

# **Determination of Stress Pattern Using Fem on MPV during the Blast**

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**ABSTRACT:** A blast in the immediate vicinity of a vehicle can cause catastrophic damage on the vehicle's external and internal structural frames. This kind of scenario is expected to armed vehicles of defence department. It is hoped that the blast take place from a distance to the vehicle. This distance is called as standoff distance. In addition, major catastrophes resulting from explosions result in large dynamic loads, greater than the original design loads. Due to the threat from such extreme loading conditions, efforts have been made during the past three decades to develop methods of structural analysis and design to resist blast loads. The analysis and design of structures of vehicle subjected to blast loads require a detailed understanding of blast phenomena and the dynamic response of various structural elements. Elaborate experiments were at university of Sheffield and also by defence sector, to find the transients of the pressure developed by explosion/blast. In this project an attempt is made to determine the stress field developed in the plates of the vehicle for an impulse/blast. This project is aimed at an analysis of an ordnance vehicle undergoing explosive loads due to detonation. This project starts with a comprehensive overview of the effects of explosion on MPV (Mine Protected Vehicle). An explanation of the nature of explosions, their interaction with a structure, stress distribution and displacement of the special vehicle(MPV). In order to evaluate the stress and displacement finite element analyses are performed using ANSYS software for different Blast loads and boundary conditions.

**KEYWORDS:** MPV, ANSYS, Blast, Structural frames, dynamic loads, Blast loads,

## **I. INTRODUCTION**

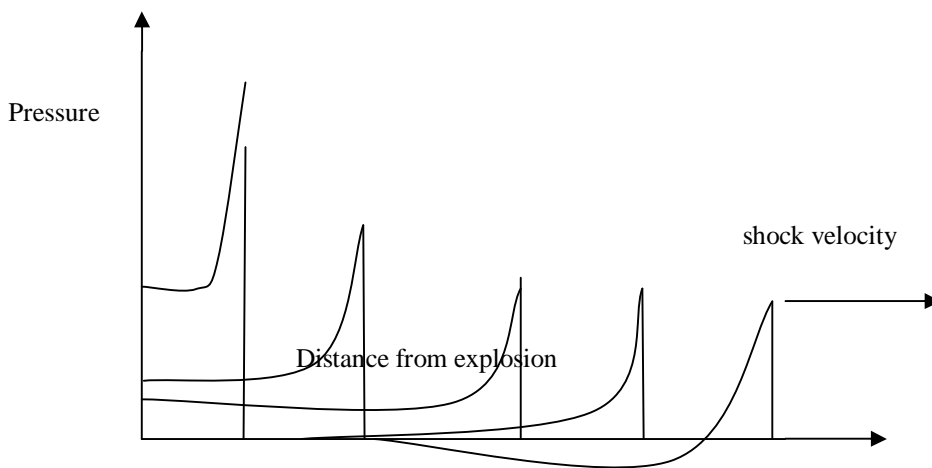
An explosion is defined as a large-scale, rapid and sudden release of energy. Explosions can be categorized on the basis of their nature as physical, nuclear or chemical events. In physical explosions, energy may be released from the catastrophic failure of a cylinder of compressed gas, volcanic eruptions or even mixing of two liquids at different temperatures. In a nuclear explosion, energy is released from the formation of different atomic nuclei by the redistribution of the protons and neutrons within the interacting nuclei, whereas the rapid oxidation of fuel elements (carbon and hydrogen atoms) is the main source of energy in the case of chemical explosions.

Explosive materials can be classified according to their physical state as solids, liquids or gases. Solid explosives are mainly high explosives for which blast effects are best known. They can also be classified on the basis of their sensitivity to ignition as secondary or primary explosive. The latter is one that can be easily detonated by simple ignition from a spark, flame or impact. Materials such as mercury fulminate and lead azide are primary explosives. Secondary explosives when detonated create blast (shock) waves which can result in widespread damage to the surroundings. Examples include trinitrotoluene (TNT) and ANFO. The detonation of a condensed high explosive generates hot gases under pressure up to 300 kilo bar and a temperature of about 3000-4000C°. The hot gas expands forcing out the volume it occupies. As a consequence, a layer of compressed air (blast wave) forms in front of this gas volume containing most of the energy released by the explosion. Blast wave instantaneously increases to a value of pressure above the ambient atmospheric pressure. This is referred to as the side-on overpressure that decays as the shock wave expands outward from the explosion source. After a short time, the pressure behind the front may drop below the ambient pressure (Figure 1). During such a negative phase, a partial vacuum is created and air is sucked in. This is also accompanied by high suction winds that carry the debris for long distances away from the explosion source.

