THE QUANTIZATION EFFECT OF MECHANICAL ENERGY ABSORBED BY METALS UNDER DEFORMATION AND FRACTURE

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In a great number of recent papers deformation and fracture processes are treated not by classical means of continuum mechanics but are rather viewed from the standpoint of quantum physics laws. Some results of the investigation conducted in the latter direction are summarized below. The real metal fracture phonon conception proposed by the author is based on the following considerations:

1. Due to dislocations in crystal volumes neighbouring their possible slip plane an atomic vibration spectrum appears different from that in other lattice volumes: the spectrum is cut on the side of minimum wavelengths $\lambda_i = 2D_i$, where D_i is the effective direction of the lattice wave propagation.
2. With increasing dislocation density their force fields interact and this results in the appearance of local volumes with an increased level of internal energy.
3. On reaching a definite dislocation density the level of internal energy in local metal volumes reaches one of its critical values, equal to $W_i = hs_i/\lambda_i = h\nu_i$, where s_i is sound velocity in corresponding directions of the lattice, ν_i - corresponding vibration mode frequency, h- Plank's constant. This energy is absorbed by the crystal lattice that results in an abrupt amplitude increase of i- mode atomic vibration.
4. The rapture of interatomic bonds in a crystal lattice occurs due to (phonons) vibration interference of i- mode.

The latent energy maximum values of the material strain hardening U_s^{max} is supposed to correspond to one of the above mentioned energy levels. It permits to carry out an immediate examination of the validity of the hypothetical model. This work was done for Al, α-Fe and their alloys.

As it has already been shown (1) U_s^{max} approximates the value of the complete (including elastic component)

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work of uniform strain A_e. On the other hand, characteristic dislocation core sizes determined by means of molecular dynamic methods are wll known for many materials. Ford α-Fe these data were published previously (2), (3). For Al dislocation core sizes were calculated by the author and his colleagues (4).

Energy levels at normal temperature for Al and α-Fe calculated on the basis of the accepted model are shown by horizontal lines in the figure. Depending on the dislocation type and the direction of lattice wave propagation they are equal to 14.6, 29.1, 43.2, 62.8 MJ/m³ for Al and 47.6, 71.4, 78.5, 104.5, 226.1* MJ/m³ for α-Fe representively. A_e values in their dependence on the lower yield point σ_s for Al, α-Fe and the most important industrial alloys on their basis are also given in the figure. Dark symbols show experimental values, while light symbols show values calculated according to the approximated formula. As it is evident A_e alloys values approximate energy levels calculated according to pure metal constants data.

One more conclusion very important for the practice can be made due to the results obtained. The effective surface energy minimum value γ^{min}_{eff}, corresponding to the fracture toughness minimum value K_{Ic} being directly connected with A_e (1), K_{Ic} criteria for alloys on the given basis must distribute on a limited number of discrete levels: in case of aluminium alloys for example, this number equals to four.

W_i (A_e) value is the minimum energy quantum absorbed by a metal in fracture condition. In the case fracture process causes great energy waste, the absorbed energy value according to the model accepted must be a multiple to W_i (A_e) constant. This effect of macroscopic quantization of the absorbed mechanical energy was confirmed experimetally in investigating the influence of stress state on fracture toughness (5).

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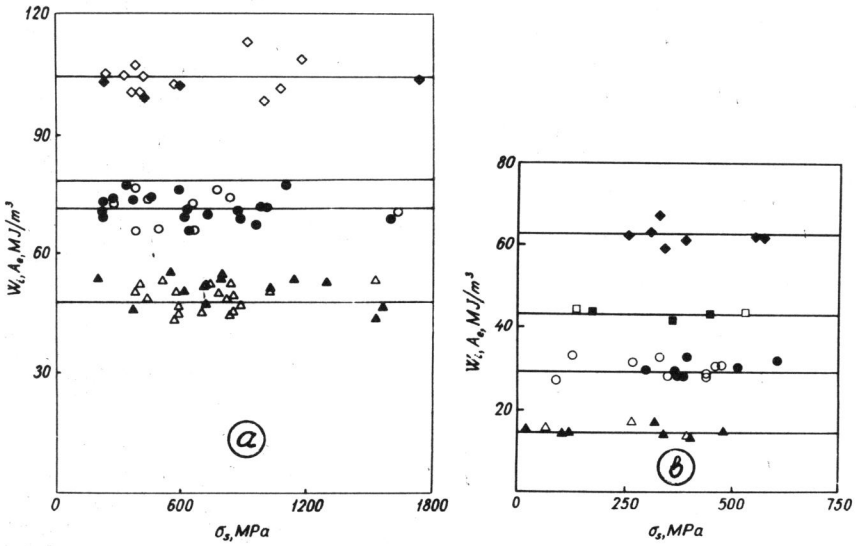

Threshold levels of energy W_i and the dependence of complete work of uniform deformation A_e on the lower yield point σ_s: a- α-Fe and its alloys; b- Al and its alloys.