of the quality of rolled billets, in conditions close to isothermal, met the requirements of technical documentation.

In fig. 3. the macrostructure of longitudinal and cross sections of rolled blanks made of AK6 alloy with dimensions Ø14 x 150 mm, corresponding to the requirements of technical documentation is presented. Rolling was performed at temperatures of blanks and rolling dies equal to 450 ° C with a degree of deformation of 50%.

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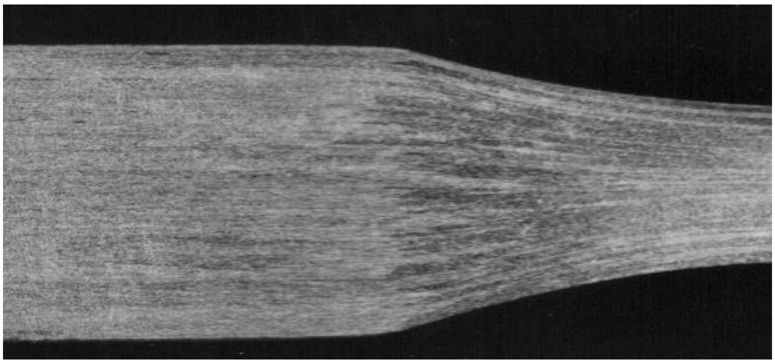
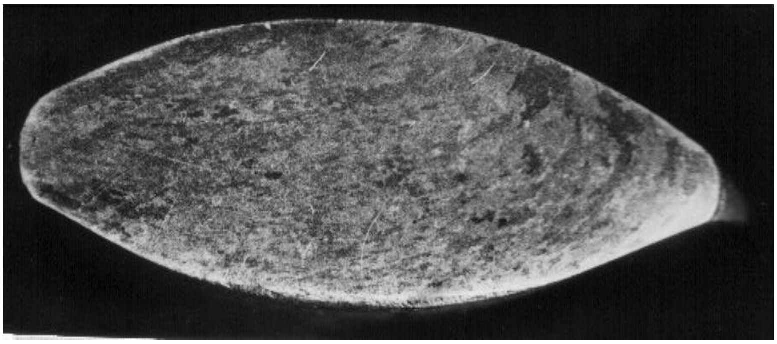


a



b

Fig. 3. Macrostructure of longitudinal (a) and transverse (b) sections of rolled workpiece in oval caliber: alloy AK6, Ø14x150; degree of deformation 50%; temperature of blanks and rolling dies 450 ° C

Investigation of ductility of D16 alloy reinforced with filamentary crystals of SiC material under isothermal and near-deformation conditions/

Experimental studies of the ductility of heavily deformed aluminum alloy D16 reinforced with filamentary crystals of SiC material were performed.

Rolling of workpieces with dimensions Ø14 x 150 mm was performed in oval calibers at a temperature of 460 ° C and strains of 30, 40 and 50%. The temperature of the rolling dies was 20, 200, 250, 300, 350, 400, 450 ° C. The workpieces were heated in an electric furnace chamber to a temperature of 460 ° C and rolled in an oval caliber at a degree of deformation of 30%. At the temperature of the rolling dies equal to 20 ° C and the coefficient of drawing 1.45, the workpiece during deformation stratified in the longitudinal and transverse directions, Fig.3-1, *a*.

Metallographic studies showed that the fracture was not associated with the initial structure, which had no deviations from the technical requirements and the blanks for the experiments were taken from a rod of one melting.

Increasing the heating temperature of the rolling dies to 200 ° C avoided the appearance of strata shown in Fig. 3-1, *b*. However, there were many cracks in different parts of the rolled workpieces, 3-17 mm long, 0,4 – 2,6 mm deep, and the caliber overflow along the detachable line up to 3,6 mm on the side. At the temperature of the rolling stamp 250 ° C, the number of cracks, as well as their size decreased significantly in length to 2 - 9 mm and were observed mainly at the end of the rolled workpieces up to 32 mm long. Caliber overflow along the detachable line remained the same, ie up to 3,6 mm per side. Increasing the temperature of the rolling dies to 300 ° C led to the elimination of cracks along the entire core of the rolled blanks, except for the end of the rolled blanks in the area up to 10–17 mm from the end. Caliber overflow was up to 3–3,2 mm per side. At the temperature of rolling dies 350–400 ° C no defects were observed, except for overflow of calibers up to 2,2–2,6 mm. When the temperature of the rolling dies increased to 450 ° C, overflow of calibers up to 1,6 - 2 mm per side was observed, but there were no defects in the form of cracks.