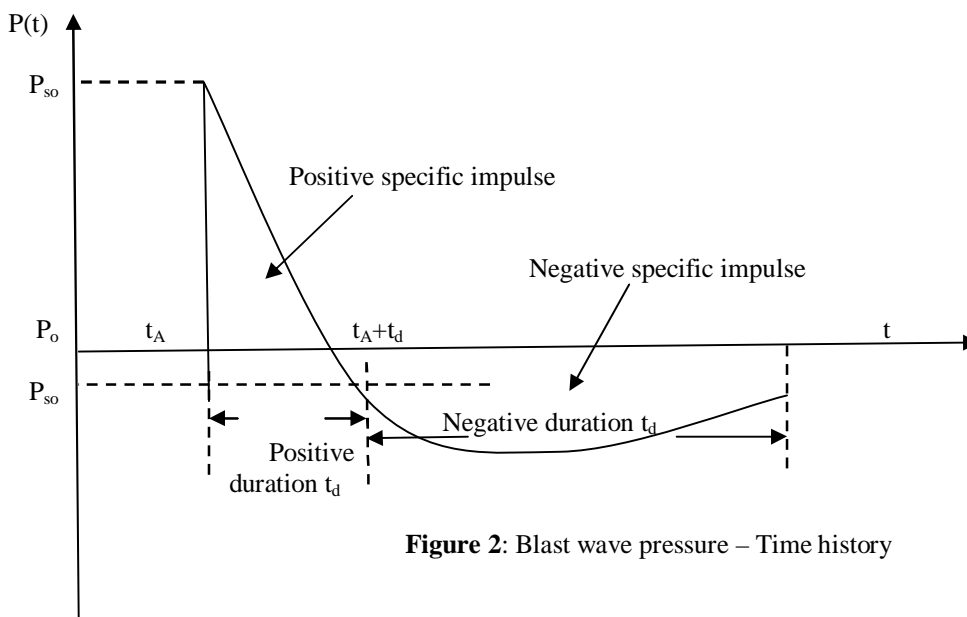
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**Fig 1 :** Blast wave propagation



**Figure 2:** Blast wave pressure – Time history

## 1.1 explosive air blast loading

The threat for a conventional bomb is defined by two equally important elements, the bomb size, or charge weight  $W$ , and the standoff distance  $R$  between the blast source and the target. Figure 2 shows a typical blast pressure profile. At the arrival time  $t_A$ , following the explosion, pressure at that position suddenly increases to a peak value of overpressure,  $P_{so}$ , over the ambient pressure,  $P_o$ . The pressure then decays to ambient level at time  $t_d$ , then decays further to an under pressure  $P_{so}$  - (creating a partial vacuum) before eventually returning to ambient conditions at time  $t_d + t_d$ . The quantity  $P_{so}$  is usually referred to as the peak side-on overpressure, incident peak overpressure or merely peak overpressure (TM 5-1300, 1990). The incident peak over pressures  $P_{so}$  are amplified by a reflection factor as the shock wave encounters an object or structure in its path. Except for specific focusing of high intensity shock waves at near  $45^\circ$  incidence, these reflection factors are typically greatest for normal incidence (a surface adjacent and perpendicular to the source).

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## 1.2 Dynamic Response to an Impulse Load.

One of the most common in structural system is an impulse load, i.e. a load that has a short duration with respect to the fundamental period of the structure (i.e.  $t_d \ll T$ ). A schematic plot of such load is shown in below fig.

The impulse of this load is by definition :  $\int_0^{t_d} P(t) dt$

It can be shown that the response of a SDOF to this load is given by:

