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Safety and performance for different high explosives in oil mining industry

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Abstract: Several explosives have been tested numerically to study their effect and performance of the produced jet characteristics and predicted jet penetration into concrete target material. The velocity of the jet has been determined for different explosives as TNT, cyclotol, RDX, HMX, PETN and LX-17 which have been used in this research as a shaped charge oil well perforator, where the Autodyn hydrocode has been implemented with the jetting analysis solver and jet penetration to estimate both the jetting output data and the relevant penetration depth for these studied explosives. Results show that HMX explosive exhibiting the highest detonation velocity, has the largest hole penetrated into Concrete 26 MPa target. The relative jet tip velocity to the Gurney characteristic velocity in (m/sec) of an explosive has been found to be around 2.5 for the used explosive charges, whereas the scaled jet tip velocity to the detonation velocity of an explosive has been found to be one for the studied six explosives. ICT code is used for calculating the explosion heat and this result obtained are used for calculate the equivalent weight and shock factors. The resulted data obtained used for prediction the shock factor of 1 kg of explosives at distance equal 1000 m and shows complete reliability and safety for all explosives in underwater mining. The ignition temperature is measured using heating block thermometer DT 400 with raising temperature gradually to 200 □C. also sensitivity to the electrostatic discharge (ESD) using ESD machine operates by generating an electric charge at 5,000 V DC. No initiation results for both tests reveals the complete safety for 1 kg of shaped charges in underwater environments.

Keywords: Explosives, Shaped charge, Oil well perforator, shock factor.

1. INTRODUCTION

Shaped charges have wide range of application such in civilian applications as Oil industry as oil well perforator, Explosive ordnance disposal, Cautious blasting and demolishing works, Break, crack or form holes in rock, Explosive welding and Generation of transient antennas to countermeasure the use of electromagnetic pulse (EMP) weapons [1]. On the other side, shaped charges are extremely useful for penetrating armor or piercing barriers in the field of military applications. It can be used as a part of torpedoes, missiles or particularly as an anti-tank ammunition. Its military application started from World War II when the so-called hollow charge projectiles were proposed. Figure (1) shows schematic drawing of a shaped charge configuration. The shaped charge geometry design and the liner thickness are the most effective parameters governing the performance of a shaped charge [2]. Apart from its cone diameter; conical shaped charge (CSC) liner performance in terms of its breakup time is governed and controlled by various factors [3] as the production method of the liner material, quality of both the inside and the outside surfaces of the copper liner, the adhesive material between copper and high explosive materials, the type of the high explosive, and amount of it as well as other parameters such as the presence of air cavities in the explosive material and any error of the shaped charge elements. Different thermodynamics codes have been developed. Some of the more common include the ICT code, NASA CEA, and HSC. Here we use the ICT code for determine the explosion heat which is the source for calculating the shock factors that represent the safety indication for the explosive used in underwater environment. Another study has been done for comparing different sensitivity values for explosion temperature and electrostatic spark which simulate the more factors affect in underwater environment.

