INVESTIGATION OF THE PHYSICAL PROPERTIES OF MATERIALS FOR FUEL ELEMENTS AND CARBON NANOSTRUCTURAL MATERIALS BY MEANS OF ACOUSTIC WAVES OF GIGAHERTZ RANGE

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Introduction

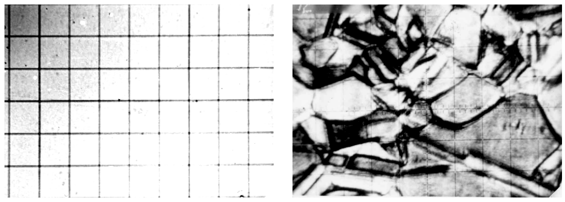
The problem of nondestructive express control of physic-mechanical properties of materials in condense state is at present one of the most important scientific problems. Objects of investigations of the most interest were materials, used in processing of fuel elements, and carbon nanostructural materials.

In this paper the results of experimental work with the help of acoustic waves gigahertz range are given. The essence of the subjected methods is first inlayer visualization of subsurface structures of the objects under investigation and second in the definition of velocity values of acoustic waves and calculate the elasticity constant of solid material. The nondestructive methods of investigation of structure and characteristics used have not limits by the nature of materials – the objects may be dielectrics, metals, crystals, and other substances, including nanostructural materials. Metals have been chosen as model objects for experimental investigation. Chemical and phase composition, structural, thermo- and deformation properties influence the characteristic properties of the named substances.

Results and discussion

By means of method of visualization with the help of acoustic waves [1,2] we could get the microstructure images of steel samples on different depths from the surface. The analysis of acoustic images gave the possibility to calculate the dimensions of grains, to observe their transformation in the period of time or under external influences. In accordance with the theory of Hall – Peach [3] there were defined the strength characteristics, for example flow limit ($\sigma_{0,2}$) of the materials under study. The significance obtained $\sigma_{0,2}$ are in proper correspondence with values which are table one for the type of steel under consideration.

Example of the obtained acoustic microscope image is represented on Fig.1. It demonstrated with ~220^x magnification, the structure of steel BHC-2M.



a) b)

Fig.1. Comparable optical (*a*) and acoustical (*b*) images of subsurface layers *BHC-2M* steel (*a*) ~200^x; *b*) H_2O, *f* = 407 MHz, scale: 28 μm /div., Z = -12 μm).

The comparative optical photo with the same magnification gives the image of a polished surface without revealing structure elements. Structure transformation has been observed after deformational and thermal influences. Acoustomicroscope method of V(Z) – curves essentially increases possibility of obtaining information about investigated materials [3]. It allows to get the specific curves, for given materials, which are connected with elastic – mechanical constant ones. The example of such dependence for carbonaceous steel is demonstrated in Fig.2.

According to the principles, introduced before [4], the curve receiv-ed permits to determine the value of SAW veloci-ty. For this it is necessary to measure the distance

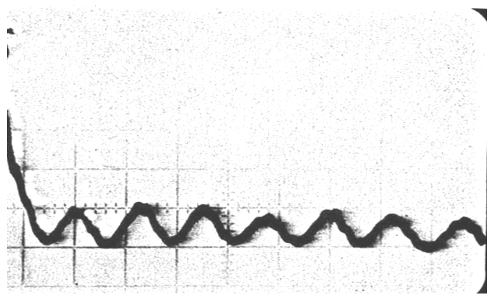


Fig.2. V(Z)-curve for carbonaceous steel(H_2O, vertical scale: 1,0 V/div., horizontal scale: 10 μm/div.).

