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Numerical simulation of high-velocity projectile interactions with groups of spaced rods and plates

Alexander V. Gerasimov[a,*], Sergey V. Pashkov[a]

[a]*Research Institute of Applied Mathematics and Mechanics, National Research Tomsk State University, 36, Lenin av., Tomsk, 634050,Russia.*

Abstract

The study of the problem of protecting the elements of constructions from impact loadings is very important due to the constant perfection of the means of shock-wave impact on the objects of modern technology. Creating of a reliable way to protect structures from destruction by high-velocity elongated projectiles dictates a need to develop different ways to counter the penetration into target.

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Keywords: Projectiles; protection; plates and rods;numerical simulation;

1. Introduction

The interaction of projectiles with plates and rods which are thrown towards projectile by HE is investigated. The problem is solved in 3-D statement in view of natural heterogeneity of real materials structure affecting distribution of physical-mechanical characteristics along the volume of the elements of the construction and being one of the factors, defining destruction character of the latter. The necessity to account the given factor for equations of deformable solid mechanics dictates the application of probabilistic laws of distribution of physical-mechanical characteristics into the volume of the construction under consideration. The equations describing spatial adiabatic movement of the strong compressible solid are differential result of fundamental laws of conservation of mass, pulse and energy. In general they have the following form [1-3].

* Corresponding author. Tel.: +7-913-805-0074; fax: +7-382 -252-9547.
E-mail address: ger@niipmm.tsu.ru

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To calculate elastoplastic flows used technique implemented on tetrahedral cells and based on the combined use of the Wilkins method [4] for calculation of internal body points and Johnson method [5] for calculating contact interactions. The most common way to protect objects is to use materials with high physical and mechanical properties, such as ceramics and composites based on it. Layered barrier enable prevent damage and destruction of protected structures or stretching of the pressure pulse in the layered system due to multiple reflection of waves from layers with different acoustic impedances, or pressure pulse energy dissipation during plastic deformation of highly porous layers or fragmentation of ceramic materials.

The second possible way to counter high-velocity projectiles is to throw groups of spaced plates and rods from conventional and composite materials towards projectiles. As a result of the dynamic interaction and intense deformation occurs the partial destruction of the projectiles or the deviation projectiles from the line of collision. Consequently, the projectiles can rebound from the surface barrier, or deviate from the object to be protected and do not interact with the barrier. All these factors reduce the penetration of projectiles into the protected object. In this work numerical simulation of the interaction of high - velocity projectiles with groups of spaced rods and plates is carried out.

2. The equations describing the motion of a compressible elastic-plastic body taking into account probabilistic nature of fracture

The equations describing spatial adiabatic motion of a solid compressible medium are differential consequences of the fundamental laws of conservation mass, pulse and energy. In general they have the following forms [1-3]:

continuity equation

$$\frac{1}{\rho}\frac{d\rho}{dt}+\frac{\partial v_i}{\partial x_i}=0; \tag{1}$$

equation of motion

$$\rho\frac{dv_i}{dt}=\rho F_i-\frac{\partial P}{\partial x_i}+\frac{\partial S_{ij}}{\partial x_j}; \tag{2}$$

energy equation

$$\rho\frac{dE}{dt}=S_{ij}\varepsilon_{ij}+\frac{P}{\rho}\frac{d\rho}{dt}, \tag{3}$$

where x_i - the coordinates; t - time; ρ_0 - the initial density of the medium; ρ - the current density of the medium; v_i - components of the velocity vector; F_i - components of mass forces vector; S_{ij} - components of stress tensor deviator; E - specific internal energy; ε_{ij} - components of deviator of strain rate tensor; P - pressure.

To equations (1) - (3) we must add the equations taking into account relevant thermodynamic effects associated with adiabatic compression and strength of the medium. In general case, under the influence of the forces on the solid-deformable body, both volume (density) and the shape of the body are changed by different dependencies. Therefore, stress tensor is the sum of spherical tensor and the stress tensor deviator.

$$\sigma_{ij}=S_{ij}-P\delta_{ij},\ i,j=1,2,3,$$
$$\delta_{ij}=1,\quad i=j,$$
$$\delta_{ij}=0,\quad i\neq j,$$