UKRAINIAN JOURNAL OF MECHANICAL ENGINEERING AND MATERIALS SCIENCE
Vol. 3, No. 1, 2017

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APPLIED MODEL OF ASSESSMENT OF INTENSITY OF THE STRESSED DEFORMED STATE OF PIPELINES BY EVALUATION OF MAGNETIC ANISOTROPY OF COERCIVE FORCES. PART 1

Received: February 13, 2017 / Revised: March 30, 2017 / Accepted: June 26, 2017

Abstract. The problem of applied diagnostics, statistically rigorous by the proposed model analogue, running stressed-deformed state of the main (trunk) shell is studied by the method of magnetic coercimetria.

The relationship between the parameters of the loop of magnetic hysteresis is stochastically related with structural and mechanical state of the material of the pipeline wall and with the rest of equal conditions allows to effectively detect the zone of concentration of local stresses on the stage of their forming and development (propagation) on the basis of quantitative comparative analysis of their value with calculated equivalent mechanical stresses in principal (main) planes for particular pipe material considering that the operational stresses shouldn’t be larger than 30–50 % of the yield limit.

The hypothesis H_0 about the possibility of description of the measurement data of the stressed mechanical state by the magnetic-static method of coercimetria is made taking into account the peculiarities of disturbances caused by the operation of electric chains of the measuring apparatus during its metrological calibration. This hypothesis confirms that the arcsine function is a law of distribution probability density of the measured values of the coefficient of magnetic anisotropy as a response of the mechanical state of the pipe shell, that the parameter Q equals 0.95 on the confidence level and substantiates the evaluation of frequency of the influencing equivalent stresses in the whole range of loads applied to the shell by the inside normalized variable pressure.

On the basis of corresponding scaling and renormalization of investigative values of the coefficient of magnetic anisotropy, the technique of determination of the level of mechanical stresses in the object of diagnostics is developed and the statistically rigorous compatibility in the certain range of influence of internal pressure in the pipeline is demonstrated using the results of preliminary metrological calibration of coercimeters obtained for different pipe steels.

Keywords: stressed deformed state, main pipeline, magnetic anisotropy, coercive forces, coercimetria, mechanical stress, internal pressure, metrological calibration.

Problem statement

The design (useful) life of structures is based on the condition, which states that operational (exploration) stresses shouldn’t be larger than 30–50 % of the yield limit of material [1].

However, during the process of operation, the local zones of stresses concentration develop (propagate) under the influence of stressed-deformed state. They are caused by both operational and not foreseen factors (geometrical, climatic, geological, physical and mechanical, electrophysical etc.) and by residual stresses of technological character [2]. Actually, the zones of concentration of local stresses are considered to be the main factor of development of material damage and of reducing of the overhaul period of the item (product) to emergency one.

It is explained that the formation of the zones of concentration of local stresses is caused by material’s operation under slipping and shearing strains (deformations) evaluated by means of the bands of dislocations slipping (gliding). Thus, the increasing of dislocations density to the level of 108-109 cm-2 causes the degradation of mechanical properties of the material. This means that the strength limits increases by 10–15 %, but the relative (percentage) contraction reduces by 10–30 %.

In order to estimate the value of the stressed-deformed state and to detect the zones of concentration of local stresses, various physical methods are used. Among them, we may highlight the method of evaluation of the running stressed state of the material taking into account its magnetic characteristics. The measurements of the residual magnetic induction, magnetic permeability and coercive force are being frequently used for investigating pipelines. The coercive force is based on the measurement of the parameters of the loop of magnetic hysteresis and is complicated for correlation (Q = 0.85) with structural and mechanical state of the material, in particular, with the changing of dislocation density in material.

The determination of the overhaul period of pipelines taking into account the formation and dynamics of development (propagation) of revealed zones of concentration of local stresses by the method of coercive force requires the measurement of its value in the main (major) planes of mechanical stresses. Their equivalent values are being estimated by corresponding coefficients of magnetic anisotropy (different values of coercive force along the direction of the vectors action of axial and radial force acting upon the pipeline loaded by the pressure of the working substance).

