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ANALYSIS OF THE SOUTH AFRICAN SURROGATE FOR A TMRP-6 ANTI-TANK MINE

IM Snyman, FJ Mostert

Defence, Peace, Safety and Security, CSIR, PO Box 395, Pretoria

A surrogate for the TMRP-6 anti-tank landmine is analysed numerically with regard to the explosively formed projectile (EFP) morphology. The threat posed by a TMRP6 mine in the field is the impact of the EFP transferring its kinetic energy to the vehicle in addition to the blast wave impulse transferred from the products of the explosive. Flash X ray photography is used to experimentally characterise the shape of the EFP and its velocity. The shape and velocity of the EFP are compared with the results of the numerical analysis.

INTRODUCTION

Anti-tank landmine threats are a reality when the armed forces of any country are deployed all over the world. This is also true for South Africa because of its peace keeping role in advancing democracy in Africa. In order to develop landmine protected vehicles for the armed forces the threat must be known as well as the ability of the mines to cause damage. The mines that are posing a threat are usually not available for research, so surrogates are developed that model the threat. The threat can be an explosive blast mine on its own or with an added armour penetrating EFP. The TMRP-6 anti-tank mine belongs to this latter class of mines that have a penetrating capability (see for instance [1]).

The vulnerability of the bottom sections of a vehicle is exploited by this class of mines. An EFP is accelerated by the explosion with the purpose of perforating the hull. The consequence is spalling of the hull and the entry of hot detonation products into the vehicle. The projectile formed in this manner is commonly referred to as explosively formed projectile (EFP) or sometimes as self forging fragment (SFF). The impact and perforation process of an EFP mine cannot be decoupled from the blast wave of the device. For both instances the blast is confined underneath the vehicle so that the total amount of blast energy and impulse delivered to it over time is more or less the same. So, the damage mechanism is similar to the blast mines with the added impact and perforation mechanism of the EFP.

In this paper a surrogate for a TMRP-6 mine developed in South Africa is analysed with respect to the EFP morphology by numerical computation and comparing the results to experimental flash X-ray photographic results.

EXPERIMENTAL EVALUATION OF SURROGATE

The surrogate for the TMRP-6 mine was developed by a local company in South Africa. In order to characterise the surrogate, the first step is to capture the EFP with flash X-ray radiography at short standoff as it is accelerated by the explosive. This poses a challenge as normally the TMRP-6 mine is detonated below a vehicle with the EFP accelerated upwards. The TMRP-6 surrogate was turned on its side so that the EFP can travel in a horizontal direction. The frame with the flash X-ray equipment was put close to an earth mound in which the surrogate was placed [2]. The set-up is shown in Figure 1. Sandbags were packed to protect the frame and equipment from blast damage.

The experiments yielded the shape of the EFP at two time instances with flash-X-ray radiography. From these radiographs the velocity, diameter and depth of the plate were obtained. A number of surrogate mines were detonated and some of the measurements are given in Table 1. A 50 mm mild steel witness plate was about 4000 mm from the charge.

Figure 1: The set-up of the experiment, showing the FX and surrogate mine position.

Table 1: EFP velocity measurement

	Explosive	Charge mass (kg)	EFP velocity (m/s)	Depth of Penetration (mm)	Comments
Test #A	TNT	5.16	1751	50 (no bulge, no perforation)	EFP asymmetrical
Test #B	TNT	5.16	1752	38	EFP symmetrical

The EFP of the TMRP-6 surrogate detonated in test #B is shown in Figure 2 at approximately 640 microseconds and in Figure 3 at 780 microseconds after detonation. The EFP diameter is 175 mm and the height is measured as 79 mm.

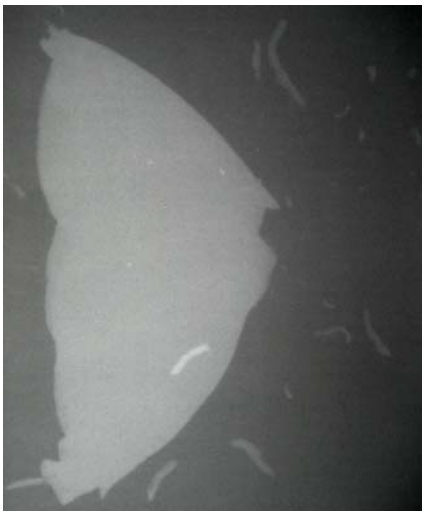

Figure 2: The EFP at 640 microseconds after detonation.