$$Y(t) = \frac{I}{m\omega_d} e^{-\xi\omega_d t} \sin \omega_d t$$

Where  $(\omega_d) = \omega \sqrt{1 - \xi^2}$

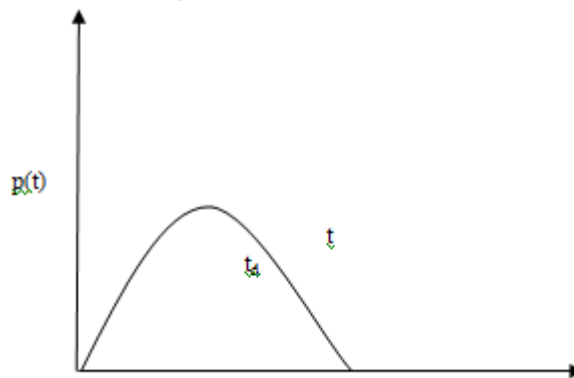


Fig:3. Impulse load

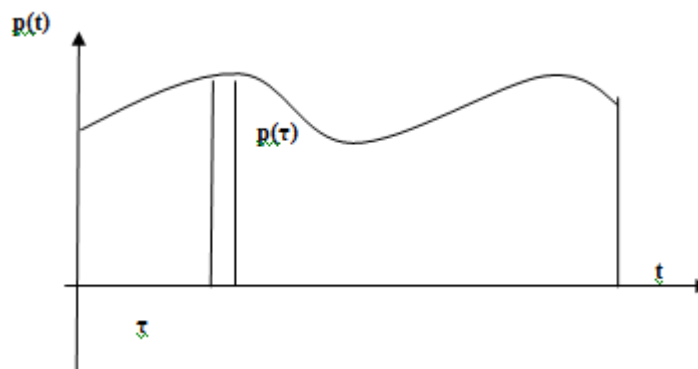


Fig: 4. General dynamic load

## 1.3 fundamentals of blast and blast waves

The defining characteristic of a blast wave at any point in space is the variation in ambient pressure over time (its pressure-time history). The increased pressure (above normal atmospheric pressure) from a blast is termed the blast overpressure. The level of overpressure depends upon the energy of the explosion, the distance from the point of detonation, the elapsed time since the explosion, and the measurement technique. Blast strength is defined as the ratio of overpressure to ambient pressure. Some exotic explosives, such as fuel-air mixtures, can produce large overpressures with long positive durations (that is, the time over which the pressure is greater than the ambient undisturbed pressure). Blast waves that arise from weapon noise have small positive durations (usually less than 5 msec and modest peak overpressures (less than atm) and are accompanied by negligible blast winds. Nuclear weapons can generate blast waves that have overpressures of several atmospheres, positive durations lasting several seconds, and

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Vol. 5, Issue 2, February 2016

blast winds of hundreds of miles per hour. The molecules of gas in the atmosphere around us are in constant thermal motion. On average, at sea level, there are 30 million billion molecules in every cubic millimeter of air, moving at speeds on the order of 300 m/s and bumping into one another 100 million times each second, after traveling only 0.001 mm. This continual bombardment of gas molecules against any solid surface exerts a force on every part of that surface and is most appropriately expressed as a force per unit area, or a pressure. The average energy of motion of individual molecules is measured by the temperature of the gas, while the mass of molecules in a given volume is measured by the density of the gas. Pressure, temperature, and density are measures of the state of the gas.

## 1.4. Blast wave from high explosives

### Blast effect

Blast wave is generated by an explosive event, when an unconfined charge detonates in air, it gives rise to a shock wave with a practically discontinuous pressure front that propagates with supersonic speed. The shock wave is initiated by the very rapid release of a large amount of energy in the surrounding medium with a sudden increase of pressure at the shock front followed by a gradual decrease of pressure as shown in Fig. 1. The maximum overpressure that occurs at the shock front is called the peak overpressure. As this wave moves away from the centre of the explosion, the overpressure in the shock front decreases steadily. The pressure behind the front also falls off exponentially

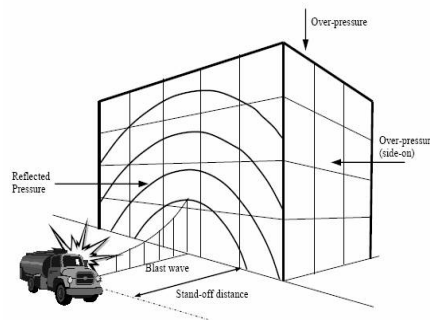


Fig. 5 Variation of overpressure with distance at various times

After a short time, the overpressure behind the shock front drops rapidly and becomes smaller than that of the surrounding atmosphere, as shown in Fig.3. This pressure domain is known as the negative phase. The front of the blast wave weakens as it progresses outward and its velocity drops toward the velocity of sound in the undisturbed atmosphere. The characteristics of a blast wave resulting from an explosion depend mainly on the physical properties of the source and the medium through which blast waves propagate. To create reference blast experiments, some controlled explosions have been conducted under ideal conditions. To relate other explosions with non-ideal conditions to the reference explosions, blast scaling laws can be employed. The most widely used approach to blast wave scaling is that formulated by Hopkinson, which is commonly described as the cube-root scaling law. The scaled distance,  $Z$ , is defined using the Hopkinson-Cranz's cube root law.