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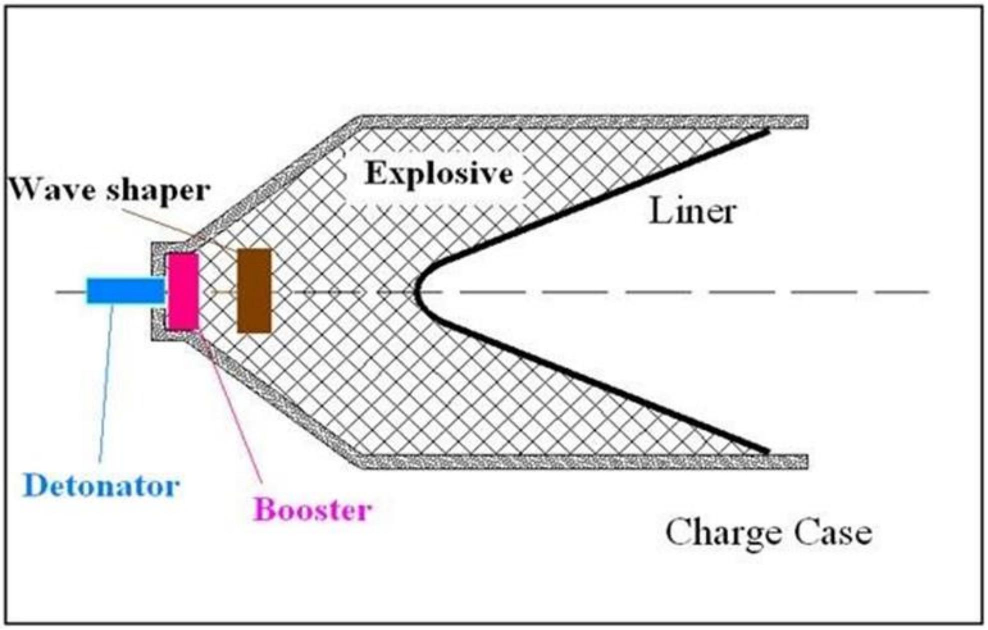

Figure 1; A schematic drawing of a shaped charge configuration.

2. DESCRIPTION OF THE HIGH EXPLOSIVE

It is noted that more energy content of secondary explosives produces more kinetic energy and more penetration ability for different target [4]. The resulted energy from explosion directly related to the constant named Gurney constant for the tested explosives which transferred further to the form of mechanical work. Increasing in the values of the Gurney constant produce more increases in jet velocity. The jet velocity is the more performance parameter controlled the penetration depth and the resultant kinetic energy.
Table 1 illustrates the explosive properties of some high explosives. It is expected that shaped charges filled with HMX, which has the highest Gurney velocity, will produce higher penetration depth, as shown by Tamer and Li (2010) [5]. The input data required to run the ICT program are the percentage and density, heat of formation and the summary formula of each component. Those values were obtained from the library of ICT program and the percentage of each component was chosen to be 100%. The resulted heat of explosion obtained from ICT CODE was shown in table (1).

Table 1: Explosive properties for some high explosives.

Parameter / H.E.	Density ρ (g/cm^3)	Detonation velocity (m/s)	Gurney velocity (m/s)	Calculated Heat of explosion (kJ/kg)	Detonation pressure (GPa)
HMX	1.891	9100	2960	5563	420
LX-14 (HMX/Estane)	1.835	8800	2800	5549	370
RDX	1.73	8489	2870	4128	330
Cyclotol (RDX/TNT)75/25	1.754	8250	2790	5235	320
PETN	1.72	8142	2920	5470	220
TNT	1.6	6913	2390	3671	210

Keshavarz et el (2010) demonstrate the Gurney velocity for Cyclotol, they proved that the Gurney energy V_G of an

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ideal explosive is D/3.08 where D is detonation velocity [6]. It is also known that the penetration depth of the shaped charge jet into concrete material increases with the increase of the amount of high explosive used in the shaped charge, which also causes the increase of the damage of the crushed region around the penetration path [7].
The selection of high explosive in the design of gun perforator is very important for both its performance and sensitivity issues. The temperature of the down-hole can be greater than 260 ^{o}C [8], which should be considered because it is close to the ignition temperatures of some high explosives. Therefore, care should be taken in the design of the main explosive charge and the degree of casing confinement. Comparisons for different explosion temperature for all used explosives produce an indication for the more suitable explosives will be used. Another important issue related to the high explosive filling of the OWP is the manufacturing technique. The explosive density, the presence of air bubbles and cracks inside the explosive also affect the performance of OWP. The explosive should be manufactured under pressing conditions to remove the resulted air bubbles, as shown by Renfre et al (1996) [9].

