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TECHNOLOGICAL PASSPORT STUDY PISTON AND CONNECTING ROD BARE MATERIAL AXIAL ROTARY PISTON PUMP

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A technological passport of the alloy steel material has been formed, from which a piston-connecting rod pair of an axial-rotor piston pump is made in the form of functions: flow curve, plasticity diagram, Bauschinger curve, calibration graph.

Using the approximation of the neck contour by the Gaussian function at any moment of deformation of a cylindrical specimen in the supercritical region, the main parameters used in engineering calculations are related: the minimum diameter of the specimen, the current diameter of the specimen with a given coordinate, the relative (absolute) elongation and contraction with the parameters referred to the moment of rupture sample. In addition, the elongation and contraction of the sample after fracture are unambiguously associated. The approximation avoids the inconvenient and relatively expensive video filming for studying the history of deformation.

It is shown that the effect of heat treatment on the mechanical properties of these steels is not the same for different stress state schemes. The tensile strengths of these steels are close as delivered.

The plasticity characteristics of steel 30Kh3MFA exceed the plasticity of steel 38Kh2MYuA by 1.5 times. The flow curves of the steels under consideration have the following tendency: so the coefficient of approximation of the flow curve for 38Kh2MYuA steel in the delivery state exceeds its value in relation to steel 30Kh3MFA by 1.23 times. After heat treatment of these steels, the value of the approximation coefficient increases: for steel 38Kh2MYuA by 1.11 times, for steel 30Kh3MFA by 1.46 times.

The results obtained make it possible to control the mechanics of the technological operation of rolling the piston-connecting rod pair and create a process control mechanism in order to prevent rejects during the rolling process, which manifests itself in the form of going beyond the tolerance field for the axial clearance of the piston-connecting rod pair, as well as destruction during rolling of the inner part of the piston.

Key words: *technological passport, piston-connecting rod, axial-rotor piston pump, flow curve, plasticity diagram, Bauschinger curve, calibration graph.*

F. 32. Fig. 6. Table. 1. Ref. 11.

1. Problem formulation

Modern industrial production is associated with the use of various hydraulic machines. In hydraulic machines, one of the most important structural elements is an axial-rotor piston pump, in which the driving link is a piston-connecting rod pair. During the technological operation of rolling the piston-connecting rod pair, the problematic issue is the instability of the axial clearance between the piston and the connecting rod. Obtaining a stable clearance depends significantly on the mechanical properties of the piston-connecting rod material.

For the experimental construction of the mechanical properties of the material (characteristics), it is necessary to use the methods of their construction for steels 38Kh2MYuA and 30Kh3MFA, both in the state of delivery and after heat treatment (after improvement). The piston and the connecting rod of the axial-rotor piston pump, respectively, are made of the indicated materials.

The results obtained will make it possible to control the mechanics of the technological operation of rolling the piston-connecting rod pair and create a process control mechanism in order to prevent rejects in the rolling process, which manifests itself in the form of going out of the tolerance field for the axial clearance of the piston-connecting rod pair, as well as destruction during rolling of the inner part of the piston.

2. Analysis of last researches and publications

Traditional concepts of the mechanical characteristics of a material in the mechanics of a deformable solid are limited by such parameters as yield strength $\sigma_{0,2}$, ultimate strength σ_{np}, endurance limit σ_r, as well as plasticity characteristics: relative residual elongation - δ , relative residual narrowing - ψ. In the theory of metal forming by pressure, the most important tasks are: assessment of the stress-strain state of workpieces, the study of technological inheritance for the quality of products obtained by pressure processing, assessment of the used plastic resource of workpieces in the process of their shaping, etc. The solution of these problems is based on a deeper knowledge of the mechanical characteristics of the material.

Such universal mechanical characteristics of materials are functions that reflect the properties of the material depending on the degree of deformation (the ability to harden), the stress state diagram, and the history of deformation. These ideas about the material are reflected in the works devoted to the formation and development of the phenomenological theory of deformability [1-4].

In the phenomenological theory of the deformability of metals, one proceeds from the following functions that form the so-called technological passport of the material [5-12]:

1) material flow curve in coordinates - stress intensity - σ_u , strain intensity - ε_u (accumulated strain intensity - $\overline{e_u}$);

2) a diagram of plasticity in coordinates - the limiting degree of deformation (the accumulated intensity of deformation - $\overline{e_u}$ to the moment of destruction - e_p), an indicator of the stress state $\eta = \frac{\sigma_1 + \sigma_2 + \sigma_3}{\sigma_u}$;

3) diagram of stability in coordinates - deformation at the moment of loss of stability e_{kr} (appearance of a “neck” during tension) - indicator of the stress state η;

4) Bauschinger's curve in coordinates - Bauschinger's coefficient $\beta = \frac{(\sigma_u)'}{\sigma_u}$, where is $(\sigma_u)'$ the yield stress after the change in the direction of deformation, σ_u - the yield stress before unloading before the change in the direction of deformation;

5) calibration graph - hardness (HV, HB, HRC) depending on stress intensity σ_u , strain intensity ε_u ;

6) the dependence of hardness on the specific potential energy $HV = f(W_{yg})$.

