Experimental-Numerical Study of Inclined Impact of 0.3 AP projectiles in Al7075-T7351 Targets

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Abstract

In the case of oblique impact between projectile and target, the penetration prevention mechanism can be the changing of the projectile's trajectory, as opposed to absorbing its kinetic energy. This concept enables the use of materials that are lighter and weaker than steel, e.g., aluminum, yet achieve better ballistic efficiency. In this paper, we present an experimental and numerical study of the inclined impact between a 0.3" API hardened steel projectile and a plate of Al7075-T7351 (thicknesses of 30, 20, 15 and 10 mm), at angles of 30°, 35°, 45°, 50°, 55° and 60° to surface norm (NATO). The experimental impact velocities were measured to be 850±15 m/s, and the impact events were recorded using two high-speed cameras, positioned at the side and top of the loaded aluminum plate. In the experiments, oblique ricochet resulted when impact angles were above 40° to norm. In the experiment at the smallest tested angle, i.e., 30°, the target was partially penetrated and the projectile was reflected back from the target strike face. Projectiles/fragments that were reflected from the targets were caught in soft foam panels on the ballistic lab wall. Post-experimental analysis showed that brittle fracture of the projectiles occurring approximately at the midpoint along their length. The experimental results were successfully predicted in simulations that were compiled using the commercial finite element code, LS-DYNA, and used a Lagrangian 3D mesh with one plane of symmetry. The dynamic response of materials was described via a combination of Johnson-Cook constitutive and damage models. In order to calculate the parameters required for the numerical description of a material's behavior, a series of planar impact experiments were performed. The rear (unloaded) surfaces of the samples in these experiments were monitored using a Doppler laser interferometer system (VISAR) with a time resolution of 0.16 ns. Material models were then calibrated using 1D planer impact model simulations based on the free surface velocity profiles recorded in the planar impact tests. Substitution of the calibrated parameters into 3D simulations shows reasonable agreement between the results of the ballistic experiments and the simulations. An additional result found in this study is that using a rigid projectile model instead of an elastic-plastic model with failure can lead to inaccurate predictions. The high ballistic efficiency of inclined aluminum armor is thus demonstrated clearly in this study, both experimentally and numerically.