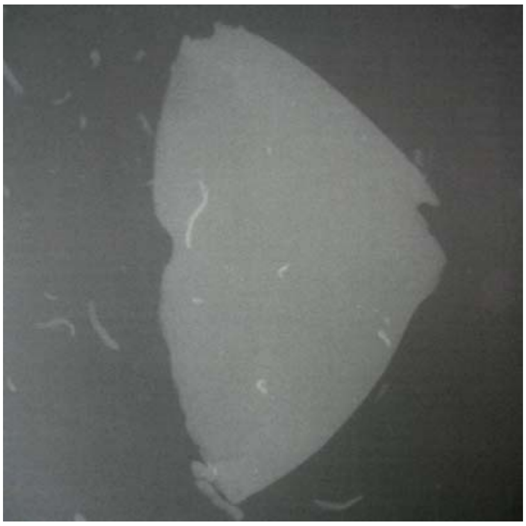

Figure 3: The EFP position at 780 microseconds after detonation.

COMPUTATIONAL RESULTS

The detonation of the TMRP-6 surrogate was modelled in Autodyn2D. The model is axial symmetrical, using the Euler solver for the explosive, sand and air. The metal liner is modelled with the Lagrange solver. Four elements through the thickness of the EFP provided adequate resolution to track the motion and shape after detonation. The detonation products and air are allowed to escape over the boundary of the Euler mesh. The mesh is shown in Figure 4 without the air and the image rotated 180° about the symmetry axis.

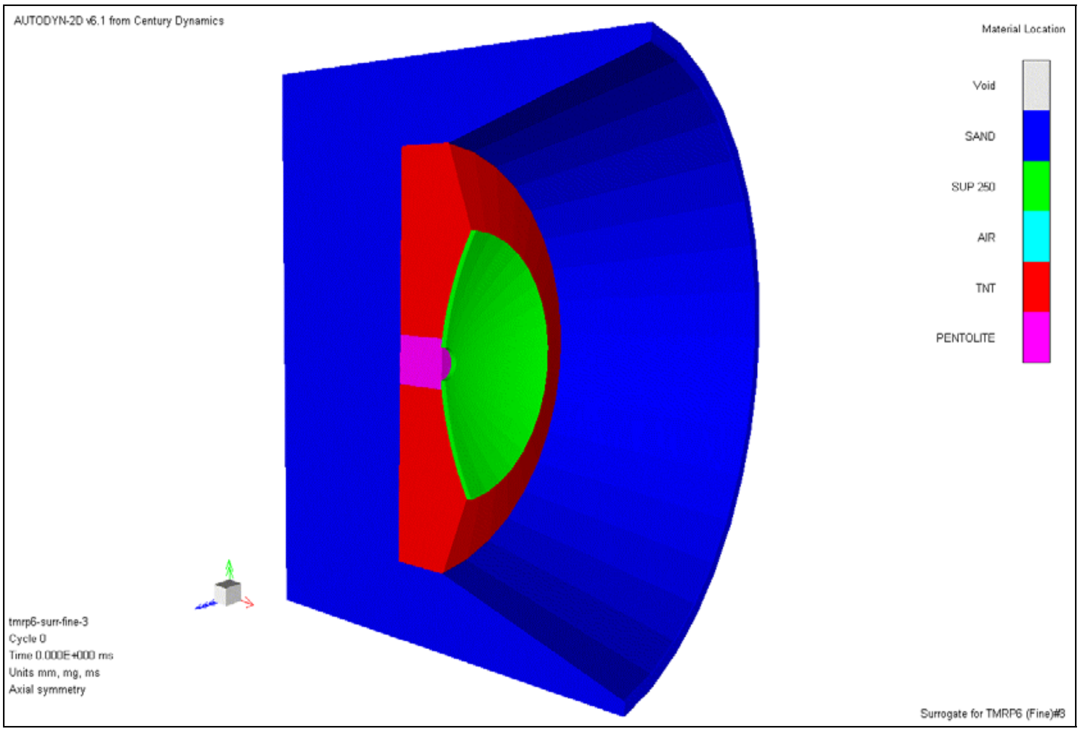

Figure 4: The mesh set-up of the surrogate TMRP6 in axial symmetry

The Johnson Cook material model is used for the liner with parameter values for 1006 steel in the Autodyn material library and a quasi-static yield stress of 300 MPa. The JWL equation of state is used for the booster (Pentolite) and the TNT charge, while a compaction and granular material model is used for the sand. The air is modelled with an ideal gas equation of state. All the parameters are from the Autodyn material library.

