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LONG-ROD PENETRATION INTO TARGETS OF FINITE THICKNESS AT NORMAL IMPACT

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Summary—In this paper, a theory for one-dimensional penetration of long-rods into targets of finite thickness (plates) is developed. The target is defined as a "finite" mass that resides within the bulk of the target so that an equation of motion for the target mass can be constructed. This, together with an equation of motion for the penetrator and erosion equations for the two masses, provides a penetration solution for the finite-thickness target problem. The axial extent of the target mass is simply the thickness of the plate. Results provide expected penetration rates into plate targets, as well as unpenetrated target thickness (plug or spall) and residual penetator length, mass, and velocity. Good agreement was found between the theory, hydrocode results and experimental data. Also, the formulation becomes hydrodynamic penetration in appropriate limits and therefore encompasses jet penetration of these targets as well.

NOTATION

A_p, A_t, A_c	rod, target, and plug cross-sectional areas
A_s, $A(y)$	plug contact surface areas
d, d_s	diameters of rod and plug
E_f	energy dissipated in the fracture process
l_0, l, l_r	initial, intermediate, and residual rod lengths
l_a, l_b, l_c	specific rod lengths during penetration process
M_p, M_r	intermediate and residual rod masses
M_t, M_c	intermediate and residual target masses
M_d	target mass for plate beyond the critical thickness
P_s, P_f	erosion of the semi-infinite and finite-thickness targets
S_p, S_t, S_s	strength of rod, target, and target (shear)
t	time
u_0, u	initial and intermediate target erosion rates
v_s, v, v_e	initial, intermediate, and specific rod velocities
v_f, v_r	residual rod velocities based on momentum and energy
w	target material velocity in laboratory frame
x_0, x, x_a, x_c	initial, intermediate, and final lengths for critically thick target
y	plug displacement
z_0, z, z_c	initial, intermediate, and final target thicknesses
ρ_p, ρ_t	densities of rod and target

INTRODUCTION

The impact of long rods with targets of finite thickness (plates) has been investigated extensively through experimental observation, analytic modelling, and hydrocode computer analyses. The features that appear behind the rear of the target or "residual properties" are of considerable importance, and it is desirable to establish a relationship between these and the initial conditions of the problem such as rod and target geometries, material properties, and rod striking velocity, for example.

The semi-empirical equation of Lambert and Jonas [1] provides a means to estimate residual properties but does not address dynamics of penetration and perforation. Elsewhere, mechanistic models developed by Recht and Ipson [2], Awerbuch and Bodner [3], Woodward and de Morton [4], and Woodward *et al.* [5] provide insight into the plate