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CHARACTERISTIC, EFFECTS, AND SPREADING OF THE BLAST WAVE

Abstract

During the service of soldiers in foreign missions the units are exposed to the danger of death in the battlefield and at the military base. While in contact with the enemy, their danger is particularly at risk of conventional infantry weapons, the enemies are usually using large bombs hidden in cars which are transported to the base. With such large explosion lots of lives and material would be lost. This article deals about the characteristics of blast waves and their effects on the human body and constructions. Using the knowledge of spreading blast wave can improve internal structure of buildings and to prevent large losses of human and materiel.

Keywords: Blast wave, Pressure, Damage, ANSYS Software

1. Introduction

Not so far ago the war conflict was characterized by conventional attitude of belligerents. There were two armies in the traditional concept of fighting, which by using former weapons and tactics prove the abilities to lead and win the combat. In the present time the conflicts are mostly performed far beyond the participating countries and in different climatic conditions.

Soldiers face to danger in the contact with the enemy as well as on military bases where they are accommodated. Actually in the recent years, military bases mostly became the targets of terrorist attacks which are made to cause great mass loss. These attacks are carried by the cars loaded with explosives, which are driven by suicide bombers. With the blast of such a big quantity of explosives is formed the large blast wave which crucially destroys humans and material at the base. The knowledge of the blast wave spreading and its size are important for a better arrangement of bases and also to improve the protection of the base.

For detecting the effects of blast waves is convenient to use software from ANSYS Inc. For this reason, the article is focused on using software such as ANSYS Workbench platform, and ANSYS AUTODYN as software which is supplied as an integral part of the ANSYS Workbench environment.

2. The effects of the explosion

Explosion is a physical phenomenon in which there is a sudden, very rapid release of energy. It also contains local increase of temperature and pressure (called as entropy). This rapid change of pressure is spread to the area as a blast wave.

Blast wave is rapidly spreading wave of compressed air in the atmosphere characterized by a gradual change in pressure, density and temperature. Usually it is created and started by the explosion. The trajectory of spreading is in the direction from epicenter of explosion. If the environment is continual, than the speed of the blast wave is the same in each direction.

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TNT equivalent is used to express the real effects of blast waves and for their easier interpretation. As the name itself suggests, TNT equivalent is the amount of TNT (trinitrotoluene), which causes the same explosion blast wave and destructive effects of the same parameters as the tested explosive. This model can be used for the gas, vapor or dust clouds in the limits of explosion, or condensed (solid) explosive. To assess the effects of non-condensing explosion it is only relevant for comparison range of blast waves.

Fig. 1 An Iraqi army soldiers looks at damaged vehicles, after a suicide car bomb attack, in Kirkuk, 290 kilometres North of Baghdad, Iraq, September 17, 2006 [1].

TNT equivalent can be determined from the experimentally observed parameters of explosion waves, or can be calculated from the values of the heat equation. With the equivalent weight of TNT explosive it is possible to estimate the characteristic of blast wave by the maximum pressure in the front at any distance from the epicenter of the explosion. According to this fact it is possible to define the adequate damage. It is clear that only a relatively small part of the total available energy of combustion is actually involved in the creation of blast wave. For this unexceptionable fact there was accepted a general consensus on the TNT equivalent of 3% of the theoretical value. The equivalent increases only in the case of reactive gases (eg. propylene oxide) to 6%. For highly reactive gases (eg. ethylene oxide) it is heightened to 10%. [2]

3. Formation of Blast Wave

As a result of the very high temperatures and pressures at the point of detonation, the hot gaseous residues move outward radially from the center of the explosion with very high velocities. Most of this material is contained within a relatively thin, dense shell known as the hydrodynamic front. Acting much like a piston that pushes against and compresses the surrounding medium, the front transfers energy to the atmosphere by impulses and generates a steep-fronted, spherically expanding blast or shock wave. At first, this shock wave lags behind the surface of the developing fireball. However, within a fraction of a second after detonation, the rate of expansion of the fireball decreases to such an extent that the shock catches up with and then begins to move ahead of the fireball. [3]

As it expands, the peak pressures of the blast wave diminish and the speed of propagation decreases from the initial supersonic velocity to that of sound in the transmitting medium. However, upon reflection from the earth's surface, the pressure in the wave will be reinforced by the fusion of the incident and the reflected wave (the Mach effect) described below. [3]