On rolled blanks made at a temperature of rolling dies in the range of 350-450°C and a degree of deformation of 40% (coefficient of drawing 1.55), defects in the form of cracks were not observed, but there was overflow caliber up to 1,7-2,2 mm per side, which does not allow rolling in the next transition. Rolling of workpieces at the temperature of rolling dies in the range of 350-450 ° C and the degree of deformation of 50% (extraction coefficient 1,65) showed that defects of surface and macrostructure were not detected, but there was an overflow of caliber up to 1,8 – 2,3 mm side.

a

b

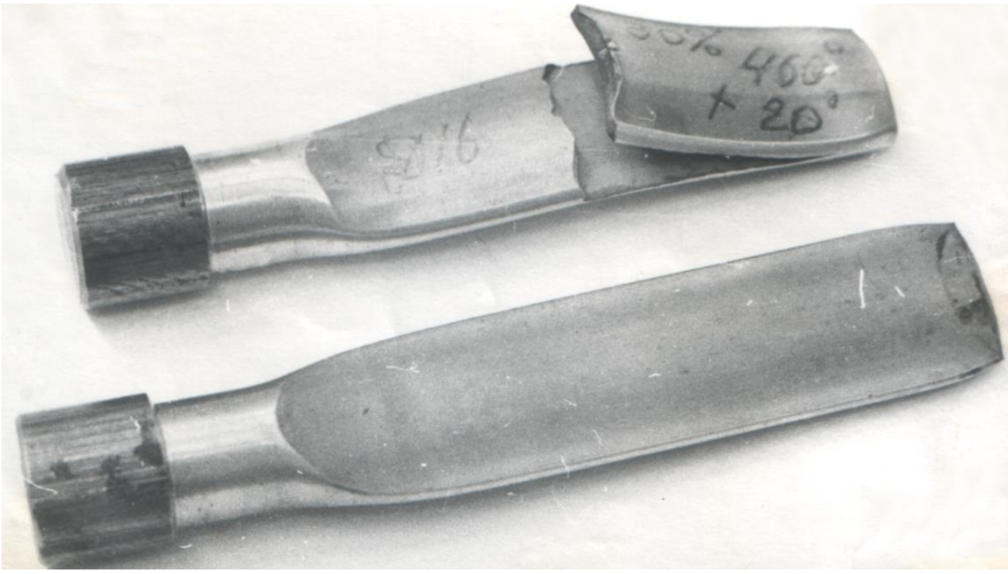


Fig. 3 - 1 Rolled blanks of D16 alloy reinforced with SiC filamentary crystals:
a - at a temperature of a rolling stamp of 20 ° C
and degree of deformation of 30%;
b - at a temperature of the rolling stamp 250 ° C
and a degree of deformation of 50%.

Previous experiments have shown good ductility of aluminum alloy AK6 under conditions of isothermal deformation, which can not be said about the alloy D16, reinforced with filamentous crystals of SiC material. It is established that the heating temperature of rolling dies, the degree of deformation and the ratio of geometric shapes of the caliber and rolled workpiece play a significant role in the manufacture of high-quality rolled workpieces with isothermal deformation.

Experiments have shown that the calibration calculations are performed according to the method developed for rolling billets of aluminum alloys, require its adjustment for the manufacture of high-quality rolled billets from D16 alloy reinforced with filamentary crystals of SiC material.

Expansion during rolling of blanks of oval section in rhombic calibers.

Expansion in rhombic calibers depends on their shape and the degree of non-uniformity of deformation during rolling of workpieces in these calibers. The inclination of the side walls of rhombic calibers reduces the expansion compared to the free expansion when rolling workpieces in smooth rolls.

To determine the expansion, the workpiece after rolling in oval calibers (Table 1), with the dimensions specified in table. 3, rolled in rhombic gauges having angles at the top of 105 °, 110 °, 115 ° and the same height h_p = 8,4 mm.

Table 3

The dimensions of the cross section of the workpieces obtained after rolling in oval calibers

Теміпера- туру|тур-агента| вальцовоч-| ных| штампів, °З|із| Temperature t_v,°C||	Ступінь деформації ε					
	30 %		40%		50%	
	Width, mm	Height, mm	Width, mm	Height, mm	Width, mm	Height, mm
20	16,36	9,8	17,50	8,7	19,0	7,4
50	16,31	9,8	17,45	8,7	18,9	7,4
100	16,23	9,8	17,35	8,7	18,8	7,4
200	16,15	9,8	17,23	8,7	18,65	7,4
250	16,13	9,8	17,20	8,7	18,60	7,4
300	16,13	9,8	17,20	8,7	18,60	7,4
350	16,13	9,8	17,20	8,7	18,60	7,4
400	16,03	9,8	17,10	8,7	18,50	7,4
450	15,70	9,8	16,70	8,7	18,00	7,4

The results of the experiments are presented in Fig. 4 From the analysis of this figure it is seen that the nature of the dependences of the expansion on the degree of deformation and heating temperature of the rolling dies is similar to that described previously. As the heating temperature of the rolling dies increases to 250 ° C, the expansion of the workpieces decreases relative to the expansion during deformation in rolling dies having a temperature of 20 ° C by 12.85%; 18.2%; 8.8% with degrees of deformation 30, 40, 50%, respectively.

