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Influence of the Shape of Explosive Charge on the Blast Wave Propagation

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Abstract. For several decades, a blast wave due to explosive detonation has been investigated extensively. Base on a significant amount of experimental data, the blast wave propagation has been predicted at specific conditions. However, only spherical shape of explosive has been considered in most studies. Recently, it was noted that the shape of explosive influences the blast wave propagation significantly. In this study, a finite element analysis was carried out to investigate the effect of the shape of explosive on the blast wave propagation. Two different shapes of explosive were compared in blast wave propagation; spherical and cylindrical shape. It was found that the spherical and cylindrical shape blast show different characteristics in the blast wave propagation. The spherical blast showed the isotropic wave propagation as verified by experimental data. However, the cylindrical blast showed more concentrated and faster propagation in the axial direction.

1 Introduction

In defense industry, the effects of explosive blast have been an important issue to address. A considerable amount of research was performed on the blast wave propagation due to explosive blast. There are many parameters which affect the blast wave propagation due to explosive blast. The medium where the explosive is detonated is one of the most important parameters [1].

From early stage of investigating the explosive blast, only spherical shape of explosive was investigated in terms of the pressure, impulse, arrival time and other parameters [2]. Although these empirical data enabled predicting the blast phenomena, the shape of explosive influences the blast wave propagation considerably [3,4].

Due to the lack of experimental data on various explosive shapes, a finite element analysis has been used to predict the blast wave propagation. With the aid of the computer, it is possible to calculate complex equations fast and efficiently. There are three methods to discrete meshes: Lagrangian, Eulerian and Arbitrary Eulereian Lagrangian(ALE). Each method has its own advantages in calculating the behaviour of solid structures or gas flows [5].

In this study, two different shapes of explosive were simulated by using a finite element analysis to investigate the influence of the shape of explosive charge on the blast wave propagation.

2 Free Air Blast

From the empirical data, researchers have found the fundamental parameters which explain the blast wave propagation due to the detonation of explosives such as TNT. Fig. 1 show the blast pressure pulse with relevant parameters [6].

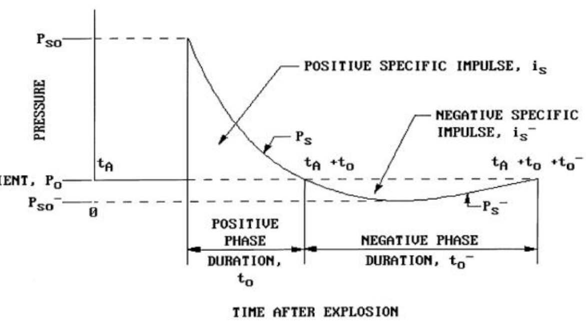

Figure 1. Blast pressure pulse [6].

From the ambient pressure, P_o, pressure increases rapidly to the peak pressure, P_{so} as the explosion pressure arrives. After the pressure reaches the peak value, pressure drops to ambient value. The time from the peak pressure to the ambient pressure is called a positive duration time. Subsequently, pressure drops to the negative value and restores to the ambient pressure. The time between these two points is called a negative duration time. The critical damage is mostly from a positive phase. However, a negative phase is also important in specific material [7]. The TNT shape influences the blast wave propagation. Hence, two different shapes of TNT are analysed to investigate the effect of TNT shape on the blast wave propagation. Fig. 2 shows two different shapes of TNT.

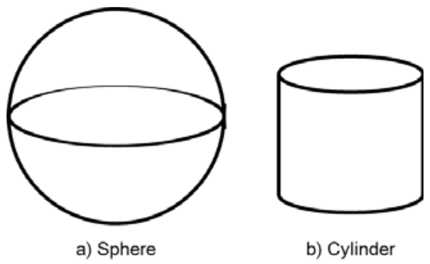

Figure 2. Two different shape of TNT

3 Simulation Setup

Fig. 3 shows the two different shapes of explosive model inside the medium area. 500mm x 500mm x 500mm of medium area (air) were generated by using 20mm mesh size. Both spherical and cylindrical explosives have a 1 kg of TNT equivalent mass. For TNT, Jones-Wilkins-Lee (JWL) equation of state (EOS) is used. See Eq. 1 where A, B, R_1, R_2 and ω are parameters for the JWL equation. The input parameters for TNT are shown in Table 1. All units are in mm, kg and ms.

