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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF V-SHAPE PLATES SUBJECTED TO BLAST LOADINGS

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ABSTRACT

This paper presents the experimental and numerical investigation of angled shape metal plates response when subjected to an air blast loading. V shaped plates were fabricated at angles of 90º, 120º and 150º respectively. The charge weight of 1 kg (PE4) was used to create a spherical blast wave at several standoff configurations. The experimental results were then compared with the numerical simulation model computed using LSDYNA3D.

Keywords: deflector; armoured vehicle; landmine; detonation; explosive.

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1. INTRODUCTION

There are several published works that have reported the response of metal plate when subjected to blast loadings [1-10]. Most of researchers studied about the V shaped vehicle hull which is commonly known able to deflect blast wave emitted from landmine detonation [4, 6, 9, 11-13]. In [11] have conducted experiments to study the difference angle of "V" structured plates from blast loading effect. In [11, 13] have reported the attenuation analysis of "V" hulls blast test results subjected to explosive charge and also have studied different plate angles varying from 140 to 180 degrees with standoff distance level from 0 to 1.5 inches. The explosive weight used was 0.636g and was buried underground to represent landmine attacks. Besides that, other researchers have [4, 13-20] formulated a 2D and 3D computational patterns to analyze the blast attack on vehicle structures. However, there a few studies have been found to correlate the experimental findings with numerical simulation results. This paper presents the experimental and numerical investigation on several 'V' shape plates (with different angles) subjected to a spherical air blast loading. The experimental data obtained in terms of deflection was compared with the numerical simulation for verification purposes.

2. RESULTS AND DISCUSSION

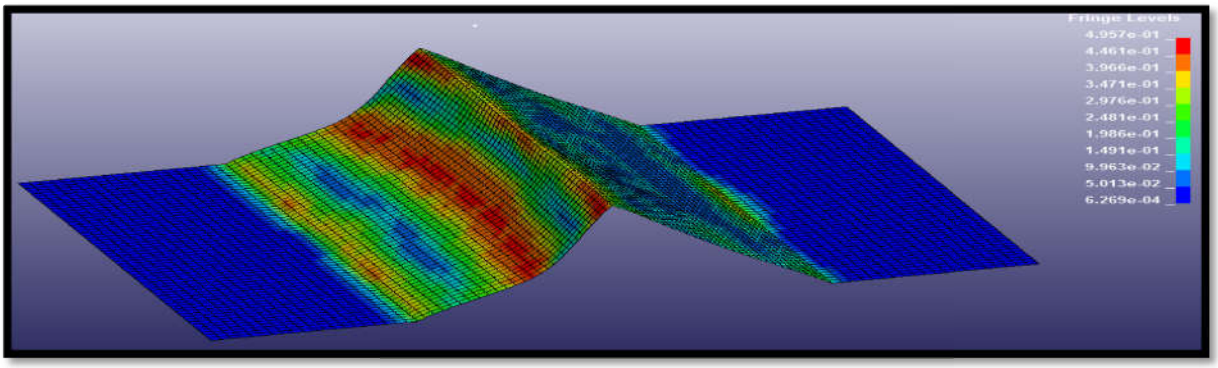
The experimental results are as shown in Table 1. From this results, it can be observed that 150-degree V plate exhibited the highest deflection of 120 % whereas 90-degree V plate showed the lowest V plate deflection of 40 % can be observed that at 90-degree and 120-degree V plate angle provide a substantial resistance which was observed made from the deformed plates (deflection) compared to 150-degree V plate angle. This observation is in agreement with the results by [11]. Fig. 1 shows the different deflection depth on the "V" shape at a cross sectional view.

Table 1. Blast loading results

Angle (^{o})	Charge Weight (kg) PE4	Thickness (mm)	Standoff (mm)	Deflection on the Mid-Point (mm)			
				Origin	After Blast	Deflection	Percentage Different
90	2	2	1000	0.4331	0.2586	0.1745	40%
120	2	2	1000	0.3048	0.1155	0.1893	54%
150	2	2	1000	0.1578	-0.0387	0.1965	120%

The 90-degree V plate experimental results were used as verification data for the finite element simulation. Fig. 2 shows that the simulated V plate deformation are near similar to the observed deformation of the tested V plate.