In the range of temperatures of 250 - 350 ° C at a constant degree of deformation of expansion practically does not change, and change of degree of deformation to 40 and 50% relative to 30%, accordingly increases

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absolute values of expansion by 63,6 and 41,4%. Expansion at a degree of deformation of 50% relative to 40%, increases the absolute values by 65%.

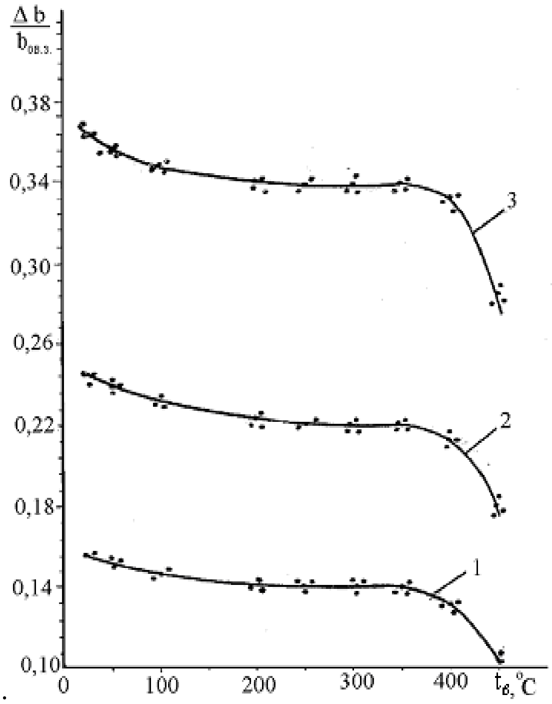

Fig. 4. Dependence of expansion at rolling of preparations of oval section in rhombic calibers on temperature of heating of rolling stamps and degree of deformation: 1 - 30%; 2 - 40%; 3 - 50%.

A further increase in the heating temperature of the rolling dies to 450 ° C leads to a decrease in the expansion of the workpieces compared to the expansion during deformation in rolling dies having a temperature of 20 ° C by 58; 51.2 and 34.3%, and for the values of expansion at heating temperatures of the stamps 250 - 350 ° C by 40; 27.9 and 23.75% with degrees of deformation of 30, 40, 50%, respectively.

Influence of rhombic caliber angle on expansion during rolling of oval section blanks.

The aim of further experimental studies was to determine the effect of rhombic caliber angle on the expansion during rolling of oval sections under conditions of isothermal deformation.

To determine the expansion, the workpiece after rolling in oval calibers with the dimensions specified in table. 4, rolled in rhombic calibers having angles β at the apex of 105 °, 110 °, 115 ° and the same height h_p = 9,4 mm.

During the experiments, blanks of the above aluminum alloys with dimensions Ø14 x 150 mm were heated in a chamber furnace to a temperature of 470 ° C [1] and rolled in dies having a temperature of 20 - 450 ° C on a system of calibers circle - oval - rhombus, the dimensions of which are given in table. 4.

Table 4

Dimensions of oval and rhombic calibers, mm

№ sample	Caliber radius, R mm	Height, h mm	Angle β ° at the vertex of the rhombus
Oval calibers			
1	11,7	9,3	-
2	11,9	8,3	-
3	12,0	7,0	-
Rhombic calibers			
1	-	9,4	105
2	-	9,4	110
3	-	9,4	115

In the table. 5 and in fig. Figure 5 shows the dependences of the expansion on the degree of deformation and the angle of the rhombic caliber when rolling the workpieces with dies heated to a temperature of 250-350 ° C. Rolling was performed at a heating temperature of the workpiece 470 ° C. The analysis of the results of the experiments shows that with increasing degree of deformation and angle at the apex of the rhombic caliber expansion increases.

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Table 5

Dependence of the extension on the angle at the top of the rhombic caliber

Relative expansion $\frac{\Delta b}{b_{ов.з.}}$	№ sample	Rhombus angle, β°		
		105°	110°	115°
	1	0,225	0,32	0,405
	2	0,25	0,355	0,457
	3	0,275	0,365	0,495