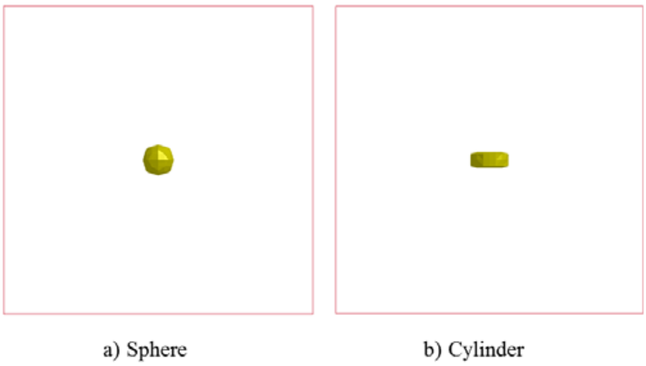

Figure 3. Shapes of explosive

The EOS for air is a linear polynomial. See Eq. 2 where C_0 to C_6 are coefficients for air. In case of ideal gas, C_4 and C_5 are 0.4, while the other coefficients are 0 [5]. The input parameters for air are shown in Table 2. All units are in mm, kg and ms.

4 Results

Fig. 4 shows the simulation results. Fig. 4a shows the initial stage of two different explosive model; spherical and cylindrical shapes in a quarter size. Each explosive contains 1 kg of TNT equivalent mass.

After detonation, the difference in pressure propagation is shown in Fig. 4b. The spherical blast shows the isotropic pressure propagation from the detonation point. However, the cylindrical blast shows a different trend. After detonation, the pressure propagates faster in the radial direction than the axial direction.

As the pressure propagates, this difference becomes more significant as shown in Fig. 4c. At 0.16 ms, the pressure propagation of the spherical explosive still shows the isotropic propagation, while that of the cylindrical explosive shows a significant difference between the radial and axial directions.

Fig. 5 shows the incident pressure distribution at a distance of 400mm from the detonation point. For the spherical blast, the pressure distribution is identical in the x and y directions. However, for the cylindrical blast, the pressure distribution shows a difference between the two directions. The pressure in the axial direction shows a larger peak pressure than the pressure in the radial direction. The peak pressure in the axial direction is 2.12 MPa, while the peak pressure in the radial direction is 1.62 MPa, which is same as the peak pressure in the x and y directions for the spherical blast.

$$P = A\left(1 - \frac{\omega}{R_1 V}\right) e^{-R_1 V} + B\left(1 - \frac{\omega}{R_2 V}\right) e^{-R_2 V} + \frac{\omega E}{V} \quad (1)$$

$$P = C_0 + C_1\mu + C_2\mu^2 + C_3\mu^3 + (C_4 + C_5\mu + C_6\mu^2)E \quad (2)$$

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Table 1 Input parameters for TNT

Density	Detonation velocity	Chapman Jouget pressure				
1.658 x 10^{-6}	6930.0	21.0				
A	B	R_1	R_2	ω	E_0	V_0
373.76	3.7347	4.15	0.9	0.35	7.0	1.0

Table 2 Input parameters for air

Density	E_0	V_0				
1.2 x 10^{-9}	2.5 x 10^{-4}	1.0				
C_0	C_1	C_2	C_3	C_4	C_5	C_6
0.0	0.0	0.0	0.0	0.4	0.4	0.0