However, the use of traditional magnetic means of diagnostics of the stressed-deformed state, which are based on the active interaction of the signal with material when the directed external field creates a dynamic superposition with the material’s field and irreversibly changes it, Significantly influences the results self-descriptiveness of the measurement of the stressed-deformed state because of the following reasons:

1) The change of the own magnetic field on the level of crystalline lattice and of the substructure of the domain areas formed by the preliminary technological cycle of treatment and operation of the structure (the magnetic memory or magnetic prehistory of material) is to be defined by the dynamics of interaction of energies of the directed external probing field with the existent own one;

2) The dependence on the magnetic permeability. However, the analysis of the value of coercive force $H_c = H_s - N \cdot B_r$ (where H_s is the intensity (strength) of the field of technical saturation of the material, B_r is the residual induction; N is the magnetising factor) shows that the magnetising factor is complicatedly functionally related with the geometry and structure of the material, with magnetic permeability of the measuring zone etc.;

3) The objective impossibility of taking into account the nature, value and time of the existence of such changes leads to obtainment of indirect information about the stressed-deformed state of the structure;

4) The possibility to carry out the diagnostics on the inoperative structure allows to define the actual value of the residual stressed-deformed state, in which the fields of stresses and deformations are critically different from the working ones;

5) The possibility of getting into the measurement zone of violations of material solidity, which were not detected by the control, have their own stressed-deformed state, and form a local zone of critical stresses;

6) The possibility to adopt a priory homogeneity of the stressed-deformed state and the material structure for the cross-section being controlled;

7) The reliability of the received estimation of the stressed-deformed state depends on subjective factors, such as qualification and experience of the operator, etc.;

8) The need for preliminary calibration of devices (instuments) with the simultaneous lack of a metrological base for their certification that leads to errors in the development of diagnostic techniques;

9) In most cases, the testing of devices (instruments) is carried out on prototype samples that inadequately reflect the actual energy state of the diagnostic object.

The lack of normative (regulatory) and methodological bases for metrological testing (verification) of equipment and for carrying out particular measurements objectively leads to obtainment of locally informative data without their integrative statistical analysis.

In the works [3; 4], the approach to the metrological testing (verification) of devices (instruments) for measuring the coercive force based on the universal approach of creation of physical and probabilistic models of dependence of the probability density of the distribution of the measured values of the coefficients of magnetic anisotropy $a_2 = \Delta H_C = H_\perp - H_{\mathbf{P}}$, $a_1 = \dfrac{H_\perp - H_{\mathbf{P}}}{H_\perp + H_{\mathbf{P}}}$ (where H_C is the measured value of corresponding coercive force in normal $H_\perp$ and axial $H_{\mathbf{P}}$ directions of pipeline loading caused by the stressed state of the shell) is proposed.

However, their usage as an estimate of the stressed-deformed state and for detection of zones of concentration of local stresses have a certain limitation, in particular, the coefficients of any statistical model of the type $a_i = f(s)$ (where s is the equivalent stress in the wall under the testing pressure P calculated on the basis of the array of experimental data on the prototype samples) may be used for obtainment of reliable (valid) estimates of the state of the real pipeline by the reverse model of the type $s = F(a_i)$ only under the correlation $r = 1$ of actual measured values of the estimation coefficients of the coercive force anisotropy a_i with model ones $\tilde{a}_i$.

Taking into account that the volume of the dispersion ellipsoid $V(\tilde{b}_j) = \sqrt{|c|}$ (where c is the determinant of the dispersion matrix, b_j is the dispersion vector of the estimates of the model coefficients) almost cannot be minimized even in laboratory conditions of testing (calibration) of metrological base of measuring equipment (instruments), so, in the conditions of practical usage of such equipment on real pipelines, the accuracy of prediction of development (propagation) of zones of concentration of local stresses becomes significantly worse.

Statement of research purpose

The purpose of the work consists in solving the reverse physical and probabilistic models for predicting the value of the stressed-deformed state by the equivalent stresses in the main (major) planes of the pipe shell, which is under the influence of different internal pressures, using the estimation coefficients of magnetic anisotropy of coercive forces in radial and axial directions.