## 1.5 stand-off distance and the effects of blast

Energy from a blast decreases rapidly over distance. In general, the cost to provide asset protection will decrease as the distance between an asset and a threat increases. However, increasing stand-off also requires more land and more perimeter to secure with barriers. As stand-off increases, blast loads generated by an explosion decrease and the amount of hardening necessary to provide the required level of protection decreases.

The critical location of the weapon is a function of the site, the building layout, and the security measures in place. For vehicle bombs, the critical locations are considered to be at the closest point that a vehicle can approach on each side, assuming that all security measures are in place. Typically this is a vehicle parked along the curb directly outside the building, or at the entry control point where inspection takes place. For internal weapons, location is dictated by the areas of the building that are publicly accessible (e.g., lobbies, corridors, auditoriums, cafeterias, or gymnasiums). Range or stand-off is measured from the center of gravity of the charge located in the vehicle or other container to the

# International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 2, February 2016

building component under consideration. Defining appropriate stand-off distance for a given building component to resist explosive blast effects is difficult. Often in urban settings, it is either not possible or practical to obtain appropriate stand-off distance. Adding to the difficulty is the fact that defining appropriate stand-off distance requires a prediction of the explosive weight of the weapon. In the case of terrorism, this is tenuous at best.

## 1.6 TNT

TNT (2,4,6-Trinitrotoluene) is produced both at military arsenals and commercial facilities and is used as an explosive in military munitions. TNT is also used in underwater blasting and in industrial explosive uses. Other industrial uses include chemical manufacturing as an intermediate in the production of dyestuffs and photographic chemicals. It may be mixed with other explosives, such as Royal Demolition Explosive (RDX) and High Melting Explosive (HMX). It is a manufactured chemical not occurring naturally in the environment 2,4,6-Trinitrotoluene is a yellow odorless solid, commonly known as TNT. It is not naturally occurring, but can be produced by the nitration of toluene by  $\text{HNO}_3$ . TNT is insoluble in water but dissolves in benzene and acetone. It reacts with nucleophiles which attack the positively charged nitrogen atoms. TNT will undergo violent decomposition in the presence of a detonator, such as Mercury fulminate ( $\text{Hg}(\text{ONC})_2$ ). It is therefore a useful explosive agent, used by the military in shells, bombs, and grenades. It was one of the principle explosives used in World War One, but had been replaced by more powerful explosives by 1939. TNT molecules collapse when jolted. The oxygen atoms then combine with carbon and hydrogen atoms, making carbon monoxide and water. The nitrogen atoms are freed and nitrogen gas is released. This transformation from a compact solid to a volumous cloud of gas produces a powerful explosion. TNT has a melting point of 82 degree C but it does not decompose below 240 degree C. This means that it can be melted and then poured into casts without danger of explosion. There are number of ways for TNT to be entered into the food chain, including bad disposal of waste water and solids by TNT manufactures. Some TNT released into the environment is broken down rapidly to other chemicals by sunlight and more is broken down by microorganisms. Despite this small amounts can still build up in fish and plants. Human exposure to this TNT can lead to abnormal liver function, anemia, and, in the long term, cataracts. TNT can also be absorbed through the skin, again causing the above effects. There is a possibility that TNT may be a human carcinogen.

Grams TNT	Symbol	Tons TNT	Symbol	Energy
gram of TNT	g	microton of TNT	$\mu\text{T}$	$4.184 \times 10^3 \text{ J}$
kilogram of TNT	kg	milliton of TNT	mT	$4.184 \times 10^6 \text{ J}$
megagram of TNT	Mg	ton of TNT	t	$4.184 \times 10^9 \text{ J}$
gigagram of TNT	Gg	kiloton of TNT	kt	$4.184 \times 10^{12} \text{ J}$
teragram of TNT	Tg	megaton of TNT	Mt	$4.184 \times 10^{15} \text{ J}$
petagram of TNT	Pg	gigaton of TNT	Gt	$4.184 \times 10^{18} \text{ J}$

