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COMPARISON OF BLAST PRESSURE PROFILE FOR MILITARY AND COMMERCIAL EXPLOSIVE WITH DIFFERENT POINT OF INITIATION

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Abstract

A blast wave profile caused by an explosive explosion has been thoroughly studied for several decades. The propagation profile of the blast wave under circumstances has been predicted based on a sizable amount of experimental data. However, most investigations have merely considered the explosive's centre point of initiation. In this study, the goal has been designed to compare the detonation velocities of commercial explosive (Emulex) and military explosive (PE-4), as well as to examine how different initiation points for the two types of explosives affects the blast peak overpressure value. Three points of initiation have been set to each charge which is top, centre and bottom. Experimentally, 500 g of PE-4 and 500g of Emulex were hung in the air and detonated at 1.2 metres above the ground. At various distances of 0.5 m, 1.0 m, 1.5 m, 2.0 m, 2.5 m, 3.0 m, 3.5 m, and 4.0 m, pencil probes were set pointing at the explosive to capture the data from the explosion. With high accuracy of high-speed data acquisition system (DAQ) and free field pencil probe at each distance, the blast peak overpressure was recorded. In this experiment, the fibre optic cable technology was used to measure the detonation velocity (VOD) for each explosive to validate the strength of the explosive before the blast took place. From the reading, the PE-4 was measured at 8,400 m/s whereas 5117 m/s for Emulex. The findings indicate that the PE-4 has a higher detonation velocity compared to Emulex. During the experiment, each explosive's peak overpressure has been recorded. The PE-4 explosives produced the highest among all with a top point initiation of 4.21 MPa. With respect to the commercial explosive Emulex, the highest pressure of 3.12 MPa has been recorded also at the top point of initiation. The findings demonstrate that for both types of explosives, the top point of initiation produces the largest peak overpressure, followed by the bottom point, while the centre point of the explosion recorded the lowest peak over pressure.

Keywords: Blast profile, Commercial explosive (Emulex), Military explosive (PE-4), Peak overpressure, Point of initiation.

1. Introduction

An explosive is described as a mixture of solid, gaseous, or liquid substances that can quickly undergo a chemical reaction and release a significant quantity of energy [1]. Explosives are materials that have an oxidizer and fuel that, when they react, produce a significant quantity of potential energy. The explosion's energy was lost as a blast wave, gas, and heat. Nitrogen, carbon monoxide, carbon dioxide, and nitrogen oxides are the gases produced when an explosive detonates. Typically, an explosive is used to reduce the size of rocks so that they can be used as gravel for concrete or asphalt roads. By detonating tanks, shells, and bombs, explosives can also be utilised in military operations during conflict to protect the nation against foreign incursions. According to Fig. 1, explosives can be divided into high and low explosives. Primary high and secondary high explosives are further categories for high explosives. Under the category of secondary high explosives are both commercial and military explosives.

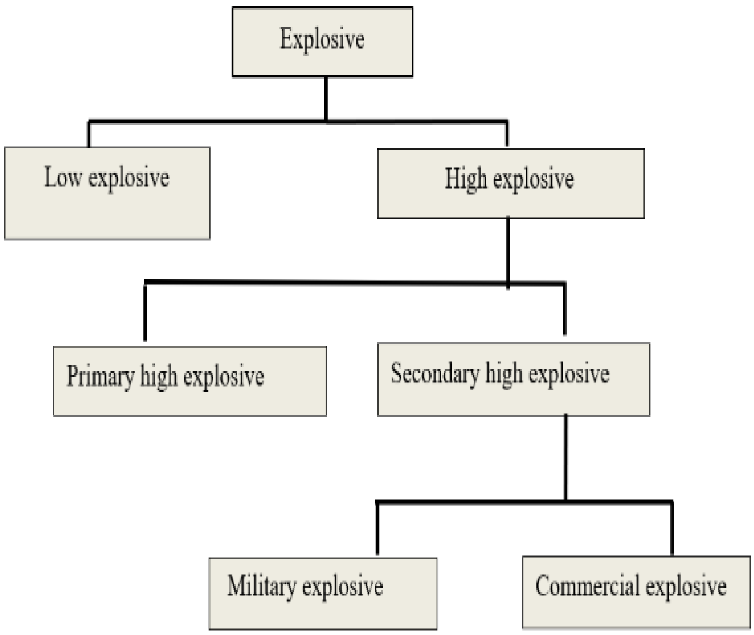

Fig. 1. Explosive classification [2].