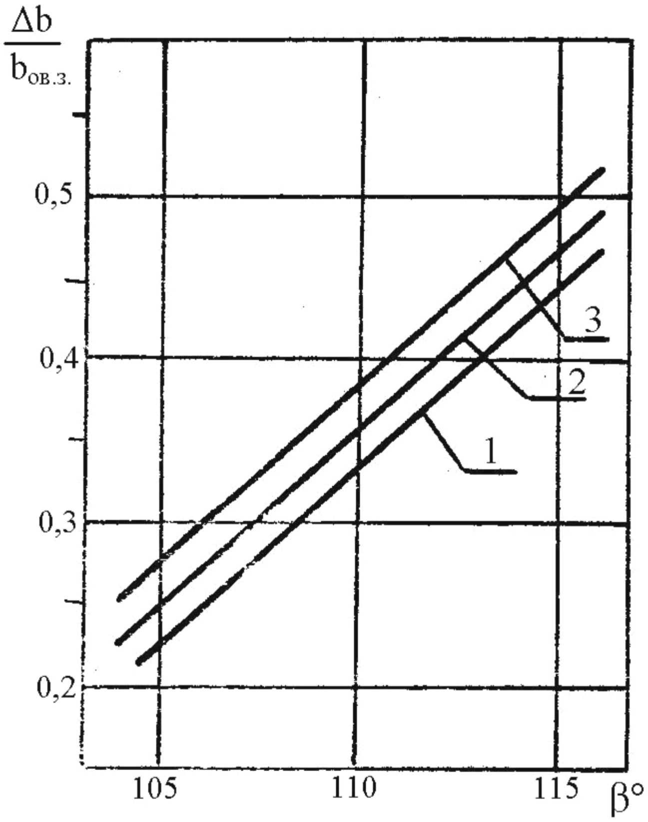


Fig. 5. Dependence of expansion on the angle of rhombic caliber when rolling blanks with stamps heated to a temperature of 250 - 350 ° C (1, 2, 3 - rolled blanks of 1, 2, 3 oval calibers)

In fig. 6 shows the dependence of the expansion on the heating temperature of the rolling dies and the angle of the rhombic caliber when rolling oval blanks in the calibers given in table. 3.

The results of the analysis of the experiments presented in table. 6 and in fig. 6 also confirm the regularity that with increasing heating temperature of the rolling dies the expansion decreases, and with increasing angle at the top of the rhombic caliber increases. This is explained by the fact that with increasing heating temperature of the rolling dies, the expansion decreases due to the increase in the plasticity of the treated metal and the flow of softening processes. The increase in expansion with increasing angle at the top of the rhombus is due to a decrease in lateral pressure from the walls of the rhombic caliber and, as a consequence, an increase in the volume of metal moved in the transverse direction.

Table 6

The value of expansion depending on the heating temperature of the rolling dies tv and the angle at the top of the rhombic caliber (data are given on measurements of samples 2, 5, 8, fig. 6)

	20 °C	250 °C	450 °C
Expansion Δb, mm	β = 105°		
	0,3	0,25	0,18
	β = 110°		
	0,42	0,38	0,32
	β = 115°		
	0,56	0,48	0,42

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. This is due to the course of softening processes, achieving equality of axial compressive stress directed along and across the center of deformation, as well as the equality of displaced volumes in these directions and the absence of areas of difficult deformation. This pattern was observed in previous experiments in the rolling of blanks of round cross section in smooth rolls and oval calibers, under conditions of isothermal and close to it deformation.

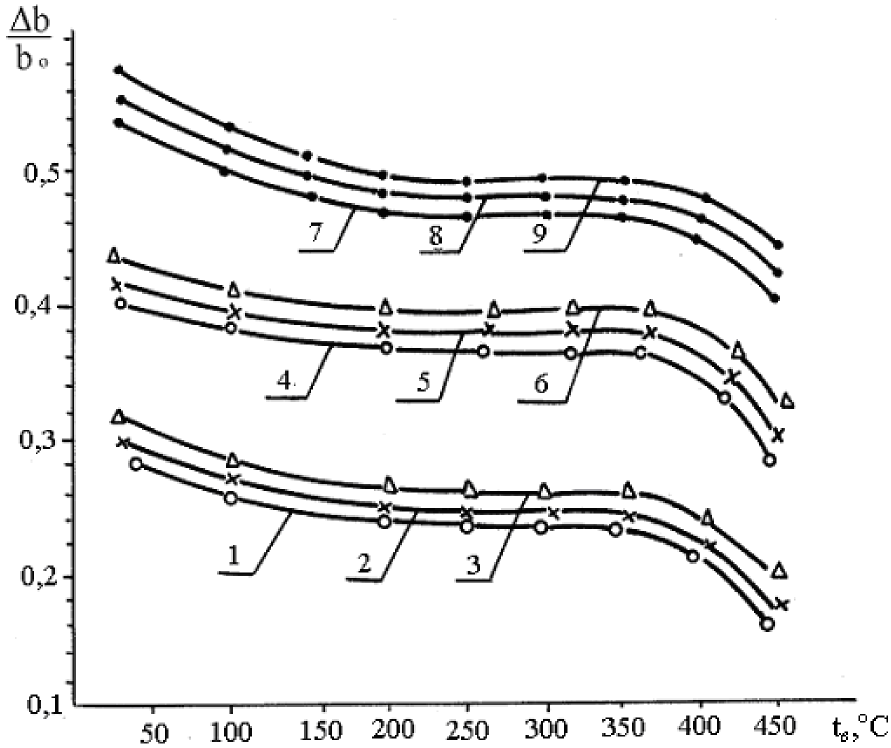


Fig. 6. The dependence of the expansion on the heating temperature of the rolling dies during rolling:

1, 2, 3 - blanks of 1, 2, 3 oval streams in rhombic caliber with an angle at the apex of 105 °;

4, 5, 6 - blanks of 1, 2, 3 oval streams, respectively, in a rhombic caliber with an angle at the apex of 110 °;

7, 8, 9 - blanks of 1, 2, 3 oval streams, respectively, in a rhombic caliber with an angle at the apex of 115 °.

