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IMPACT OF 7.62 MM AP AMMUNITION INTO ALUMINIUM 5083 PLATES

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Because of its lightweight, corrosion resistance and high strength properties, aluminium 5083 alloys are used in different fields such as ship building, military vehicle bodies and armour plates. This paper deals with the prediction by numerical simulations of the response of Al 5083 plates subjected to dynamic loading from 7.62 mm AP NATO or P80 ammunition. Ballistic experiments have been performed the results of which have been used to calibrate the material models. Much effort has been made in the dynamic characterization of aluminium 5083.

INTRODUCTION

Industrials constantly try to reduce the overall weight of the armoured vehicles which they produce. This is usually done by means of lightweight materials. It is clear that the ballistic performance of the vehicle's armour has to be insured such that the crew is well protected against ballistic threats e.g. small calibre projectiles. Aluminium alloys are widely used as lightweight armour material. In this paper, the aluminium 5083 alloy is examined. It has been used since the early 50's in military applications [1] because of its low cost, mechanical strength, corrosion resistance, good ballistic properties, and also because of its weldability.

In order to understand the response of Al 5083 plates subjected to ballistic impacts, a series of firing tests [2] has been conducted at normal impact against 25 mm thick plates, and numerical simulations have been performed. For the material modelling, most effort has been devoted to the dynamic characterization of Al 5083, as experiments showed that the hard steel projectile core did not deform or fracture during penetration or perforation of the aluminium plates. For this purpose, a Split Hopkinson Bar Pressure has been used [2].

BALLISTIC IMPACT TESTS

Normal impact tests have been performed upon Al 5083 plates using the P80 ammunition. This projectile consists of three parts: the hard steel core (which is also the tip), the lead core and the brass jacket which encapsulates the two cores (Fig. 1). The projectile mass is 9.75 g (42.9% brass, 38.6% steel and 18.5% lead).

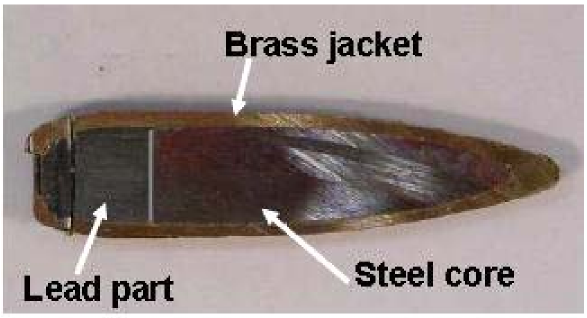

Figure 1: A cross section of the P80 ammunition

The nominal thickness of the Al plates was 25mm. The impact velocity was 864 ± 6 m/s. The remaining projectile velocity was also measured after perforation of the plates. Its value was 673 ± 10 m/s.

Macroscopic examination of the impacted plates revealed a ductile hole growth failure mode accompanied by a petaling mechanism at the entrance as well as at the exit of the channel formed by the passage of the projectile (Fig. 2). Pictures taken with a high speed camera showed that during penetration, the brass jacket was stripped from the projectile and only the hard steel core of the ammunition was found to be intact after perforation of the plates (Fig. 3-a).

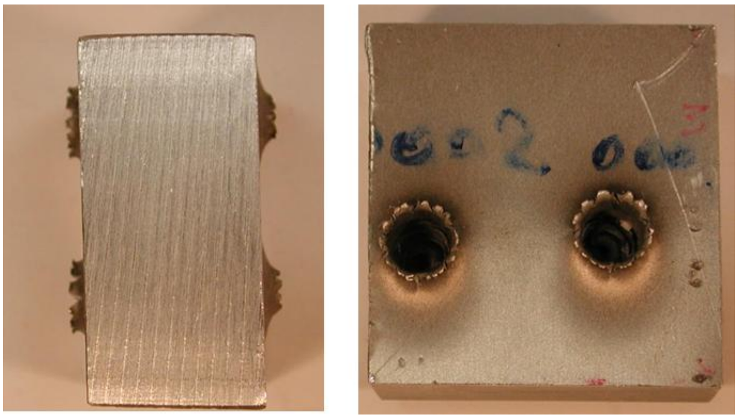

Figure 2: Petaling at the entrance and at the exit

The longitudinal cross section of the channel at figure 3-b provides more insight of the penetration mechanism. One can clearly see two channels with different diameters separated by the highly deformed brass jacket of the projectile. The first channel has a diameter slightly greater than the projectile diameter. The brass jacket, the steel and the lead core are actively involved in the formation of this channel which ends when the jacket is completely stopped in the plate. Contrary to the first channel, the second one has a diameter equal to the hard steel core diameter of the projectile. The numerical simulations, which are further discussed in this paper, show the contribution of each part of the projectile to the penetration and perforation mechanisms.