Military explosives are frequently used in bombs, warheads, and demolitions. These explosives are extremely stable and unaffected by friction, heat, or shock. They may be used in a variety of temperature and environmental conditions and have a long self-life, high density, high detonation velocity, good storage capabilities, and long self-life. The most often used explosives in the military include TNT, C-4, RDX, HMX, PETN, and PE-4 [3]. A type of military explosive known as plastic explosive (PE-4) is white solid and has a consistency akin to modelling clay. It is easily sculpted into any desired shape. The British Army refers to it as PE-4, and the American armed forces refer to it as C-4. This explosive has RDX as the primary component and plasticizer in a 91% concentration. PE-4 is extremely stable and unaffected by most physical shocks. When ignited or exposed to microwave radiation, it does not explode. It can only explode when a detonator is used. Nitrogen and carbon oxides, as well as other gases, will be released during the detonation of PE-4. It is frequently used to cut steel, wood, destroy concrete structures, and perform demolition work. It has a detonation velocity of 8,092 m/s [4].

Ammonium nitrate and fuel are combined to create commercial explosives. Compared to military explosives, they detonate with a lower velocity. Commercial explosives are frequently employed in the tunnelling, civil engineering, mining, and quarrying industries. Commercial explosives include ANFO, emulsion explosive, slurry, and water gel, as examples. Egly and Neckar created the emulsion explosive in 1964 [3]. Ammonium nitrate, water, fuel, waxes, emulsifiers, and hollow particles like glass micro balloons, resin-based materials, or perlite as a sensitizer are all components of an emulsion explosive [5]. Its high detonation velocity, which is 6,000 m/s, is greater than ANFO's. Most of this explosive is utilised in mining, tunnelling, and rock blasting operations.

Emulsion explosive, a water-resistant explosive, solves the issue that ANFO has in a wet environment. Emulex, which was employed in this experiment, is a typical instance of an emulsion explosive. Detonators are typically used to ignite high explosive. Alfred Noble created the detonator for the first time in 1864 [6]. There are several different kinds of detonators on the market, including conventional, electric, and electronic detonators. Electric detonators are the most often used detonators, and they are typically inserted in the primary explosive's centre to start the secondary explosion. The detonator's placement inside the secondary explosive is referred to as the site of initiation as seen in Fig. 2.

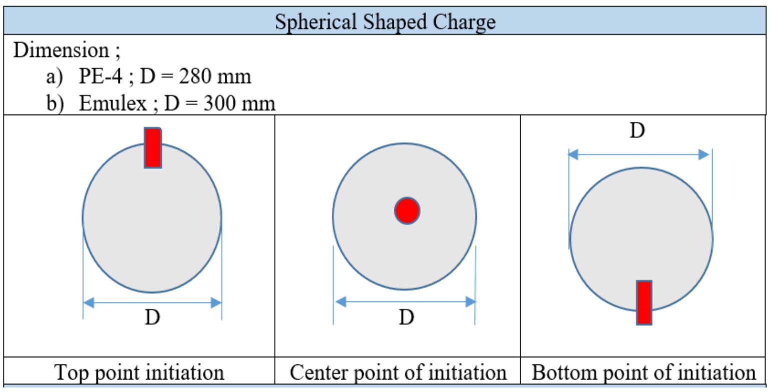

Fig. 2. Point of detonation.