Main material presentation

In order to develop the models by the averaged results of measurement of coercive forces in the direction of action of the vectors of axial and radial stresses of the pipe shell loaded by the internal pressure, we make the following statements:

1) The model is being developed for such estimation coefficient of magnetic anisotropy a_1, which has the best self-descriptiveness;

2) The model belongs to the class of probabilistic distributions typical for technical (engineering) systems;

3) The invariance of the values of coercive force (within the limits of experimental error) with respect to the action of the load (for thin-walled shells, the value of such stresses is the same under the influence of internal or external pressure);

4) The polygon of probability density distribution of the coefficient a_1 is centred and symmetric, with a distribution centre that corresponds to a zero value of the internal pressure of the pipe shell (the weight of the tube stand between the supports and the weight of the working body in the pipe are not taken into account);

5) The renormalization and scaling of calculated and measured values of stresses and of the coefficient of magnetic anisotropy while developing the histograms and distribution polygons, as well as their model analogues, take into account the following statements: a) the experimental measurements of coercive forces $H_\perp$ and $H_{\mathbf{P}}$ indicates their maximal asymmetry at the unloaded stand. This phenomenon is related with the influence on the formation of the domain structures of crystals anisotropy (size, shape, direction of orientation) effected by the technology of material processing, etc.; b) When the level of stresses in the pipe wall reaches corresponding limit of proportionality, the values of coercive forces are almost unambiguous (ingle-valued). This may be explained by the multiplication (propagation) of the closing (locking) domains around the zones of local internal stresses and

around the zones of concentration of local stresses. The closing (locking) domains are being formed inside the initial domain structure of the material and during the development of the zones of concentration of local stresses, their influence by the capacity, form and vector of magnetic moment most fully corresponds to minimum free energy of the system at the current stressed state; c) The destructive tests [4] confirm the following statement: when the shell material reaches the yield limit, the values of coercive forces for radial and axial components of the equivalent stressed state in the main (major) planes are minimal and almost unchangeable (within the instrumental measurement error) up to the moment of destruction of the shell. This fact allows to use only instrumental error of the applied measuring base during the renormalization of the calculated values of coefficients of magnetic anisotropy; d) during the renormalization, it is necessary to avoid the possibility of forming the probability density distribution of the measured data with "heavy tails" [5], which predict large deviations of the set of measured values of the investigated parameter from the average ones, which are equal to the initial values of the measured magnetic anisotropy (the loading pressure equals zero). The stresses in the shell are caused by its weight between the supports and by the working body. In addition, this type of distribution is a model of fragrant errors that is the combination of the basic real distribution and the contaminating one.

The analysis of the data and the practice of the use of the proposed approach to the development of the physical and probabilistic models of estimation of the stressed-deformed state by the coefficients of magnetic anisotropy taking into account the given above material demonstrate that in order to choose (renormalize) the coordinate system, it is enough to use: a) the encoding of anisotropy coefficient a_{ik} (its minimal measured actual value after renormalizing should have the minimal error at the stage of experiment but shouldn't be less than the error of the measuring base); b) the encoding of the values of the stressed state s_k or of the loading of the of the pipe shell P_k is being chosen by the calculated intervals of the histogram of distribution of experimental data and of the number of its columns taking into account the following condition $m_{\min/\max} = (0.55-1.25)\cdot n^{0.4}$ (where m is a number of columns, n is a number of points of measurement).

Taking into account the presented above material, the functional $a_{ik} = f(s_k[P_k])$ is to be modelled in the view of analytical expression of probability density distribution:

$$p(x) = A\exp\left[-(\frac{x}{X})^{a}\right], \tag{1}$$

where x is the running value of pressure or of equivalent stresses; A, X are the parameters of the shape and the scale of distribution. The parameter $A = p(x)$ when $x = 0$.

Equivalent stresses and coefficients of Lode $J = \dfrac{2s_2 - s_1 - s_3}{s_1 - s_2}$:

$$s = \frac{1}{\sqrt{2}}\sqrt{(s_1 - s_2)^2 + (s_2 - s_3)^2 + (s_3 - s_1)^2},\ s_3 = 0, \tag{2}$$

where $s_1 = PD/2d$; $s_2 = PD/4d$; P, D, d are the testing pressure, normalized diameter and the actual thickness of the pipe shell, correspondingly.

