23RD INTERNATIONAL SYMPOSIUM ON BALLISTICS
TARRAGONA, SPAIN 16-20 APRIL 2007

EXPERIMENTAL SIMULATION OF FRAGMENTATION EFFECTS OF AN IMPROVISED EXPLOSIVE DEVICE

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The most common and deadly threat in urban warfare has become the Improvised Explosive Device (IED). Occurring as both vehicle borne and ground threats, this weapon can take on many forms, it often combines both blast and fragmentation hazards and is typically well concealed.

This paper examines the fragmentation effects of a 155mm artillery shell used as a ground threat IED. Existing standards for the characterization of an artillery shell fragment assume that the shell is airborne at the time of detonation (distances greater than 6m from target) and not when the shell is on the ground. When a shell is detonated, the fragmentation pattern is relatively random and not conducive to repeatable laboratory testing. In order to provide a repeatable simulation of a fragment shell, a fragment simulating projectile (FSP) is used. The current standard for the simulation of a 155mm artillery shell assumes a fragment mass and velocity that occurs when the shell detonates airborne, but preliminary testing has shown that these values are not representative of the fragments generated by a shell on the ground.

This paper evaluates the penetration potential of a shell fragment from an IED on the ground and attempts to determine a standard fragment mass, geometry and velocity that will allow repeatable testing that simulates the fragmentation effects of a ground borne IED.

INTRODUCTION

Improvised explosive devices (IEDs) are inherently difficult to detect, defeat, and protect against, due to the method of their construction. IEDs are made with whatever materials are available, and can be extremely simple or complex in design. They must be designed with three core elements to be effective.

1. Command Element – this can be as simple as a pressure plate or switch that creates contact in an electric circuit, or as complex as a radio frequency (RF) controller. The role of this element is to give the IED controller command of the system by determining when or where it functions.
2. Explosive Initiator – the role of this element is to receive a signal from the command element in electrical, chemical, or mechanical form. The signal triggers the explosive reaction in the explosive booster or main charge.
3. Explosive Charge – the role of this element is to achieve the goal of the IED. The explosive charge can be any size within the means of the builder and emplacer. Its construction will depend on the desired effect, but can include incendiary elements, preformed fragments, or fragmenting casing.

Artillery, mortar, and rocket rounds are abundent in current theatres of operation and are well suited for IED construction because they provide an explosive charge and fragmenting casing that was designed to inflict injury or damage. Current tactics used in low intensity urban combat clearly demonstrate that the use of artillery shells as IEDs pose a credible threat.

The 155mm “H” artillery shell is often used to simulate the effects of an IED due to its combined blast and fragmentation characteristics. The fragmentation pattern of a 155mm shell is somewhat dependant on the material characteristics of the munitions casing. Statistical data presented in TM-9-1907 Ballistic Data Performance of Ammunition [1] depicts the fragmentation pattern that would occur when the shell is detonated at rest at ground level.

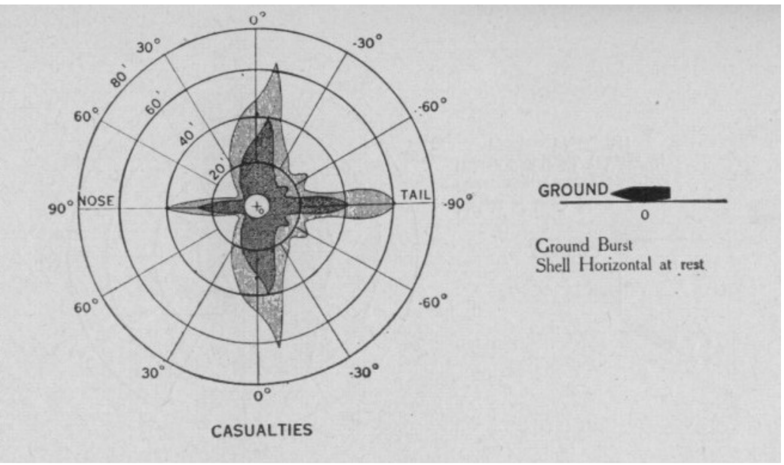

Figure 1: Damage Pattern - 155mm HE Shell M107 [1]

Studies conducted by Armatec and DRDC-Suffield have shown that while the overall pattern is fairly consistent, the size and number of fragments will vary from shell to shell, even between shells manufactured in the same lot. This variation is likely a symptom of the casing material being inhomogeneous and the irregular placement of the fuse and booster charge. Due to this somewhat random fragmentation effect, using a 155mm shell in repeatable tests is not practical. This leads to the need for a fragment simulating projectile (FSP) to be able to show repeatability in tests of armour performance against an IED type threat.