Experiments on the above method on blanks of aluminum alloys AK4, AK8, AMg6, AMC with dimensions Ø 18, 20, 25 x 150mm showed that the behavior of the dependences of expansion on the degree of deformation and heating temperatures of rolling dies and blanks, other things being equal, similar to rolling in smooth rolls and calibers of different systems, fig. 1, 4, 6.

Comprehensive research (- macro, - micro, mechanical properties) of the quality of rolled blanks made under conditions of isothermal and close to it deformation, met the requirements of technical documentation.

Formulas for determining the expansion during rolling of workpieces, under conditions of isothermal and approximate deformation

Previous experimental studies to determine the expansion during rolling of blanks under isothermal and approximate deformation showed that the nature of changes in these parameters depending on the heating temperatures of rolling dies and blanks, as well as the degree of deformation during rolling in smooth rolls and calibers of different systems. Only their quantitative ratios change, depending on the degree of deformation and the geometric ratios of caliber and rolled workpiece.

Analysis of experimental data shown in Fig. 7 showed that the difference in the values of expansion obtained by rolling workpieces in rolling dies having a temperature of 20 ° C and heated to temperatures of 250-350 ° C (interval characterized by constant values of expansion - Fig. 1, 4, 6) is for any degree of deformation of the workpiece in the study area (30-50%) the value determined by the formula

$$\frac{\Delta b_{20}}{b_0} - \frac{\Delta b_{350}}{b_0} = \frac{\Delta h}{h_0}\left(tg\alpha - tg\alpha_1\right) \quad (1)$$

where Δh – absolute compression, mm;

h_0, b_0|| – height and width of the initial workpiece, mm;

Δb_{20}, Δb_{350}| |– expansion obtained by rolling workpieces in rolling dies having a temperature of 20 ° C and 250-350 ° C;

tg α, tg α_1 ||– angles of inclination, which determine the dependence of the expansion on the degree of deformation during rolling in dies having a temperature of 20 ° C and 250-350 ° C.

For a round blank $b_0 = h_0$||, then

$$\Delta b_{20} - \Delta b_{350} = \Delta h\,(tg\,\alpha - tg\,\alpha_1) = \Delta h \cdot K^{u}_{уш}, \quad (2)$$

where $K^{u}_{\text{уш}}$ - temperature coefficient of expansion, which depends on the heating temperature of the rolling dies.

$\Delta h \cdot K^{u}_{\text{уш}}$ - the value that determines the difference between the expansion obtained by isothermal and traditional rolling.

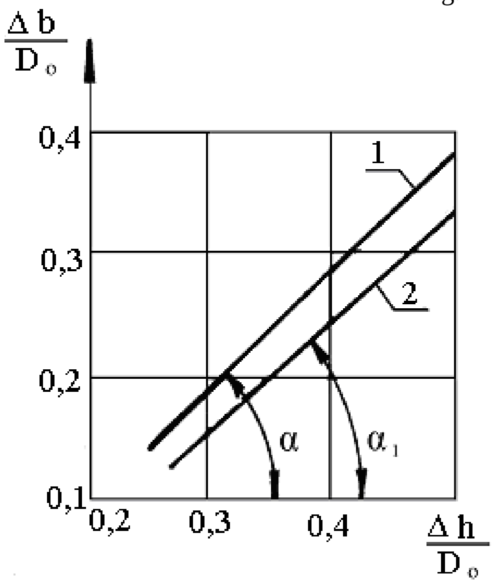


Fig. 7. Dependence of expansion on degree of deformation at rolling of preparations of round section in the smooth rolls having temperature:
1 - 20 ° C; 2 - 250 - 350 ° C.

When rolling blanks with a 90 ° edging in systems of calibers, oval - rhombus, oval - square, oval - rhombus - circle, etc. absolute compression is expressed as the difference between the width of the workpiece bz obtained after rolling in the previous caliber and the height of the subsequent hk. Therefore, the values of expansion during rolling in dies heated to 250-350 ° C will be determined similarly, but taking into account the ratios of geometric shapes of caliber and rolled workpiece

$$\Delta b_{20} - \Delta b_{350} = (b_{\text{з}} - h_k) K^{u}_{\text{уш}} = \Delta h \cdot K^{u}_{\text{уш}} \quad (3)$$

When rolling in isothermal conditions and approximate deformations, the values of expansion determined by the formulas used in traditional rolling are subject to adjustment taking into account the values obtained in the calculation by the above method. This means that when rolling workpieces in smooth rolls and calibers, their width must be reduced according to the values of the values determined by formulas (1 - 3).

In fig. Figure 8 shows the dependences of expansion on the degree of deformation during rolling of workpieces with rolling dies having a temperature of 20 ° C and 250-350 ° C. The values of tg α , tg α_1, are easily found in this graph.