3. NUMERICAL CALCULATIONS

Numerical simulation is one of the main methods used to study the penetration phenomenon, which can be used to solve nonlinear problems related to impact, penetration, perforation and explosion. It has built-in mathematical models such as shaped charge jetting analysis [10]. Autodyn hydrocode is based on different form of energy equation named state equations and also models (strength model) [11]. The Euler method used for simulating the jet properties at many time intervals. Components including explosive, casing and the materials of the liner are inserted using Euler equations [11]. This simulated process is suitable during early formation of jet and the resulted high strain rate of values 107 s^{-1} [12]. Lagrange method used for penetrations between targets and shaped charges used. The used shaped charge has a conical copper liner of angle 45 degree, a wall thickness of 1.4 mm and a charge caliber of 36.6 mm, while the charge casing is made of steel 4340. The properties of the used copper liner material and the Johnson cook strength model for steel 4340 according to reference [13].

4. RESULTS.

I. Numerical calculations for Autodyn hydrocode

Figure 2 shows the dependence of the jet tip velocity and the Gurney velocity on the explosion heat of the used explosive charge. The relation between the jet tip velocity and the detonation velocity of the explosive is illustrated in Figure 3.

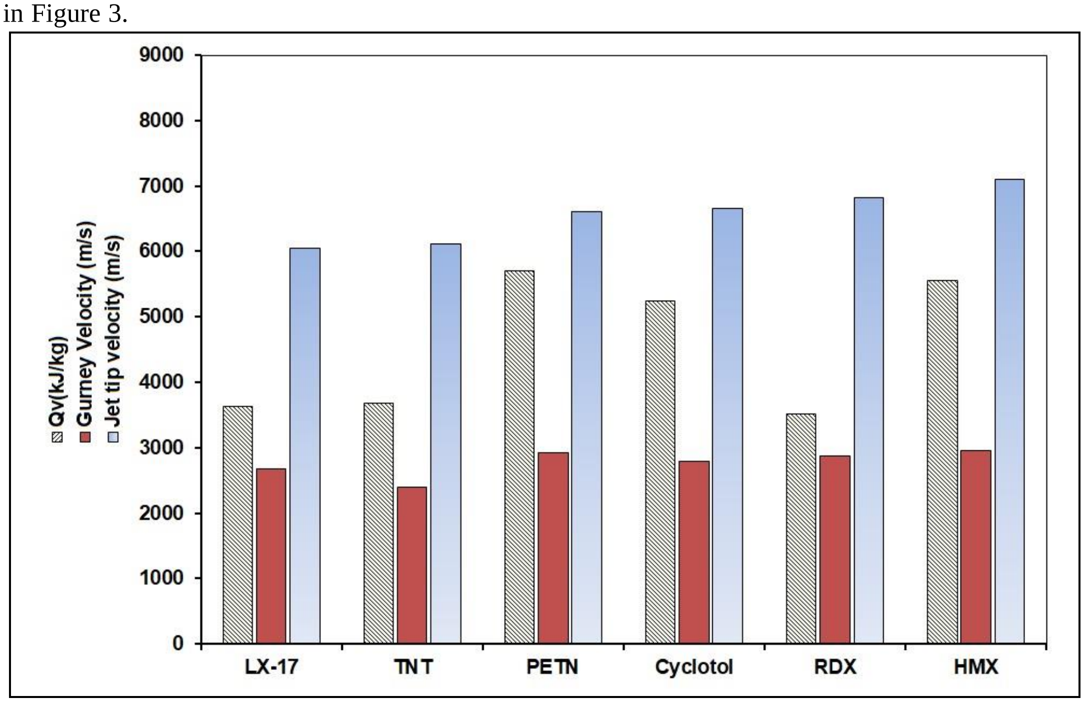

Figure 2: Relation of jet tip velocity and Gurney velocity on the explosion heat **.**

