

# EVALUATION OF IMPACT OF THE DEFLECTOR SHAPE ON EFFECTIVENESS OF WEAKENING THE BLAST WAVE ORIGINATING FROM A MINE OR IED

Robert Panowicz, Jacek Nowak, Marcin Konarzewski

Military University of Technology  
Department of Mechanics and Applied Computer Science  
Kaliskiego Street 2, 00-908 Warsaw, Poland  
tel.: +48 22 6839849, fax: +48 22 6839355  
e-mail: rpanowicz@wat.edu.pl, jnowak@wat.edu.pl  
mkonarzewski@wat.edu.pl

## Abstract

The situations which our forces faced during various stabilization military missions showed that light armored vehicles are not secure enough in the case of the mine or improvised explosive devices explosion. Nowadays, the primary way of protection against this type of threat is application of a V-shape bottom in the vehicle. Such a configuration of the bottom allows dissipation of explosion energy whereby the impulse, which is transmitted to the construction – the vehicle bottom or frame, has a much lower value than in the case where the bottom is flat.

In the literature it is possible to find the results of model tests on an experimental laboratory test stand. These studies show that the value of the impulse which is transmitted to the structure depends on the shape of the deflector, actually on its angle.

Assuming the above condition, there were performed numerical analyses of the values of the impulse transmitted to the construction for deflectors with different angles and for a variety of loads masses.

The aim of the numerical analyses was to find the optimal angle of the deflector for the considered situation. In this model, the optimal value of the angle is that in which the considered value of the impulse transmitted to the construction reaches the minimum value. For this purpose, there was made a finite element model of deflector corresponding to the conditions of the experiment. The shell elements were used in this model. The model was loaded with a pressure impulse derived from the detonation of an explosive. The blast wave interaction with the structure was modeled using the fluid structure interaction.

The numerical analyses were based on the finite element method with the explicit time integration method implemented in the LS-DYNA program.

**Keywords:** finite elements method, simulation, military vehicles, deflector

## 1. Introduction

The situations which our forces faced during various stabilization military missions showed that light armoured vehicles are not secure enough in the case of the mine or improvised explosive devices explosion.

Nowadays, the primary way of protection against this type of threat is application of a V-shape bottom in the vehicle. Such a configuration of the bottom allows dissipation of explosion energy whereby the impulse which is transmitted to the construction – the vehicle bottom or frame, has a much lower value than in the case where the bottom is flat, resulting in less damage to the vehicle and the people moving in it. An example of vehicle of such construction is KMW Dingo (Fig. 1) [1]. This vehicle has a high level of mine resistance allowing it to withstand mine explosion at Level-2 [2] according to the STANAG 4569 standard.

In the literature it is possible to find the results of model tests on an experimental laboratory test stand [3]. These studies show that the value of the impulse which is transmitted to the structure depends on the shape of the deflector, actually on its angle.

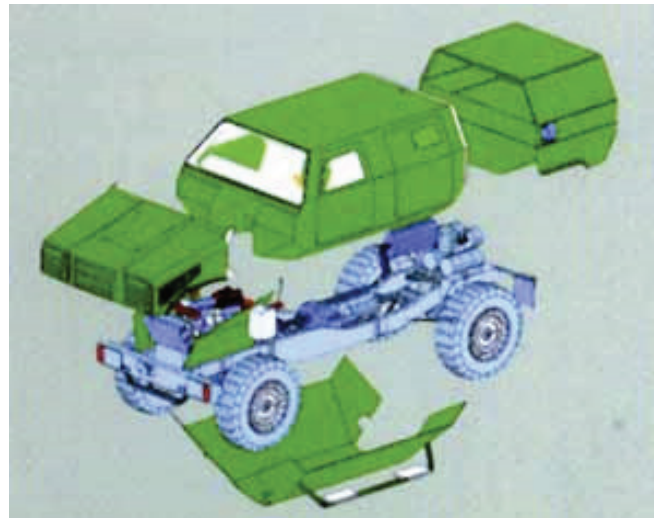


Fig. 1. KMW Dingo [1]

Assuming the above condition, there were performed numerical analyses of the values of the impulse transmitted to the construction for deflectors with different angles and for a variety of loads masses. The paper presents results of impact of the pressure wave, originated from explosion of 100, 200 or 300 g TNT charges, on the considered construction.