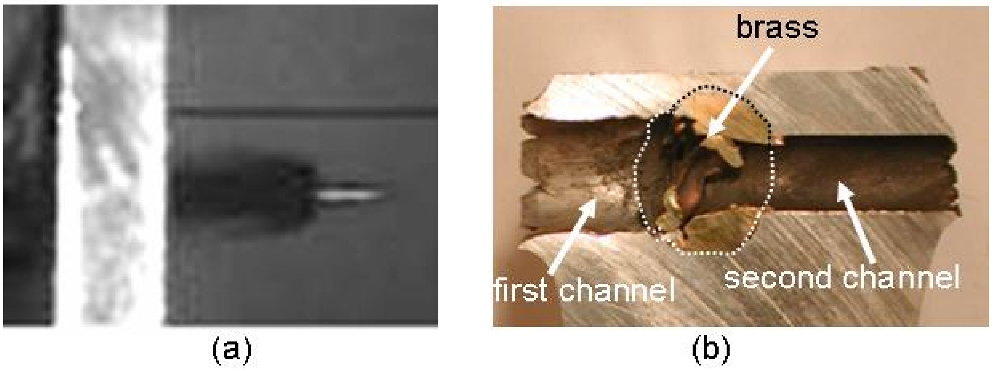

Figure 3: (a) The hard steel core after impact
(b) The cross section of the projectile channel with the deformed brass jacket

A SEM examination was performed on the perforated target plates, which revealed the characteristics of a ductile hole formation process. A soft bullet trap was used to retrieve the remains of the projectile after perforation of the plate. It was clear that the steel core did not deform during the penetration process (Fig. 4). Besides the steel core, a lead plug was also recovered. A paper foil which was put behind the plate indicated the scattering of very small debris coming from the plate and/or the projectile.

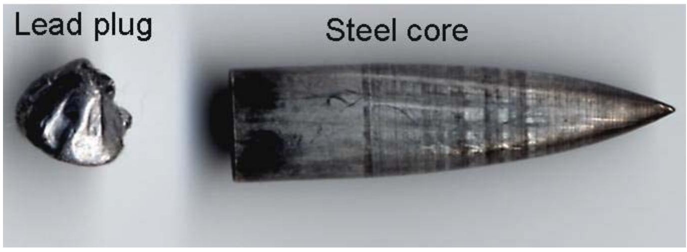

Figure 4: Recovered lead plug and hard steel core after plate perforation

NUMERICAL SIMULATIONS

Numerical simulations have been carried out using the Autodyn hydrocode. Figure 5 shows how the projectile has been modelled (the materials are represented in the upper part and the corresponding geometrical subgrids in the lower part). Lagrangian processors were used to model both the projectile and the target.

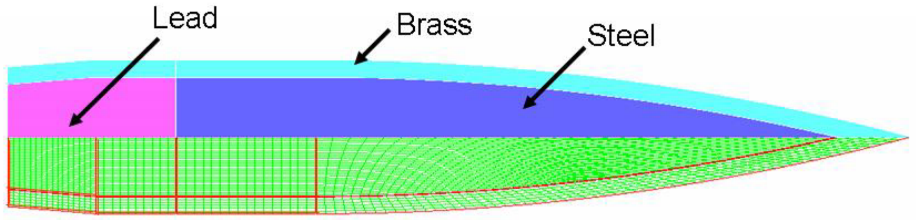

Figure 5: The modelling of the projectile

In the simulation, “sliding” controlled by friction between the different materials of the projectile was allowed. The frictional coefficients were defined such that they decreased from the nose towards the base of the projectile. No friction was introduced between the projectile and the armour plate. The nominal impact velocity was set to 860 m/s.