The model analogues of the correlation relation between the coefficient of magnetic anisotropy and the pressure or the stressed deformed state of the material of the shell wall (Figs. 1, 2) are as follows:

$$\text{Steel 13HSU} - \tilde{a}_{1k} = 3.27\exp\left[-(\frac{P_k}{3.91})\right]^3,$$
$$\text{Steel 17H1S} - \tilde{a}_{1k} = 16.66\exp\left[-(\frac{s_k}{7.943})\right]^3, \tag{3}$$

with the following statistical estimates presented in Table 1.

Table 1

Statistical estimates of physical and probabilistic models

Estimate	Shell material	
	Steel 13HSU	Steel 17H1S
The estimate of dispersion of deviation of actual values of the coefficient from their average value S_{ak}^2	1,6	36,764
The estimate of root-mean-square error (standard deviation)	1,26	6,063
The estimate of the dispersion of deviation of actual model values of the coefficient $\tilde{a}_k$ from their actual values S_{Δ}^2	0,0425	0,42655
The estimate of root-mean-square error (standard deviation)	0,206	0,653
The estimate of the dispersion of the experiment error S_e^2	0,229	5,121
The estimate of the dispersion of the model adequacy $S_{a\partial}^2$	0,057	0,569
Fisher's criterion F_p	0,249	0,1083
Entropic ratio g_e	0,1	0,0622
Correlation coefficient r	0,985	0,994
Indeterminacy (indefiniteness) band ±Δ	0,48	1,51

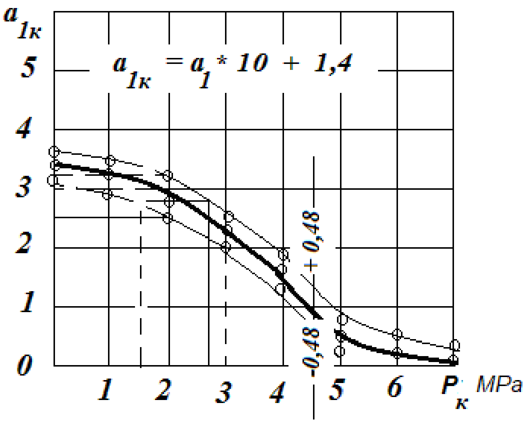


***Fig. 1.** Graphical interpretation of the model $\tilde{a}_{ik} = f\left[P_k\right]$, where k is the index of data renormalization. For all models the confidence coefficient (probability) $Q = 0.95$*

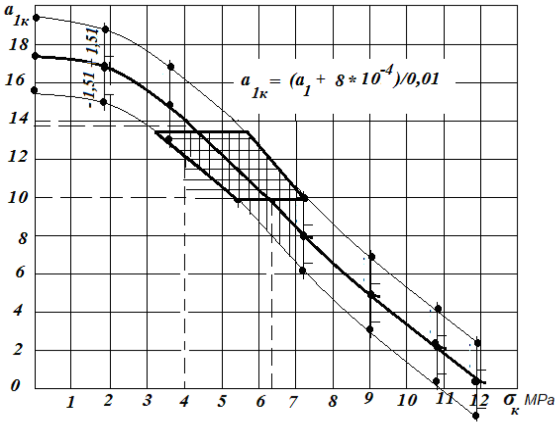


***Fig. 2.** Graphical interpretation of the model $\tilde{a}_{ik} = f(s_k)$, where k is the index of data renormalization (the dashed field is the predicted variation of the estimates of the stressed deformed state)*

On the basis of the data given above, we may state that while using the model functional $\tilde{a}_{ik} = f(s_k[P_k])$ in practice for evaluation of the stressed deformed state of the pipe shell by the measured values of magnetic anisotropy, the accuracy of prediction is in the range of 10–20 % when the confidence coefficient (probability) $Q = 0.95$. The last statement may be inadmissible taking into account the fact that the magnetic state of the real object significantly differs even if there are full geometrical similarity and the same materials of the testing stand, on which the testing (calibration) of instrumental measurement equipment has been carried out.

So, the solution of the problem of evaluation of the stressed deformed state with the simultaneous detecting of the zones of concentration of local stresses on the object of diagnostics using such models may be not very effective.

