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Experimental Study of Quality of Plastic Details of the Oil-Field Equipment

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ABSTRACT- In article quality of plastic details of the oil-field equipment depending on modes of production of their various constructions and composition of press materials was reviewed. By adjusting the operating parameters during production of details are defined quality indicators: tensile strength, hardness of details and others. Mathematical dependencies between quality indicators (shrinkage and strength) of details and processing temperature are established. The determination of optimal production rejimes for plastic products requires experimental and theoretical researches, the volume of which increases significantly with the number of shapes and sizes. The organization and conduct of such researches with a view to developing recommendations for the production and operation of these products can lead to a significant expenditure of material and labour resources. In practice of designing of machine details and the equipment for assessment the hazard of a tense situation usually use not criteria of strength, only the safety margin coefficient or equivalent stress. Methods of calculation of equivalent stress are considered on the basis of a method of calculation of criterion of strength depending on synchronous change of all three principal stresses. Obtained theoretical results are confirmed experimentally and the method of calculation of equivalent stress is developed that is necessary for practice.

KEYWORDS- Elastic deformation, Phenoplast, Plastic details, Specific energy, Strength

I. INTRODUCTION

It is known that the quality of plastic parts is characterized mainly by some of their operational properties, such as high strength, low surface roughness, wear resistance, good resistance to aggressive media, and finally, high manufacturability, which make polymers indispensable for their use in a variety of engineering structures [1].

II. EXPERIMENTAL

The strength theory is based on two assumptions. The first of them concerns the number and physical meaning of those factors that, in our point of view, have a decisive influence on the strength of the material; the second assumption concerns the nature of the functional relationship between these factors in the expression for the strength criterion. Classical strength theories take into account one factor, as a result of which these theories turned out to be unsuitable for describing the strength of various materials under all kinds stressed of state. One of the most developed promised theories of strength Yu.I.Yagn theory takes into account three factors, due to which it gives a much better approach to experience. However, in order to achieve full agreement between theoretical and experimental values of ultimate s in the case of rigid plastics, this is not enough. The first assumption is that we believe that five factors characterizing stressed of state of the material at a hazardous point have a decisive effect on the strength of the material, the factors we consider are of the form

$$z_1 = \frac{1}{3}(\sigma_1 + \sigma_2 + \sigma_3), \qquad (1)$$

$$z_2 = \frac{1}{2E}(\sigma_1^2 + \sigma_2^2 + \sigma_3^2), \qquad (2)$$

$$z_3 = \mu \frac{1}{E}(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1), \qquad (3)$$

$$z_4 = \frac{1}{\sqrt{3}}\sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2}, \qquad (4)$$

$$z_5 = \frac{1}{3}\sqrt{(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2}. \qquad (5)$$

The factors introduced can be divided into two groups:

1) factors that give a general characteristic the stressed of state of the material;
2) factors characterizing its energy state.

The most general idea of various tense states can be obtained from the average value of normal s equal to z1. The value is a component of a ball tensor of that characterizes a comprehensive uniform compression or compression in the material at a given state. Depending on the sign and the magnitude of factor z1, the tense state may have different degrees of hazard. Thus, many authors, on the basis of experiments on hydrostatic compression, believe that the imposition of uniform compression on a given tense state does not change the strength of the material. However, by one value of z1, it is difficult to judge how loaded the material is at the point under investigation. Indeed, it may turn out that z1=0, while the main tensions are different from zero. Indeed, it may turn out that z1=0, while the principal voltages are different from zero. Therefore, we enter the value z4, which is the mean quadratic deviation of given strained state from the zero strenuous state. Obviously, the larger the z4, the more loaded the material, the more dangerous the strenuous state. It is known that any brittle material under certain conditions can pass into a plastic state; therefore, it is necessary to derive a factor in the strength criterion that would reflect the possibility of the onset of a plastic state. The onset of the plastic state is determined by the value of the minimum mean quadratic deviation of the given strenuous state from the equiaxial strenuous state closest to the study one. This value, equal to z5, is introduced by us into the strength criterion for rigid plastics as the third value giving, together with the values z1 and z4, a general characteristic of the strenuous state of the material [2]. The strength of the material depends on the amount of energy expended on its deformation until the moment of destruction. For rigid plastics characterized by the brittle nature of destruction, the value of the specific potential energy stored in the material can be found according to the formula of the theory of elasticity:

$$W=\frac{1}{2E}\left(\sigma_1^2+\sigma_2^2+\sigma_3^2\right)-\mu\frac{1}{E}\left(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1\right) \quad (6)$$