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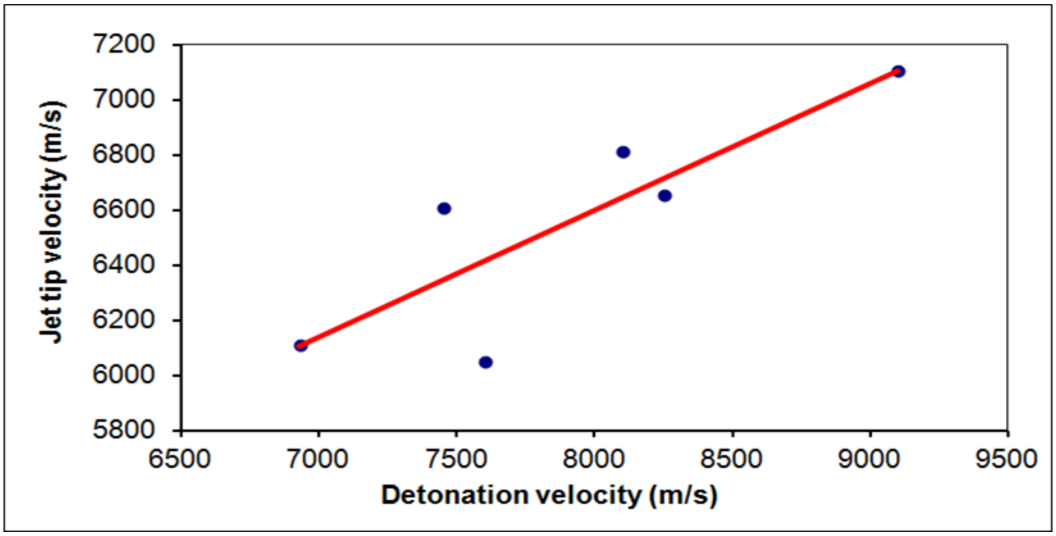

Figure 3: The relation between the jet tip velocity and the detonation velocity of the used explosive.

It shows that the most powerful explosive is HMX, which has a Gurney velocity of 2960m/s and detonation velocity of 9100 m/s.

II. Sensitivity of explosion temperature and electrostatic charge.

The values used during testing of all explosives according to the military standard for explosion temperature and the electrostatic stimulus with various intensities. The explosion temperature test has been performed using different rates. the increasing rate was selected to be 0.1 sec for comparison. No ignitions occur for all tested samples and this verify the standard values for explosives as in figure (4). As shown in figure (4). All explosives have standard measured values above the boiling point of water which indicates its safety during application in the hotter water environments. A sample of all explosives subjected to electrostatic stimulus of various intensities range from 15 mJ to 18 J according to the standard VG-Norm 95378-11. shows no positive evidence (initiation, ignition, spark, noise) for unconfined charge.

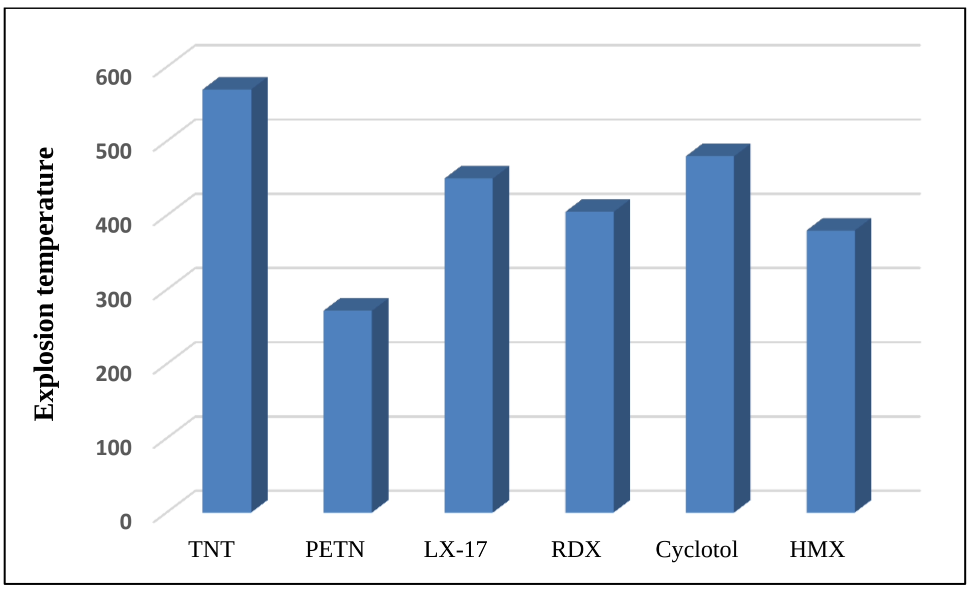

Figure 4: Explosion temperature for different used explosives in shaped charge.