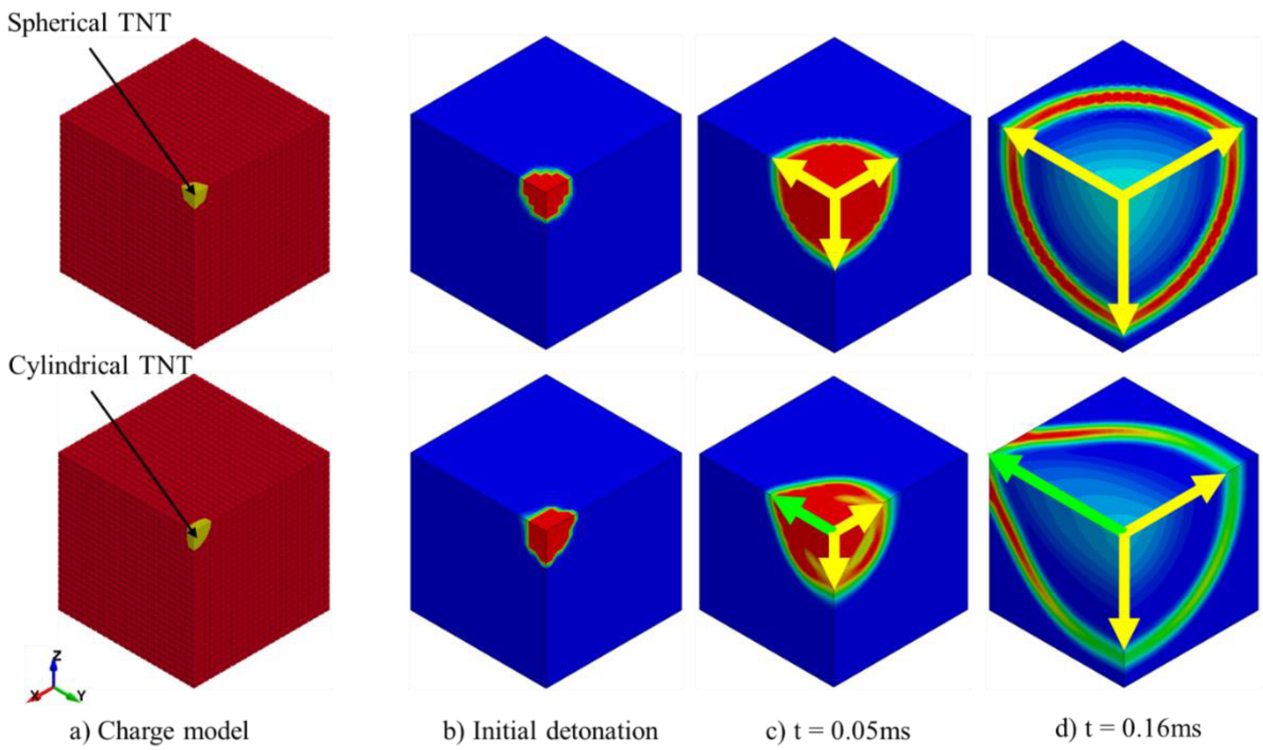

Figure 4. A quarter model of two explosive shapes and pressure propagations

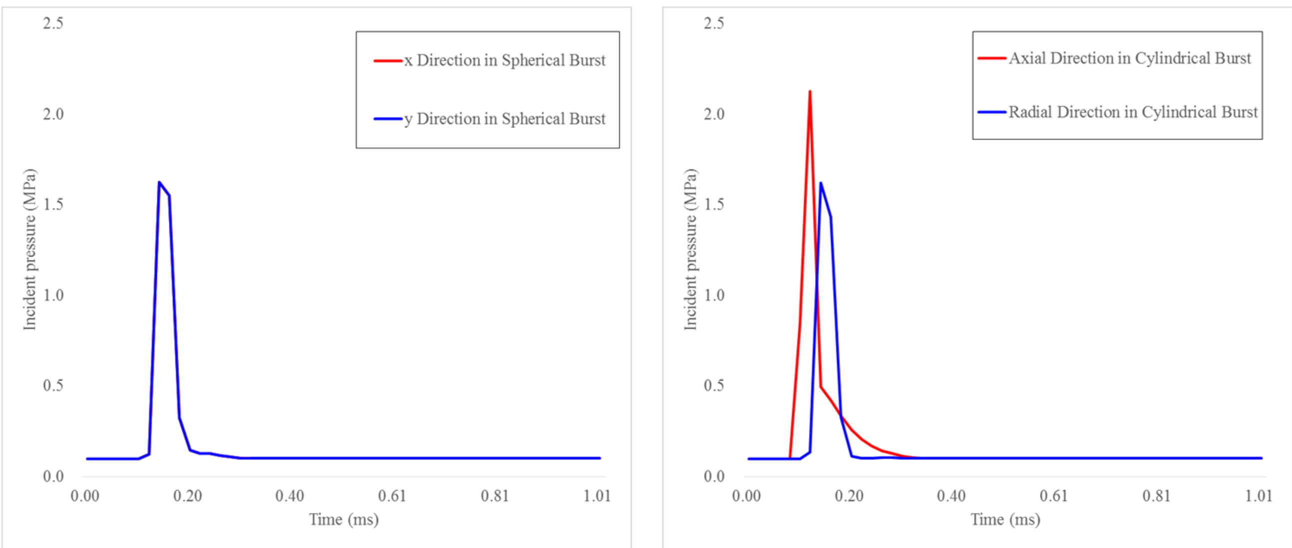

Figure 5. Incident pressure distribution at a distance of 400mm from detonation point

5 Summary

Two different shapes of explosive were simulated with an equal explosive weight. The results showed the difference in the blast wave propagation between the spherical and cylindrical shapes of explosive. The spherical blast showed the identical wave propagation in all directions. However, the cylindrical blast showed a different wave propagation depending on the direction. The pressure propagated faster and more concentrated in the axial direction than the radial direction.

For the spherical blast, the peak pressure values in the x and y directions were the same. For the cylindrical blast, the peak pressure value in the axial direction was larger than that in the radial direction. Consequently, it is conceivable that the influence of cylindrical blast is more significant in the axial direction than the radial direction, while the influence of the spherical explosive is isotropic.

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