When an explosive is detonated, a large explosion occurs at a temperature of between 3,000 - 4,000 ^{o}C, releasing gases including carbon monoxide and nitrogen oxide as well as high-pressure waves of up to 30 GPa [7]. Figure 3 depicts this pressure wave, also referred to as a blast wave and moving at the speed of sound.

The idealised pressure-time history profile illustrated in Fig. 4 can be used to depict the blast wave that results from the explosion of an explosive.

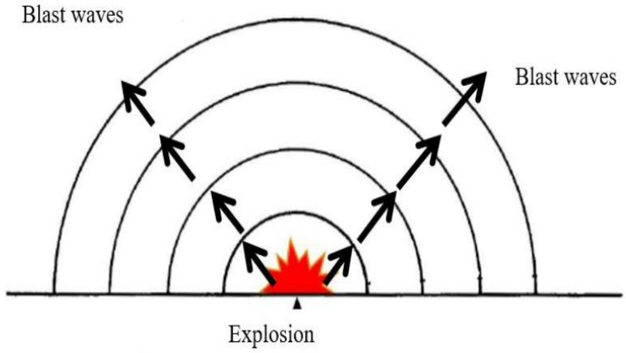

Fig. 3. Illustration of blast wave profile from an explosion [2].

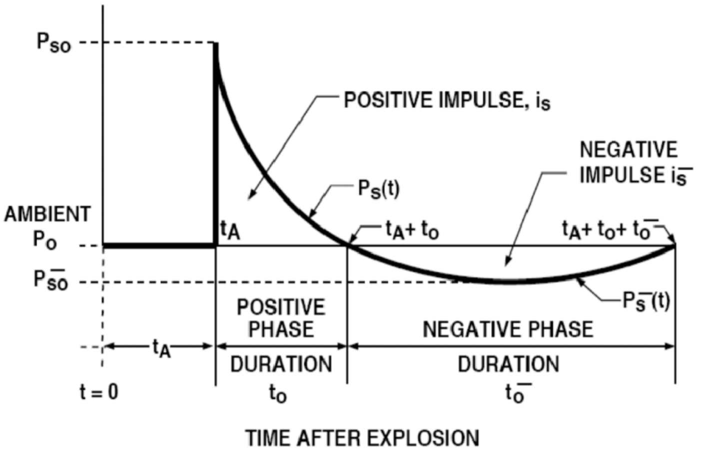

Fig. 4. Illustration of blast wave profile from an explosion [2].

A good indicator of the explosive's performance is its detonation velocity. It is regarded as a crucial indicator of the detonation's total energy or force, and more specifically of the brisance or shattering effects. For instance, low explosives like black powder have modest detonation velocities between 600 and 1,000 m/s. TNT, PETN, RDX, and C-4, on the other hand, have high detonation velocities that range from 1,000 m/s to 9,000 m/s. The velocity of detonation of an explosive can be determined using the Dautriche method, the photographic method, and the fibre optic cable method, claim in [8, 9].

According to Cai et al. [10], the point of detonation significantly affects the distribution of overpressure. Other experiments revealed that the geographical distribution of overpressure will be influenced by the site of detonation within the explosive, particularly for cylinder shapes. The spatial distribution of overpressure will also be influenced by the explosive's point of detonation, particularly for cylindrical charges. Because the detonator and booster charge were attached to the end of the cylindrical charge, the pressure distribution in the near field was highly irregular [10, 11]. Peak overpressure, impulse, and time of arrival are only a few of the elements that may have an impact on the blast parameter [12]. The emulsion explosive was used in the experiment along with two cylindrical charges that were each slightly different in shape, as well as a spherical charge. In this experiment, the maximum overpressure of a centrally initiated cylindrical emulsion explosive was compared to that of a sphere-shaped charge at the same distance and distance of 1,100 mm. The charges have a scale distance of 0.79 $mkg^{-1/3}$ to 1.5 $mkg^{-1/3}$ with 1.6 kg of mass [13]. All distances have been measured starting at the charge's centre. The findings demonstrate that, in comparison to cylindrical and shaped charges, spherical charges which are centrally initiated create larger peak overpressure [14].