To solve such a problem, we may use the reverse solution, in particular, the model evaluation of the functional $s = F(\tilde{a}_i)$. It is well known [6] that probability density of the measurement error of a large number of analog-digital electric and electronic apparatus with the circuits of alternating current may be defined by the class of arcsine-distribution of the following view:

$$f_a(x) = \frac{\sin a \cdot x}{p} \cdot x^{-a} \cdot (1 - x)^{a-1}. \tag{4}$$

If $0 \le a \le 1$, so we'll have:

$$p(x) = \frac{1}{p \cdot \sqrt{x(1-x)}}.$$

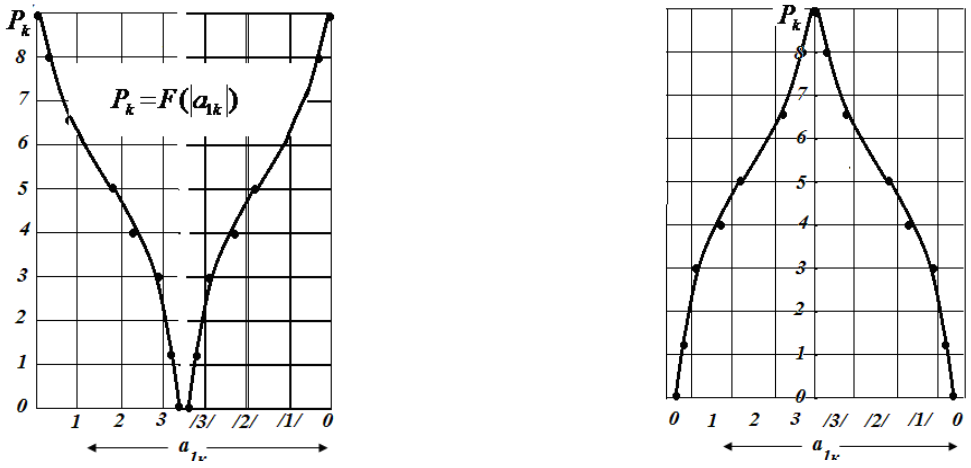
In the particular case taking into account the theory of restitution, they are well concerted with physical model of reaction of the magnetic state of the material investigated by the method of coercimetria using the description of random deviations of the values of magnetic moments of the domain structure from their averaged values.

Depending on the presence of entropic informational noise of different physical nature in the signal, the probability density distribution of the measured value may be correctly defined by the combined arcsine-distribution:

$$p(x) = [p \cdot \sqrt{l^2 - (x-m)^2}\,)]^{-1}, \tag{5}$$

where m is the location parameter; l is the scale parameter.

On the basis of analysis of graphical interpretations (Figs. 1, 2) of the direct functional solution, the hypothesis H_0 about the solution of the reverse problem using the given above distributions is made. The possibility of such approach is confirmed by a reversal (inversion) with the mapping of coordinate axes and taking into account the loading values and the coefficient of magnetic anisotropy in modulus. For example, for the direct problem functional (Fig. 1), it is presented in Fig. 3, *a*, *b*.



a *b*

Fig. 3. *Graphical solution for transformation of the functional* $\tilde{a}_{ik} = f[P_k]$ *for the reversed problem* $\tilde{P}_k = F(|a_{1k}|)$

In order to carry out the statistical verification (confirmation) of the proposed hypothesis, the following parameters were calculated: a) the measure of kurtosis $e = m_4 / m_2^2 \cdot n = 1.42$ (where the central statistical moments equals $m_i = \int_{-\infty}^{+\infty} [x - M(x)]^k f(x)dx$, $M(x)$ is the mathematical expectation of the measured value, $f(x)$ is its probability density); b) the entropy interval $\Delta_e = \frac{1}{2}\exp^{H(x/x_n)} = 0.695$ (where $H(x/x_n)$ is the entropy of this value after carrying out the measurement); c) the counter-kurtosis measure $x = 0.704$.

The additional confirmation was obtained during the analysis of topographic classifier of statistical distributions (the affiliation of data to the region of the curve 12–13 [6]), which doesn't deny the correspondence of experimental data to the class of unimodal composite arcsine-distribution.