2.1. Numerical Simulation Result



(a)

(b)

Fig.1. Photograph showing simulation and experiment failure; (a) LSDYNA 3D simulation model, (b) experimental image after blast load

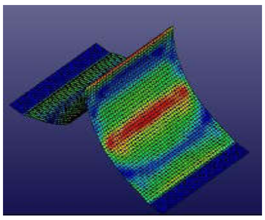
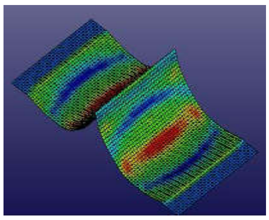
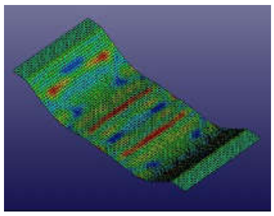
Fig. 2 shows the computed deflection of the 90 degree, 120-degree and 150-degree of V plates using 2 types of material models. The computed results were compared with the experimental data for verification purposes. Based for the results, the computed 120-degree and 150-degree of V plate results shows near similarity in terms of deflection curve compared to 90-degree. It can be assumed that during blast testing, the plastic explosive may not perfectly have placed in line with the mid plane of the V plate, thus producing a non-uniformity pressure loading to the V plate structure.

Fig.2. Deflection after blast loading, experiment, Johonson Cook model and Plastic Kinematic model (a) 90º angle (b) 120ºangle and (c) 150º angle

Fig. 3 represents a comparison by outcomes for cross sectional deflection of the V plates when using two different material model functions. Based from Table 2, it can be observed that Johnson Cook material model provide the nearest value when compared with the experimental results. This may be due that for blast modeling the material model should be capable of predicting the flow stress as a function of plastic strain, strain rate, temperature and provide a comprehensive description for a progressive ductile failure model. The Johnson Cook material model is favoured due to the multiple functions available in the material model compared to a much simple Plastic Kinematics model.

Table 2. Comparison of mid plane deflection from experiment and simulation results

Inclination Angle (^{o})	**Center Point Experiment (mm)**	**Center Point Simulated Using Johnson Cook Model (mm)**	**Center Point Simulated Using Plastic Kinematic Model (mm)**
90	202	346	360
120	116	170	162
150	-39	-90	-103

Plastic Kinematic Model V Shape Angle (^{o})			
	90	**120**	**150**
Mass of PE4 2kg Standoff 1m			
Displacement on Mid-Point (mm)	80	134	265
Johnson Cook Model V Shape Angle (^{o})			
	90	**120**	**150**

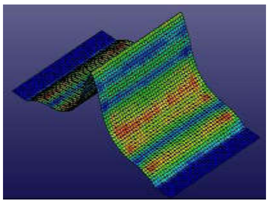
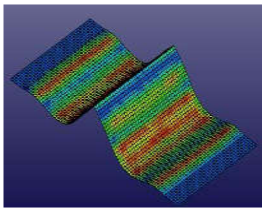
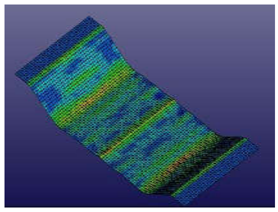
Mass of PE4 2kg Standoff 1m			
Displacement on Mid-Point (mm)	74	130	248

Fig.3. Contours of displacement between Plastic Kinematic model and Johnson Cook model

3. EXPERIMENTAL

3.1. Experiment Setup

Three metal plates of different V shape angles were fabricated which are (a) 90°, (b) 120° and (c) 150° respectively. Fig. 4 shows the test setup for the plates where a plastic explosive is placed vertically 1 meter on top of the mid plane of the plate. The properties of the plastic explosive (PE4) is as shown in Table 3.

