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ULTRASOUND CONTROL AND STUDY OF PHYSICAL MODEL CONDUCT OF 20 GL STEEL TENSILE

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One of the most important problems in solid state physics is searching new patterns in the performance of the physical characteristics of metals in the external radiation on them. This research deals characteristics of ultrasonic testing on plastic molded metal, based on the connection speed of ultrasound with elasticity module and the analysis of the stress-strain on the example of steel 20GL brand. According to the results of the experiment there is a new theoretical basis of a physical model of metal pattern in tension. It was found that the previously proposed a parabolic response function is not applicable when there is maximum deformation. It was given an analytical expression for the response function. It is shown that as the response function fits the function displayed in the form of an ellipse. It was found that exactly that function describes the experimental data satisfactorily.

Keywords: elastic constants, elastic modulus, plastic deformation, the longitudinal ultrasonic wave, tensile test, steel 20GL.

Introduction

Today the research and ultrasound technique are used, for example, to detect violations of the metal continuity, it cracks and weld defects etc. Recently, an interest in it has increased even more, as a link between acoustic and strength properties of metals.

Currently, methods of non-destructive testing in toughness and elasticity are considered for structural steels pearlite as a class issued in the form of forgings and rolled [3], for a low-carbon and low-alloy steels after rolling and heat treatment [4]. In this research was [5] made a special study of the correlations between the ultrasonic velocity, hardness and toughness in hot-rolled steel 09G2S. In contrast to the above forgings and rolled, the heterogeneity of cast metal structure reduces the accuracy of ultrasonic testing, therefore, is urgent search for new methods of ultrasonic cast metal control. This subject is partially considered in the research [6], which offers acoustic emission method for non-destructive testing of internal defects in molded parts of rolling stock.

The continuously increasing level of quality requirements for parts involves the development of new physical models of the metals pattern when exposed to shock and tensile loads. In this sense, interesting presentation of JF Bell [1, 2], which proves that the function describing the dependence of the stress-strain in plasticity, is a parabola.

The aim is a relationship of ultrasonic velocity with the plastic properties of cast metal. A new model of destruction of metal samples after stretching was developed.

1. The methodology of the analysis.

The propagation velocity of longitudinal ultrasonic wave generated by the transducer with a frequency of 4 MHz, measured on the device UST A 1209 using a calibration mode on a given metal thickness. For that, we prepared samples with KCU hub, according to GOST 9454 ("GOST" means in Russian “ГОСТ”) [7] with different heats of steel 20GL brand, in the amount of 20 peaces. Then on the sample measured the velocity of propagation of longitudinal and transverse ultrasonic waves at ambient and low temperatures. Static tensile test cylindrical samples 10 mm in diameter was performed on the same samples at room temperature in a car one main static preloading «WAW-600C» with stretching chart entry in accordance with GOST 1497 [8], with the measurement of physical yield strength, ultimate strength, relative uniform elongation and contraction.

2. Results and discussion.

Modulus of elasticity (Young's modulus) can be determined by stretching the diagram and the propagation velocity of ultrasonic waves in the metal [9]. Generally speaking, the velocity of longitudinal sound wave has two meanings. If the wave propagates in a solid medium, from Lame equations an expression for the speed of sound. In fact, the Lame equation is

$$\rho \frac{\partial^2 \vec{\omega}}{\partial t^2} = (\lambda + \mu)\, grad\ \ div \vec{\omega} + \mu \Delta \vec{\omega}$$

where the vector displacement of the rigid body, λ and μ are Lame coefficients.

In the case of longitudinal wave $rot\vec{\omega} = 0$, a $div\vec{\omega} \neq 0$ and as

$$grad\ \ div\vec{\omega} = rot\ \ rot\vec{\omega} + \Delta\vec{\omega} = \Delta\vec{\omega}\text{, so}$$

$$\frac{\partial^2 \vec{\omega}}{\partial t^2} = \frac{\lambda + 2\mu}{\rho} \Delta\vec{\omega}$$

It shows that the longitudinal wave velocity in a solid sample is:

$$C = (\lambda + 2\mu)^{\frac{1}{2}} \rho^{-\frac{1}{2}} = \sqrt{\frac{\lambda + 2\mu}{\rho}}$$