Table no:1 Energy and wt of TNT

## II. RELATED WORK

Youngdahl, C.K [11] in blast and impact, structures usually undergo large plastic deformations or failure, and they absorb considerable energy. In this paper, the characteristics of blast loads and corresponding structural response, as well as the current advances in this area, were briefly reviewed. The concept and effects of blast wave, the main means of blast impact, are introduced. Several critical structural responses are classified and briefly illustrated. The major experimental methods were introduced with a brief description of corresponding experimental devices such as ballistic pendulums and a wide range of sensors to measure impulse, pressure and acceleration and displacement of structures. Several commonly used analytical models were presented and compared to estimate the dynamic behaviour of structure under blast loading. The numerical approaches to analyze the structure responses to blast impact were also summarised with a number of available constitutive relations of explosive charge and material properties of structures.

# International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 5, Issue 2, February 2016

Zhu, L.[12]This study is concerned with the numerical study of fully fixed stiffened plates. The aim of this research is to determine the dynamic response of the plates with different stiffener configurations and considering the effect of standoff distance. Numerical solutions are obtained by using the finite element method and the central difference method for the time integration of the nonlinear equations of motion. Special emphasis is focused on the evolution of mid-point displacements, von mises stresses and strain energy vs. kinetic energy. The results obtained allow an insight into the effect of stiffener configurations and of the above parameter on the response of the plate under uniform blast loading and indicate that stiffener configurations, standoff distance and time duration can affect their overall behavior. From the study, it is observed that the stiffeners effectively sustain the blast pressure, and the cover plate with HAT stiffener can sustain stresses more than the plate with T and I stiffener, and are deformed with less relative displacement.

Wen, H.M., Yu, T.X., and Reddy, T.Y [10]This paper reviews various aspects of modeling an explosion on an aircraft, which can be extended to more general structures. A brief summary of material and structural models is given, followed by a detailed history of pulse–pressure loading models with an emphasis on free–free beams and how pulse characteristics affect a structure’s response. Techniques to desensitize pulse shape effects are discussed, which culminate in the form of pressure–impulse isodamage curves. Studies using random loading models are also presented.

