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Improvement of Stamping by Rolling Processes of Pipe and Cylindrical Blades on Experimental Research

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Abstract. During the experimental study, a pronounced beating and sealing of the side surface of the tubular, cylindrical blanks was recorded. It is established that cracks appear and develop in the central part of the lateral surface, i.e., it are destroyed. This fact confirms the claim that the destruction of tubular, cylindrical blanks of some materials begins on the side surface. It is established that the bases of analytical dependencies between the components of deformations describe the obtained results of the experimental study of SR tubular, cylindrical blanks within the error of the experimental data, which made it possible to construct a number of mathematical models for the purpose of further study of the SDS and the method of their determination.

Introduction

Research methods and determination of limit value of the ratio of the height of the workpiece sample to its diameter regularities of deformation kinematics, formation of stress-deformed state of use of plasticity resource and loss of stability of billets and development on the basis of management of resource-saving processes of stamping by rolling (SR) [1-10].

Purpose. Establishment of real patterns of change of operating parameters of the universal vertical-boring machine 2A-135, and two installations prefix punching-1 (PSR-1), and (PSR-2), with mechanical control system of electromechanical drive.

Determination of the relative magnitudes of the difference between the results of theoretical and experimental studies [11, 12].

Methodology. Effective methods of experiment. The initial workpiece at SHO are segments of axisymmetric rolled metal, welding, stamping, obtained by the foundry method of the workpiece, as well as workpieces separated by a plastic offset from the pipe, strip or sheet. As shown by the analysis of the SR workpiece can be used in the production of a large number of parts such as flanges, bushings, bearing rings, gear couplings, workpieces precipitated by spherical punching, radiator flanges, radiator caps, workpieces by external flanges, products with bottoms and necks, flat round products, products with a rolling tool, stamping by rolling of plastic billets of a disk type, stamping of details difficult about the relief.

Improvement of processes of local rotational deformation is restrained due to the insufficiently developed computational apparatus of mechanics of formation, which is intended to provide: determination of kinematics of metal flux and estimation of influence on it of parameters of technological processes; determination of plasticity of metals; analysis of stress-strain state and accumulation of damage in the workpiece material; determining the effect of the amount of plasticity resource used on product performance.

Analysis of Research Methods

During the experimental studies of the processes of stamping by rolling of the SR on the PSR-1 and PSR-2 attachments, with the mechanical control system of the electromechanical actuator for molding of billets of lead and alloy materials AD 1 it is necessary to determine:

1) to investigate the influence and develop models of contact interaction of the tool with the workpiece and the formation of workpieces depending on the parameters of the SR processes;

2) to develop methods for evaluating the deformability of the workpiece material during stamping by rolling in the developed molding schemes, to establish the influence of technological parameters on the margin of plasticity and technological heredity of products;

3) develop recommendations for the rational design of SR processes.

The process of stamping rolling (SR) can be implemented with both the drive of the workpiece and the drive of the roll. When designing the equipment, we provide for the rotation of the workpiece, and the roller is able to rotate freely around its axis and move along the axis of the workpiece, to create the necessary rolling force. For realization of the SR process we have developed the equipment on the basis of the universal vertical-boring machine 2A-135, and the attachments PSR-1, and PSR-2, with a mechanical control system of the electromechanical drive for the molding of blanks.

The equipment involves the use of conical and cylindrical rolls with the possibility of changing their position relative to the workpiece for purposeful control of the flow of metal. As a result, advanced opportunities for forming difficult profiled blanks according to the beading schemes were obtained, as well as for bending, trimming and distributing the pipe, cylindrical blanks by the SR method, as well as implementing typical and combined molding schemes under the most favorable conditions.

Presenting Main Material

The study was conducted on a pilot universal vertical drilling machine 2A-135, and prefixes PSR-1, and PSR-2 [13].

An important factor during the experimental study of the processes of stamping by rolling tubular, cylindrical blanks is the flow of material during deformation. The criterion for the stability of deformation processes is the limit ratio a_{0*} of the longitudinal dimensions of the sample to the transverse, which characterizes their shape change without breaking and loss of stability.

