DAMAGE ACCUMULATION AND FRACTURE OF ENGINEERING MATERIALS SUBJECTED TO IMPULS LOADING

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The physico-mechanical model of metallic thick-wall cylinders fracture under impuls loading is proposed, which explains the phenomenon of multiple fracturing (fragmentation) under high rates of straining. Here it is supposed that fracture process is controlled by damage volume concentration and by the stress value and gradient. Corresponding quantitative theory based on the nucleation theory of microfracture origins and on the kinetic dislocational approach is developed taking into account the stochastic nature of the phenomenon under consideration. The algorithm of fragmentation parameters calculation is given.

To utilize impact and pulse loading in metal working technology (plate forming and die forging, welding and cutting, hardening, etc.) knowledge broadening, as to the material behaviour under various loading of this kind, is needed. Modern investigations of fracture processes in explosive loaded thick-wall cylinders seem to be the excellent instrument in physics and mechanics of fracture and they play an important role in the development of metalworking technologies.

Noting insufficient research in the above mentioned direction, this work considers thick-walled tube specimens failure by pulse loading, which accounts for the plural breaking (crushing, fragmentation) of rigid bodies under high rate deformation.

This paper tries to avoid popular difficulties and to accomplish calculation of fragments distribution analytically, proceeding from initial data according to physical and mechanical properties, including crack resistance.

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Let us choose a cylindrical thick-walled shell as an object of investigation, which is loaded by internal pulse pressure.

On the basis of existing ideas in the field of mechanics of fracture let us describe the fundamental statements of the physical model of fragments formation under the pulse loading. The elastic and plastic wave while moving through the shell: a) contributes to the growth of the available microdefects of materials; b) forms new microdefects; c) changes the structure and properties of material.

It should be noted, that the above described picture does not define concretely the kind of failure - by break away or by shear, and defects are not only proper cracks but also the places of localized shears (strips of adiabatic shear), etc. The type of fragmentation is not defined here, be it either connection of the shear zones or break-away zones, or shear and break-away zone. The paper deals only with the phenomenon of failure proper.

Thus, the marking out of the surface of failure takes place during the wave phase. Loading conditions being similar, the marking out is influenced by: a) initial structure of materials; b) ultimate strength and deformation properties alongside with properties of failure resistance of the shell material; c)degree of initial presence of defects in material; d) geometrical dimensions and mass of shell; e) properties of loading medium, rate of detonation and mass in particular. This effect is manifested both in mass and qualitative composition of fragments, and also in mechanisms of failure and the form of the fragment proper.

The development of damage into macrofailure is controlled by concentration of damage in the bulk of the material and the stress level. The latter, through diminishing with the growth of cracks, remains, because of the considerable loading medium spare energy, more than sufficient for growing up, simultaneous at that, of the main fragment forming cracks. The further development of failures accompanied by growth and merging of cracks, fragments formation should be considered as a self-sustaining, self-organizing phenomenon similar to transition under the static loading from stable to unstable material failure.

Corresponding quantitative theory based on the nucleation theory of microfracture origins and on the kinetic dislocational approach is developed taking into account the stochastic nature of the phenomenon. Some equations and formulas are obtained for calculations and prediction of materials fragmentation using mechanical characteristics of metal, including fracture toughness, specimen geometry, loading environment, and parameters of the dynamical stress state of the solid.

The algorithm of fragmentation parameters calculation is given. It consists of the calculation of stress-strain state of the specimen under given boundary conditions, of determination of critical cracks dimensions and orientations in dynamical stress fields. The specific defects density is calculated taking into account cracks growth rates and self-similarity conditions of their evolution. This density is compared to with the real defects density in solids, determined experimentally when the defects substructure in deformed materials was examined. From such a comparison the calculation is made about materials fragmentation quantities.

The results of the verification of the proposed model using published experimental data are presented in Figure.

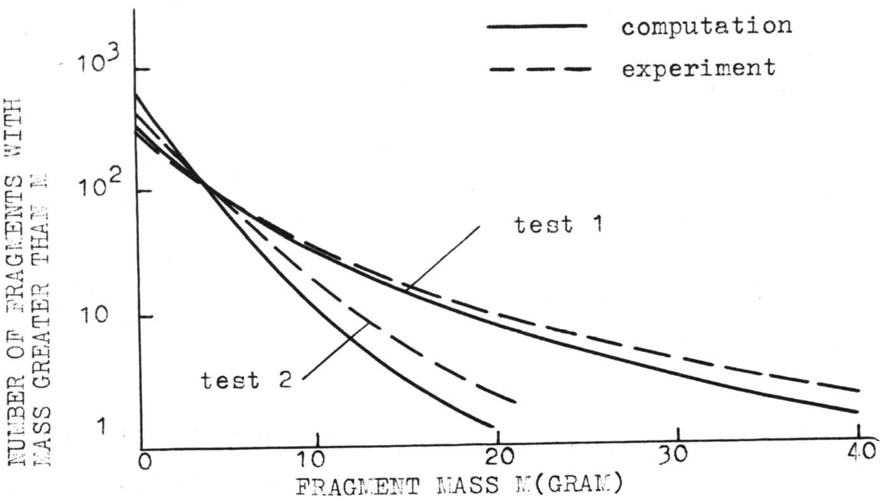

Figure. Comparison of measured and calculated frag - ment mass distributions for the steel cyliders