The aim of the numerical analyses was to find the optimal angle of the deflector for the considered situation and how it varies depending on the mass of the explosive charge. In this model, the optimal value of the angle is that in which the considered value of the impulse transmitted to the construction reaches the minimum value.

## 2. Description of the computational model

For numerical analysis several models of deflectors with different angle were prepared. As a starting model numerical model of deflector showed in Fig. 2a with the angle  $124^\circ$  was taken. This deflector is made from 2 mm thick S235 steel. Its characteristic dimensions are shown in Fig. 2b.

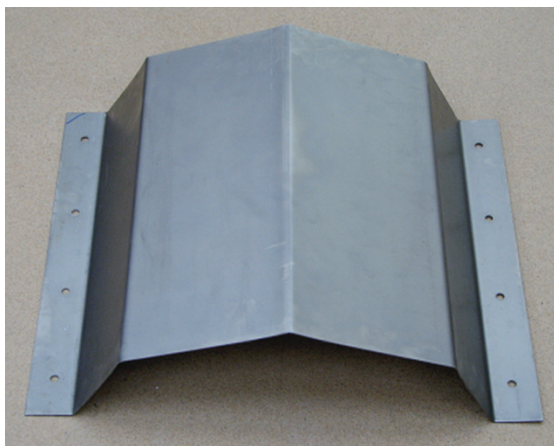


Fig. 2. Model of deflector with  $124^\circ$  angle (a) and characteristic dimensions (b)

Numerical model of considered structure made using Pre-Post program is shown in Fig. 3. Numerical model consists of three parts:

- 550×500 mm deflector,
- cylindrical explosive charge,
- air.

Behavior of the deflector is described by mechanics conservation laws in Lagrangian terms. The propagation of detonation wave in explosive charge and a pressure wave in air are described using the same equations but in Eulerian terms [9, 10]. For the coupling of this two elements fluid-structure interaction approach [4, 5] was used.

Complete model consists of more than 530,000 solid elements (air, explosive charge) and 3,740 shell elements (deflector). Air with explosive charge has dimensions of 600×600×750 mm (Fig. 3a) which allows for placement deflector in it. It represent only a part of surrounding medium, which is why non-reflecting boundary conditions were used as well as pressure corresponding to atmospheric pressure was applied.

The behavior of air has been described with the Mie-Gruneisen equation [5]:

$$p = p_0 + \gamma \rho E, \quad (1)$$

where:

$p$  – pressure,

$p_0$  – initial pressure,

$\gamma$  – Gruneisen coefficient,

$\rho$  – density,

$E$  – specific internal energy.

The following values constant in the equation (1) [6]:  $\gamma = 1.4$ ,  $\rho = 1.185 \text{ kg/m}^3$ ,  $p_0 = 1013 \text{ hPa}$ .