The parameter a_{0*} will be determined according to the relation (1) which is proposed V.A. Croha[14]. At SR of pipe cylindrical billets with smooth ends $\nu = 0,5$. The results of the parameter calculation a_{0*} for the experimentally studied materials are given in the Tab. 1. The values of the hardening curve parameters are taken from the reference [14].

$$a_{0*} = \frac{h_0}{d_0} = 2,24 \cdot \frac{\sqrt{m}}{\nu}. \qquad (1)$$

Table 1. The value of the limiting ratio of the height of the sample to its diameter

Material	ν	n	$a_0^* = h_0/d_0$
Plumbum	0.5	0.486	3.123
Alloy AD 1	0.5	0.206	2.03

Carrying out an Experimental Study of Punching by Rolling Cylindrical Billets

To determine the features of the deformation process, the study of stress-strain state (SDS) and deformability of the tubular cylindrical billets at SR, as well as the basis of approximations of dependencies between the components of deformation, an experimental study of the SR process [14, 15].

On Fig. 1 and 2, 3, 4, 5 a general view of research machines is presented [14-16].

Fig. 1. Vertical-drilling machine 2A-135, to conduct a study of the SR process

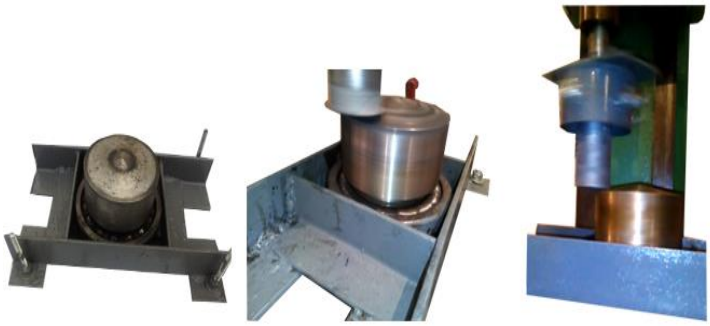

Fig. 2. General view of the PSR-1 console for the study of the SR process

Fig. 3. General view of the PSR-2 console for the study of the SR process

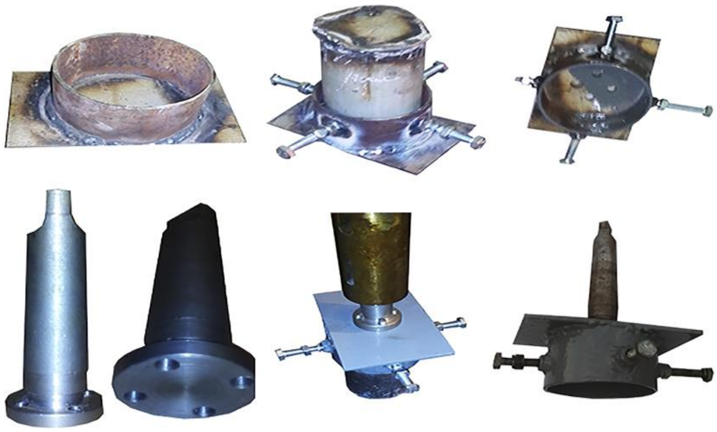

Fig. 4. General view of the matrix intended for fixing different types of billets for PSR-1 consoles; PSR-2, and to conduct a study of the SR process

Fig. 5. General view of experimental blanks

Each sample was assigned an ordinal number during the experimental study, and the values of height (*h*) and maximum diameter (*d*) were measured in three meridional planes before and after the test. Using the obtained size values, their average values were calculated. The values of measurements and calculations of the dimensions of the workpieces are given in Tab. 2 and 3.

During the preparation of lead tubular, cylindrical billets, of lead and aluminum alloy AD 1, samples of the required height were cut with the help of a locksmith tool to conduct an experimental study of the SR process with a certain ratio *h/d* of tubular, cylindrical billets with a diameter of 40-80 mm. On Fig. 6 - Fig. 7 and Fig. 8 - 12 the tubular, cylindrical blanks before and after the experiment, the SR processes, are shown.