Abdul Rahim et al. [15] and Anas et al. [16] performed a blast test to measure the blast pressure caused by the spherical forms of commercial and military explosives. To evaluate the behaviour of the charges after detonation, the military explosive PE-4 and Emulex, a commercial explosive, were both utilised. Investigating the PE4 equivalent of a spherical-shaped explosive at various points of initiation is the goal of this study. During this test, nine (9) military explosive (PE-4) and nine (9) commercial explosive (emulsion) samples totalling 18 explosive samples were evaluated. The charges were tested at a distance of 1.2 m from the ground and each weighed 500 g. To achieve the blast peak pressure result, three (3) points of initiation; the top, middle, and bottom point of initiation along with the charges have been designed. The peak pressure values for PE-4 and Emulex have been computed into a ratio based on the experiment to create the PE-4 comparable to the Emulex.

The goal of this study is to compare the detonation velocities of commercial explosive Emulex and military explosive PE-4, as well as to examine how different initiation points in the two types of explosives affect the blast peak overpressure (Emulex).

2. Methods

Two (2) different types of explosives were examined in this experiment. The first is the plastic explosive used by the military (PE-4) provided by The Malaysian Armed Forces. The commercial explosive known as Emulex was the second type of explosive tested. This kind of explosive is frequently employed in mining and quarrying areas. Tenaga Kimia Sdn. Bhd., a small explosive manufacturer in Malaysia, was the source of this explosive. Figures 5 and 6 show samples of commercial explosive (Emulex) and military explosive (PE-4) respectively.

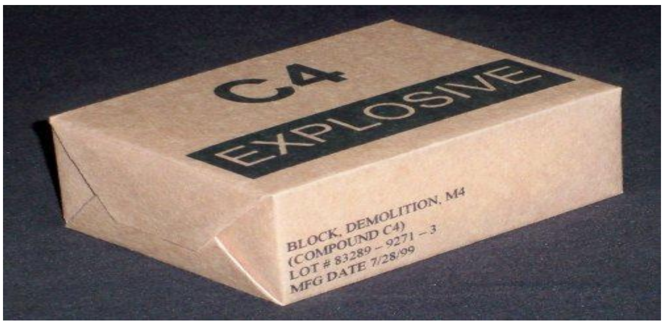

Fig. 5. Military explosive (PE-4).

Fig. 6. Commercial explosive (Emulex).

At the Malaysian Army Camp, a field blast test was carried out. The charges have been experimental by conducting a free air blast test to each charge. First, to make sure the explosive utilised in this experiment is in good condition and stable, the detonation velocity of commercial and military explosives was determined by using the fibre optic cables and the detonation velocity will be recorded by VOD metre. Secondly, the spherical shape charges were moulded from both materials (Emulex and PE-4). After that, these explosives were blasted by placing the detonator at the top, middle, and bottom of the charge, respectively. Pencil pressure probes placed at eight different locations, ranging from 0.5 to 4.0 metres from the explosive's centre, were used to measure the peak overpressure. In Fig. 7, the experimental flowchart is displayed.