One of the first attempts to use expression (6) as a strength criterion was made by Beltrami, who proposed the theory of the total specific strain energy. However, this theory sharply separated from the experiments, in connection with which many authors [3, 4], starting with Maxwell, proposed to divide the total specific energy of deformation into two parts: the energy of change in volume W_{vol} and the energy of the form change W_f, which are determined by the following expressions:

$$W_{vol}=\frac{1-2\mu}{6E}\left(\sigma_1^2+\sigma_2^2+\sigma_3^2\right)+\frac{1-2\mu}{3E}\left(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1\right) \quad (7)$$

$$W_f=\frac{1+\mu}{3E}\left(\sigma_1^2+\sigma_2^2+\sigma_3^2\right)-\frac{1+\mu}{3E}\left(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1\right) \quad (8)$$

Apparently, the influence of quantities (7) and (8) on the strength of brittle materials is much more complicated, in this regard, we introduce into the strength criterion not expressions (7) and (8), but analytically simpler factors z_2 and z_3.

From equalities (4), (5), (7) and (8) it is easy to establish that the factors z_2 and z_3 are linear combinations of the values W_{vol} and W_f, namely:

$$z_2=\frac{1}{1-2\mu}W_{vol.}+\frac{1}{1+\mu}W_{t.M} \quad (9)$$

$$z_3=\frac{2\mu}{1-2\mu}W_f-\frac{\mu}{1+\mu}W_{t.M} \quad (10)$$

In addition, in our opinion, the factors z_2 and z_3 have an independent meaning, which follows from expression (8). The expression for the full specific potential energy consists of two terms: the first of them contains the values of the main normal voltages independently of each other, and the second, in a dependent form. Obviously, if the mutual influence of normal voltages on the magnitude of deformations along the main axes were absent ($\mu = 0$), then the second term in expression (8) would disappear. Therefore, it can be considered that the potential energy of elastic deformation is the result of the impact on the elastic body of two reasons: the independent action of the main stresses and their mutual action. Then the factors z_2 and z_3 can be used, respectively, as an independent and dependent part of the full specific energy of deformation.

The second assumption, on the basis of which the theory of strength of rigid plastics is based, is that a linear function from the factors z_1,..., z_5 is taken as a strength criterion. In this case, the onset of a dangerous state, which is destruction for rigid plastics, is determined by the fact that this function takes on a constant value for any type of complex strenuous states. Thus, the strength criterion has the form

$$z_1+p\,z_2+q\,z_3+r\,z_4+s\,z_5=t \quad (11)$$

where *p, q, r, s* – constant parameters..

According to the hypothesis of flat sections in relation to the voltages of the extreme fibers A and B are equal

$$\left.\begin{aligned}\sigma_A&=\sigma_{\text{comp.}}+\sigma_{\text{man.}}=p\,\frac{1+6E}{b}\\ \sigma_B&=\sigma_{\text{comp.}}-\sigma_{\text{man.}}=p\,\frac{1-6E}{b}\end{aligned}\right\} \quad (12)$$

where b – section height; E – relative eccentricity.

In the future, substituting instead of z_1, ... , z_5, their values and dividing both parts of the equality by *t*, we obtain

$$\frac{1}{3}\frac{1}{t}(\sigma_1+\sigma_2+\sigma_3)+\frac{p}{t}\frac{1}{2E}\left(\sigma_1^2+\sigma_2^2+\sigma_3^2\right)+\frac{q}{t}\mu\frac{1}{E}(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1)+$$
$$+\frac{r}{t}\frac{1}{\sqrt{3}}\sqrt{\sigma_1^2+\sigma_2^2+\sigma_3^2}+\frac{1}{3}\frac{s}{t}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}=1 \quad (13)$$

Let us introduce new designations for constant coefficients in equation (13) and write the strength criterion in the following form

$$A\left(\sigma_{z_1}+\sigma_{z_2}+\sigma_{z_3}\right)+B\left(\sigma_{z_1}^2+\sigma_{z_2}^2+\sigma_{z_3}^2\right)+C\left(\sigma_{z_1}\sigma_{z_2}+\sigma_{z_2}\sigma_{z_3}+\sigma_{z_3}\sigma_{z_1}\right)+$$
$$+D\sqrt{\sigma_{z_1}^2+\sigma_{z_2}^2+\sigma_{z_3}^2}+E\sqrt{(\sigma_{z_1}-\sigma_{z_2})^2+(\sigma_{z_2}-\sigma_{z_3})^2+(\sigma_{z_3}-\sigma_{z_1})^2}=1 \tag{14}$$

