ACCELERATION OF SOLID PARTICLES BY A CUMULATIVE EXPLOSION

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The development of methods for projecting solid bodies at high velocities and the study of high-velocity impact constitute a new, rapidly developing branch of mechanics. Methods and devices for projecting bodies have been described repeatedly (^{1}), including with the aid of an explosion. We describe a technique for projecting particles by a cumulative explosion, developed at the Institute of Hydrodynamics in 1961-1966 and making it possible to accelerate bodies of size 0.1-10 mm to velocities of 8-14 km/sec.

It is known that, when a hollow cylindrical charge is exploded in a cavity, a cumulative jet of detonation products is formed, moving at a superdetonation velocity. For example, for a charge made of a TNT–hexogen 50/50 alloy (detonation velocity 7.6 km/sec), the jet velocity reaches 13 km/sec in an explosion in air and increases considerably when the experiment is carried out in vacuum. If a solid body is placed in the path of the jet, it will be accelerated by the jet. In order that the velocity of the body be comparable with the velocity of the jet, the condition

$$l\rho / r\rho_1 \gtrsim 1, \tag{1}$$

must be satisfied, where l is the length of the jet, ρ is the density of the jet, ρ_1 is the density of the body, and r is the characteristic size of the body.

Thus, a gas-cumulative charge for projecting bodies is a hollow cylinder of high explosive, initiated from one of its ends by an auxiliary pellet; the projected body is placed on the axis of the channel at some distance from the outlet opening (see Fig. 1a).

The design parameters of the charge are selected experimentally, proceeding from the following considerations:

1) Condition (1) must be satisfied. It has been established in this case that the optimal channel length is close to 25–30 calibers. Shortening the charge may lead to destruction of the projected body, especially a brittle

one. Excessive lengthening of the charge is ineffective because of losses during interaction of the jet with the channel walls.

2) It is advantageous to increase the initial recess up to a certain limit (usually not more than 1/4 of the charge length), so that the detonation wave does not have time to overtake the body during acceleration.
3) The density of the jet is selected in accordance with the strength of the body, so that the stresses in the body do not exceed the critical destructive value. Calculations of the stresses in an elastic sphere accelerated by a supersonic flow showed that, for this, it is sufficient to satisfy the approximate condition

$$\rho v^2 \lesssim H, \tag{2}$$

where ρv^2 is the dynamic pressure of the jet and H is the hardness.

Such simple charges are expedient to use in acceleration up to the detonation velocity of the high explosive. In acceleration to higher velocities, for weight considerations it is more advantageous to use composite charges (Fig. 1b). Increasing the acceleration path of the body in charges of this type requires an increase in the caliber

charge *II* to prevent destruction of the channel walls by the jet of charge *I*. The inert lens *III* provides the necessary detonation delay. When accelerating relatively fragile bodies (glass, ceramics), in order to preserve their integrity it is necessary to resort to profiling the wall thickness of the charge.

With the aid of charges 1a, 1b, it proved possible successfully to launch compact bodies made of metals, glass, and ceramics. The ratio of the charge weight to the weight of the body was, as a rule, 10^4—10^6. Maximum velocities (up to 14 km/sec) were obtained when accelerating nichrome balls of the 80-100 μ fraction by a charge weighing 200 g in vacuum. With body dimensions of a few millimeters, velocities of 10-12 km/sec are attained under laboratory conditions.

Fig. 1

In the process of acceleration, intense ablation of the body occurs, and its final dimensions may differ substantially from the initial ones. Measurement of the final dimensions of bodies in flight was carried out by several independent methods: X-raying the flying body simultaneously with a set of stationary calibration bodies, and measuring the holes left by the moving body in films and foils of various thicknesses.

Known methods (explosive and electrical) for producing gas jets with velocities of tens and hundreds of kilometers per second may be used to obtain still faster particles simulating meteorites; however, the mass of gas in the jet in these cases, as a rule, proves to be insignificant, and accordingly the dimensions of the bodies to be launched must be small. The creation of methods for measuring the dimensions of microscopic particles flying at very high velocities would make it possible, with the aid of gas-dynamic devices, to obtain experimental data on high-velocity impact in the range 10–100 km/sec.

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Note: Figure translations are in progress. See original paper for figures.