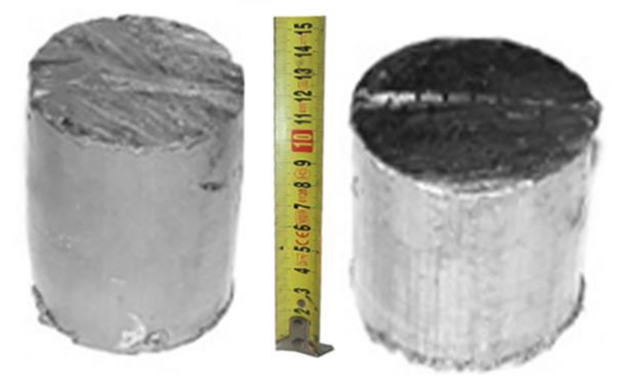

Fig. 6. Lead cylindrical blanks prior to the experiment

Fig. 7. Lead cylindrical blanks after the experiment

Fig. 8. Pipe cylindrical lead blanks before the experiment

Fig. 9. Pipe cylindrical blanks of lead after the experiment

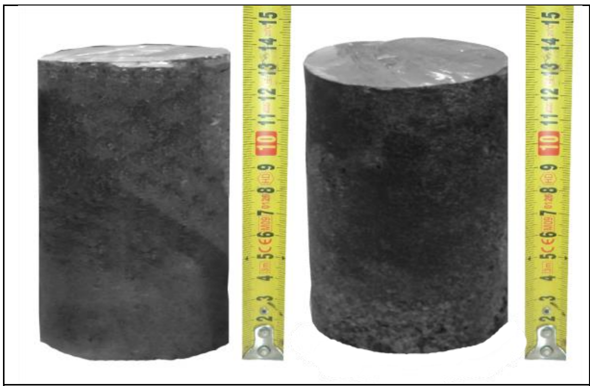

Fig. 10. Cylindrical billets of aluminum alloy AD 1 before the experiment

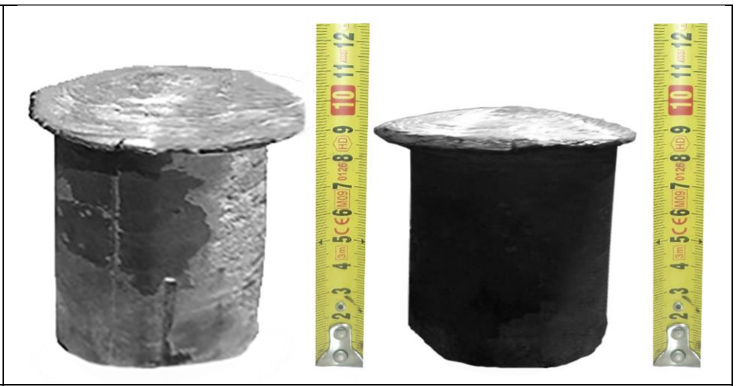

Fig. 11. Cylindrical billets made of aluminum alloy AD 1 after the experiment

Fig. 12 – Pipe cylindrical billets made of aluminum alloy AD 1 before the experiment

Table 2. The value of the height and maximum diameter of the tubular cylindrical specimens before the test experiment

№ specimen	Plane	*h*	*d*		*h/d*	Material
1(Fig. 6.)	1	150.1	60.3		2.4892	Plumbum
	2	150.4	60.2		2.4983	
	3	150.5	60.1		2.5041	
	Medium size	150.33	60.2		2.49375	
2	1	150.2	60.1		2.49911	Plumbum
	2	150.0	60.5		2.47793	
	3	149.8	60.0		2.49666	
	Medium size	150.0	60.2		2.49169	
3	1	150.1	60.1		2.49750	Plumbum
	2	150.2	60.0		2.50333	
	3	150.1	60.0		2.50166	
	Medium size	150.1	60.0		2.50083	
№ spicemen	Plane	*h*	*d*	*s*	*h/d*	
4(Fig. 8.)	1	149.5	60.1	9.99	2.48918	Plumbum
	2	149.6	60.2	10.0	2.47429	
	3	149.9	60.3	10.0	2.48590	
	Medium size	149.66	60.2	10.1	2.48312	
5	1	150.4	60.0	10.1	2.50666	Plumbum
	2	150.3	60.1	10.1	2.50083	
	3	150.3	60.4	11.3	2.48841	
	Medium size	150.33	60.16	10.2	2.49863	
6	1	150.1	80.1	5.2	1.87390	Plumbum
	2	149,9	80.2	5.3	1.86907	
	3	149,8	80.1	5.1	1.87016	
	Medium size	149.93	80.2	5.0	1.87104	