Table 3. Properties of explosive PE4 [21]

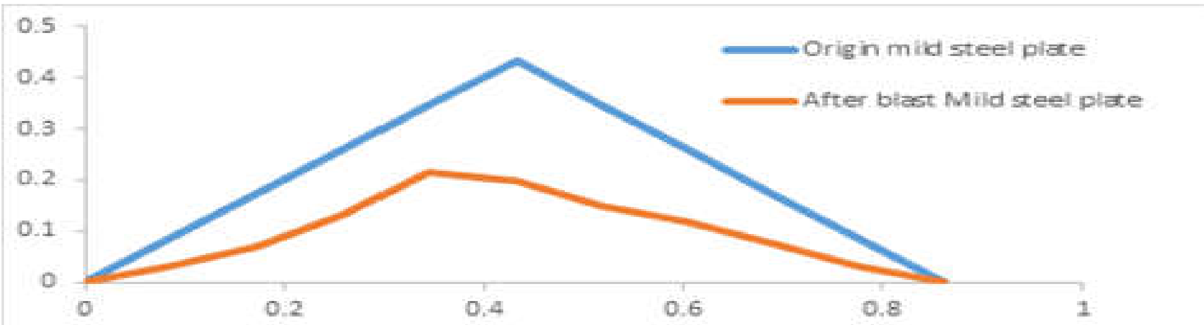
Description	Values
Material	2kg PE4
Explosive Density	$1600\ kg/m^3$
Explosive Internal Energy	$3.2 \times 10^{10}\ kg.m^2/s^2$

Fig. 4 shows the actual test setup where the V plate was fixed (at both ends) into a rig and PE4 was moulded into a spherical shape. This is to ensure that during detonation, spherical air blast will propagate down towards the V plate mid-section.

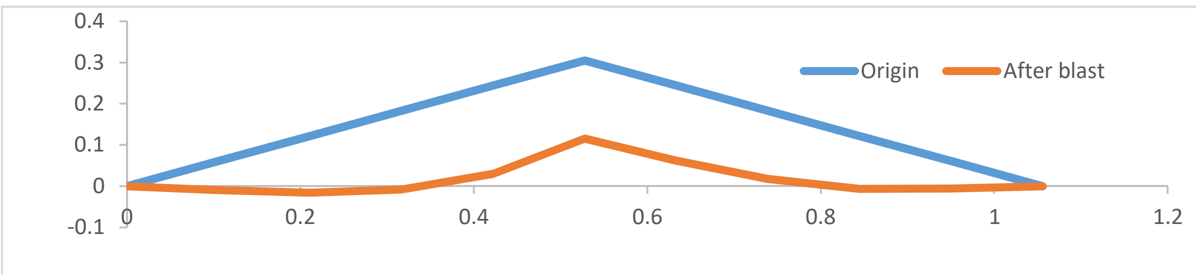
(a)

(b)

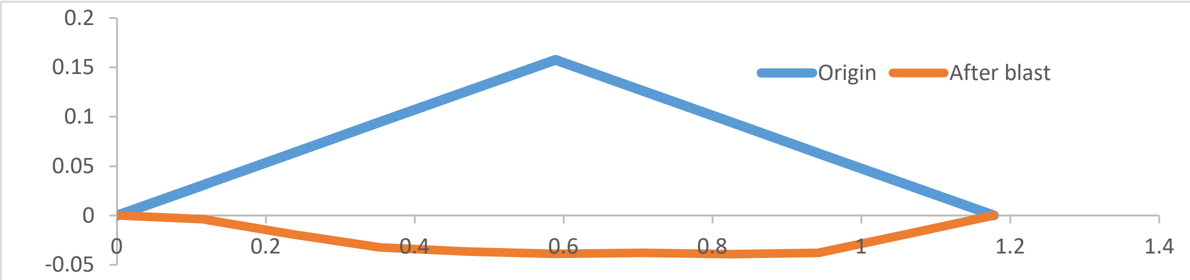
Fig.4. Experiment setup (a) V plate setup (b) standoff of explosive



