

MODELING OF OBLIQUE IMPACT OF YAWED PROJECTILES ON CERAMIC TARGETS

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Summary The investigation of three-dimensional problem of oblique interaction of yawed projectiles with ceramic plates in a velocity range up to 4000 m/s was carried out by the finite element method. The paper presents an advanced constitutive model of AD995 Alumina. The model of damaged medium is used; it is characterized with possibility of crack initiation and propagation under impact loading. A kinetic fracture model of the active type developed earlier for the simulation of fracture in various materials is used for numerical modeling of ceramic failure at high velocity impact. Temperature effects are taken into account in the constitutive model.

SETTING UP THE PROBLEM

The model of a damageable medium that is characterized by microcavities (cracks and pores) is used. According to [1] the total volume of the medium W consists of the undamaged part, which occupies the volume W_c and is characterized by the density ρ_c , and the microcavities, which occupy the volume W_T ; the density of the microcavities is assumed to be zero. The mean density of the damageable medium is related to the parameters introduced by the formula $\rho = \rho_c(W_c/W)$. The degree of the damage of the medium is characterized by the specific volume of cracks $V_T = W_T/(W\rho)$. The set of equations describing time-dependent adiabatic motion of a compressible medium (in the case of both elastic and plastic deformation), taking into account the growth and accumulation, of microdamages consists of equations of continuity, motion, energy, and the equation that describes the variation of the specific volume of cracks. To investigate the effects of fracture and temperature in ceramic target during oblique impact of yawed projectiles in a range of velocities up to 4000 m/s a number of simulations was performed. The interaction of steel cylinder with 7.6 mm in diameter and 50.8 mm in height with AD995 plate with 10 mm in thickness was modeled. The model parameters for AD995 ceramics were adjusted using the data from plate impact experiments. The characteristics of the AD995 employed in computation were [6]: $\rho_0=3890$ kg/m³, $\sigma_0=4.7$ Gpa, $G_0=160.0$ Gpa, $V_1=1.46 \times 10^{-6}$ m³/kg, $V_2=0.875 \times 10^{-7}$ m³/kg, $V_3=5.83 \times 10^{-5}$ m³/kg, $V_4=1.75 \times 10^{-4}$ m³/kg, $K_4=0.5$ (m s)/kg, $P_k=0.45$ GPa, $a=7700$ m/s, $b=1.3$, $c_s=10560$ m/s, $T_m=2327$ K, $V_{TK}=1.0 \times 10^{-5}$ m³/kg, $d=1.6 \times 10$ K, $c_p=775.2$ J/(kg K), $\gamma_0=1.32$, $\sigma_p=0.3$ Gpa, $P_{fr}=-8.8$ Gpa. The characteristics of the steel were: $\rho_0=7850$ kg/m³, $\sigma_0=1.01$ Gpa, $G_0=79$ Gpa, $V_1=9.2 \times 10^{-6}$ m³/kg, $V_2=5.7 \times 10^{-7}$ m³/kg, $V_3=2.55 \times 10^{-5}$ m³/kg, $V_4=6.37 \times 10^{-5}$ m³/kg, $K_4=0.54$ (m s)/kg, $P_k=-1.5$ GPa, $a=4400$ m/s, $b=1.55$, $c=206$ Gpa, $d=1.6 \times 10$ K, $c_p=446.7$ J/(kg K), $\gamma_0=1.91$.

RESULTS OF NUMERICAL CALCULATIONS

Computations have been done for yaw up to 10^0 . Figure 1 shows configurations of projectile and plate during interaction at 4000 m/s impact velocity for obliquity 45^0 and yaw 10^0 at 10 μ s. In this case the computation evidences that process of perforation is observed and completed up to 15 μ s.

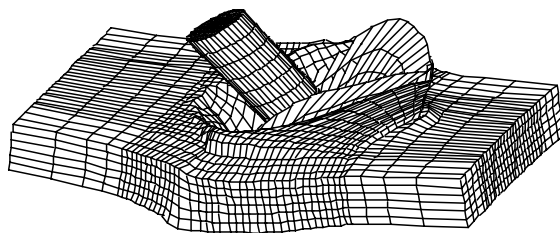


Fig. 1. Penetration process at 4000 m/s impact velocity for obliquity 45^0 and yaw 10^0

Figure 2 shows the histories of components of forces of resistance during penetration at 4000 m/s impact velocity for obliquity 45° . Curves show that at initial moment the vertical components of forces of resistance are greater. After $6 \mu\text{s}$ the horizontal components of the forces of resistance are greater for both angles of yaw.

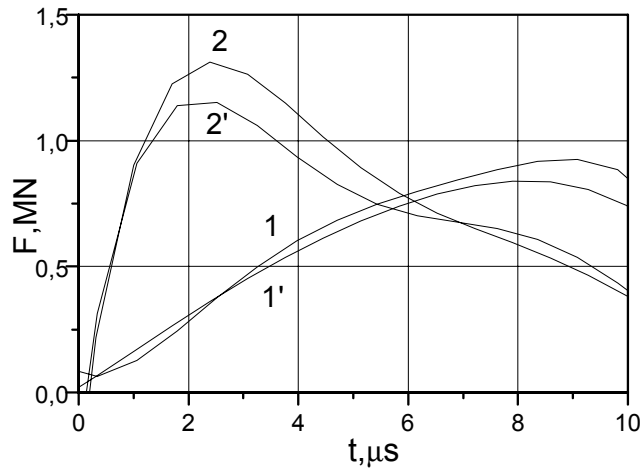


Fig.2. Histories of components of forces of resistance during penetration at 4000 m/s impact velocity for obliquity 45° : 1– F_2 , Yaw= 0° ; 1'– F_2 , Yaw= 10° ; 2– F_3 , Yaw= 0° ; 2'– F_3 , Yaw= 10° .

The histories of temperature near contact surface in target and in projectile were investigated. Results evidence that temperature effects are important for impact velocity range over 4000 m/s and they are more expressed for ceramic target. To further investigate the ceramics model the contours of specific volume of cracks were generated. The computations show that the maximum values of damage occurred in the bottom of ceramics near axis of impact for both angles of yaw and only for yaw 100 in face layer of ceramics near the leading edge of the projectile-target interaction region. Effect of yaw on the fracture was clearly expressed. In summary it may be said that results of numerical simulations using the shock-wave propagation based finite element code revealed that both temperature effects and fracture of ceramics are important at 4000 m/s velocity. Stages in the penetration process, surfaces and contours of temperature and specific volume of cracks were generated for different moments of time. Results evidence that temperature effects in ceramic targets for impact velocity of 4000 m/s are clearly expressed. It was revealed that values of the horizontal components of the forces of resistance are greater than the values of the vertical components of forces of resistance during second stage of penetration. It results in normalization of vector velocity of mass center of projectile during the second stage of the process of the penetration at obliquity 45° .

The research was supported by the Russian foundation for basic research (grant no. 99-03-32200).

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