A large part of the destruction caused by a explosion is due to blast effects. Objects within the path of the blast wave are subjected to severe, sharp increases in atmospheric pressure and to extraordinarily severe transient winds. Most buildings, with the exception of reinforced or blast- resistant structures, will suffer moderate to severe damage when subjected to overpressures of only 35.5 kiloPascals (kPa) (0.35 Atm). The velocity of the accompanying blast wind may exceed several hundred km/hr. Most materiel targets are drag-, or wind-sensitive. [3]

In passing through the atmosphere, the blast wave imparts its energy to the molecules of the surrounding air, setting them into motion in the direction of the advancing shock front. The motion of these air molecules is manifested as severe transient winds, known as "blast winds," which accompany the blast wave. The destructive force associated with these winds is proportional to the square of their velocity and is measured in terms of dynamic pressure. These winds constitute decay forces which produce a large number of missiles and tumbling of objects. These dynamic forces are highly destructive. [3]

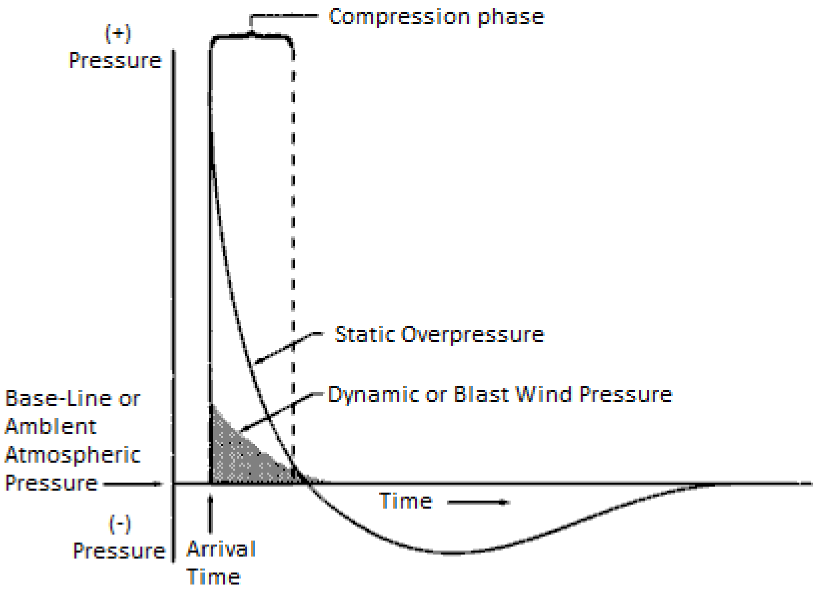

Fig. 2 Variations of Static Overpressure and Dynamic Pressure with Time [3]

The material damage caused by an explosion is caused by a combination of the high static overpressures and the dynamic or blast wind pressures. The relatively long duration of the compression phase of the blast wave (Fig. 2) is also significant in that structures weakened by the initial impact of the wave front are literally torn apart by the forces and pressures which follow. The compression and drag force phases together may last several seconds or longer, during which forces many times greater than those in the strongest hurricane are present. These persist even through the negative phase of a blast wave when a partial vacuum is present because of the violent displacement of air. [3]

Most blast damage will be experienced during the positive or compression phase of the wave. Because of the much longer duration of the blast wave from an explosion, structures are subjected to maximum loading for correspondingly longer periods of time, and damage will be much more extensive for a given peak overpressure than might otherwise be expected.

During the negative phase, which is generally of even longer duration, the static pressure will drop below normal atmospheric pressure and the blast winds will actually reverse direction and blow back towards ground zero. However the damage sustained during the negative phase is generally minor, because the peak values of underpressure and wind velocity are relatively low. Blast effects associated with positive and negative phase' pressures are shown in Figure 3. [3]