The current 20mm FSP and velocity matrix for artillery threat specified in AEP-55 Annex C [2] is based on conventional artillery attack and an airburst no closer than 25m from the vehicle. Preliminary studies indicates the existing STANAG 4569 Level 4 standards [3] using a 20mm FSP suffices for the majority of fragmentation arising from a bulk explosive vehicle borne IED. The existing standard does not however adequately simulate the effects of large non-design fragments that occur when the case of the munition does not fragment evenly around the circumference of the shell.

FRAGMENTATION OF 155mm “H” SHELL

Several studies were conducted by Armatec and DRDC-Suffield over the last two years using 155mm “H” artillery shells against a variety of targets. Initially trials were conducted with the axis of the shell parallel to the ground, both at ground level and varying distances above ground level. More recently, trials have been conducted with the axis of the shell perpendicular to the ground.

Instrumentation used in these trials was focused on the characterization of the types of fragments produced when this type of artillery threat was detonated at rest, at ground level and not in the air as was the original operational intent. The fragments were photographed using high speed digital video cameras that allowed the flight of the fragments to be captured and an approximate velocity to be calculated. Following the trial, the fragments were recovered and weighed to calculate the kinetic energy of the fragments.

High Speed Video Analysis

High speed video footage was taken of each of the detonations. Early on in the trial series, an impact velocity of the fragment as it hit the target was calculated. In subsequent trials, a reference board with 100mm stripes was used to determine the position of the fragment in flight. The reference board allowed the velocity of the fragments to be taken at several points during flight and an impact velocity to be extrapolated for impact distances that were not tested.

The location of the fragment in space and the distance it had traveled in a given time was found using a still frame taken from the high speed video footage. The frame rate of the video and the frame number were used to calculate the elapsed time from detonation. The time and distance could then be used to calculate the velocity of the fragment. This velocity is an approximation since the trajectory of the fragments can only be analyzed on a 2-dimensonal plane and the quality of the images from the high speed video are low resolution due to the large area that is required to be photographed.

The velocities that have been calculated from these videos are approximately 30% higher then the velocities dictated in STANAG 4569 for FSP testing. This increase in velocity could be due to the relatively short flight of the fragments, thereby reducing the deceleration caused by aerodynamic drag.

Fragment Weight Analysis

After the trial as many fragments as possible were collected and weighed. On early trials (Trial 1 and Trial 2 in Figure 2) a target was tested so the fragments were not captured as part of the test setup. On later trials (Trials 3, 4 and 5 in Figure 2), large sandbags were used to collect the fragments. When using the sandbags to collect fragments, approximately 50% of the shell mass was recovered. The data shown in Figure 2 has been corrected to account for only 50% of the fragments being collected and represents data for an entire shell.