In [6], formulas for determining the expansion in the traditional rolling of aluminum alloy billets in smooth rolls and various caliber systems, which are part of a mathematical model for calculating the expansion in the rolling of billets in conditions close to isothermal.

Following formula (3), the expansion during rolling of billets of aluminum alloys under conditions of isothermal deformation and close to it in the calibers of different systems will be determined by the formulas:

- blanks of round section in oval calibers

$$\Delta b = K^{\text{ов}}_{\text{уш}} \sqrt{(d - h_{\text{ов}}) 0,5 D^{\text{ов}}_{\text{к}}} \, \frac{d - h_{\text{ов}}}{d} - (d - h_{\text{ов}}) K^{u}_{\text{уш}} \quad (4)$$

where - expression $(d - h_{\text{ов}}) K^{u}_{\text{уш}}$ - the value that determines the difference between the expansion obtained by isothermal and traditional rolling;

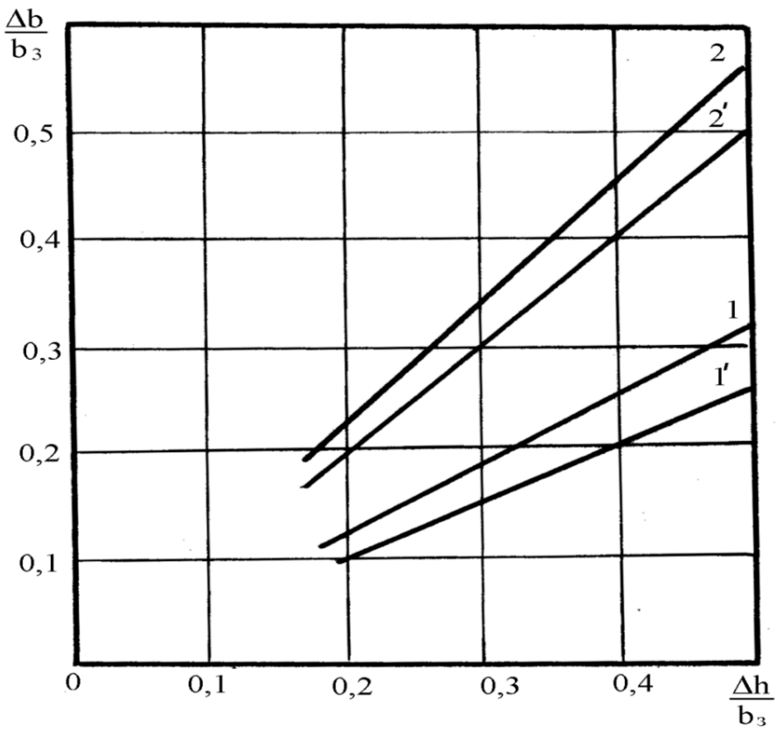


Fig. 8. Dependence of expansion on the degree of deformation during rolling of workpieces in rolling dies having a temperature of:
1, 1′ - 20 ° C (rolling of a round workpiece in oval caliber);
2, 2′ - 250 - 350 ° C (rolling of an oval workpiece in rhombic caliber).

$K^{и}_{уш}$ - temperature coefficient of expansion, depending on the heating temperature of the rolling dies.

$K^{ов}_{уш}$ - coefficient that takes into account the impact on the expansion of the non-uniformity of deformation in the width and height of the workpiece depending on the curvature of the oval caliber, Fig.9, *a*.

As a result of processing of experimental and settlement data the following formula for definition is received $K^{ов}_{уш}$

$$K^{ов}_{уш} = -\sqrt{0,0582\iota^2 - 0,02123\iota + 0,2015} + 0,2265\iota - 0,049 \quad (5)$$

$h_{ов}$ - height of oval caliber, mm

d - diameter of the deformable workpiece, mm;

$D^{ов}_{к}$ - rolling diameter of oval caliber, mm;

$$D^{ов}_{к} = A - (2/3)\, h_{ов} \quad (6)$$

A - intercenter distance of rolls/

- oval blanks in rhombic calibers

$$\Delta b = K^{ов}_{уш\,р}\sqrt{\left(b_{ов\,з} - h_р\right)\frac{D^р_к}{2}}\,\frac{b_{ов\,з} - h_р}{b_{ов\,з}} - \left(b_{ов.з} - h_р\right)K^{и}_{уш} \quad (7)$$

where $K^{ов}_{уш\,р}$ - coefficient that takes into account the effect on the expansion of the non-uniformity of deformation along the width of the caliber when rolling an oval workpiece in it, Fig. 9, *b*;

$b_{ов\,з}$ - width of the oval workpiece, mm;

$h_р$| - height of rhombic caliber, mm;

$D^р_к$ - rolling diameter of rhombic caliber, mm

$$D^р_к = A - 0,5h_р. \quad (8)$$

As a result of processing of experimental and settlement data the formula for definition is received $K^{ов}_{уш\,р}$

$$K^{ов}_{уш\ р} = \sqrt{2 - 0{,}000633\psi^2 + 0{,}00626\psi - 0{,}00336} + 0{,}00553\psi + 0{,}0437 \qquad (9)$$

where $\psi = a_{ов\ з}\ a_{р\ з}$.

