Journal of Applied Mechanics and Technical Physics, Vol. 49, No. 5, pp. 723–724, 2008

SPECIFIC FEATURES OF INTERACTION OF A SHAPED-CHARGE JET WITH A TARGET

E. V. Proskuryakov,[1] M. V. Sorokin,[1] and V. M. Fomin[2]

UDC 532.2

Coaxial interaction of a copper shaped-charge jet with a thin tungsten rod is considered. A theoretical model of spraying of the shaped-charge jet on the rod and results of experiments performed are presented.

Key words: *shaped-charge jet, shaped charge, shaped-charge jet spraying, tungsten rod.*

A theoretical model of spraying of a shaped-charge jet (SCJ) on a metallic rod is based on solving the problem of opposing jets in a hydrodynamic formulation (Fig. 1).

We use the following notation: α is the angle of SCJ expansion, ρ_J and ρ_T are the jet and target densities, r_J and r_T are the jet and target radii, and u_X is the velocity of the jet interface (velocity of penetration).

At the stagnation point X (in a moving coordinate system), the expression for the pressure P is

$$P = \rho_J (V_J - u_X)^2/2$$

on the left of the interface or

$$P = \rho_T u_X^2/2$$

on the right of the interface.

From the conditions of identical pressures at the stagnation point

$$\rho_J (V_J - u_X)^2/2 = \rho_T u_X^2/2,$$

we obtain

$$u_X = V_J/(1+\lambda), \qquad V_J - u_X = u_X \lambda, \qquad \lambda = \sqrt{\rho_T/\rho_J}. \tag{1}$$

As the target material in the hydrodynamic model is converted to a "sheet" with a velocity u_X, the jet velocity in this "sheet" is $V_J - u_X$. The expressions for the impulse of the substance entering the stagnation zone in a unit time are

$$I_1 = \rho_J (V_J - u_X)^2 \pi r_J^2$$

on the left of the interface and

$$I_2 = -\rho_T u_X^2 \pi r_T^2$$

on the right of the interface. The specific impulse of the substance moving in the axial direction has the following form at the exit from the stagnation zone:

— for the jet,

$$I_3 = \rho_J (V_J - u_X)^2 \pi r_J^2 \cos\alpha;$$

[1]Novosibirsk Higher Military Academy (Military Institute), Novosibirsk 630117. [2]Khristianovich Institute of Theoretical and Applied Mechanics, Siberian Division, Russian Academy of Sciences, Novosibirsk 630090; saper67@mail.ru. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, Vol. 49, No. 5, pp. 24–26, September–October, 2008. Original article submitted December 21, 2006; revision submitted July 25, 2007.

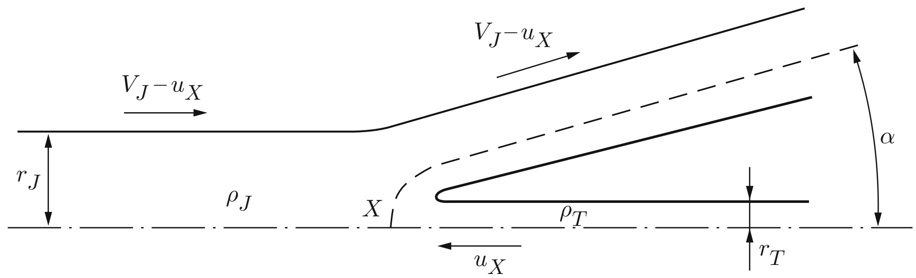

Fig. 1. Schematic interaction of jets in a moving coordinate system: the dashed curve is the interface between the jet and the rod.

Fig. 2. SCJ spraying on a metallic rod (X-ray data).

— for the target,

$$I_4 = \rho_T u_X^2 \pi r_T^2 \cos\alpha.$$

Taking into account the law of conservation of momentum $I_1 + I_2 = I_3 + I_4$, we obtain

$$\rho_J(V_J - u_X)^2 \pi r_J^2 - \rho_T u_X^2 \pi r_T^2 = [\rho_J(V_J - u_X)^2 \pi r_J^2 + \rho_T u_X^2 \pi r_T^2] \cos\alpha. \tag{2}$$

Dividing Eq. (2) by ρ_J and taking into account Eq. (1), we obtain the expression [1]

$$\pi r_J^2 u_X^2 \lambda^2 - \pi r_T^2 u_X^2 \lambda^2 = [\pi r_J^2 u_X^2 \lambda^2 + \pi r_T^2 u_X^2 \lambda^2] \cos\alpha,$$

which implies that

$$\cos\alpha = (r_J^2 - r_T^2)/(r_J^2 + r_T^2). \tag{3}$$

The angle of expansion of the "sheet" α is independent of the jet density ρ_J and target density ρ_T, which yet affect the value of the pressure P at the stagnation point X. Assuming that the jet radius is $r_J = 0.06D$ and the target radius is $r_T = 0.002D$ (D is the shaped-charge diameter), we use Eq. (3) to find the angle of expansion of the "sheet": $\alpha = 4°$.

As the SCJ has a variable diameter (at the beginning, the jet is thinner than at the end), it becomes sprayed in a certain range of angles. The value of the SCJ spraying angle can be changed by rod contouring (e.g., by making the rod thinner). The magnitude of the sprayed SCJ depends on the rod length and is determined within the framework of the hydrodynamic theory [2].

Experiments were performed to study the interaction of a copper SCJ with a tungsten rod placed into a foam-plastic container ahead of the shaped-charge jet. Dispersion of the SCJ into extremely fine particles on the tungsten rod was observed (Fig. 2). It should be noted that the sprayed SCJ forms a hole with a larger diameter, whereas the use of a rod reduces the penetration depth of the shaped charge.

Thus, we considered the phenomenon of spraying of a copper shaped-charge jet on a thin tungsten rod. The spraying phenomenon can be used for creating large-diameter holes in armor protection, impacting complex targets [3], depositing the SCJ material onto the target surface, etc.

REFERENCES

1. M. I. Gurevich, *Theory of Ideal Fluid Jets* [in Russian], Nauka, Moscow (1979).
2. M. A. Lavrent'ev and B. V. Shabat, *Hydrodynamics Problems and Their Mathematical Models* [in Russian], Nauka, Moscow (1973).
3. D. Rototaev and V. Grigoryan, "Missile versus armor: Which is stronger?" *Voen. Parad*, No. 2, 32–34 (1999).