## III. BLAST ANALYSIS OF A RECTANGULAR PLATE WITH 10KG TNT BLAST

### 3.1. Fe formulation & GUI

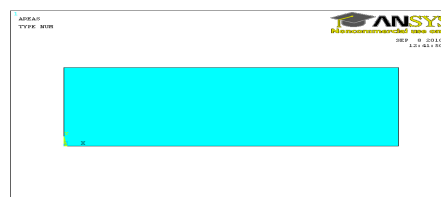


FIG 6.:Geometry of rectangular plate

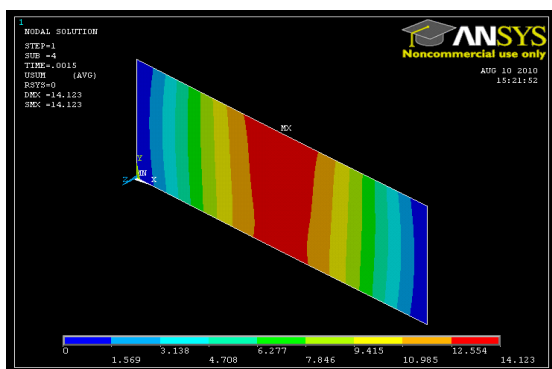


Fig 7.Displacements result for load

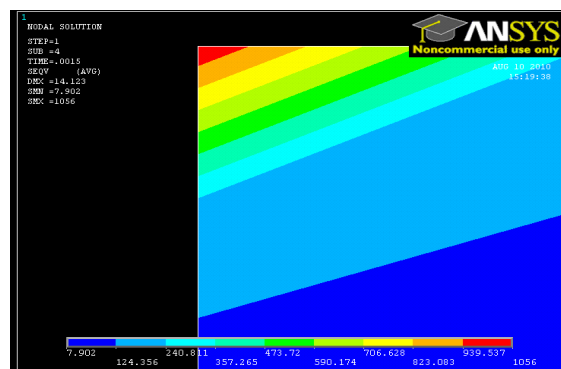


Fig 8: Max & Min stress result for load

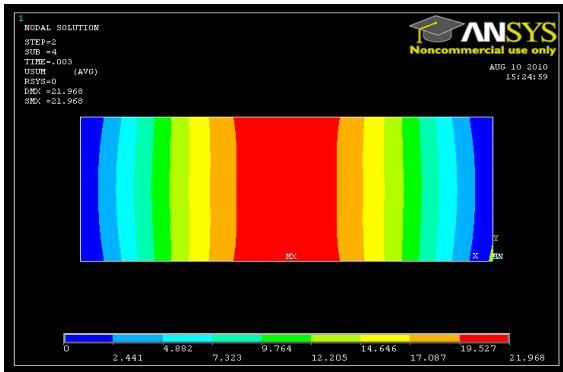


Fig 9: Displacements result for load

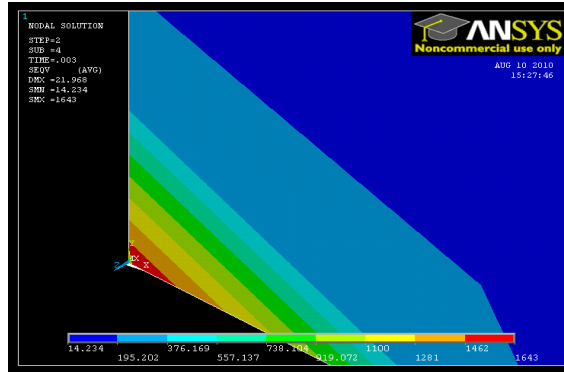


Fig 10: Max & Min stress result for load

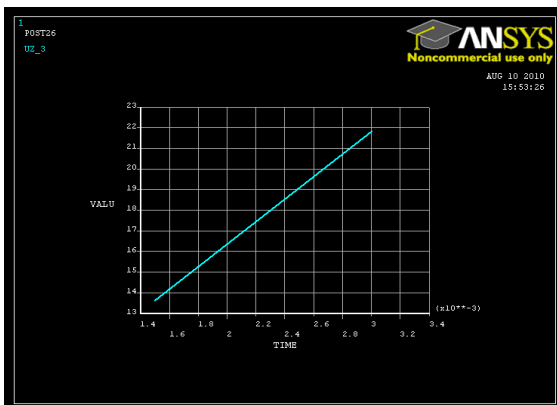