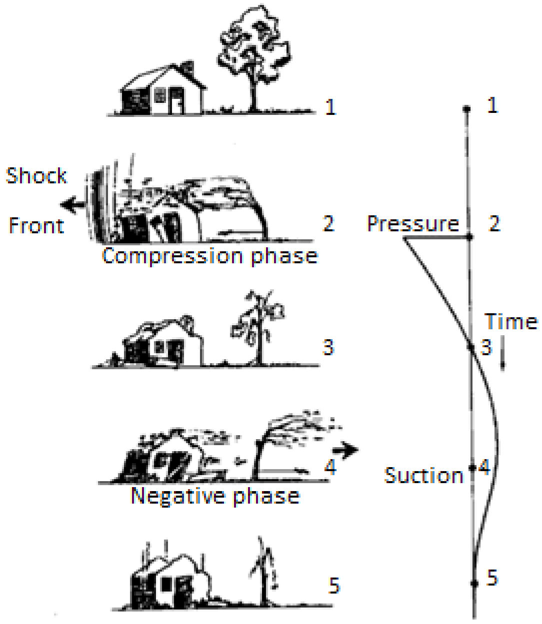

Fig. 3 Variations of Blast Effects Associated with Positive and Negative Phase Pressures with Time [3]

4. Blast Loading and the effects to the structures

When a blast wave strikes the surface of a hard target, such as a building, the reflected wave will reinforce the incident wave, and the face of the building will be subjected to overpressures 2 to 8 times that of the incident wave alone. The severity of this additional stress depends on many factors, including the peak overpressure of the incident blast wave, as well as the angle at which the wave strikes the building. As the shock front advances, it bends or diffracts around the building, and the pressure on the front wall decreases rapidly. [3]

Fig. 4 Effects of the blast wave on a typical wood framed house [4]

However, during the brief interval in which the blast wave has not yet engulfed the entire structure, a considerable pressure gradient exists from front to rear that places a severe stress on the building. For small objects, this period of so-called diffraction loading is so small that no significant stress is encountered. For large buildings, however, the stress of diffraction loading will be considerable. Even after the shock front has passed across the building, the structure will still be subjected to a severe compression force and to severe drag forces from the transient winds. The actual overpressures required to produce severe damage to diffraction sensitive targets are actually quite low. Table 1 depicts failure of sensitive structural elements when exposed to overpressure blast loading. [3]

Structural element	**Failure**	**Approximate side-on peak overpressure [kPa]**
Glass windows	Shattering usually, occasional frame failure	3.45 – 6.9
Corrugated asbestos siding	Shattering	6.9 – 13.8
Corrugated steel or aluminum paneling	Connection failure followed by buckling	6.9 – 13.8
Brick wall panel, 20 cm thick (not reinforced)	Shearing and flexure failures	20.7 – 69.0
Wood siding panels, standard house construction	Usually failure occurs at the main connections, allowing a whole panel to be blown in	6.9 – 13.8
Concrete or cinder-block wall panels, 28 cm or 30 cm thick (not reinforced)	Shattering of the wall	10.35 – 38.0

Tab. 1 Failure of Overpressure Sensitive Structural elements [3]

5. The character of personal injury caused by blast wave

Usually there are three categories of personal injury which are determined by the mechanism of injury:

The first category is the primary damage caused by the direct effects of blast wave, where there are numerous fatal injuries due to bleeding into the lungs. If the external pressure greater than the internal pressure in the body, chest is going to squeezes in. It leads to contusions of internal organs, or even internal bleeding. The most common immediate effect of injury due to blast wave is the rupture of eardrum. The eardrum is damaged due to pressure, because the characteristic period of vibration of ear organs is smaller than the duration of blast wave.

The second category is defined by secondary damage caused by flying fragments from the explosion epicenter. Injuries caused by fragments are lacerations and penetrations. Cutting pieces are often light (with the weight of 10 grams or less) they are often made of glass shards and other sharp splinters. Large objects are more dangerous because of causing huge internal injuries. It is not theoretically possible to predict the probability or magnitude of the injury due to the effusion of flying fragments.

The third category is characterized by injuries that were caused by a man collision with an obstacle due to throwing person by the blast wave. This can happens during the positive and negative pressure phase. The most significant injuries occur when the person is at the moment of explosion in the standing position.

To estimate the probability of death due to blast wave is used so-called method "probit function" (equation). It is used in risk analysis to estimate the physiological consequences of the blast wave. The experimentally observed effects of explosions and the respective values of overpressure blast wave are presented in the Table 2.

The size of blast wave [kPa]	Impact to the human body
16.5	1% Eardrum damage
19.3	10% Eardrum damage
34.5	50% Eardrum damage
43.5	Lung damage
100	1% Death
121	10% Death
141	50% Death
176	90% Death
200	100% Death

Tab. 2 Failure of Overpressure Human body [2]

6. The simulation of the blast wave and its use for military

For detecting the effects of blast waves is advantageous to use software from ANSYS Inc. For this reason, the article is focused on using software such as ANSYS Workbench platform, and ANSYS AUTODYN as software which is supplied as an integral part of the ANSYS Workbench environment.