3. Purpose of the research

Generate a technological passport of the alloy steel material, from which the piston-connecting rod pair of the axial-rotor piston pump is made in the form of functions: flow curve, plasticity diagram, Bauschinger curve, calibration graph. Create a process control mechanism in order to prevent scrap in the seaming process.

4. Results of the research

Plotting the flow curve of the materials under study.

The flow curves of steels 30Kh3MFA and 38Kh2MYuA were plotted according to the results of static tests for uniaxial tension and compression of cylindrical specimens. The tensile test obtains data only for limited strains equal to the critical value corresponding to the onset of plastic deformation buckling (neck formation). In this case, the stress intensity:

$$\sigma_u = P/A, \quad (1)$$

strain rate

$$e_u = l_n \frac{l}{l_0} \text{ : (stretching)}, \qquad e_u = 2ln\frac{d}{d_0} \text{ : (compression)}. \quad (2)$$

Based on the incompressibility condition, relations (1) and (2) are reduced to the form

$$\sigma_u = p \cdot \exp(e_u) / A_0 \text{, (under tension)} \quad (3)$$

$$\sigma_u = p / A_0 \cdot \exp(e_u) \text{, (under compression).} \quad (4)$$

In relations (1), (2), (3), (4): P - is the deforming force; A_0, A - sectional area before and after deformation; l, l_0 - are the length of the working part of the sample before and after deformation.

To construct the flow curve $\sigma_u = f(e_u)$ with deformations $e_u > e_{kp}$, we used the solutions of N.N. Davidenkov and N.I. Spiridonova [6]:

$$\sigma_u = \frac{4p}{\pi d^2\left(1+\frac{d}{8R}\right)}, \tag{5}$$

$$e_u = 2\ln\frac{d_0}{d}, \tag{6}$$

where d_0, d – respectively the initial and current smallest diameters of the neck cross section; R – is the radius of curvature of the neck contour at the point of its smallest cross-section.

Let us also give a technique developed by us for the purpose of developing and refining the technique for constructing the flow curve by tensile testing in tension of a cylindrical specimen. At any time when the neck is formed, its outer contour can be described by the Gaussian function

$$d(x) = d_{уст} + \left(d_{\min_i} - d_{уст}\right)\exp\left[-\left(\frac{x-x_c}{w}\right)^2\right], \tag{7}$$

where $d(x)$ – is the current diameter of the sample with the x coordinate; ($d_{\min_i}$) - is the minimum current diameter of the sample at the place of the greatest localization of deformation and subsequent rupture; x_c - coordinate; $d_{\min_i}$; $d_{уст}$ - sample diameter corresponding to stable deformation (at a distance from the break); W - is a parameter of the Gaussian function.

For steel 30Kh3MFA, the character of the approximating function is shown in fig. 1.

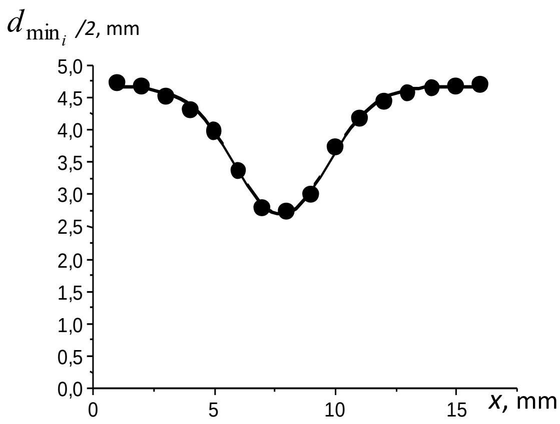


Fig. 1. Approximation of the neck contour by the Gaussian function (7) (steel 30Kh3MFA)

Similar data were obtained for steels of grades (30Kh3MFA after heat treatment, 38Kh2MYuA, 38Kh2MYuA after heat treatment). As can be seen, the choice of function (7) is justified by a sufficiently accurate description of the contour (χ^2 = 0.0025, 99.6% compliance).

In expression (7) to determine ($d_{\min_i}$), we use the experimental data obtained by P. Bridgman [7].

With an accuracy sufficient for practical calculations, it can be assumed that the dependence of the minimum relative radius of curvature on the accumulated intensity of deformations is linear up to fracture. Taking into account the boundary conditions

$$\frac{d_{\min_i}}{R_i} = \frac{d_ш}{R_ш}\frac{e_i - e_y}{e_ш - e_y}, \tag{8}$$

where $e_{уст} = 2\ln\frac{d_0}{d_{уст}}$, $e_ш = 2\ln\frac{d_0}{d_ш}$.

The xc coordinate in formula 7 can be taken $x_c = l_0/2$. Wherein $d_{\min_i} = d_{уст}$.