(a)



(b)



(c)

Fig.5. Deformation of the V plate after explosion (a) V plate 90º (b) V plate with 120º and (c) angle 150º of plate

3.2. Numerical Solution of V Plates

The LSDYNA3D software was used to simulate V shape deflection when subjected to blast loading. The blast simulation was performed using Arbitrary Lagrange Euler (ALE) blast method available in LSDYNA3D function card. Fig. 5 shows the meshing process of V-shape plate model using of mild steel material's property. The V plate edges was fully restrained at the flat plane section in order to represent the clamped boundary conditions at the actual test rig.

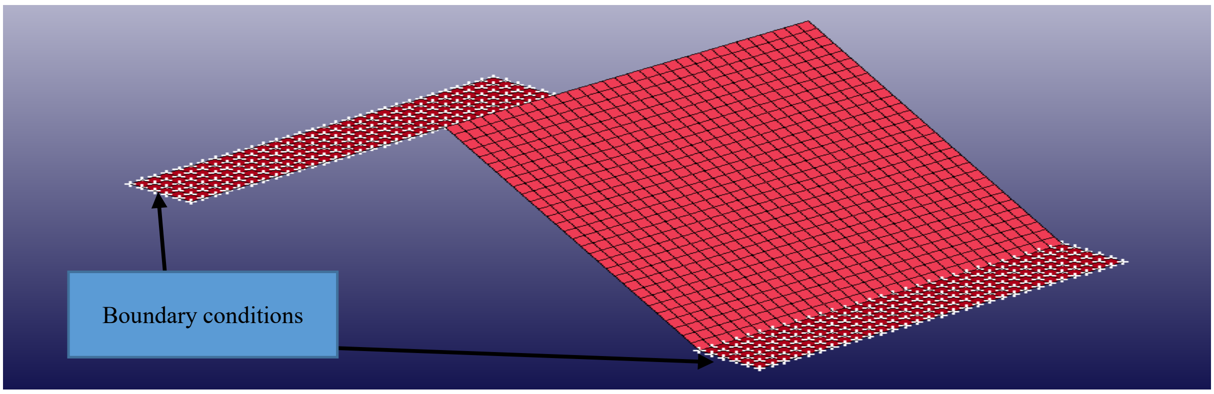


Fig.6. V shape plate 90º

3.3. Properties and Failure Model for the V Shape Model

The Johnson and Cook [22-24] material model is applied to the model. The Equation (1) and (2) as show the material flow stress as a function of strain, strain rate and temperature

$$\bar{\sigma} = [A + B(\varepsilon^{-PI})^n]\left[1 + Cln\left(\frac{\dot{\varepsilon pl}}{\dot{\varepsilon 0}}\right)\right](1 - \theta^m) \tag{1}$$

$$\bar{\theta}^m = \left[\left(\frac{T - 300K}{Tmelt - 300K}\right)\right] \tag{2}$$

where $\bar{\sigma}$ is the yield stress at non zero strain rate, ε^{-PI} is the equivalent plastic strain, εpl

is the normalized equivalent plastic strain rate, T is the material temperature (K) and Tmelt is the melting temperature of the material. The constants A, B, n, C and $\varepsilon 0$ are material dependent parameters and may be determined from an empirical fit of flow stress data. Table 4 lists the material dependent parameters used in the model [11], in this case material are using is mild steel.

Table 4. Material properties of mild steel [11]

A, Mpa	B, Mpa	n	C, S^{-1}	m	Tmelt, K
217	234	0.643	0.017	0	373

4. CONCLUSION

The difference geometries of the V shape plate 90º, 120º and 150º degree and difference material model have been investigated using experimental and numerical approach. Based from the obtained results, V shape plate with angle 90º and 120º were found to deform significantly compared to V plates of 150º angle. The numerical simulation results also concurred with the experimental findings and Johnson material model was found to compute results, which shows close similarity in terms of deflection values compared to Plastic Kinematic material model.

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