

# NUMERICAL SIMULATIONS OF AN EXPLOSIVE REACTIVE ARMOUR REAR PLATE IMPACTING A LIGHTWEIGHT ARMoured VEHICLE'S HULL

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**Abstract:** A numerical study using the explicit non-linear transient dynamic finite difference code AUTODYN-2D has been undertaken to examine the effect of a rear plate from an explosive reactive armour (ERA) impacting lightweight armoured vehicle hulls at normal incidence. Four thicknesses of ERA plate impacting high hardness steel armour and an aluminium alloy (7039) armour were simulated. The deformation of the vehicle hull and the measured strains are reported indicating critical areas around the fixings and the central region of impact.

## INTRODUCTION

For many years now, explosive reactive armour (ERA) has been well proven in reducing the penetration of shaped-charge jets into MBT hulls. Indeed, this kind of appliqué protection is more suited to heavy vehicles than lightweight armoured vehicles for two reasons.

Firstly, a single ERA sandwich is not able to reduce totally the effect of a shaped-charge jet. The ERA sandwich is unable to disturb the front portion of a jet due to the time it takes for the explosive to detonate and accelerate the plates to a velocity that would cause sufficient disturbance. Typically a single ERA sandwich can reduce the penetration of a shaped-charge jet into a semi-infinite block of material by 90%. Without ERA, an RPG7 warhead would penetrate 300 mm into a semi-infinite Rolled Homogenous Armour (RHA) target. With ERA, the depth of penetration would be reduced to 30 mm, which means that a lightweight armoured vehicle hull is still likely be vulnerable to perforation by the jet. Nevertheless, with the use of suitable spall liners the vulnerability of the crew can be reduced substantially.

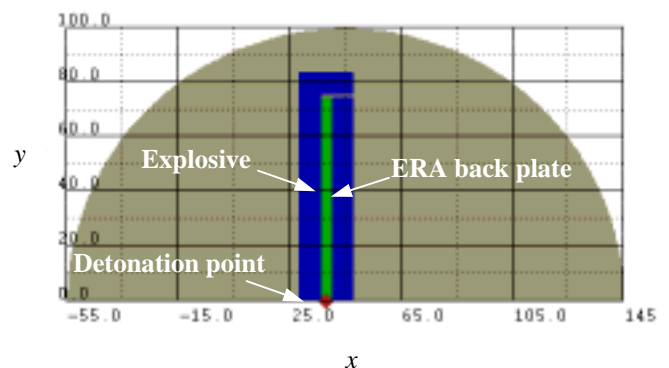
The second reason is that the sandwich plate closest to the vehicle hull is accelerated towards the hull by the explosive detonation products. This accelerating plate can cause substantial deformation and ultimately failure of a vehicle hull. It is this interaction between the ERA plate and the vehicle hull that is considered in this paper, which presents numerical analysis that examines the impact of a rear ERA flyer plate on a vehicle hull. The structural response of two lightweight armoured vehicle hulls is presented.

## ERA BACK PLATE GEOMETRY AND VELOCITY

On detonation by a shaped-charge jet tip, the gaseous products that are formed by the explosion accelerate the plates of the ERA sandwich apart. To establish the plate velocity and geometry a two-dimensional non-linear finite difference hydrocode AUTODYN<sup>TM</sup> was used. This software is explained in detail elsewhere [1]. However in brief, this code solves the conservations laws of mass, momentum and energy based on initial boundary conditions. The user is prompted for an equation of state that describes the pressure in terms of the internal energy and volume and a constitutive relationship that calculates the flow stress in terms of a number of material and application dependent parameters including strain, strain-rate and temperature. Failure models can be introduced to describe the failure.

Both Euler and Lagrangian processors were used. The Euler processor was used to model the expansion of the detonation products and a Lagrangian processor was used to simulate the plate acceleration and deformation.

The initial model geometry is shown below in Figure 1. An Euler processor was used to model the explosive (PBX9010) and a Lagrangian processor was used to model the ERA sandwich plates and vehicle hull. A detonation point was chosen for the explosive that closely approximated the detonation point that would occur due to the central perforation of the sandwich by a shaped-charge jet. A "Flow-Out" boundary condition [1] was applied to the Euler subgrid to simulate the presence of a larger mesh and thereby reduced the run-time of the simulations. All simulations were completed in axially symmetrical two-dimensional space.



**Figure 1. Initial set-up for of the ERA plate. The diamond indicates the detonation point.**

Four different ERA plate geometries were evaluated using this method maintaining a flyer plate to explosive thickness ratio of 2. The ERA plate thicknesses that were used to evaluate the effect on the vehicle hull were: 4, 6, 8 and 10 mm. The axi-symmetrical half-length of the plates was 75 mm. The average velocities respective kinetic energies of the flyer plates are presented below in Table 1. The residual shapes of the ERA rear plates are shown below in Figure 2. Each plate's deformation is due to the detonation of the explosive. The thicker plates demonstrated more resistance to bending than the thinner plates due to their higher flexural rigidity.

Thickness	4 mm	6 mm	8 mm	10 mm
Velocity (m/s)	575	562	565	542
KE (kJ)	105.7	132.2	178.3	205.4

**Table 1. Terminal velocities of the ERA flyer plate.**

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