Prolongation Tab. 2

№ spicemen	Plane	*h*	*d*	*s*	*h/d*	Material
7(Fig. 10.)	1	148.3	59.9		2.47579	AD 1
	2	149.3	60.0		2.49997	
	3	149.4	60.0		2.49998	
	Medium size	149.0	59.9		2.49191	
8	1	150.2	60.0		2.50333	AD 1
	2	150.2	60.1		2.49169	
	3	150.0	60.1		2.49584	
	Medium size	150.13	60.06		2.49695	
9	1	140.0	80.0		1.75	AD 1
	2	140.1	80.0		1.75125	
	3	140.0	80.2		1.74563	
	Medium size	140.0	80.0		1.74621	
№ spicemen	Plane	*h*	*d*	*s*	*h/d*	
10(Fig. 12.)	1	140.0	80.1	7.0	1.74254	AD 1
	2	140.0	80.5	7.0	1.73913	
	3	140.3	80.6	7.8	1.74069	
	Medium size	140.1	80.23	7.0	1.74078	
11	1	140.3	80,1	7.1	1.75156	AD 1
	2	140.5	80.0	7.2	1.75625	
	3	140.0	80.2	7.3	1.74563	
	Medium size	140.26	80.1	7.2	1.75114	
12	1	140.3	80.2	7.6	1.74937	AD 1
	2	140.3	80.5	7.7	1.74285	
	3	140.2	80.3	7.4	1.74595	
	Medium size	140.26	80.33	7.56	1.74606	

According to the experimental-analytical approach by which the stress-strain and boundary states are investigated, the dependence between the axial ε_z and circular ε_φ deformations of the lateral surface of the cylindrical specimen at the SR is established by the results of measurements of the dimensions *a*, *b* and the distorted coordinate grid at intermediate stages of deformation:

$$\varepsilon_z = f(\varepsilon_\varphi) \quad (2)$$

as a tabular function. Deformations ε_z and ε_φ are determined by expressions [17]:

$$\varepsilon_z = \ln\left(\frac{b}{b_0}\right); \quad \varepsilon_\varphi = \ln\left(\frac{a}{a_0}\right). \quad (3)$$

On the side surface of the workpiece on Fig. 13 by changing the dimensions of which in accordance with formulas (3) determine the values of the circular ε_φ and axial ε_z logarithmic deformations [18-20].

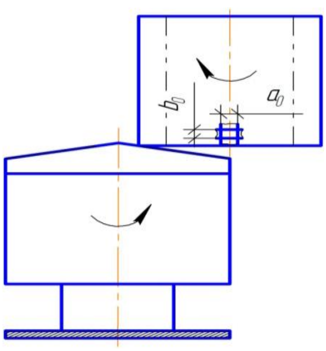

Fig. 13. A dimensional grid for the experimental determination of deformations

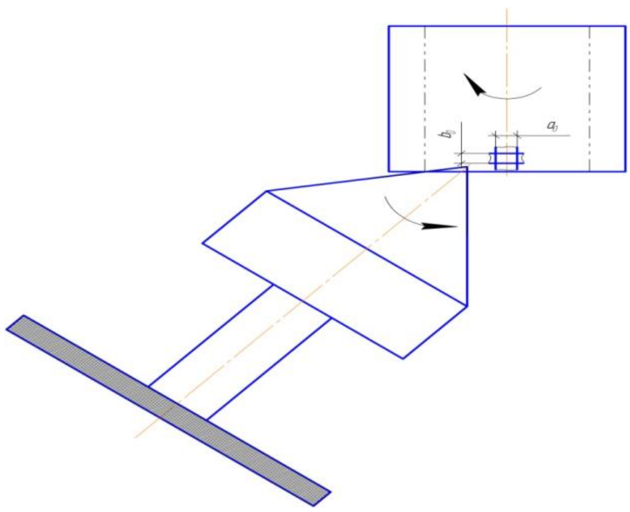

Fig. 14. A dimensional grid for the experimental determination of deformations

The working bodies (rolls) of SDS-1 and SDS-2 machines are located at the top of them, so the SR process will occur from top to bottom.

On Fig. 7 and 10 lead sample № 4 and aluminum sample № 11 at SR are depicted [18-20].