(ΔZ_N) between maximums, situated on the right of the main one. If the value of acoustic wave velocity υ_l in the immersion liquid and the working frequency *f* are known, then by means of definite experimental interval SAW velocity υ_R can be calculated:

$$\upsilon_R = \upsilon_l \left[1 - \left(1 - \frac{\upsilon_l}{2 \cdot f \cdot \Delta Z_N} \right)^2 \right]^{-1/2}$$

In order to calculate the value of the elastic modules in the local area of the studied material one should use the tabular values ρ_S of density and of Poisson coefficient (ν), or their quantity, determined by one of the certain standard methods:

$$E = \upsilon_R^2 \cdot \frac{2 \cdot \rho_s \cdot (1+\nu)^3}{(0{,}87 + 1{,}12 \cdot \nu)^2}$$

and

$$G = \upsilon_R^2 \cdot \rho_s \cdot \left(\frac{1+\nu}{0{,}87 + 1{,}12\nu} \right)^2$$

There have been developed the acoustomicroscopy methods which allow to extract not only certain values of physical-mechanical properties of materials, but also their correlation dependence on time, schedules of thermal and mechanical processing etc. The examples of the received dependence of arising flocks amount, of speed change of SAW characteristics of fading ($\Delta V/V$), and sizes of appearing heterogeneity on concentration of diffusion hydrogen, appropriate for a number of steels, approve of the thesis above [5]. Adding to it, V(Z) – method makes it possible to distinguish the characteristics of steels with different deformation degree or with textures. A typical example of revealing such differences is depicted in Fig.3.

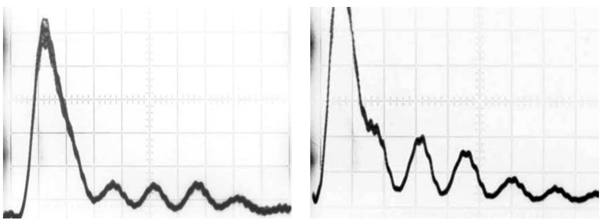


Fig.3. Evaluation of elastic-mechanical steel parameters with different deformation degrees using the methods V(Z)-curves (H_2O, vertically: 1V/div., a) 5% deformation; section is parallel to the plane of rolling; horizontal scale: 10,6 μm/div., ΔZ_N = 13,74 μm, $\upsilon_R = 2{,}98 \cdot 10^3$ m/s; *b*) 50% deformation; section is parallel to the plane of rolling; horizontal scale: 12,5 μm/div., ΔZ_N = 14,95 μm, $\upsilon_R = 3{,}11 \cdot 10^3$ m/s).

Finally, let us move to the investigating of the physical properties of nanostructural carbon materials. As mentioned already the methods of acoustomicroscope defectoscopy are applicable to almost all materials in condensed state. The opportunity of their usage for carbon materials is demonstrated on the graphite ПРОГ , that is chosen as a model. Its main characteristics, determined with the help of acoustomicroscope methods, are illustrated in the table 1.

Table 1

Characteristic	Value
SAW velocity, υ_R (10^3 m/s)	2,01
Module of elasticity, E (10^9 Pa)	12,77
Interval, ΔZ_N (10^{-6} m)	5,6
Poisson coefficient , ν	0,14
Porosity, θ (%)	14
Density, ρ_s (10^3 kg/m^3)	1,124

The sensitivity of the employed materials towards nanoinhomogeneities, which sizes are much less than the resolvable ability of SAM, deserves an individual examination. The example of a form change in V(Z) – curves for the glass of different nanopore density is presented in Fig. 4.

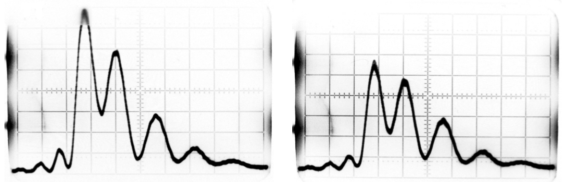


Fig. 4. Change V(Z)-curves form in the areas of different nanopore density in the glass trade ТПС (H_2O, vertically: 0,25 V/div., horizontal scale: 12 μm/div., ΔZ_N = 19,37 μm, $\upsilon_R = 3{,}53 \cdot 10^3$ m/s; $(\Delta V/V)_{max}$ = 41%).

Conclusions

To sum up, the acoustomicroscope defectoscopy methods are promising in studying the physical characteristics of the materials, employed for fuel elements and for carbon nanostructural materials.

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