When approximated by a Gaussian function in the form (7), it seems possible to determine the minimum radius of curvature corresponding to the extremum of the function

$$R_{i\min(x=x_c)} = R_i = \frac{\dfrac{\partial^2(d(x))}{\partial x^2}}{\left(1+\left(\dfrac{\partial(d(x))}{\partial x}\right)^2\right)^{3/2}} = \frac{w^2}{d_{усm} - d_{\min_i}}. \quad (9)$$

The volume constancy condition must be met at any stage of sample deformation.

$$\Delta = \frac{1}{l_0 d_0^2}\int_0^{l_i} d(x)^2 dx = 1, \quad (10)$$

where l_0, d_0 – are the initial length and diameter of the sample; l_i - is the current length.

From condition (10) for a given current length l_i (or elongation Δl_i) of the sample, we find the minimum diameter ($d_{\min_i}$).

For the studied steel grades (30Kh3MFA, 30Kh3MFA after heat treatment, 38Kh2MYuA, 38Kh2MYuA after heat treatment), using the tension diagram, we obtained experimentally - the calculated points shown in fig. 2.

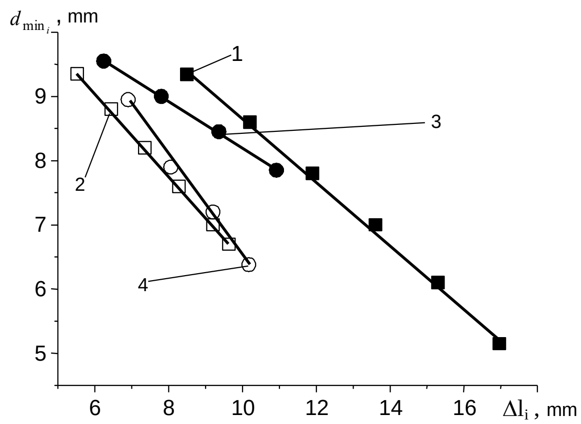


Fig. 2. Dependence of the minimum current diameter on the absolute elongation of the studied steel grades: 1 – 30Kh3MFA, 2 – 30Kh3MFA after heat treatment, 3 – 38Kh2MYuA, 4 – 38Kh2MYuA after heat treatment.

Thus, absolute elongation and minimum diameter correlate fairly accurately. The final dependence can be determined based on the boundary conditions

$$d_{\min_i}(\Delta l) = \frac{\left(d_{усm} - d_{ш}\right)\Delta l_i + d_{ш}\Delta l_{усm} - d_{усm}\Delta l_{разр}}{\Delta l_{усm} - \Delta l_{разр}}. \quad (11)$$

The intensity of stresses and strains in the supercritical region can be calculated using the formulas

$$e_i = \ln\frac{A_0}{A_i} = 2\ln\frac{d_0}{d_{\min_i}}, \quad (12)$$

$$\sigma_i = \frac{P_i}{A_i\left(1+\dfrac{d_{\min_i}}{8R_i}\right)} = \frac{4P_i}{\pi d_{\min i}^{\,2}\left(1+\dfrac{d_{\min_i}}{8R_i}\right)}. \quad (13)$$

Thus, the technique for constructing the flow curve is as follows:

1) Pre-determined by appropriate measurements of the value l_0, d_0 , $d_{усm}$, $d_{ш}$, $R_{ш}$.

2) We divide the section of neck formation on the machine diagram with the necessary number of points for plotting, thus setting Δl_i , and, respectively, P_i .

3) According to the formula (11), we determine the current minimum diameter of the sample $d_{\min_i}$ and the corresponding intensity of deformations $e_i = 2\ln\frac{d_0}{d_{\min_i}}$

If empirical evidence shows that addiction nonlinear, then first calculate the parameter w - under boundary conditions $l_{разр}$, $\frac{d_ш}{R_ш}$, $R_ш$ from expression (9) with mandatory control and refinement according to condition (10). Further, from condition (10), using a computer, for a given Δl_i, find $d_{\min_i}$.

Comment. Since the last point of the neck formation area is the limiting point at which hypothesis (a) - is violated, it is the same as the area adjacent to this point. To improve the accuracy when constructing the flow curve, this section should be excluded from consideration. An analysis of a number of experimental data shows that the violation of the macrostate of the material occurs already at deformations exceeding approximately half of the deformation calculated from the diameter of the collapsed neck. Those. the condition must be met $e_i \le 0{,}5 e_ш$. Points for which this condition is not met are excluded.

4) Using the formula (8), we determine the current ratio $\frac{d_{\min_i}}{R_i}$ (by e_i).

5) Determine the stress intensity using expression (13).

In order to verify the proposed method, flow curves were constructed by testing short cylindrical specimens for compression (the technique is given, for example, [4,8] and tensile tests. The degree of deformation was calculated as the arithmetic mean by measuring the height of the sample, the cross-sectional area, and the change in the size of the square grid applied to the lateral surface of the sample with a pyramid of a hardness tester. To reduce the effect of friction on the ends of the sample, graphite grease with lead and brass gaskets was applied. Standard tenfold cylindrical specimens were tested in tension.