Fig 11 : Time to Displacement plot

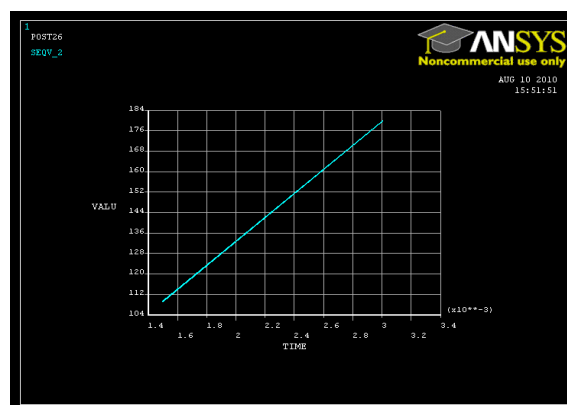


Fig 12 : Time to Von mises stress

## IV.BLAST ANALYSIS OF A V-SHAPE OF MPV(MINE PROTECTED VEHICLE) WITH 10KG TNT BLAST

### 4.1 Fe formulation

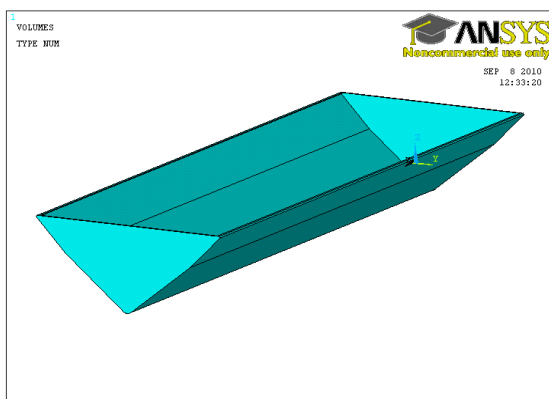


Fig 13: Bottom V-shape hull of Mine protected Vehicle

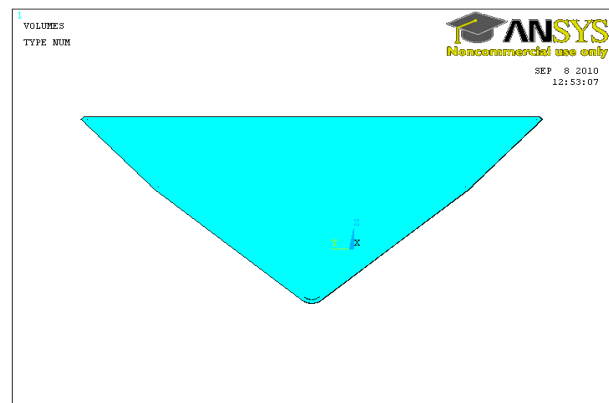
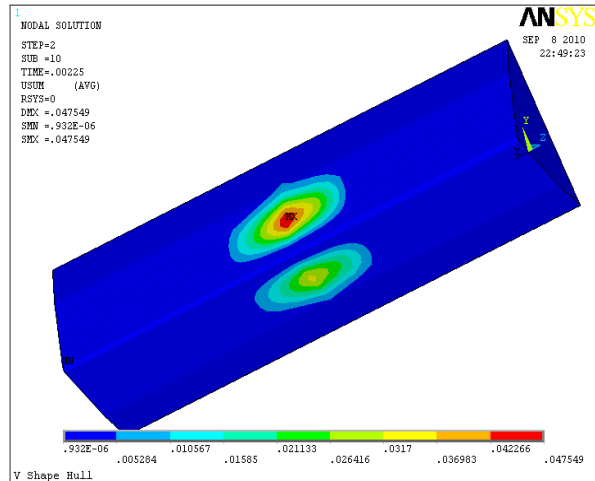
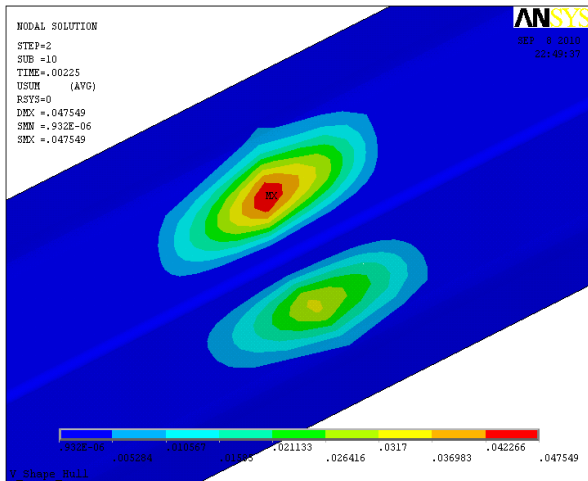
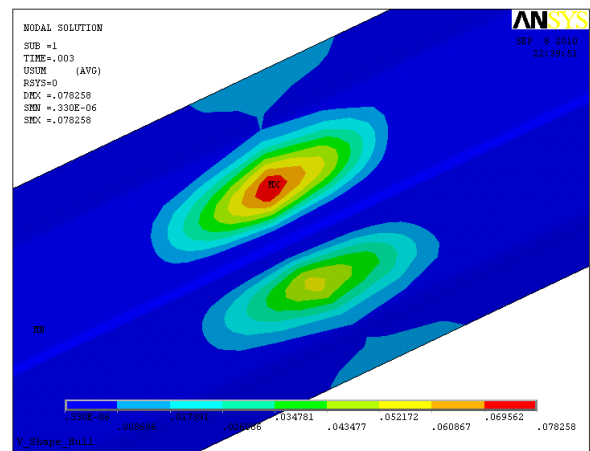
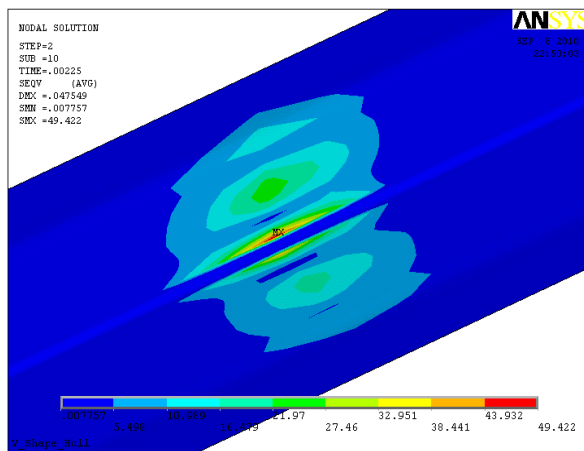


Fig 14: Geometry of v-shape hull(Mine Protected vehicle)