On the basis of the given above material, the analytical physical and probabilistic models of the distribution density of equivalent stresses in the main (major) planes of the pipe shell are calculated using the results of measurement of magnetic anisotropy estimated by the coefficient a_1 [7].

For the considered pipe steels, these models have the following generalized form:

$$s_i = \frac{m_s}{m_a} \frac{s_{\max}}{c + d \lg \dfrac{\sqrt{1 - p(a_0)^2}}{\sqrt{1 - p(a_i)^2}}}, \tag{6}$$

or in the user-friendly simplified form:

$$s_i = \frac{m_s}{m_a} \frac{s_{\max}}{c + d \lg \dfrac{\sqrt{1 - p(a_0)^2}}{\sqrt{1 - p(a_i)^2}}} = \frac{s_{\max}}{c + d \lg[a_{1\max} \sqrt{1 - (\dfrac{a_{1i}}{a_{1\max}})^2}]}. \tag{7}$$

Thus, for the pipe shell made of Steel 13HSU, we have:

$$\tilde{s}_i = \frac{m_s}{m_{a_1}} \cdot \frac{s_{\max}}{4.39 + 2.15 \lg \dfrac{\sqrt{1 - (\dfrac{a_{10}}{a_{1\max}})^2}}{\sqrt{1 - (\dfrac{a_{1i}}{a_{1\max}})^2}}}, \tag{8}$$

and for the pipe shell made of Steel 17H1S, we have:

$$\tilde{s}_i = \frac{m_s}{m_{a_1}} \cdot \frac{s_{\max}}{3.25 + 1.775 \lg \dfrac{\sqrt{1 - (\dfrac{a_{10}}{a_{1\max}})^2}}{\sqrt{1 - (\dfrac{a_{1i}}{a_{1\max}})^2}}}, \tag{9}$$

where m_s , m_{a_1} are the scales of transformation (normalization) of the values of the stresses and of the coefficient of magnetic anisotropy; a_{10} is the measured value of magnetic anisotropy when there is loading of the pipe shell by the working pressure; $a_{1\max}$ is the measured value of magnetic anisotropy from the whole range of the pipe shell loading changing located as far away from the distribution center as possible ($a_{central} = a_{10}$); a_{1i} is the running value of the coefficient of magnetic anisotropy obtained under the loading of the pipe shell by the internal pressure P_i ; $s_{\max}$ are the maximal equivalent stresses during the calibration (checking) of the instrumental base on the testing stand.

The practice of usage of the models (8) and (9), which is based on the statistical distributions, demonstrate the complicity of their perception by operators. In order to facilitate the calculations and to ensure the maximal perception of the obtained information and to make the correct (reliable) conclusion about the running stressed deformed state of the pipeline, the arcsine-distributions of the probability density of the measured value of magnetic anisotropy are presented in the following form:

$$p(a_{1k}) = (p \cdot a_{1k\max} \sqrt{1 - (\frac{a_{1ki}}{a_{1k\max}})^2})^{-1}. \tag{10}$$

If we carry out the corresponding normalizing of axes and the symmetric central distribution of the probability density of the values a_1 (coefficient of magnetic anisotropy estimated by the frequency of changing of the stressed state $p(a_1) \equiv \dfrac{s_{ki}}{\sum s_{k_i}} = s_k^*$) and if we present (5) in the following form:

$$\lg L = \frac{1}{p \cdot a_{1\max} \sqrt{1 - (\dfrac{a_{1i}}{a_{1\max}})^2}}, \tag{11}$$

so a priori $p(x) \equiv s^*_к$ graphical interpretation (Fig. 4) is the class of hyperbolic curves, which may be transformed to the linear one by the coefficients c and d of the model (Figs. 5, 6) using the transformation $\frac{1}{s^*_к}$ of the following kind:

$$\frac{1}{s^*_к} = \frac{c}{d} - \frac{p(a_{ki})}{d}. \tag{12}$$

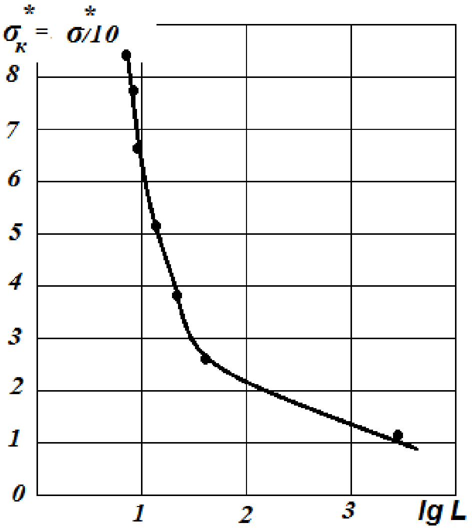


***Fig. 4.** Hyperbolic presentation of the probability density of distribution of the value a_1 (coefficient of magnetic anisotropy) for Steel 13HSU*

When using such approach to the determination of the stressed state, the linear models are as follows:

– for Steel 13HSU: $$\frac{1}{s^*_k} = 4.39 - 2.215(\lg L_i - \lg L_0); \tag{13}$$

– for Steel 17H1S: $$\frac{1}{s^*_k} = 3.25 - 1.775(\lg L_i - \lg L_0), \tag{14}$$

where L_i, L_0 are the running and centred values at the range of changing of the value L (9).

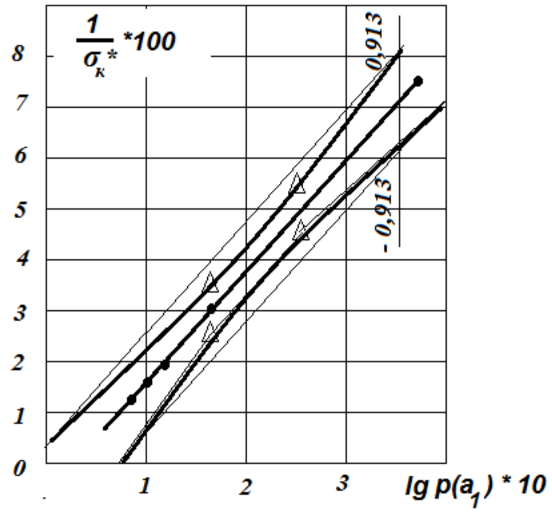


***Fig. 5.** Graphical interpretation of the model (13) for the Steel 13HSU*

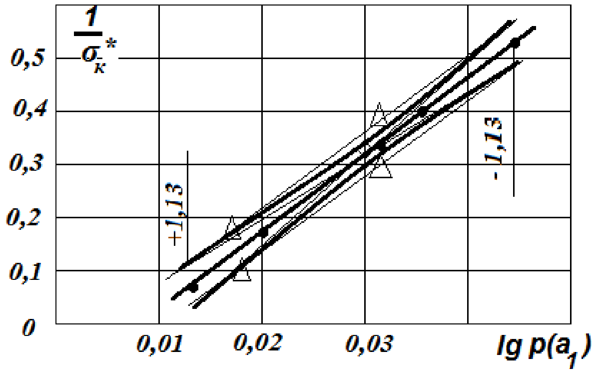


***Fig. 6.** Graphical interpretation of the model (14) for the Steel 17H1S*

Statistical characteristics of linear analytical models (Figs. 5, 6) for determination of the practical stresses depending on the measured values of changing the probability density of the estimates of the ratio of coercive forces in the main (major) planes are as follows:

– the model for Steel 13HSU: $r = 0.977;\ g_e = 0{,}124;\ \Delta = \pm 1{,}13;$

– the model for Steel 17H1S: $r = 0.989;\ g_e = 0{,}084;\ \Delta = \pm 0{,}913.$

If there is the same scaling of the values $\frac{1}{s_k}$ for different materials, it is possible to determine the region of existence of the physical and probabilistic models (Fig. 7), which allows to evaluate the stressed state of the pipe shell in the given range of the measured values of the coercive force in the main planes recalculated with a help of the calculation coefficient $a_1 = \frac{H_\perp - H_P}{H_\perp + H_P}$ from the value of internal pressure 170 MPa and to the yield limit of the material (for the Steel 13HSU $s_T = 275 MPa$; for the Steel 17H1S $s_T = 355 MPa$) using the metrological calibration of the coercimeter only for one material of the pipe.