For the plane case ($\sigma_{z_3}=0$), the strength criterion proposed by I.N.Mirolyubov, taking into account Mohr's theory of strength, in the final version takes the following form

$$A\left(\sigma_{z_1}+\sigma_{z_2}\right)+B\left(\sigma_{z_1}^2+\sigma_{z_2}^2\right)+C\sigma_{z_1}\sigma_{z_2}+D\sqrt{\sigma_{z_1}^2+\sigma_{z_2}^2}+$$
$$+E\sqrt{(\sigma_{z_1}-\sigma_{z_2})^2+\sigma_{z_2}^2+\sigma_{z_1}^2}=1 \tag{15}$$

According to modern concepts, expression (14) is the limit surface in the space of principal stresses, and expression (15) is the equation of the limiting curve on the plane of principal voltages. The constant parameters included in equations (14) and (15) are determined from the data of five experiments. We used to determine the parameters A, B, C, D, E the values of limiting stresses obtained when testing rigid plastics under conditions of a flat strenuous state. Table 1 shows five pairs of ultimate voltages values for two types of phenoplasts.

Table 1: Limit voltage value for five types of loads

Material	Voltage, MPa	1	2	3	4	5
03-010-02	σ_{z_1} σ_{z_2}	250 440	0 466	–315 440	–1930 0	–2250 –1200
E2-338-02	σ_{z_1} σ_{z_2}	305 427	0 470	–315 443	–1930 0	–2165 –1103

The data from table 1 were substituted into equation (15), as a result of which the following systems of linear equations of the fifth order were obtained for each material:

for 03-010-02

$$\begin{aligned}
&0{,}69\cdot10^3A+0{,}2561\cdot10^6B+0{,}11\cdot10^6C+0{,}50606\cdot10^3D+0{,}54056\cdot10^3E=1\\
&0{,}466\cdot10^3A+0{,}21716\cdot10^6B+0\cdot C+0{,}466\cdot10^3D+0{,}65902\cdot10^3E=1\\
&0{,}8\cdot10^2A+0{,}3074\cdot10^6B-0{,}1505\cdot10^6C+0{,}55444\cdot10^3D+0{,}95697\cdot10^3E=1\\
&-0{,}193\cdot10^4A+0{,}37249\cdot10^7B+0\cdot C+0{,}193\cdot10^4D+0{,}27294\cdot10^4E=1\\
&-0{,}345\cdot10^4A+0{,}65025\cdot10^7B+0{,}27\cdot10^7C+0{,}255\cdot10^4D+0{,}27577\cdot10^4E=1
\end{aligned} \tag{16}$$

for E2-338-02

$$\begin{aligned}
&0{,}732\cdot10^3A+0{,}27535\cdot10^6B+0{,}13024\cdot10^6C+0{,}52474\cdot10^3D+0{,}53873\cdot10^3E=1\\
&0{,}47\cdot10^3A+0{,}2209\cdot10^6B+0\cdot C+0{,}47\cdot10^3D+0{,}664468\cdot10^3E=1\\
&0{,}128\cdot10^3A+0{,}29566\cdot10^6B-0{,}113968\cdot10^6C+0{,}54375\cdot10^3D+0{,}9331\cdot10^3E=1\\
&-0{,}193\cdot10^4A+0{,}37249\cdot10^7B+0\cdot C+0{,}193\cdot10^4D+0{,}27294\cdot10^4E=1\\
&-0{,}3268\cdot10^4A+0{,}59027\cdot10^7B+0{,}23869\cdot10^7C+0{,}24296\cdot10^4D+0{,}26517\cdot10^4E=1
\end{aligned} \tag{17}$$

The above systems of linear equations were solved using a computer. Table 2 shows the values of parameters A, B, C, D, E for two batches of phenoplasts obtained on a computer. Even more accurate results can be obtained with approaching by the method of the minimum of the average quadratic deviation, but the amount of computational works in this case increases dramatically.

Table 2: Values of constant parameters for two batchs of phenoplasts

	03-010-02	E2-338-02
A	0,846153·10-3	0,944981·10-3
B	0,04409·10-6	0,19208·10-6
C	0,713242·10-6	0,809428·10-6
D	-1,31266·10-3	-1,85106·10-3
E	1,83274·10-3	2,08134·10-3
a	0,394307	0,444141
b	0,0095699	0,0424324
c	0,154885	0,178801
d	-0,611699	- 0,8699
e	0,854059	0,978229

In this article, we have carried out an analysis to determine the strength of details made of plastics of the thermosetting group and the use of data on materials in the manufacture of details for oilfield equipment operating in the Absheron region of the Republic of Azerbaijan.

VI. CONCLUSIONS

Based on the results, an experimental-theoretical method for determining the main quality criteria (shrinking deformation and other quality indicators, strength, hardness, surface roughness) of plastic details is proposed. The developed technique for the design of plastic details makes it possible to estimate the expected life of the details, taking into account their operating conditions.

CONFLICTS OF INTEREST

The author declare that they have no conflicts of interest.

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