Here $a_{ов\ з}$ and $a_{рз}$ || - the ratio of the axes of the oval and rhombic blanks.

- oval blanks in square calibers

$$\Delta b = K^{ов}_{уш\ кв}\sqrt{(b_{ов\ з} - h_{кв})\frac{D^{кв}_{к}}{2}\frac{b_{ов\ з} - h_{кв}}{b_{ов\ з}}} - (b_{ов.з} - h_{кв})\mathrm{K}^{и}_{уш} \qquad (10)$$

where $K^{ов}_{уш\ кв}$ - coefficient that takes into account the impact on the expansion of the non-uniformity of deformation along the width of the caliber when rolling an oval workpiece in it, is determined by formula (11) or by Fig. 9, *c*;

$h_{кв}$ - height of square caliber, mm;

- rolling diameter of square caliber, mm;

$D^{кв}_{к}$ - rolling diameter of square caliber, mm;

$$K^{ов}_{уш\ кв} = \sqrt{0{,}751a^2_{ов} - 2{,}627a_{ов} + 2{,}327} + 0{,}945a_{ов} - 1{,}187; \qquad (11)$$

$$D^{кв}_{к} = \mathrm{A} - (\mathrm{c}^2 - 0{,}86\ \mathrm{r})/(1{,}41\mathrm{c} - 0{,}83\ \mathrm{r}), \qquad (12)$$

where r - radius of rounding the corners at the vertex, mm;

- rhombic blanks in square calibers, mm:

$$\Delta b = K^{ов}_{уш\ кв}\sqrt{(b_{ов\ з} - h_{кв})\frac{D^{кв}_{к}}{2}\frac{b_{ов\ з} - h_{кв}}{b_{ов\ з}}} - (b_{ов.з} - h_{кв})\mathrm{K}^{и}_{уш} \qquad (13)$$

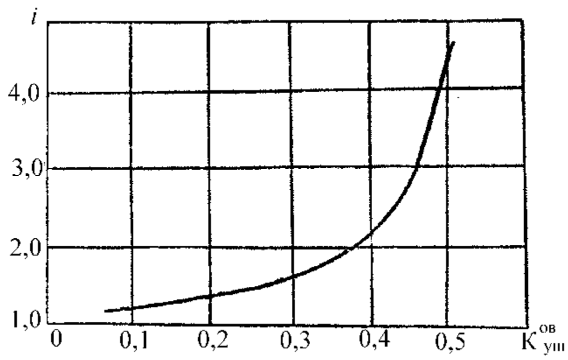
where $K^{р}_{уш\ кв}$ - the coefficient taking into account the effect on the expansion of the non-uniformity of deformation along the width of the caliber when rolling a rhombic workpiece in it is determined by formula (14) or by Fig. 9, *d*;

- width of the rhombic workpiece, mm;

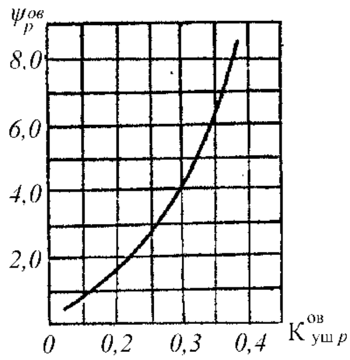
$$K^{р}_{уш\ кв} = \sqrt{0{,}0000551a_{р}^{2} - 0{,}000136a_{р} + 0{,}000119} + 0{,}207a_{р} - 0{,}177 \qquad (14)$$

- oval blanks in round calibers, mm:

$$\Delta b^{ов}_{кр} = K^{ов}_{кр}\sqrt{(b_{ов\ з} - d_{кр})\frac{D^{кр}_{к}}{2}\frac{b_{ов\ з} - d_{кр}}{b_{ов\ з}}} - (b_{ов.з} - d_{кр})\mathrm{K}^{и}_{уш} \qquad (15)$$



a)



b)