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5. PREDICTIONS OF UNDERWATER EXPLOSIVE PERFORMANCE

Many assumptions for calculating the impact of explosives underwater against different targets like building and ships. Cole empirical equation used to predict the shock pressure for any distance [14-15]. This equation is complicated as it depends on different parameter as which depends on the kind of explosives and needs to calculate the constant which depends on heat of explosion. another simple equation can be used which depends on the equivalent weight of explosives against TNT weight as the following equation.

$$SF\ (exp) = \frac{\sqrt{W}}{R}$$

Where W is the equivalent mass of the explosive (TNT) (Kg) and R is the distance. The value of shock factors < 0.1 represent no effect for explosion against any building or targets. Figure (6) represents the shock factors resulting from the different types of explosives for 1 kg formulation. The results show safety environments during underwater operation for oil industry.

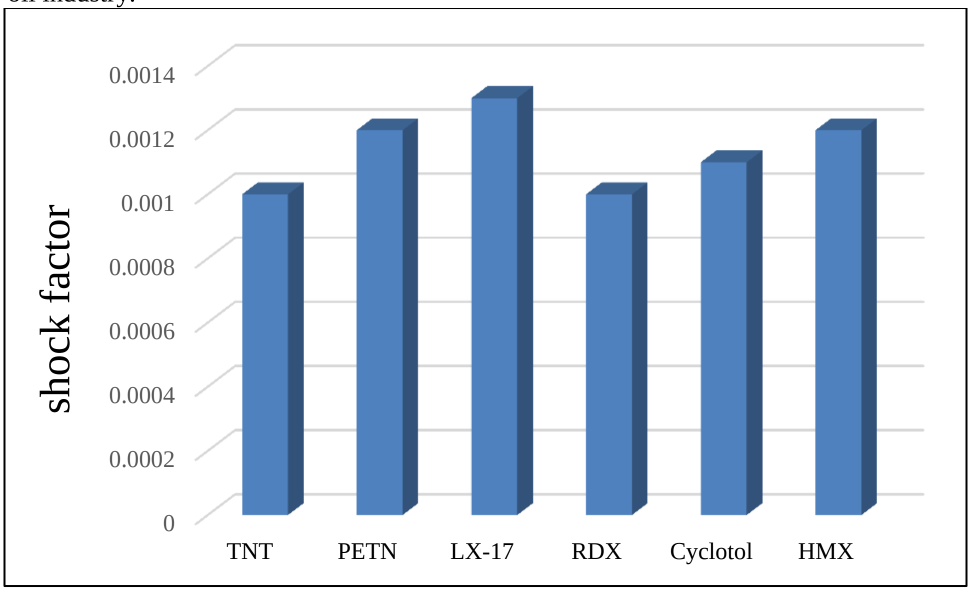

Figure 5: Shock factors for different used explosives in EFB

6. CONCLUSION

The most powerful explosive; HMX, which has a Gurney velocity of 2960 m/s and detonation velocity of 9100 m/s was found to have the best performance form jetting analysis andits highest penetration performance into concrete target in comparison with other studied explosives. The high values of both Gurney velocity and detonation velocity produces a jet tip velocity of 7103m/s, which achieved the largest penetration depth of 74.88 cm into concrete targets. The scaled jet tip velocity to the Gurney characteristic velocity of an explosive has been found to be around 2.5 for the used explosive charges, whereas the scaled jet tip velocity to the detonation velocity of an explosive has been found to be one for the studied six explosives. All used explosives show high safety levels against explosion temperature and electrostatic discharge which is the more effective environmental underwater conditions. Shock factors in underwater mining proved that it can be used for prediction the safety distance in oil industry for all new formulated explosives by researcher.

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