As experiments had shown that the hard steel core of the projectile did not deform nor fracture, it was considered as a rigid body in the numerical simulations. A linear equation of state was used for the brass and a shock equation for the aluminium and the lead. Some material properties of Al 5083 as well as the failure models and the erosion models used in the numerical simulations are given in table 1.

Table 1 : Material properties

Strength Model	**Failure model**	**Erosion model**
Aluminium		
Johnson-Cook	Plastic strain	Geometric strain
A (MPa) = 195 ; B(MPa) = 450 ; n = 0.425 ; C = 0.28 ; m = 1.67	none	1.0
Brass		
Von Mises	Plastic strain	Geometric strain
G (GPa) = 38 ; Y (MPa) = 300	0.3	1.5
Lead		
Von Mises	Plastic strain	Geometric strain
G (GPa) = 11.3 ; Y (MPa) = 30	0.3	1.5

The numerical results corresponded quite well with the experiments. The residual velocity of the projectile was found to differ not more than 6% from the experimental values. The general geometry of the hole inside the plate and the remaining lead core were quite well predicted by the numerical simulations. They did, however, fail to catch the accumulation of the brass jacket inside the plate (although one can notice on figure 6 that there is some brass accumulating inside the plate at almost the same distance as in the experiments (compare with figure 3b)). The explanation of this discrepancy may be due to the numerical erosion of the brass but this needs more analysis.

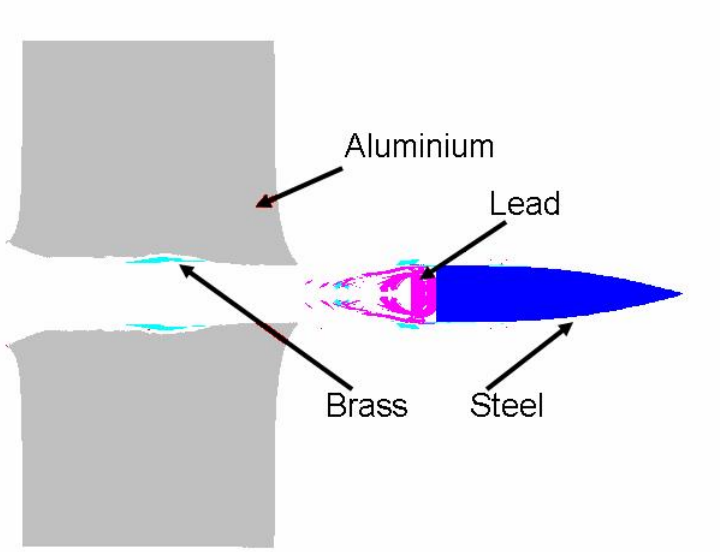

Figure 6: Numerical simulation of a P80 ammunition perforating an Al 5083 plate

Other simulations have been carried out with different configurations of the projectile and the target plate. First of all, tests were performed on a 32mm thick Al 5083 plate [2]. Here, the predicted residual velocities didn't differ from the experimental values by more than 10%.

By means of numerical simulations, the minimal target plate thickness for no perforation of the projectile (Fig. 7) was found to be 50 mm, a value that is only 5% different from those found in the literature [1].

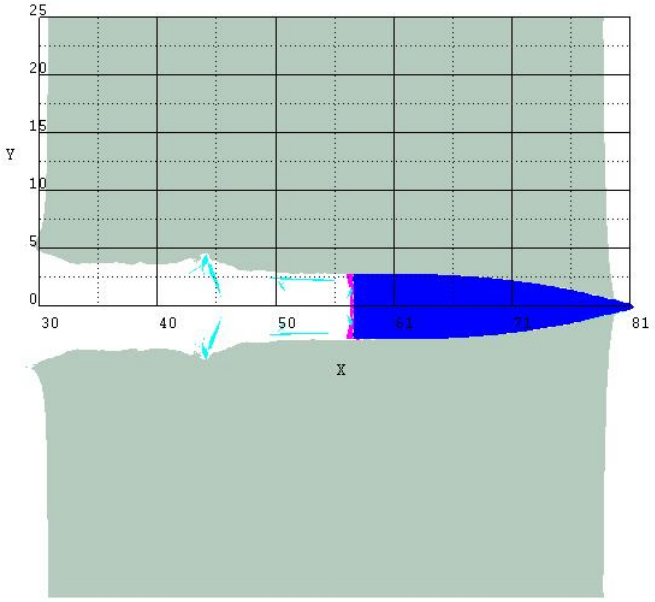

Figure 7: Minimum plate thickness for no perforation (computed by numerical simulations)