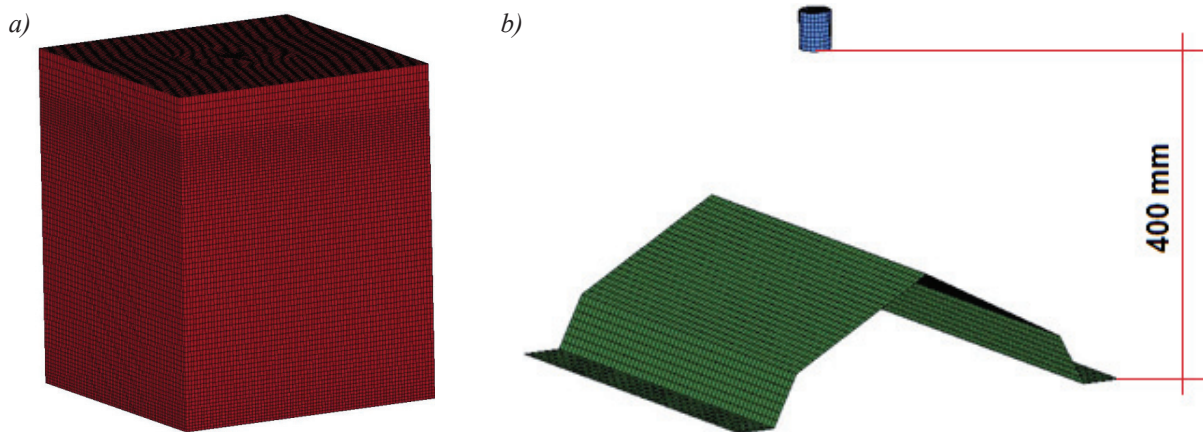


Fig. 3. Numerical model: a) ALE area with dimensions of 600×600×750 mm, b) deflector and explosive charge – in all model constant distance between bottom of deflector and explosive charge equal to 400mm was maintained

It was assumed that the explosive charge is made of TNT and the behavior of detonation products can be described using JWL equation (2):

$$p = A \left( 1 - \frac{\omega}{R_1 V} \right)^{-R_1 V} + B \left( 1 - \frac{\omega}{R_2 V} \right)^{-R_2 V} + \omega \rho E, \quad (2)$$

where:

$V = \rho_0 / \rho$ ,

$\rho_0$  – initial density,

$\rho$  – density of detonation products,

$A, B, R_1, R_2, \omega$  – values constant.

The detonation process was described using programmed burn model approximations [5, 6], The values constant of the JWL equation for TNT are presented in Tab. 1 [7].

Behavior of deflector which is made from S235 steel was described using MAT-PIECEWISE-LINEAR-PLASTICITY material model, which allows to describe 8-point plastic strain-stress material curve. Due to the dynamic interaction of pressure wave originating from detonation on the

Tab. 1. The values constant of the JWL equation for TNT [7]

Parameter	Units	Value
HIGH EXPLOSIVE		
$\rho$	[kg/mm <sup>3</sup> ]	1.6e-6
$D$	[mm/ms]	6900
$PCJ$	[GPa]	18
$A$	[GPa]	373
JWL EOS		
$B$	[GPa]	3.75
$R_1$		4.15
$R_2$		0.9
$\omega$		0.35

considered object a change in its mechanical properties was taken into account. For this purpose the Cowper-Symonds equation was used (3) [8]:

$$\sigma_d = \sigma \left( 1 + \left| \frac{\dot{\epsilon}}{D} \right|^{1/n} \right). \quad (3)$$

Parameters describing St3 steel used into numerical analyses are based on research conducted in Department of Mechanics and Applied Computer Science of Military University of Technology.

### 3. Numerical analyses

Numerical analyses of impact of pressure wave originated from detonation of explosive charge on deflector were performed for following explosive charges masses: 100 g, 200 g and 300 g.

The aim of the numerical analyses was to find the optimal angle of the deflector for the considered situation. In this model, the optimal value of the angle is that in which the considered value of the impulse transmitted to the construction reaches the minimum value.

In model it is implemented by determining the resultant reaction in nodes underlying deflector. Exemplary impulse of transmitted force is shown in Fig. 4. This graph was obtained in the case of deflector with 80° angle subjected to the influence of pressure wave from detonation of 300 g TNT charge.