Table 3. Height and maximum diameter of cylindrical specimens after testing

№ specimen	Plane	*h*	*d*	*s*	*h/d*	Material
1(Fig. 6.)	1	98.7	120.1		0.8218	Plumbum
	2	98.5	120.5		0.8174	
	3	99.4	120.3		0.8262	
	Medium size	98.86	120.3		0.8218	
2	1	100.4	122.1		0.8222	Plumbum
	2	101.3	121.8		0.8316	
	3	101.3	124.6		0.8130	
	Medium size	101.0	122.83		0.8222	
3	1	97.4	123.4		0.7893	Plumbum
	2	97.9	123.5		0.7927	
	3	98.5	124.0		0.7943	
	Medium size	97.93	123.63		0.8416	
№ specimen	Plane	*h*	*d*	*s*	*h/d*	
4(Fig. 8.)	1	96.2	121.3	8.7	0.7930	Plumbum
	2	96.4	122.6	8.9	0.7811	
	3	96.4	123.4	7.8	0.7811	
	Medium size	96.33	122.43	8.4	0.7850	
5	1	101.4	123.0	7.8	0.8243	Plumbum
	2	100.1	123.0	7.9	0.8113	
	3	101.0	123.5	7.0	0.8178	
	Medium size	100.83	123.16	7.56	0.8178	
6	1	102.0	124.3	7.9	0.8205	Plumbum
	2	102.0	124.0	7.9	0.8205	
	3	102.0	124.3	7.8	0.8205	
	Medium size	102.0	124.2	7.86	0.8205	
№ specimen	Plane	*h*	*d*		*h/d*	Material
7(Fig. 10.)	1	100.0	125.3		0.7980	AD 1
	2	101.0	125.4		0.8054	
	3	101.0	125.6		0.8041	
	Medium size	100.66	125.43		0.8025	
8	1	102.0	123.2		0.8279	AD 1
	2	102.5	124.3		0.8246	
	3	102.5	124.3		0.8246	
	Medium size	102.33	123.93		0.8257	
9	1	103.1	122.3		0.8430	AD 1
	2	103.2	122.4		0.8431	
	3	103.2	122.4		0.8431	
	Medium size	103.16	122.36		0.8430	
№ specimen	Plane	*h*	*d*	*s*	*h/d*	
10(Fig.12.)	1	95.6	125.3	9.1	0.7629	AD 1
	2	95.6	125.4	8.9	0.7623	
	3	95.5	125.3	9.1	0.7621	
	Medium size	95.56	125.33	9.0	0.7624	
11	1	94.3	124.7	10.1	0.7562	AD 1
	2	94.4	124.7	10.2	0.7570	
	3	94.5	124.9	10.0	0.7566	
	Medium size	94.4	124.76	10.1	0.7566	
12	1	90.1	123.2	9.8	0.7313	AD 1
	2	90.0	123.1	9.7	0.7311	
	3	90.4	123.4	9.9	0.7325	
	Medium size	90.16	123.23	9.8	0.1316	

Fig. 15. Pipe, cylindrical billets № 4 (left) on PSR-2 and 10 (right) on PSR-1 prefix, which are made of lead and AD 1 at SR

Lead samples were subjected to deformation by a SR test machine on PSR - 2 and PSR - 1, with a force of up to 100 kN and dry friction at the ends of the samples. At the same time, there was a beating and a beading, which is illustrated on Fig. 9 and partially reflected in Tab. 2 and 3 at different stages of the process [18, 21].

Fig. 16. Plumbum blanks № 8 before the SR (left) and after the research on the SR (right)

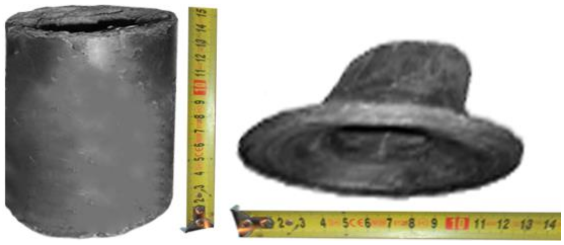

Fig. 17. Plumbum blanks № 9 before the SR (left) and after the research on the SR (right)

Fig. 18. Plumbum blanks №10 after the research on the SR

Fig. 19. Plumbum blanks №8 (left) and №6 (right) at intermediate stages on the SR

Fig. 20. Lead sample № 11 with size mesh applied to the SR (left) and lead sample № 5 after the research of the SR (right)

Samples of lead and aluminum alloy AD 1, subjected to the SR process on prefixes PSR-1, PSR-2 [18-20].

Fig. 21. Plumbum samples №1, 3, 7, 10, 12, 13 after the research on the SR of end

Sample № 11 of aluminum alloy AD 1 was tested for SR with dry friction at its ends. The sample collapsed under the load on Fig. 23 results show that the macrocracks are located on the lateral surface of the cylindrical specimen and make an angle with the specimen axis about 45°, and the damage extends to the whole height of the specimen and not to a certain part of it, as, for example, this was the case for specimen № 11. As a result of the study it was found that the material of samples № 11 - 12 is rather alloplastic and brittle and did not occur due to small plastic deformations of the visible barrel.