Young's modulus and shear modulus related to the Lame coefficients of relations:

$$E = \frac{\mu(3\lambda + 2\mu)}{\lambda + \mu}; \quad N = \mu$$

So to find E is necessary to know the shear modulus. If the wave travels along a narrow rod, then the equation of wave propagation is:

$$\rho \frac{\partial^2 \omega}{\partial t^2} = E \frac{\partial^2 \omega}{\partial x^2}$$

and the velocity of the wave is equal to:

$$C = (E/\rho)^{\frac{1}{2}}. \qquad (1)$$

According to formula (1)

$$E = C^2 \cdot \rho \qquad (2)$$

According to this formula (2) the elastic modulus was determined. After analyzing a large number of heats, empirically obtained values with an accuracy of ± 12%, were compared with the calculated data on the chart stretching. It was found that the accuracy of the result adversely affect the internal defects in the metal, in the form of foreign inclusions, cracks and blowholes, and the grain size of the structural components. For example, in samples from 9 score scale grain GOST 5639 [10], the measurement accuracy is higher than a score of 8 samples.

Let us return to the physical model tests the tensile rupture. In theory, [1, 2] is apparently not considered the maximum voltage and to break the sample. For this reason, the response function, i.e. function in the plastic region is a non-parabola, and an ellipse. Let us consider this statement. The orientation of the ellipse is shown in Figure 1.

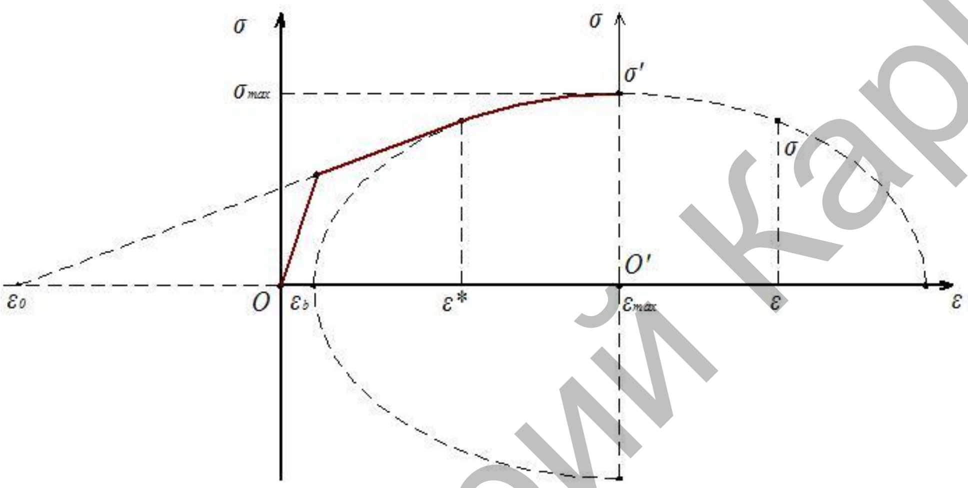

Fig.1. Schematically shows the response ellipse function.

Figure 1 shows that the axes ($\varepsilon'\sigma'$), passing through a point of the ellipse equation is:

$$\frac{\varepsilon'^2}{a^2}+\frac{\sigma'^2}{b^2}=1 \qquad (3)$$

It is also easy to see that $a=\varepsilon_m-\varepsilon_b$ и $b=\sigma_m$. Further, $\varepsilon'=\varepsilon-\varepsilon_m;\ \ \sigma'=\sigma$. Thus, the axes ($\varepsilon\sigma$) function response equation is as follows:

$$\frac{(\varepsilon-\varepsilon_m)^2}{(\varepsilon_m-\varepsilon_b)^2}+\frac{\sigma^2}{\sigma_m^2}=1. \qquad (4)$$

Solving this equation for, we obtain

$$\sigma=\sigma_m\cdot\left[1-\frac{(\varepsilon-\varepsilon_m)^2}{(\varepsilon_m-\varepsilon_b)^2}\right]^{0,5}. \qquad (5)$$

