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Numerical investigation of the influence of impact angle on the protective effectiveness of advanced ballistic protections with bulging effect

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Long-rod kinetic penetrators, composed of high density materials such as tungsten heavy alloys (WHA), are designed to deliver large amounts of kinetic energy to an extremely concentrated area of the target, traveling at velocities exceeding 1000 m/s. Advanced multilayer protections with bulging effect are designed to counter this threat, disrupting the projectile by deforming in two opposite directions, owing to their sandwich structure (high-resistance steel encapsulates lower density materials, such as rubber). These deformations act upon the slender impactor, inducing erosion and fragmentation, thus drastically reducing the capability of the threat to penetrate the underlying protection (generally made by armour steel). However, the effect of the obliquity angle on protective performance has not been systematically characterized.

This work investigates how the obliquity angle affects the protective performance in terms of kinetic energy absorption and projectile fragmentation through a parametric finite element study validated against the literature. The model represents a three-layer bulging armour (RHA, Rolled Homogeneous Armour front plate / natural rubber interlayer / RHA backing plate) subjected to impact by a WHA long-rod penetrator ($L/D = 20$).

The results show that increasing the obliquity angle (thereby extending the interaction between the projectile and the armour) leads to a non-linear increase in kinetic energy dissipation and a markedly different fragmentation morphology of the impactor. The kinetic energy dissipation is unaffected by the impact angle up to 30°; beyond this threshold, the absorbed kinetic energy increases exponentially, and the armour is fully able to stop the threat when the impact angle is 82.5 degrees. In all the considered scenarios, the projectile does not ricochet off the armour and completely perforates the front RHA plate.

Primary authors: DI FULVIO, Massimo (Politecnico Di Milano); LOMAZZI, Luca (Politecnico di Milano; Department of Mechanical Engineering); MANES, Andrea (Politecnico of Milano)

Presenter: DI FULVIO, Massimo (Politecnico Di Milano)

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