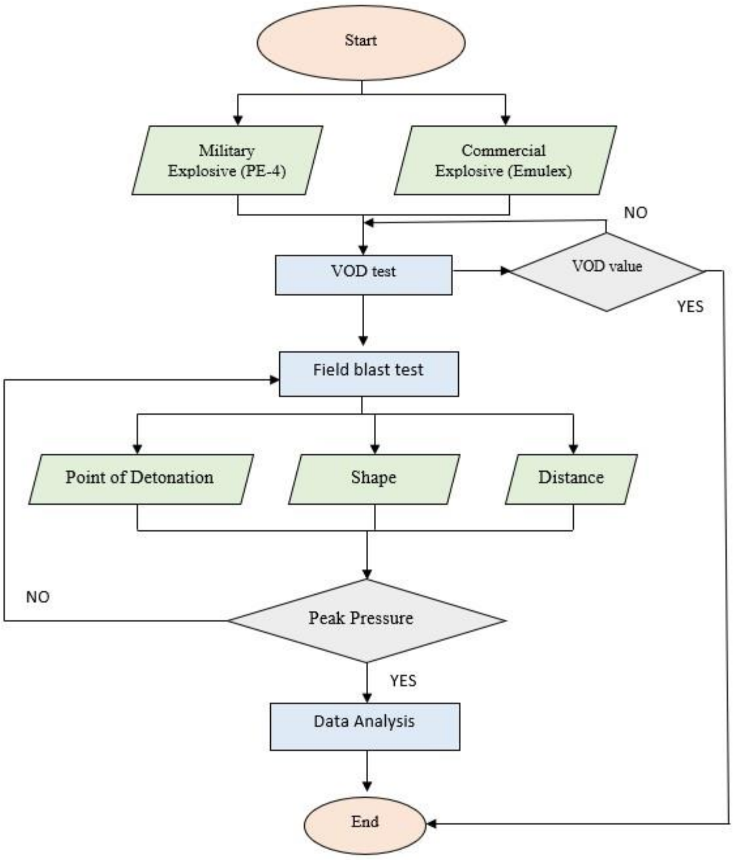

Fig. 7. Experimental flow chart.

To evaluate the explosive's detonation velocity, a total of six (6) samples, three (3) commercial explosives and three (3) military explosives were detonated. The explosive's detonation velocity was measured using a VOD metre by connecting the fibre optic cable to the charge. The explosion wave front's accompanying light signal is detected and transmitted using optical fibre cables in this technique. In this measurement technique, the first cable initiates the timing clock while the second cable, which is situated at a known fixed distance, stops it. The detonation velocity value is calculated by dividing the fixed distance between probes by the total time recorded. Figure 8 depicts the fibre optic detonation velocity testing method.

Fig. 8. Detonation velocity testing using fiber optic cables [2].

To examine the impact of the blast peak overpressure due to varied points of initiation in military explosive (PE-4) and commercial explosive, a total of 12 samples of explosive were evaluated (Emulex). This includes six samples of PE-4 and an additional six samples of Emulex. This explosive was moulded into spherical shapes using a custom-made 300 mm diameter plastic mould. Electrical detonators, which are inserted at the top, centre, and bottom of the explosive, were used to detonate this device. Figure 9 displays a picture of many points of start. Table 1 displays the sample size and detonation point information.

(a) Centre **(b) Top** **(c) Bottom**

Fig. 9. The point of initiation for spherical charge of explosive.

Table 1. Explosive samples in between 0.5 to 4.0 meters.

No.	Material	Shape	Point of Initiation	Number of Sample
1.	PE-4	Sphere	Top	2
2.		D = 280 mm	Centre	2
3.			Bottom	2
4.	Emulex	Sphere	Top	2
5.		D = 300 mm	Centre	2
6.			Bottom	2

To hold the explosive charge, a wooden support structure was built. To make sure that there is no reflection from the dirt interfering with the recorded pressure, the entire charge was positioned at a height of 1.2 m above the ground. Eight (8) pencil probes, ranging in height from 0.5 to 4.0 metres, have been placed on the scene to record the explosion's peak pressure. In Fig. 10, the field blast test setup is depicted.