The flow curves were approximated by the P. Ludwik function $\sigma_u = Ae_u^n$.

The experimental data used in the calculations are summarized in Table 1. In Fig. 3 shows the plotted compression and tension flow curves for 2 steel grades. The squares denote the experimental data for compression, the squares, crossed out with a cross - stable stretching, open circles - stretching at the site of neck formation. For approximation, the least squares method was used. Based on the above, we can conclude that the location of the curves is quite close. The insignificant discrepancy can be explained, first of all, by the influence of friction forces during compression experiments and the approximation of the proposed hypotheses.

Table 1

Experimental verification of the flow curve construction method

Material	$d_{уст}$	$d_ш$	$R_ш$	w	A,MPa	n	A,MPa	n	A, MPa	n
	mm				compression		stretching		stretching stable	
30Kh3MFA	9,34	5,15	8	5,5	103,9± 0,89	0,180 ±0,01	109,1±2,8	0,169 ±0,015	116,3±8 ,84	0,186 ±0,025
					95,5%*		96,4%*		95,4%*	
30Kh3MFA improved	9,35	6,7	5,2	3,7	152,5± 0,894	0,069± 0,004	153,0±2,8	0,056± 0,007	153,7±1 ,84	0,058 ±0,003
					93,2%*		91,5%*		99,1%*	
38Kh2MYuA	9,55	7,85	34	7,6	125,5± 1,78	0,176± 0,014	122 ±3,5	0,121 ±0,012	113,4±2 ,38	0,096 ±0,006
					88,4%*		95,3%*		99%*	
38Kh2MYuA improved	9,75	6,4	3,4	3,4	148.8 ±1,6	0.131 ±0,009	139,1 ±1,56	0,1034 ±0,004	139.6 ±1,78	0.104 ±0,004
					90,6%*		98,9%*		99,6%*	

* –correlation of the approximating function.

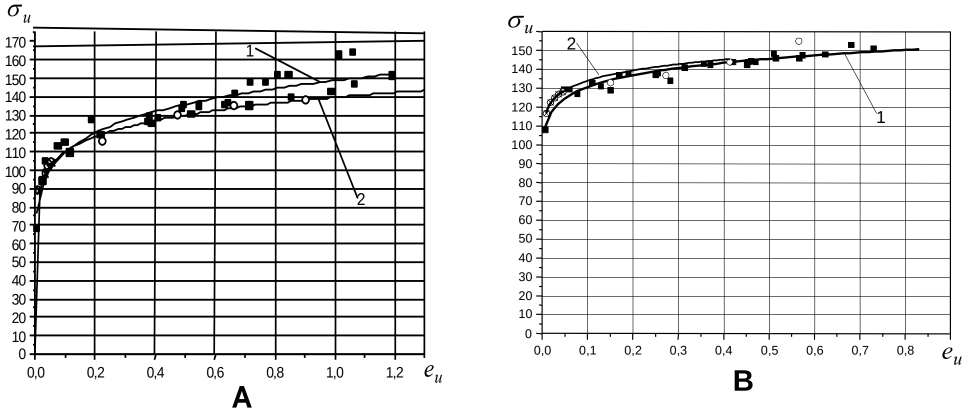


Fig. 3. Curves of the steels:
A-38Kh2MYuA after heat treatment; B- 30Kh3MFA after heat treatment
(curve 1 - compression, curve 2 - tension)

In order to use the flow curve in calculations of technological processes of metal working by pressure, it was approximated by the equations:

$$\sigma_u = Ae_u^n \tag{14}$$

where A, n - are approximation coefficients that have a physical meaning: A =σ_u at eu e_u = 1, n =$\varepsilon_{кр}$ is the critical deformation at the conditional maximum stress.

To plot the flow curve in the region of large deformations (e_u>e_{kp}), cylindrical specimens were tested for compression with dimensions h_0 = 15mm, d_0 = 10mm.

On the lateral surface of the cylindrical sample, near the cross-section, average in height, four imprints were made with a diamond pyramid under a load of 300 N. The imprints are positioned so that they form a rhombus whose diagonals a0 котороговb0 $a_0 \approx b_0 \approx$1mm coincided with the axial and circumferential directions. To take into account the uneven distribution of deformations in the circumferential direction, such rhombuses are applied at four symmetrically located points of the equator.

The sample prepared in this way is upset to various degrees of deformation e_u = 0.002; 0.005; 0.01; 0.02; 0.2; 0.4; 0.6; 0.8; 1.0 up to the appearance of visible cracks, which usually occur at the equator of the lateral surface. The intensity of deformation at degrees of deformation that do not cause barrel formation was calculated by (2), the intensity of stresses was calculated by formula (1).