The meanings ε_b were found by Bella. Point ($\varepsilon^*\sigma^*$) is the beginning of a curvilinear relationship. After the tangent at this point, i.e., extending the linear section, we get the point ($\varepsilon_0 0$). The value is determined by the formula:

$$\varepsilon_b = \frac{\varepsilon_m^* + \varepsilon_0}{2} \tag{6}$$

As an example, consider the following diagram of stretching, melting № 224 (Figure 2.), Grain size 8, the values of the stress and strain on the calculations according to the chart:

$\varepsilon_m = 16.3 \cdot 10^{-3}$; $\sigma_m = 627.0$ MPa; $\varepsilon_b = -2.74 \cdot 10^{-3}$

$\varepsilon_2 = 11.7 \cdot 10^{-3}$; $\sigma_2 = 609.40$ MPa;

$\varepsilon_3 = 8.379 \cdot 10^{-3}$; $\sigma_3 = 564.78$ MPa;

$\varepsilon_4 = 6.348 \cdot 10^{-3}$; $\sigma_4 = 516.55$ MPa.

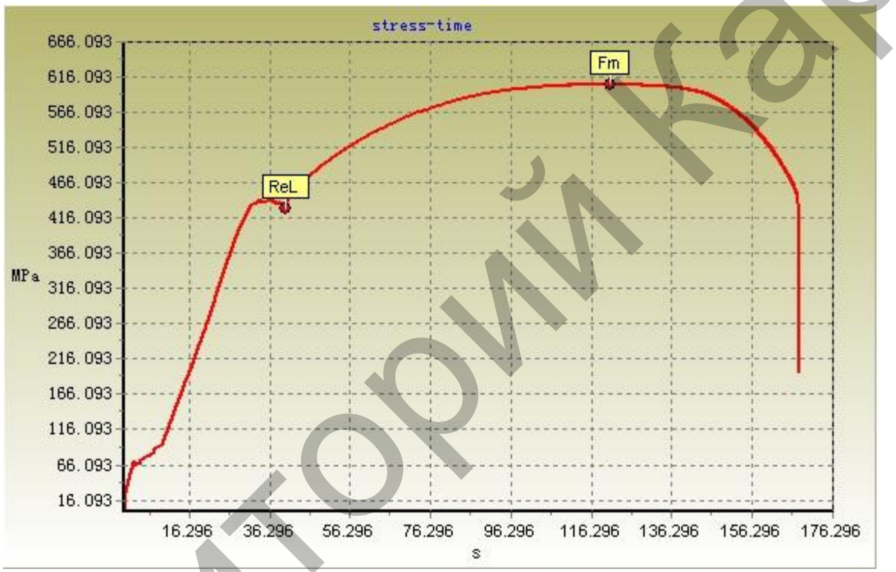

Fig. 2. Diagram of the sample stretching 20GL steel, smelting No.224, grain score 8.

Fig.3. Diagram of the sample stretching 20GL steel, smelting No.226, grain score 9

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Calculations by the formulas (5) and (6) gave the following voltages: σ_2 = 608.65 MPa; σ_3 = 570.29 MPa; σ_4 = 534.7 MPa. The maximum error of theoretical value does not exceed 3.5 %.
For sample melting №226 (Fig. 3). The following values were obtained σ and ε:

$\varepsilon_m = 14.955 \cdot 10^{-3}$; σ_m = 615.07 MPa;

$\varepsilon_2 = 11.866 \cdot 10^{-3}$; σ_2 = 603.30 MPa;

$\varepsilon_3 = 8.758 \cdot 10^{-3}$; σ_3 = 569.01 MPa;

$\varepsilon_4 = 5.427 \cdot 10^{-3}$; σ_4 = 511.44 MPa.

Calculations by the formulas (5) and (6) give: σ2 = 597.6 MPa; σ3 = 573.3 MPa; σ4 = 515 MPa. The maximum error does not exceed the theoretical values of the order of 1 %. It also follows that the plastic deformation is achieved when the voltage maximum, the response function is an ellipse rather than a parabola.

Conclusion

In the equations (5) and (6), in coupled methods a camera of speed measuring procedure longitudinal ultrasonic wave may well be used in evaluating the properties of plastics become 20GL. The parabolic response function is not able describe the dependence fully of σ on ε when there is a maximum voltage value. In this case, in our opinion, it is the best response function for the equation of the ellipse.

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