Fig. 22. Sample №11 of aluminum alloy AD 1 before SR (right) and after the destruction (left)

Fig. 23. Sample №12 of aluminum AD 1 after the destruction

Determination of Deformation of the Lateral Surfaces of the Tubular Billets During the Experimental Study of the Process of Stamping by Rolling

To ensure the tracking of changes in the coordinate grid parameters and the shape change of the sample at SR, a method for determining deformation increments based on photography was developed.

In accordance with the developed technique, photos were taken of tube, cylindrical samples and a distorted grid, while the samples were not unloaded, but only stopped the deformation for a few seconds [18-20].

The photos were taken with a SONY CYBER-SHOT camera, 14.1 megapixels using the macro capture setting. When photographing in the plane of the coordinate grid of the sample, a scale bar was located at each stage of the SR. [22-24].

Fig. 24. Cylindrical sample №18 of aluminum alloy AD31T before (up) and after (down) the research on the SR

The obtained photos were processed in the software complex Compass 3D - V16. When processing the results of the experimental studies, the obtained images of the deformed samples are opened in the CAD system Compass 3D - V16, then the worksheet is inserted into the program, which is set to the active status, and the drawing palette - to the background. Further, the photo is enlarged up to 10 times, a circle is formed at two points formed by the intersection of the horizontal and vertical lines of the grid. The corresponding circles are constructed at several points, as shown on Fig. 25, which are symmetrical about the central part of the side surface of the sample [23].

The next step in the processing of the obtained drawings is to measure the distance between the centers of circles previously constructed. The scale scale, which is located in the same plane with the coordinate grid of the samples, determines the scale factor of the image and determines the real size of the parameters *a*, *b* of the deformed grid. The distances obtained are the parameters of the investigated coordinate grid, using which the values of axial ε_z and circular ε_φ logarithmic deformations are calculated.

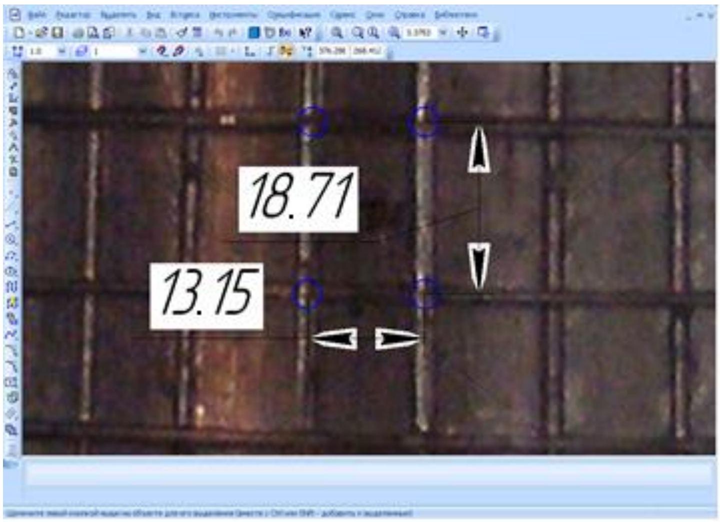

Fig. 25. Determination of the dimensions of the coordinate grid of the plumbum sample № 5

As an example, on Tab. 4 the values of the coordinates of the grid at SR lead billet № 5 are shown, which were recorded by the photo, and calculated on the basis of the obtained parameters of the mesh of the deformation components.

Using the obtained values of the deformed coordinate grid, the values of logarithmic deformations at each stage of SR were calculated for each sample, which is the end result of the experimental part of the technique of the SDS material study. The mentioned results of the study of the SR samples between the flat rigid conical, cylindrical rolls (punches) and support rings (matrix) are illustrated on Fig. 26 - 27 [25-30].