At the slightest sign of barrel formation, the accumulated strain rate

$$\overline{e_u} = \frac{2}{\sqrt{3}}\sqrt{\left(\frac{de_z}{d\delta}\right)^2 + \frac{de_z \cdot de_\varphi}{d\delta \cdot d\delta} + \left(\frac{de\varphi}{d\delta}\right)^2} \cdot d\delta, \tag{15}$$

where parameter $\delta = \frac{h_0 - h}{h_0}$ – characterizes the stage of deformation of the cylinder, and was calculated after measuring the height of the cylinder h_0, h before and after upsetting.

The calculation of the stress intensity was carried out according to the formula obtained based on the relations of the deformation theory of plasticity.

According to this theory:

$$\sigma_s - \sigma = G\varepsilon_r, \tag{16}$$

in which the hydrostatic pressure σ

$$\sigma = -G\varepsilon_r, \qquad \text{because} \qquad \sigma_z=0, \tag{17}$$

here G is the secant modulus of plasticity

$$G = \frac{2}{3}\frac{\sigma_u}{e_u}. \tag{18}$$

The components of the stress deviator S_z, S^{φ} are equal respectively

$$S_\varphi = \sigma_\varphi - \sigma = G\varepsilon_\varphi, \tag{19}$$

$$S_z = \sigma_z - \sigma = G\varepsilon_z, \tag{20}$$

then the stress tensor components

$$\sigma_z = G\varepsilon_z + \sigma = G\varepsilon_z - G\varepsilon_r = G(\varepsilon_z - \varepsilon_r). \quad (21)$$

District stresses

$$\sigma_\varphi = G\varepsilon_\varphi + \sigma = G\varepsilon_\varphi G\varepsilon_r = G(\varepsilon_\varphi - \varepsilon_r). \quad (22)$$

Therefore, knowing the secant modulus of plasticity G, it is possible to determine all the principal stresses on the lateral surface of the upsetting cylinder. Wherein

$$\sigma_1 = \sigma_\varphi = G(\varepsilon_\varphi - \varepsilon_z), \quad (23)$$

$$\sigma_2 = \sigma_r = 0, \quad (24)$$

$$\sigma_3 = \sigma_z = G(\varepsilon_z - \varepsilon_r), \quad (25)$$

therefore, the stress intensity

$$\sigma_u = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}. \quad (26)$$

For isotropic materials with anisotropic hardening, the flow curve is plotted in the coordinates: equivalent stress – $\overline{\sigma_u}$, accumulated strain rate – $\overline{e_u}$. The value $\overline{\sigma_u}$ is then calculated [2]

$$\overline{\sigma_u} = \frac{1+\beta(e_u)}{2}\sigma_u(e_u), \quad (27)$$

where $\beta(e_u) = \frac{\sigma_{0.2}}{\sigma_u}$ – is the ratio of the conventional compressive yield strength after stretching the sample to the accumulated strain. Taking into account approximation (14), it is possible to obtain

$$\overline{\sigma_u} = \frac{1+\beta(e_u)}{2}Ae_u^{\ n}. \quad (28)$$

We approximate the function $\beta(e_u)$ in the form

$$\beta(e_u) = \beta_m + (1-\beta_m)\cdot\exp(-100e_u). \quad (29)$$

Plotting the Bauschinger curve.

In order to determine the parameter β, which characterizes the tendency of the studied steels 30Kh3MFA (after improvement), 38Kh2MYuA (after improvement) to deformation anisotropy, standard cylindrical specimens with a diameter of d_0 = 10 mm, the length of the working section l_0 = 110 mm were made. The samples were stretched to deformations e_u = 0.05; 0.08. Then, samples for compression were made from the pre-stretched samples. The height of the samples is h_0 = 15mm, the diameter is d_0 = 10mm. Sample surface cleanliness 5.

The samples were upset to various degrees of deformation e_u, and the ratio of the $\beta(e_u) = \frac{\sigma_{0.2}}{\sigma_u}$ – conventional compressive yield stress after stretching the sample to the accumulated deformation e_u was calculated.

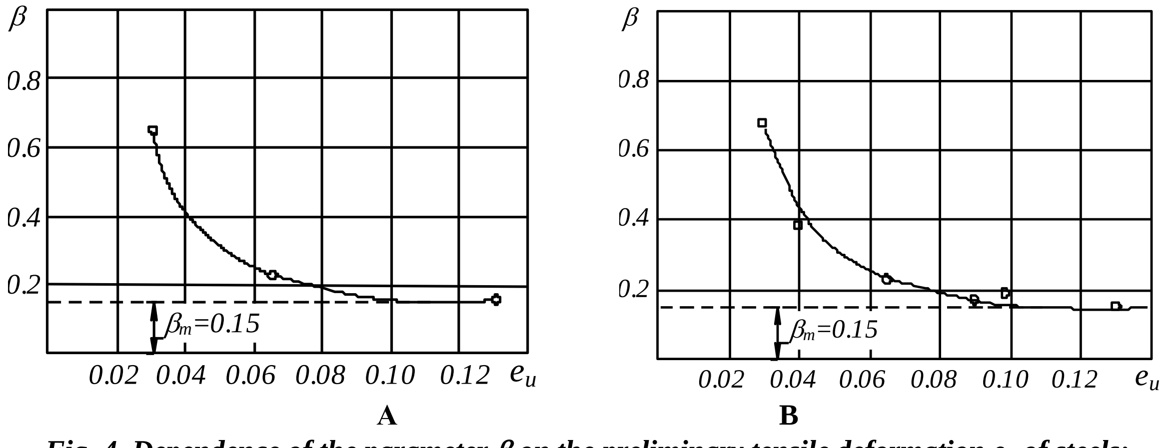


Fig. 4. Dependence of the parameter β on the preliminary tensile deformation e_u of steels: A- 30Kh3MFA after heat treatment; B- 38Kh2MYuA after heat treatment.