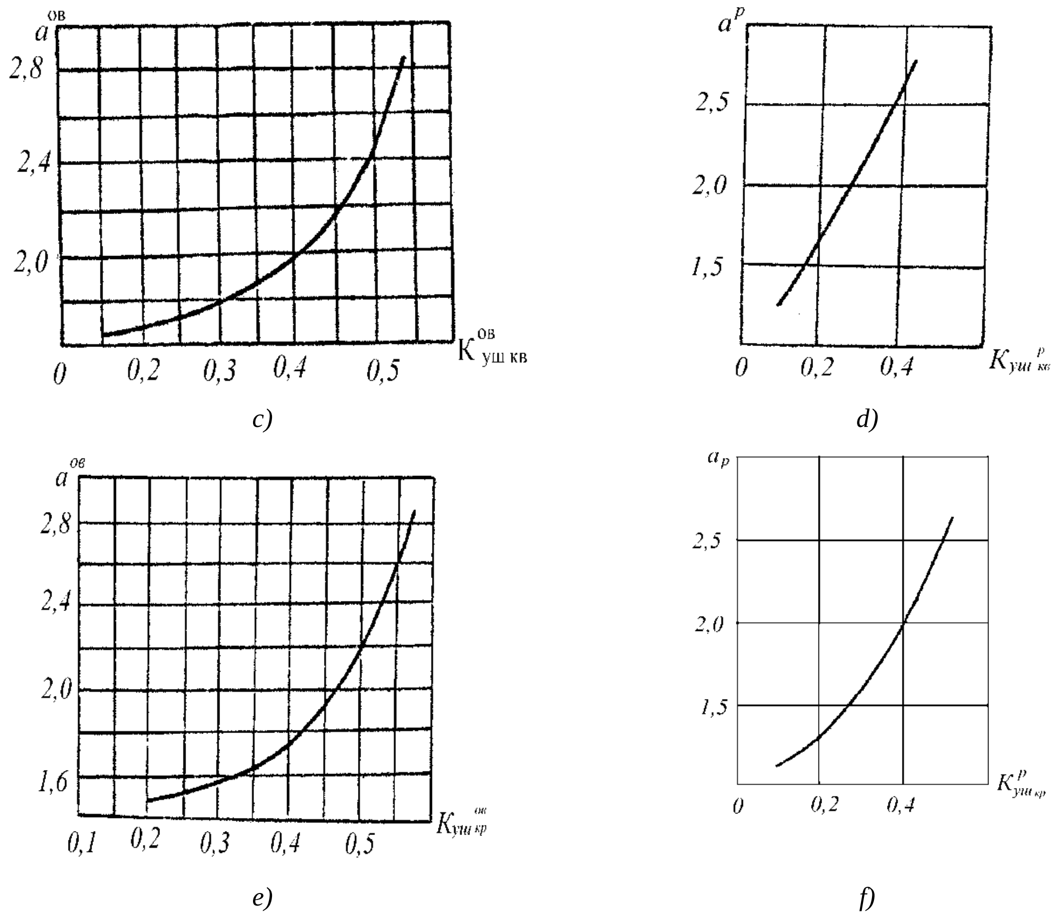


Fig. 9. Dependence of coefficients $K_{уш}^{ов}$, $K_{уш.кв}^{ов}$, $K_{уш.р}^{ов}$, $K_{уш.кв}^{р}$, $K_{уш.кр}^{ов}$, $K_{уш.кр}^{р}$

from the ratio of the geometric shapes of the caliber and the rolled workpiece to determine the expansion during rolling of workpieces made of aluminum alloys.

where $K_{кр}^{ов}$ - coefficient that takes into account the effect on the expansion of the non-uniformity of deformation along the width of the caliber when rolling in it an oval workpiece, Fig. 9, *e*;

d_0| - caliber size, mm;

$D_к^{кр}$ - rolling diameter of round caliber, mm

$$D_к^{кр} = A - 0{,}785 d_o| \quad (16)$$

- rhombic blanks in round calibers, mm

$$\Delta b_{кр}^p = K_{кр}^p \sqrt{\left(b_{р\,з} - d_{кр}\right)\frac{D_к^{кр}}{2}}\,\frac{b_{р\,з} - d_{кр}}{b_{р\,з}} - \left(b_{р.з} - d_{кр}\right)K_{уш}^{u} \quad (17)$$

where $K_{кр}^p$ - coefficient that takes into account the effect on the expansion of the non-uniformity of deformation along the width of the caliber when rolling a rhombic workpiece in it, Fig.9, *f*.

Formulas for determining the expansion (4, 7, 10, 13, 15, 17, 18) belong to the second stage in the development of the theory of expansion by gradation AI Tselikov, ie expansion is proportional not only to compression but also to the length of the capture arc. In addition, the obtained formulas take into account the ratio of geometric shapes of the caliber and the rolled workpiece, as well as the non-uniformity of deformation over the width of the caliber.

Conclusions

During the experiments it was found 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 depend on the heating temperature of the stamps. 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, metal pressure on the rolls during rolling of 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.

Mathematical models are developed and formulas for determination of expansion at rolling of preparations, in the conditions of isothermal and close to it deformation are received.Experimental studies of rolling blanks made of D16 alloy reinforced with SiC filamentary crystals under conditions of isothermal and near-deformation similar to the rolling of AK6 alloy blanks have identified a number of features of rolling this difficult-to-deform alloy.

Experiments have shown that the calibration calculations are performed according to the method developed for rolling billets of aluminum alloys, requires its adjustment for the manufacture of high-quality rolled billets from alloy D16, reinforced with filamentous crystals of SiC material.

The use of experimental studies and recommendations to determine the expansion, metal pressure on the rolls, friction will achieve greater accuracy in the manufacture of high-quality rolled blanks, the manufacture of forging rollers profiles of complex cross section, use less effort, etc.

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