Table 4. The size of the deformation mesh and the calculated deformation during the SR of the blank №5

Stage	*a*	*b*	ε_φ	ε_z
0	2.42	3.85	0	0
1	2.55	3.45	0.0499	-0.1113
2	2.59	3.29	0.0662	-0.1566
3	2.70	3.09	0.1062	-0.2208
4	2.80	2.91	0.1442	-0.2792
5	2.96	2.61	0.1987	-0.3876
6	3.10	2.35	0.2463	-0.4949
7	3.27	2.22	0.3006	-0.5500
8	3.67	1.85	0.4152	-0.7343
9	4.05	1.67	0.5138	-0.8385
10	4.52	1.44	0.6232	-0.9865
11	4.97	1.33	0.7184	-1.0664
12	5.41	1.21	0.8024	-1.1605

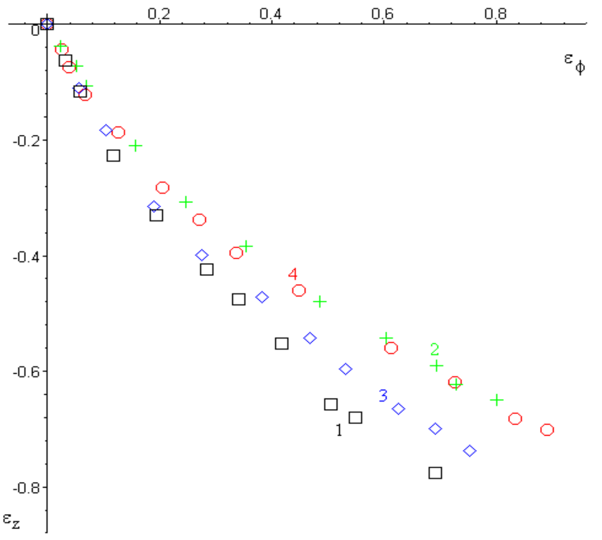

Fig. 26. The value of the axial ε_z and circular ε_φ logarithmic deformations for SR blanks №1 – 4: 1 – blank №1; 2 – blank №2; 3 – blank №3; 4 – blank №4

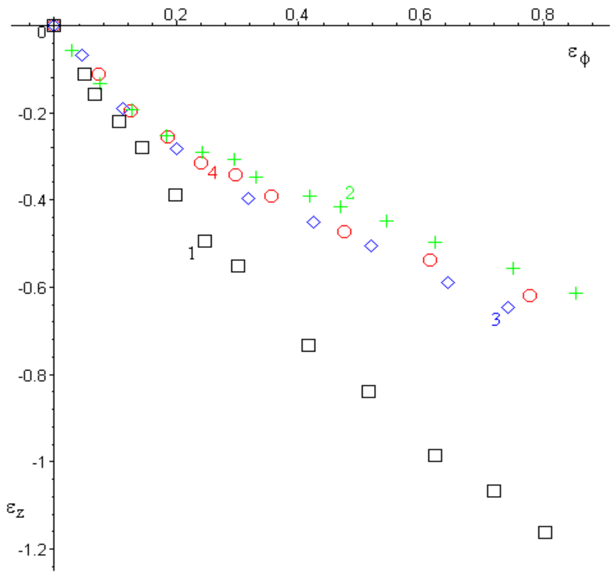

Fig. 27. The values of the axial ε_z and circular ε_φ logarithmic deformations for SR blanks № 5 – 8: 1 – blank №5; 2 – blank №6; 3 – blank №7; 4 – blank №8

Using the results of the experimental study of SR in the form of values of deformation components and the proposed base of analytical dependencies between the axial ε_z and circular ε_φ deformations in the form of ratios (4), (5), (6), (7), the approximation of the research results is shown, which is reflected in Tab. 5 and Fig. 28. The values of the parameters of the approximations of the dependences between the components of the deformations were determined in accordance with the experimental-analytical approach [26-30].

$$\varepsilon_z = -\frac{1}{2}\cdot\varepsilon_\varphi - \frac{3}{2}\cdot m\cdot arctg\left(\frac{\varepsilon_\varphi}{m}\right), \quad (4)$$

$$\varepsilon_\varphi = -2\cdot\varepsilon_z + 3\cdot p\cdot arctg\left(\frac{\varepsilon_z}{2\cdot p}\right), \quad (5)$$

$$\varepsilon_z = -\frac{1}{2}\cdot\varepsilon_\varphi + \frac{3\cdot m}{2}\cdot\left(e^{-\varepsilon_\varphi/m} - 1\right), \quad (6)$$

$$\varepsilon_z = \frac{a}{b}\cdot\left(e^{-b\cdot\varepsilon_\varphi} - 1\right). \quad (7)$$

Table 5. The value of the parameters of the approximations of thedependence between the components of deformation at SR