In fig. 4 shows the dependence of the parameter $\beta(e_u)$ on the preliminary intensity of deformations of steels 30Kh3MFA and 38Kh2MYuA after heat treatment. As follows from the presented results, the parameter $\beta_m = 0{,}15$ is for the tested steels.

Construction of plasticity diagrams

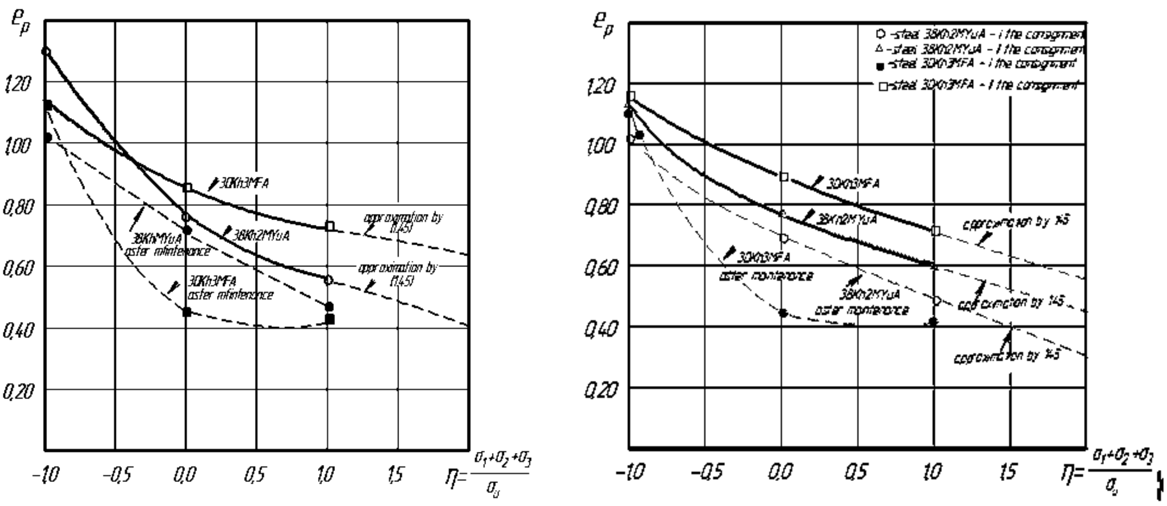
Along with the considered characteristics of the material, the plasticity diagrams of the indicated steels were constructed. The technique of their construction is described in works [4, 5]. The diagrams reflect the dependence of the limiting degree of deformation

$$\overline{e_p} = \int_0^{tp} \overset{*}{\varepsilon}_u \, d\tau \,, \qquad (30)$$

where is the $\overset{*}{\varepsilon}_u$ – intensity of strain rates from the stress state index.

$$\eta = \frac{\sigma_1 + \sigma_2 + \sigma_3}{\sigma_u} \,, \qquad (31)$$

where σ_1, σ_2, σ_3 – principal stresses, σ_u – stress intensity.



A B

Fig. 5. Diagrams of plasticity of steels 30Kh3MFA and 38Kh2MYuA in the state of delivery and after heat treatment: A - II batch of samples, B- I, II batch of samples.

In fig. 5 shows the ductility diagrams of steels 30Kh3MFA and 38Kh2MYuA as delivered and after heat treatment. The experimental data were approximated by the equation [4]

$$e_p = e_p(\eta = 0) \cdot \exp(-\lambda_i \eta), \qquad (32)$$

where λ_i – respectively: $\lambda_1 = \ln \frac{e_p(\eta = 0)}{e_p(\eta = 1)}$, coefficient of sensitivity of plasticity to a change in the stress state diagram in the area of change in the index 1≥η≥0; $\lambda_2 = \ln \frac{e_{p(\eta=1)}}{e_p(\eta = 0)}$ - coefficient of sensitivity of plasticity to a change in the stress state diagram in the area of change in the index 0≥η≥–1.

Construction of calibration curves.

Completing the formation of the technological passport of the material, calibration graphs of 38Kh2MYuA steel after heat treatment (Fig. 6) were also constructed for seven samples under study in the coordinates: hardness HV, stress intensity σ_u интенсивность деформаций strain rate e_u. Указанные графики построены по методике, изложенной в работе [9]. The indicated graphs are constructed according to the method described in [9].