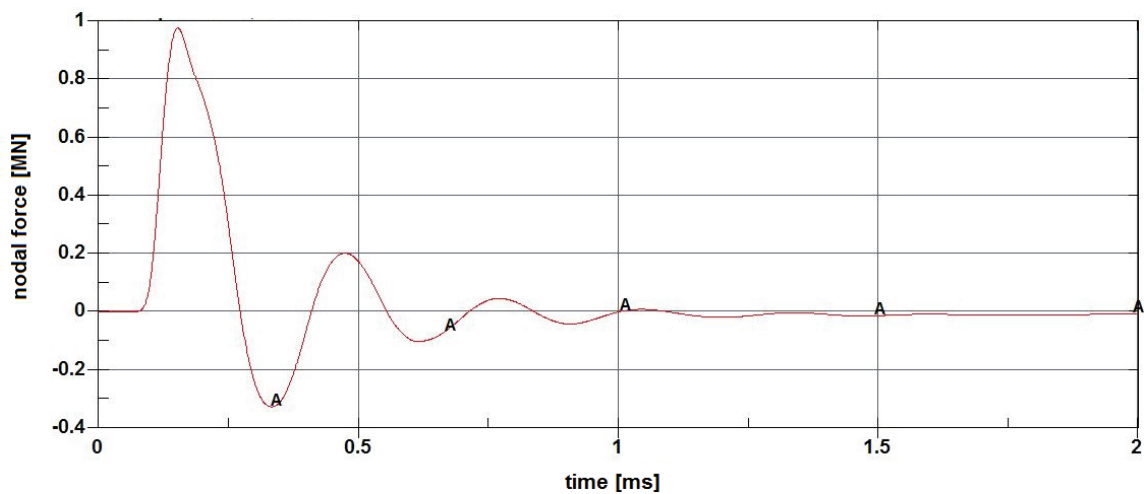


Fig. 4. Impulse of force transmitted through deflector to the tested construction (deflector with 80° angle and impulse of pressure wave originated from detonation of 300g of TNT)

For every type of explosive charge performed a series of analyses for different angles of deflector. As a result of analysis the angle at which the pulse of transmitted force is the smallest was determined (the optimum variant). Fig. 5-7 shows the results of analyses. Graphs represent relationship of the maximum value of the force transmitted by deflector – referred to the force value obtained in optimum variant – and the angle of deflector.

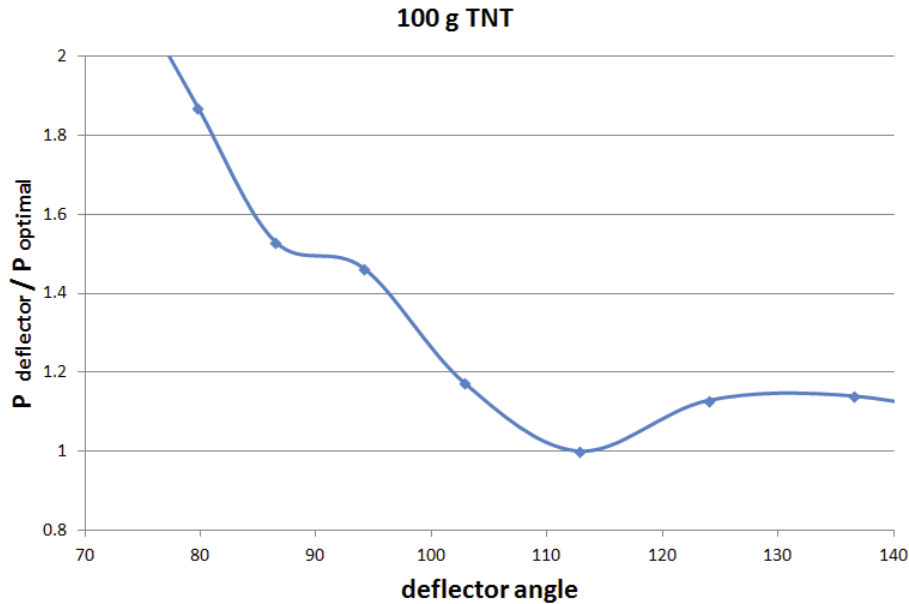


Fig. 5. A plot of relationship between maximum force transmitted by the deflector (referred to the maximum force obtained for optimal variant) and the deflector angle for 100g explosive charge