	(Fig. 3)	$\Sigma\delta_i$	(Fig. 4)	$\Sigma\delta_i$	(Fig. 5)	$\Sigma\delta_i$	(Fig. 6)	$\Sigma\delta_i$
1	0.2216	0/0020	0.3428	0.0011	0.3301	0.0012	1.9263 1.7592	0.0016
2	0.1145	0.0026	0.1506	0.0012	0.1647	0.0014	1.4772 1.7269	0.0007
3	0.1756	0.0008	0.2508	0.0009	0.2518	0.0009	1.8353 1.9577	0.0021
4	0.1204	0.0007	0.1570	0.00261	0.1734	0.0002	1.5799 1.8598	0.0021
5	0.4933	0.0022	0.8408	0.0012	0.8502	0.0069	2.2079 1.1618	0.0015
6	0.0872	0.0006	0.1101	0.0069	0.1254	0.0008	1.4773 2.1343	0.0059
7	0.1274	0.0008	0.1724	0.0017	0.1820	0.0007	1.6821 2.1331	0.0018
8	0.1100	0.0008	0.1472	0.0033	0.1584	0.0004	1.6278 2.2048	0.0011
11	0.0499	$2.91\cdot10^{-5}$	0.0768	$4.72\cdot10^{-6}$	0.0736	$5.08\cdot10^{-6}$	1.7481 6.0301	$7.32\cdot10^{-8}$
15	0.5979	0.0011	1.1072	0.0003	1.3073	0.0006	2.0188 0.5951	0.0006
16	0.1972	0.0011	0.3019	0.0005	0.2911	0.0007	1.9233 1.9840	0.0008
18	0.3287	0.0036	0.5341	0.0016	0.5106	0.0015	1.9402 1.1903	0.0015

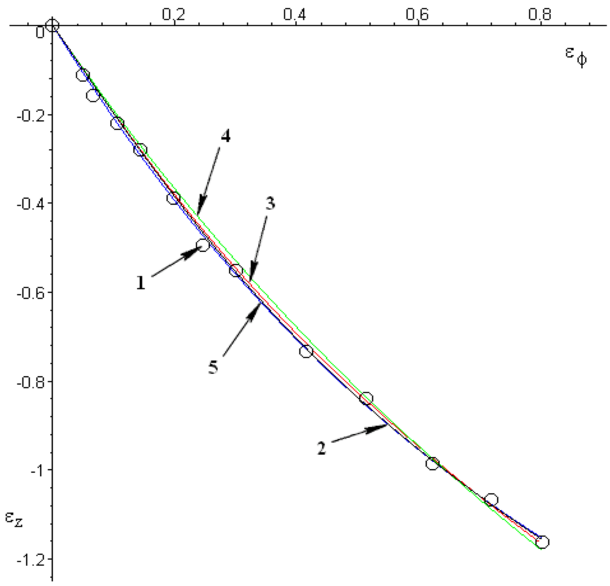

Fig. 28. Experimental axial ε_z and circular ε_φ values logarithmic deformations and graphs of their approximations for the plumbum sample №5: 1 – experimental values of deformations; 2 – dependency approximation (3); 3 – dependency approximation (4); 4 – dependency approximation (5); 5 – dependency approximation (6) [26-30]

Summary

According to the experimental study of SR tubular, cylindrical blanks, the following conclusions were obtained:

During the experimental study of tubular, cylindrical blanks, lead and aluminum alloy AD 1, a pronounced flanging and flanging of the lateral surface of the tubular, cylindrical blanks was recorded.

Analyzing the results of the SR blanks made of aluminum alloy AD 1 (Fig. 24), it is established that cracks appear and develop in the central part of the lateral surface, ie fracture. This fact confirms the claim that the destruction of tubular, cylindrical blanks of some materials begins on the side surface. That is, the potentially dangerous area, in terms of damage, is the central parts of the side surfaces.

The technique used to determine deformation increments based on photography, the main content of which is to obtain a sample and coordinate grid and process them in the CAD system, provides an opportunity not to unload the sample during the study and reduce the complexity of the experimental study without losing accuracy.

It is established that the base of analytical dependencies between the components of deformations describes the results of the experimental study of stamping by rolling tubular, cylindrical blanks within the error of the experimental data, which made it possible to construct a number of mathematical models for the purpose of further study of both SDS and material boundaries methods for their determination.

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