The computational results and the experimental results are compared in Table **2.** The computational measurements are at approximately 700 microseconds after detonation.

Table 2: The experimental and computational results

	Experiment	Computation
Diameter (mm)	175 ± 8	153
Height (mm)	79 ± 4	43
Velocity (m/s)	1752 ± 10	1785

The velocity of the liner is calculated accurately. In Figure 5 the velocity distribution of the liner at 700 microseconds after detonation is shown to range from

1770 m/s on the outer rim to 1795 m/s at the centre. The calculation produced a much flatter EFP at 700 microseconds than measured by the experiment. Numerical erosion of the EFP was not allowed in the calculation and contributes to the velocity distribution across the plate. Also, the hole in the centre of the plate is not deformed (or teared) as in the experiment.

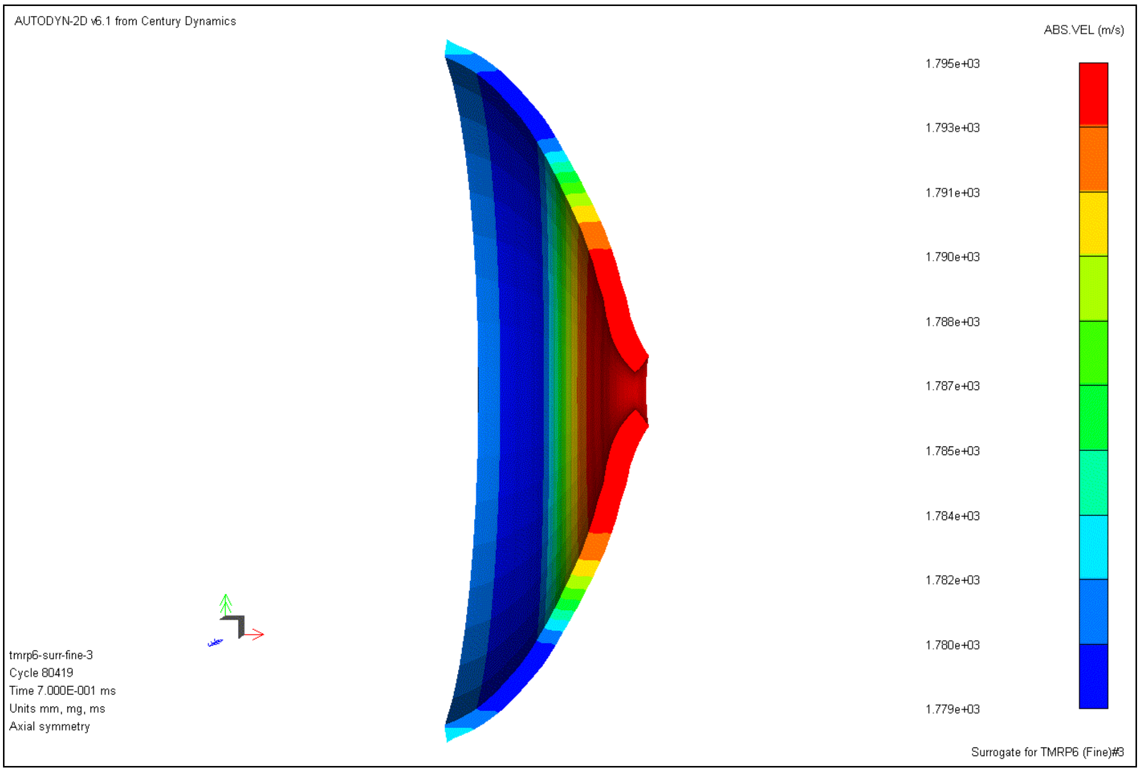

Figure 5: The calculated velocity distribution of the plate.

DISCUSSION

The TMRP6 surrogate tests yielded an average velocity of 1752m/s (2 tests) and there is a superficial resemblance to the reported characteristics of the TMRP6 [3]. The velocity is about 5% lower than the velocity reported and the maximum diameter and height of the EFP is larger.

The discrepancy between the experiment and numerical computation is most probably due to the tearing observed on the EFP in the experiment. Such tearing will allow explosive gas products to expand more freely from behind the EFP and therefore would lead to a reduction in velocity. Similarly, this expansion will have an influence on the L/D of the EFP.

REFERENCES

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