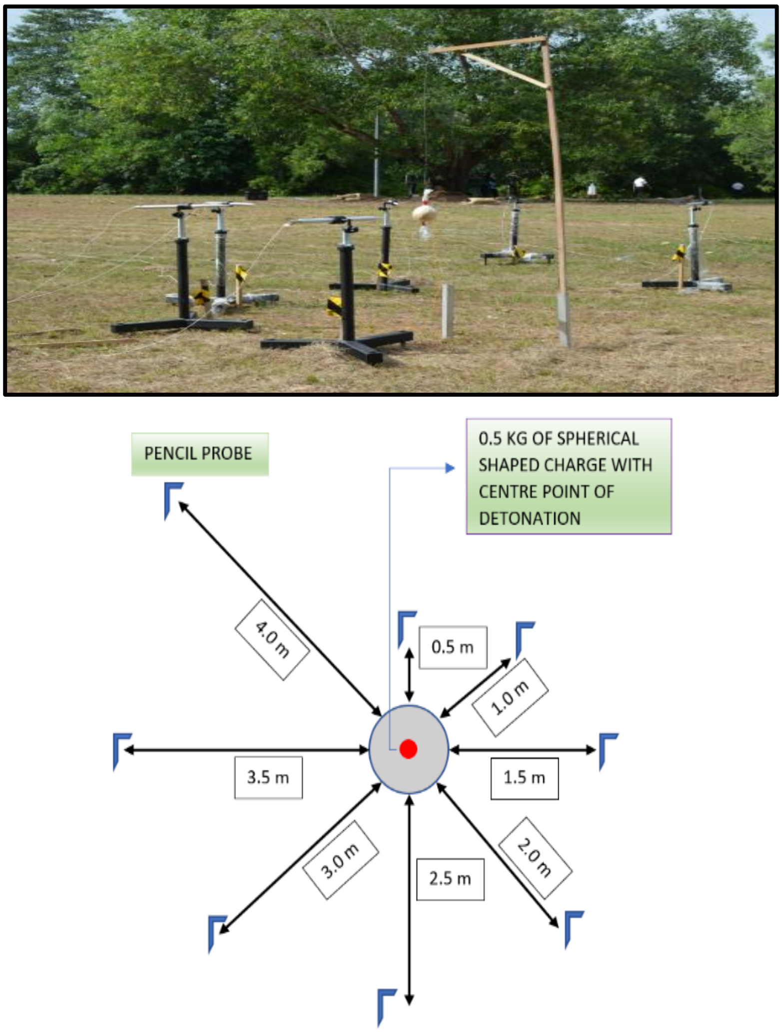

Fig. 10. Field blast test setup.

3.Results and Discussion

Emulex has a detonation velocity of 5,117 m/s, while PE-4's detonation velocity was measured at 8,400 m/s. The findings indicate that compared to commercial explosive, military explosive has a higher detonation velocity. This is because the combination of high-energy materials in PE-4, such as RDX, react much more quickly and detonate, producing higher energy for shuttering in comparison to Emulex, which is made of a combination of ammonium nitrate, which reacts more slowly and produces an explosive with a lower detonation velocity.

The pressure distribution for this test is presented in Fig. 11. Figure 11 shows the distribution of peak pressure for Emulex Spherical Shaped charge over distance. It shows the graph pattern for top, centre, and bottom point of initiation for a spherical shaped charge of explosive. According to the graph at the distance of 0.5m, the highest pressure has been recorded and the wave rapidly reduces after it reaches the peak level of the explosion. This phenomenon is usually called the positive phase of an explosion where the explosion produces strong heat and fireballs. As the distance increases, the wave drops down to zero gradually until the negative level. The highest peak pressure produced by this spherical charge of commercial explosive is 3.181 MPa from the top point of initiation.