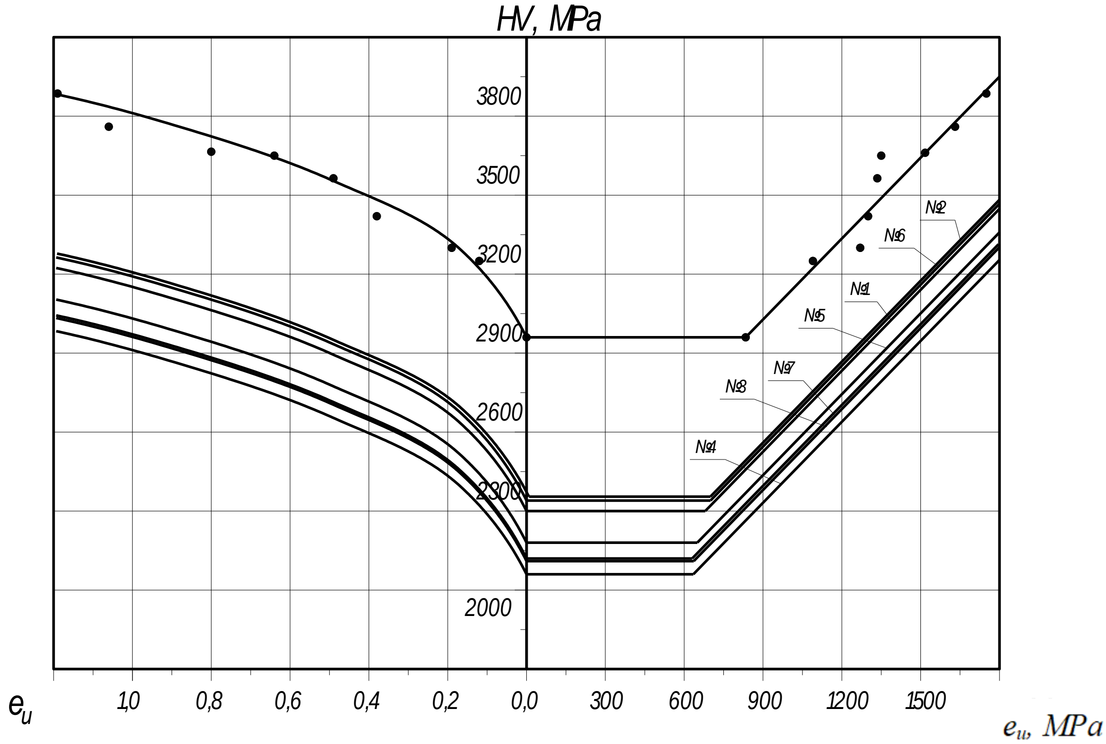


Fig. 6. Graduation charts of 38Kh2MYuA steel after heat treatment of seven investigated samples. (● - experiment, ▬ - approximation.)

5. Conclusions

1. Formed a technological passport of the material of alloy steels, from which a pair of piston-connecting rod of an axial-rotor piston pump is made. The passport is formed in the form of functions - a single flow curve $\sigma_u(e_u)$, a plasticity diagram – $e_p = f(\eta)$, a Bauschinger curve – $\beta = \beta(e_u)$, as well as a calibration graph $HV = f(\sigma_u, e_u)$.

2.Using the approximation of the neck contour by the Gaussian function in the form (7) at any moment of the deformation of a cylindrical specimen in the supercritical region, one can relate the main parameters used in engineering calculations: the minimum specimen diameter, the current specimen diameter with a given coordinate, and the relative (absolute) elongation and constriction with parameters related to the moment of sample rupture (relative constriction and relative elongation after rupture, minimum radius of the neck generatrix, stable deformation). In addition, the elongation and contraction of the sample after fracture are unambiguously associated. The approximation avoids the inconvenient and relatively expensive video filming for studying the history of deformation.

3. It has been shown that the effect of heat treatment on the mechanical properties of these steels is not the same for different stress state schemes. So the yield point of 38Kh2MYuA steel is 20% higher than the yield point of 30Kh3MFA steel. After so. The t of steel 30Kh3MFA was 20% higher than the t of steel 38Kh2MYuA. The tensile strengths of these steels are close as delivered. After so. The vr of steel 30Kh3MFA exceeds the vr of steel 38Kh2MYuA by 25%.

4. Characteristics of plasticity δ steel 30X3MFA exceed δ steel 38Kh2MYuA 1.5 times, ψ - в 1,26 times. The flow curves of the steels under consideration have the following tendency: so the coefficient of approximation of the flow curve A $\left(\sigma_u = A\varepsilon_u{}^n\right)$, for 38Kh2MYuA steel in the state of delivery it exceeds its value in relation to 30Kh3MFA steel by 1.23 times. After heat treatment of these steels, the value of A increases: for steel 38Kh2MYuA by 1.11 times, for steel 30Kh3MFA by 1.46 times.

