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Failure analysis of V-shaped plates under blast loading

Agesh Markose[a*], C Lakshmana Rao[a]

[a] *Department of Applied mechanics, Indian Institute Of Technology Madras,Chennai, Tamilnadu 600036, India.*

Abstract

Shaped plates assume importance in the design of armoured personal vehicles (APV). These plates are used as blast mitigation structures against land mine blasts. These shaped plates deflect and absorb a certain part of the energy imparted to them. The blast mitigating capacity at a particular impulse level mainly depends on material and the geometric parameters of the plate under consideration. The objective of this paper is to conduct a finite element (FE) based failure analysis and parametric study on the blast mitigating capability of steel plates. The important parameters of interest are the mass of the explosive and the included angle of the V shaped plate. A numerical study on V-shaped plates is carried out with ABAQUS to predict the midpoint deflection and impulse transmitted. The verified simulation procedure is repeated for conducting the parametric study. The study may be used in setting up guide lines for the design of V shaped plates for protecting vehicles.

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Keywords: V- shaped plates; Blast loading; Numerical investigation; Structural response.

1. Introduction

Close range blast loads from land mines pose a severe threat to the military vehicles and civil infrastructure. In most of the cases the loads are difficult to predict since a large number of independent variables are found to affect the loading. Attaching shaped metal plates below the vehicle floor is the only means of mitigating the effect of the blast loads in vehicles. In military vehicles providing a V shape hull is the most commonly used method for mitigating the blast effects, as shown in Fig. 1. As compared to a flat plate the V shaped plate deflects a part of the blast load and absorbs the remaining part to ensure sufficient level of protection. Sahu et al. [1] analyzed the

* Corresponding author

E-mail adress: ageshmarkose@gmail.com (Agesh Markose).

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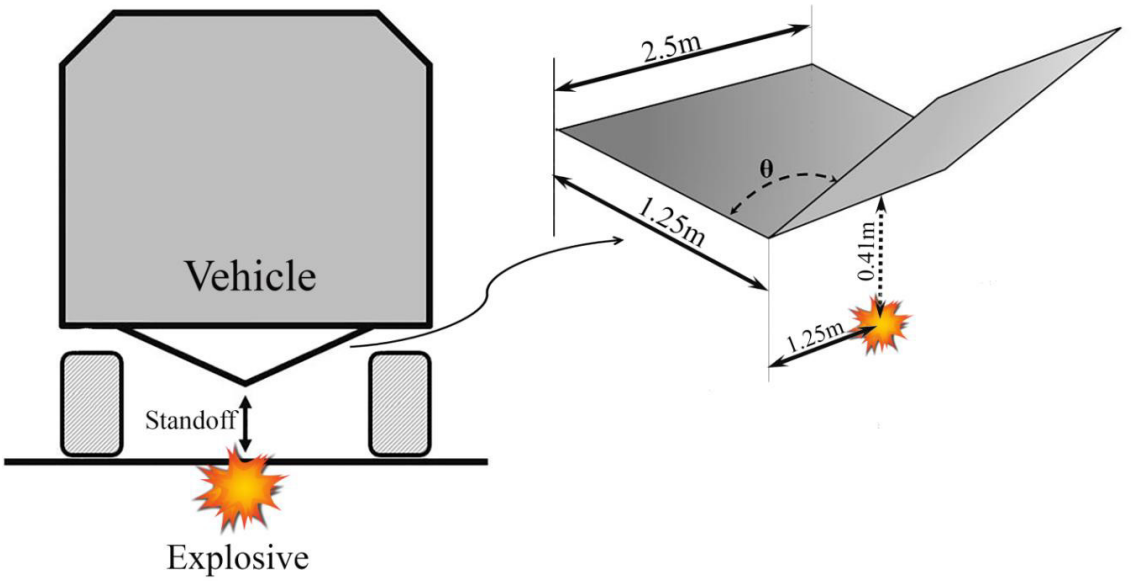
different shapes of the plate like flat shape, V shape, parabolic shape etc. and concluded that, V shape, provides the optimal protection. But the results of blast loading of V shaped plates or the details of optimum plate geometry are not easily available in open literature. But it is often used as the structural attachment in armored personal vehicles like South African Cassipir [2]. From the available literature shown in Refs. [3,4], it is seen that the plates with varying geometric parameters gives varying levels of protection against the blast loads. So it is desirable to find parameters of the V plate, which can provide the optimal protection. The objective of this present paper is to numerically analyze the blast loading response of V shaped plates. A parametric study is also conducted to find the effect of the key variables.



(Remark: Fig. 1 is attached separately in case of any formatting/resolution issues)

Fig. 1. Schematic illustrating the V-shaped plate and its terminologies.

2. Methodology

In this paper an attempt has been made to numerically simulate the blast loading response of V plate and correlate with available experimental data published by Yuen et al. [4]. A steel V plate with various included V angle (θ) is considered for the present study. These angles have been selected since plates with lesser included angles may be difficult to accommodate under the body of the vehicle. The material being considered is Domex 700 steel for which material data is readily available, Ref. [4]. The well-established Johnson -Cook model for the strain rate dependent plastic deformation is utilized. The numerical simulation is done in FE package ABAQUS . The geometry of the plate model is obtained by scaling down the dimensions of the APV, Cassipir. Here the effect of variation in mid-point deflection and the impulse transmitted with variation in parameters like a) Mass of the charge and b) V angle of the plate has been studied numerically. The results have been compared with the experimental data to ensure sufficient accuracy.

APV like Casspir have been proven to be safe for the occupants against a 14 kg TNT blast under V- shape hull, as reported in Ref. [4]. Blast loading experiments have been conducted on scaled down models of V shaped plate by Yuen et al. The geometric scaling factor used for generating the hull geometry from the actual dimensions of the APV Cassipir, has been used for obtaining other geometric parameters like stand-off distance and diameter of the explosive disc. The Hopkinson-Cranz blast scaling law, was used to scale down mass of the explosive charges for different stand-off distances. The experiments were conducted with an explosive mass range of 5g to 58g of PE4, angle range