ANSYS Workbench

The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex multi-physics analyses with drag-and-drop simplicity.

With bi-directional CAD connectivity, powerful highly-automated meshing, a project-level update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS Workbench platform delivers unprecedented productivity, enabling Simulation Driven Product Development. [5]

ANSYS Autodyn

ANSYS AUTODYN is an explicit analysis tool for modeling nonlinear dynamics of solids, fluids, gas, and their interaction.

With a fully integrated, easy to use graphical interface allowing set up, running, and post processing of problems, ANSYS AUTODYN offers:

- Finite elements (FE) solvers for computational structural dynamics;
- Finite volume solvers for fast transient Computational Fluid Dynamics (CFD);
- Mesh-free particle solvers for high velocities, large deformation, and fragmentation (Smoothed-particle hydrodynamic - SPH);
- Multi-solver coupling for multi-physics solutions including coupling between FE, CFD and SPH;
- A wide suite of materials models incorporating constitutive response and coupled thermodynamics;
- Serial and parallel computation on shared and distributed memory systems. [6]

ANSYS AUTODYN has been used in a vast array of projects and nonlinear phenomena. It is also possible to use it effectively for building protection measures and insurance risk assessment for blast effects in military bases.

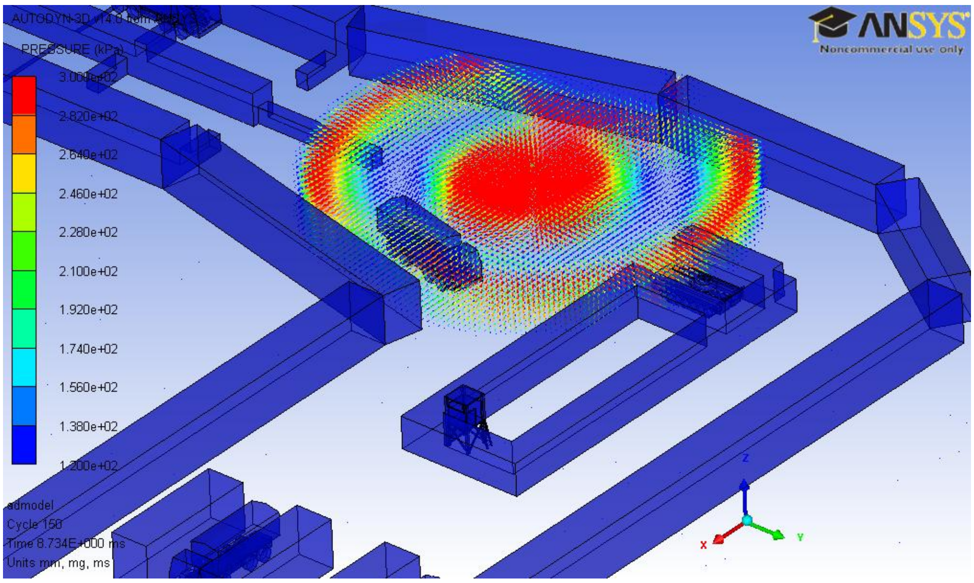

Fig. 5 ANSYS software: The demonstration of the vectors of the spreading blast wave[1]

7. Conclusion

In the present time the terrorism is currently one of the most widely threats of the present century. Its strength consists in the way of fighting which is realized by terrorists. It is important to understand that the loss of human lives and material is not primarily threat to the troops serving in foreign missions. The most significant fact is permanent threat resulting from the principle of terrorism – to feel every time in the danger of death.

This threat is achieved by continual terrorist attacks, which are aimed to the military bases and realized by huge load of explosives placed in the van. The article is aimed to familiarize the reader with the characteristic of blast wave, its spreading and possibilities of ANSYS Autodyn software which is used to evaluate the explosions. With the knowledge of spreading the blast wave it is easier to design the main parts of military base like entrance, headquarter, ammunition depot etc. It is necessary to understand that all the soldiers are serving in hostile conditions for several months. For this reason the defense of military bases should be one of the highest priorities of every army.

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