5. The results obtained make it possible to control the mechanics of the technological operation of rolling the piston-connecting rod pair and create a process control mechanism in order to prevent rejects during the rolling process, which manifests itself in the form of going beyond the tolerance field for the axial clearance of the piston-connecting rod pair, as well as destruction during rolling of the inner part piston.

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ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНОГО ПАСПОРТАМАТЕРИАЛУ ЗАГОТОВОК ПОРШНЯ І ШАТУНА АКСІАЛЬНО-РОТОРНОГО ПОРШНЕВОГО НАСОСА

Сформовано технологічний паспорт матеріалу легованих сталей, з яких виготовляють пару поршень-шатун аксіально-роторного поршневого насосу у вигляді функцій: крива течії, діаграма пластичності, крива Баушінгера, градуйований графік.

Використовуючи апроксимацію контуру шийки функцією Гаусса в будь-який момент часу деформування циліндричного зразка в закритической області пов'язані основні параметри, які використовуються в інженерних розрахунках: мінімальний діаметр зразка, поточний діаметр зразка із заданою координатою, відносне (абсолютне) подовження і звуження з параметрами, віднесеними до моменту розриву зразка. Крім того, однозначно пов'язуються відносне подовження і звуження зразка після розриву. Апроксимація дозволяє уникнути незручного і щодо дорогої відеозйомки для дослідження історії деформування.

Показано, що вплив термообробки на механічні властивості зазначених сталей неоднаково для різних схем напруженого стану. Межі міцності зазначених сталей в стані поставки близькі.

Характеристики пластичності стали 30Х3МФА перевищують пластичність стали 38Х2МЮА в 1,5 рази. Криві течії розглянутих сталей має наступну тенденцію: так коефіцієнт апроксимації кривої течії у стали 38Х2МЮА в стані поставки перевищує його величину по відношенню до сталі 30Х3МФА в 1,23 рази. Після термообробки цих сталей величина коефіцієнта апроксимації росте: у сталі 38Х2МЮА в 1,11 раз, у сталі 30Х3МФА в 1,46 рази.

Отримані результати дозволяють управляти механікою технологічної операції закочування пари поршень-шатун і створити механізм управління процесом з метою запобігання браку в процесі *закочування, який проявляється у вигляді виходу за поле допуску по осьового зазору пари поршень-шатун, а також руйнування в процесі закочування внутрішньої частини поршня.*

Ключові слова: *технологічний паспорт, поршень-шатун, аксіально-роторний поршневий насос, крива течії, діаграма пластичності, крива Баушінгера, градуйований графік.*

Ф. 32. Рис. 6. Табл. 1. Літ. 10.

ИССЛЕДОВАНИЕ ТЕХНОЛОГИЧЕСКОГО ПАСПОРТА МАТЕРИАЛА ЗАГОТОВОК ПОРШНЯ И ШАТУНААКСИАЛЬНО-РОТОРНОГО ПОРШНЕВОГО НАСОСА

Сформирован технологический паспорт материала легированных сталей, из которых изготавливают пару поршень-шатун аксиально-роторного поршневого насоса в виде функций: кривая течения, диаграмма пластичности, кривая Баушингера, градуировочный график.

Используя аппроксимацию контура шейки функцией Гаусса в любой момент времени деформирования цилиндрического образца в закритической области связаны основные параметры, используемые в инженерных расчетах: минимальный диаметр образца, текущий диаметр образца с заданной координатой, относительное (абсолютное) удлинение и сужение с параметрами, отнесенными к моменту разрыва образца. Кроме того, однозначно связываются относительное удлинение и сужение образца после разрыва. Аппроксимация позволяет избежать неудобной и относительно дорогостоящей видеосъемки для исследования истории деформирования.

Показано, что влияние термообработки на механические свойства указанных сталей неодинаково для различных схем напряжённого состояния. Пределы прочности указанных сталей в состоянии поставки близки.

Характеристики пластичности стали 30Х3МФА превышают пластичность стали 38Х2МЮА в 1,5 раза. Кривые течения рассматриваемых сталей имеет следующую тенденцию: так коэффициент аппроксимации кривой течения у стали 38Х2МЮА в состоянии поставки превышает его величину по отношению к стали 30Х3МФА в 1,23 раза. После термообработки этих сталей величина коэффициента аппроксимации растёт: у стали 38Х2МЮА в 1,11 раз, у стали 30Х3МФА в 1,46 раза.

Полученные результаты позволяют управлять механикой технологической операции закатки пары поршень-шатун и создать механизм управления процессом с целью предотвращения брака в процессе закатки, проявляющегося в виде выхода за поле допуска по осевому зазору пары поршень-шатун, а также разрушения в процессе закатки внутренней части поршня.

Ключевые слова: *технологический паспорт, поршень-шатун, аксиально-роторный поршневый насос, кривая течения, диаграмма пластичности, кривая Баушингера, градуировочный график.*

Ф. 32. Рис. 6. Табл. 1. Лит. 10.

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