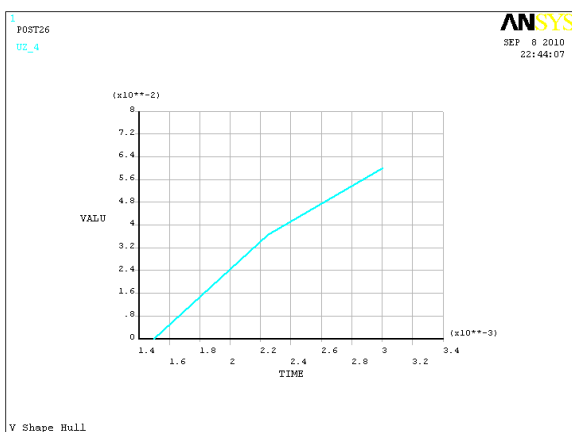




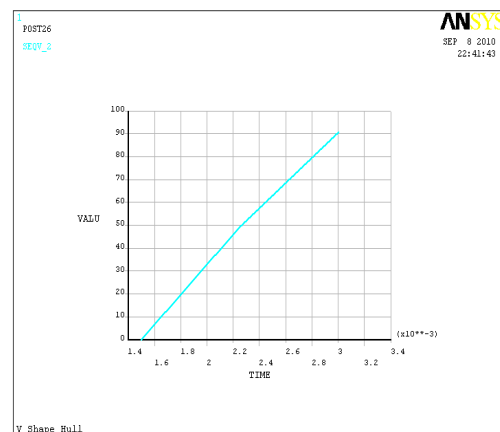
**Fig 15:** Displacements of V-shape hull (max displacement is 0.0289mm) for load 2



**Fig 16:** Displacements of V-shape hull (max displacement is 0.064071mm) for load 3.



**FIG 17:** Time vs Displacement in z-Direction plot



**FIG 18:** Time vs Vonmises Stresses plot



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Vol. 5, Issue 2, February 2016

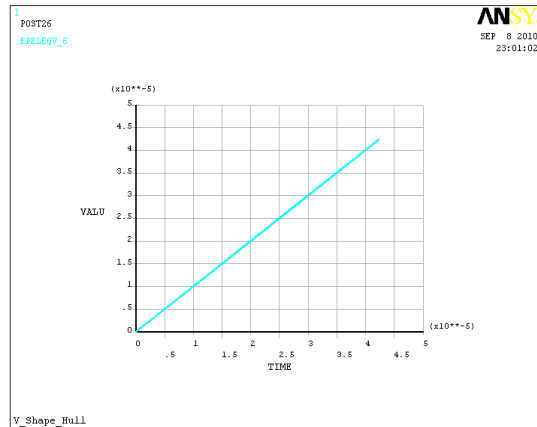


FIG 19: Time vs Elastic Strain plot

## IV. CONCLUSION

1. The impulse load has been converted as averaged time dependent load. Load has been applied insteps during Finite Element Analysis.
2. Stresses have been computed and they are found to be below the maximum stress ( $980 \text{ N/mm}^2$ ) experimentally obtained. This shows that the plates in consideration are safe.
3. This analysis suggests that the plate of thickness of 16mm can withstand three times of impact load given by blast 10 Kg TNT explosive.

### Scope of future work:

Development of theoretical model can be done. As the bottom of the vehicle is subjected for the blast load and also since the distance of the blast and the bottom plate are at sufficient distance, an approximation of a plane pressure wave of  $p(x,y,t)$  can be made. Displacements and stresses of the plate in X,Y directions can be calculated. The results of theoretical model and finite analysis results can be compared and also these can be validated with the experimental data available.

## V. ACKNOWLEDGEMENT

We would like to express my gratitude and appreciation to all those who gave me the possibility to complete this report. Wewish to express my deep sense of gratitude to my guide Dr. J V Subramanyam,, Professor, for his inspiring guidance and support he gave me throughout the course of our project would like to express our grateful thanks to B P BABU, Sr Director, ODC, for his inspiring guidance and support he gave us throughout the course of my project..A special thanks to our HOD Dr. T.Siva Prasad garu whose stimulating suggestions and encouragement, helped us to coordinate my project especially in writing this report. I would also like to acknowledge with much appreciation the crucial role of the staff of Mechanical Laboratory, who gave the permission to use all required Softwares. Last but not least, many thanks go to the Principal Dr,S. Uday Kumar Garu in achieving the goal as well as his encouragement to maintain our progress in track.

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