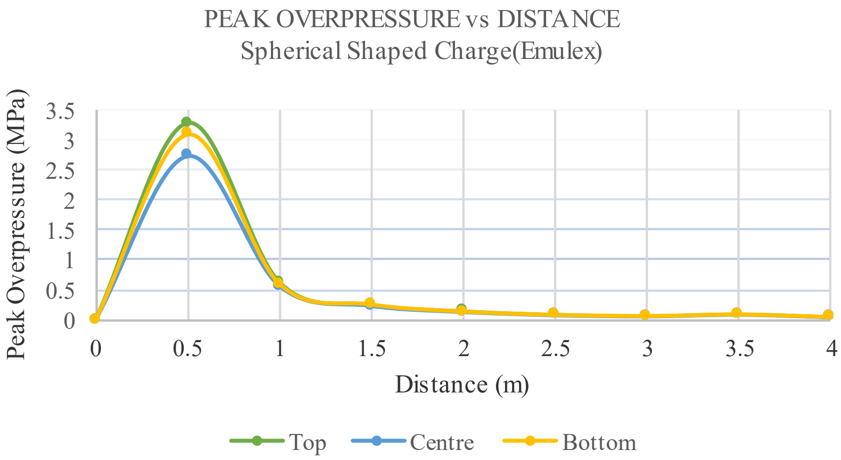

Fig. 11. Peak overpressure for emulsion explosive over the distance from 0.5 m to 4.0 m.

Figure 12 displays the outcomes for spherical military explosives. The result has been tabulated from the figure using the specified distances of 0.5 metres to 4.0 metres. Even though there is a slight variation between each position, the centre point produced the lowest value of all. The pressure distribution of the PE-4 spherical shape charge for the top, centre, and bottom point of initiation is clearly trending downward in Fig. 12. 4.216 MPa has been recorded as the highest peak overpressure value for top point initiation. The graph shows the pressure values at the top, middle, and bottom points of initiation, with the top point of initiation recording the exceptional reading. Typically, compared to hemispherical and cylindrical shapes of explosives of the same type, spherical explosives will have the lowest pressure. However, because PE-4 explosives are classified as high explosives, they produce more pressure than Emulex for the same shape.

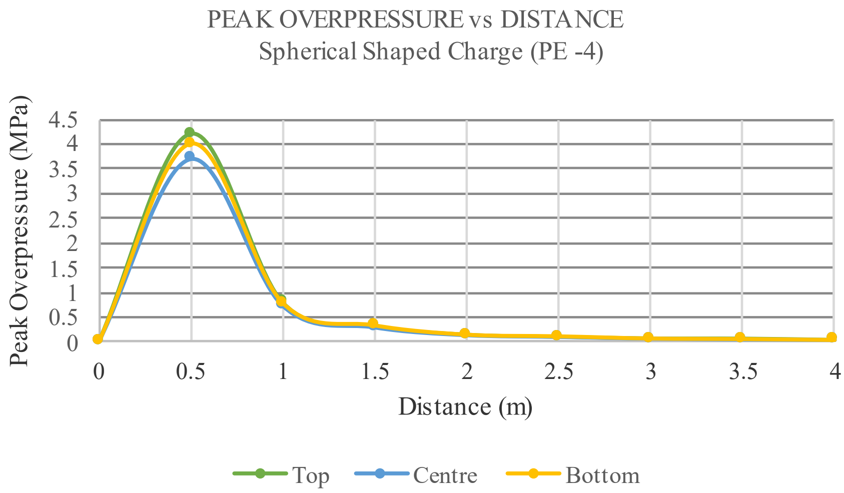

Fig. 12. Peak overpressure for PE-4 over the distance from 0.5 m to 4.0 m.

4. Conclusions

According to the test results, Emulex's detonation velocity was measured at 5,117 m/s, which is within the typical range for commercial explosives of 3,660 m/s to 5,100 m/s. On the other hand, PE-4's detonation velocity was 8,406 m/s, which is within the acceptable range for military explosives of 7,000 m/s to 10,100 m/s. Each explosive's peak overpressure has been measured, and the military explosive PE-4, which is spherical, produced the highest of all with a top point initiation of 4.21 MPa. With respect to the commercial explosive Emulex, the highest pressure of 3.12 MPa was likewise measured at the top point of initiation. According to the findings, both types of explosives produce their largest peak overpressure at the top point of initiation. follow with the bottom initiation point, with the explosive's centre experiencing the lowest pressure. From the reading, the percentage of difference between these two types of explosives was about 20%. Hence, in order to produce the same amount of pressure by using PE-4, about 1.3 kg of Emulex is needed to have the same peak pressure as 1 kg of PE-4.

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