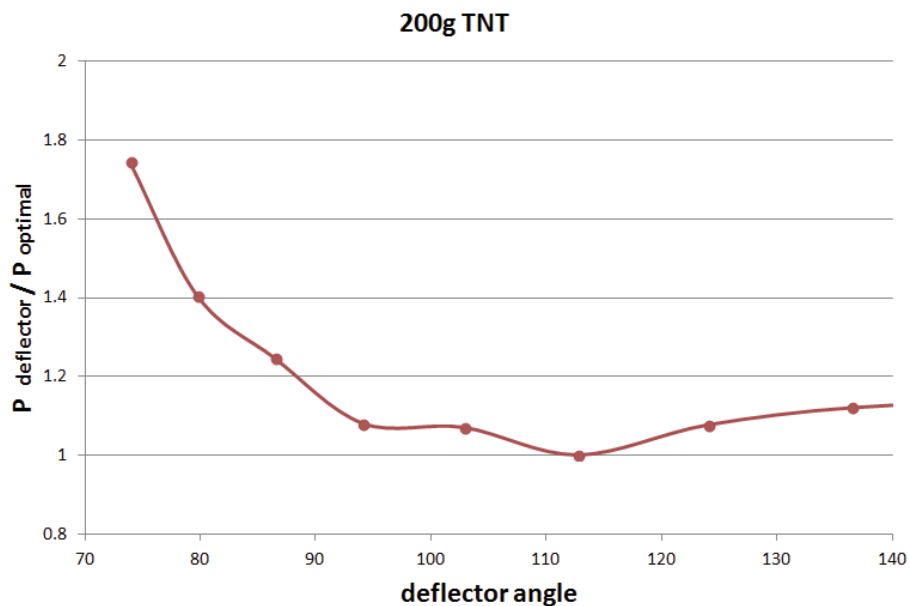


Fig. 6. A plot of relationship between maximum force transmitted by the deflector (referred to the maximum force obtained for optimal variant) and the deflector angle for 200g explosive charge

#### 4. Summary

This paper presents the results of modelling the impact of pressure wave coming from the detonation of explosive charge on the deflector model. Constant distance between ground and explosive charge was assumed. This configuration corresponds to the real situations. Obtained values of reactions match the results of experimental studies.

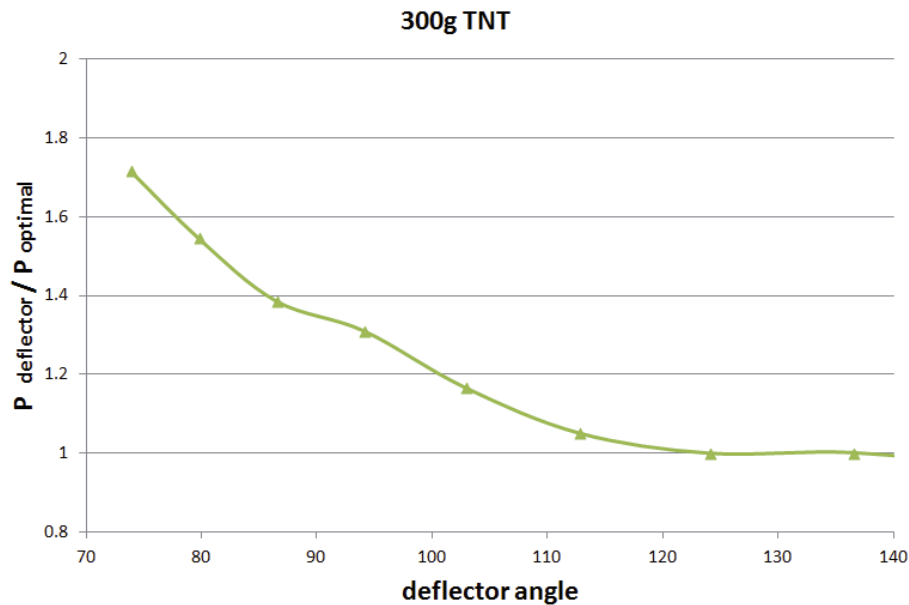


Fig. 7. A plot of relationship between maximum force transmitted by the deflector (referred to the maximum force obtained for optimal variant) and the deflector angle for 300g explosive charge

The analyzes determined the optimal angle of deflector. This angle was selected on the basis of minimum value of the resultant reaction determined in the nodes underlying the deflector. Minimum is in the range of 110–120° and moves slightly toward higher values when pressure wave has greater intensity.

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