INFLUENCE OF THE JACKET ON THE PENETRATION MECHANISM

To study and quantify the effects of the brass jacket and the lead core of the 7.62mm AP ammunition impacting Al 5083 armour plates, numerical simulations were carried out with different kinds of projectiles. Three types were used: the full metal jacket projectile, the projectile without the brass jacket, and the hard steel core on its own. The impact velocity was 860 m/s. The results are shown in figure 8.

The differences in velocities (less than 5 %) obtained with the full metal jacket projectile and the projectile without jacket indicate that within the range of the considered velocities, the jacket slightly increases the penetrating power of the 7.62 mm AP. Most of the initial kinetic energy of the jacket (which represents 42.9% of the total projectile initial kinetic energy) goes into the deformation of the jacket and into the deformation of the plate during the early stages of the penetration process. Similar observations were made previously in [3] after performing experiments using the 0.5 inch AP projectile.

The differences in velocities (less than 20%) obtained between the projectile without jacket and the steel core projectile gives the influence of the lead core onto the penetration and perforation mechanisms (Fig. 8). Although its initial kinetic energy is less than half the initial kinetic energy of the jacket, the lead core has a greater contribution to the penetration and perforation mechanisms.

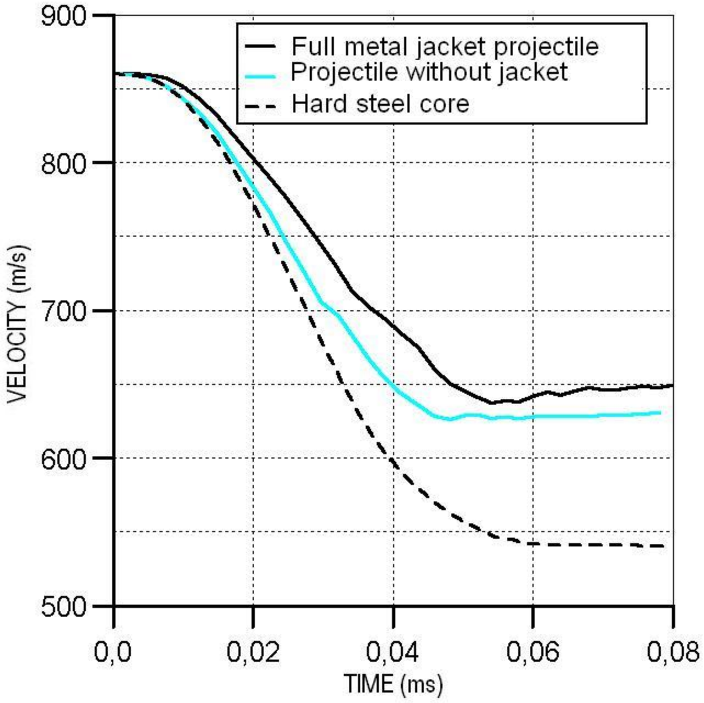

Figure 8: The effects of the jacket and the lead core on the perforation performances

CONCLUSIONS

In order to predict the response of aluminium 5083 armour plates subjected to the ballistic impact of 7.62mm armour piercing ammunition, experimental firings and 2D numerical simulations have been carried out. It has been shown that the simulations could catch the main features of the experiments (especially the residual velocity, and also in an acceptable manner the channel left by the passage of the projectile).

The numerical model was tested against different plate thicknesses. Good agreement was obtained. The minimal plate protection thickness for no perforation of the projectile has also been determined numerically and it corresponded quite well with experiments.

The influence of the jacket and the lead core in the penetration and perforation mechanisms has been examined. It has been shown that the contribution of the lead core to the armour piercing power of the 7.62 mm AP is greater than the contribution of the brass jacket although the initial energy of the brass jacket is twice the initial energy of the lead core.

More 2D numerical simulations and experiments will be carried out in the future to examine the influence of reducing the plate thickness. 3D numerical simulations will be performed for examining oblique impacts.

ACKNOWLEDGEMENTS

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