Thus, when working with linear model analogues for determination of the actual values of the stressed deformed state of the pipeline in the range of stresses 74–191 MPa, any of the studied pipeline materials may be used. And vice versa, the calibration (testing) of the instrumental equipment for estimation of the stressed deformed state by the magnetic anisotropy carried out only for one material of the pipe structure in the given range of its loading by the internal pressure (with the other conditions are equal) may be correctly used for estimation of the stressed deformed state of the pipeline shell made of other material.

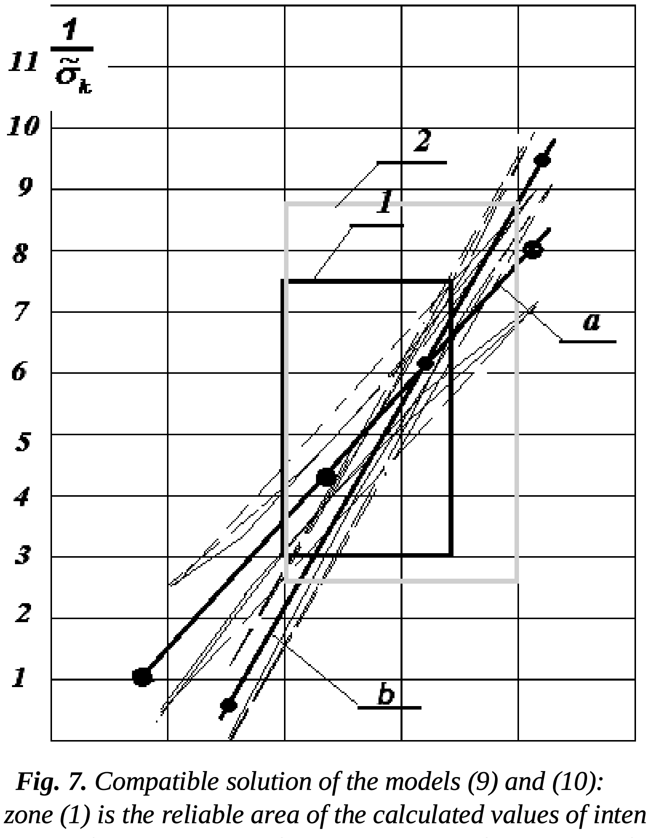


Fig. 7. *Compatible solution of the models (9) and (10): green zone (1) is the reliable area of the calculated values of intensity of the stressed state of the shell wall defined by the band of dispersion of the estimate of the averaged model (10) and (11); yellow zone (2) is the reliable area of the calculated values of intensity of the stressed state of the shell wall defined by the band of dispersion of the value of the model (10) and (11) itself; red line (a) is the model for the shell made of Steel 13HSU; blue line (b) is the model for the shell made of Steel 17H1S*

Conclusions

1. On the basis of experimental investigations on the full-size pipeline stand made of Steels 13HSU and 17H1C and loaded by the controlled internal pressure, the statistically rigorous solution of the reversed problem of prediction of the stressed deformed state of the pipeline shell by the equivalent stresses in the main planes and of the formation and development (propagation) of the zones of concentration of local stresses by the estimate of the measured value of magnetic anisotropy of coercive forces along the vectors of radial and axial stresses according to the defined arcsine-distribution of correlation of the probability density of distribution of the measured values of the coefficient a_1 of the estimate of magnetic anisotropy and the stressed state of the pipe shell material with the confidence coefficient (probability) $Q = 0.95$ is proposed. 2. The calculated physical and probabilistic models of the correlation relationship were used for testing (calibration) of the instrumental equipment for defining the stressed deformed state of the pipeline shells by the magnetostatic method. 3. The simplification of the calculation estimates of the stressed deformed state by the proposed models using the conformal transformation of the measured values of magnetic anisotropy into linear statically reliable dependencies allows the facilitated operational procedure of determination of local zones of stresses concentation in the pipe shell. 4. Within the range of stresses 74-191 MPa (the point of crossing of the linear models – 174 MPa), the linear models are statically compatible. This fact allows to use them for testing (calibration) of the instrumental base of one of the investigated materials of the pipe shell and to use the obtained metrological data for evaluation of the stressed deformed state in the given range of stresses on the pipelines made of other investigated material.

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