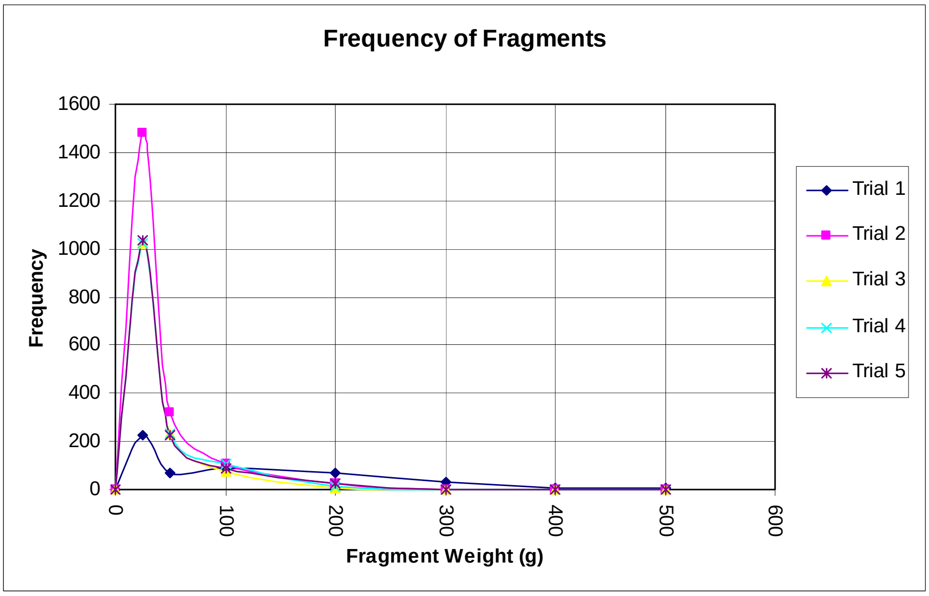

Figure 2: Fragment Weight Frequency Graph

Figure 2 shows a similar trend between all 5 trials, although the range of values for smaller fragment sizes varies. The fragments recovered from Trial 2 only accounted for 10% of the total shell weight suggesting that the correction factor used on this trial may be producing erroneous results.

Trials 3, 4 and 5 were performed with the axis of the shell perpendicular to the ground plane. The two remaining trials shown in Figure 2 were conducted with the shell axis parallel to the ground plane. Further testing to capture the fragments of a shell lying horizontally is proposed to gather more information on the effect of shell position on fragmentation pattern.

CURRENT STANAG 4569 20MM FSP METHOD

Based on STANAG 4569 for Threat Levels 4 and 5 a 20mm FSP is used to represent a 155mm artillery shell fragment.[2] STANAG Level 4 and 5 assume a burst range of 25m. The operational range of an IED in low intensity combat is typically between 1m and 5m therefore allowing for higher fragment velocity and a higher probability for larger fragments.

The 20mm FSP is defined in MIL-DTL-46593B [4]. The FSP is made from cold rolled annealed steel conforming to composition 4337H, 4340H or equivalent and has a hardness value of HRC 30±2. The mass of a 20mm FSP is calibrated during the manufacturing process to be 53.78g±0.26g. The FSP is fired from a gun into the target from a desired distance to achieve a given velocity.

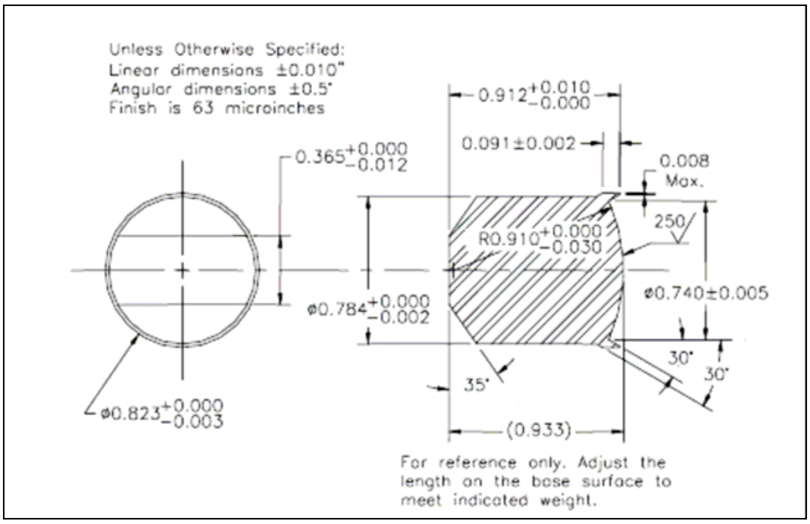

Figure 3: Fragment simulating 20mm [4]

The current STANAG assumes the shell is being used in a conventional artillery role and not as an IED. Testing performed with a 155mm shell in an IED configuration has shown the velocities and fragment weight to be above that specified in the STANAG. This increase in energy makes the current specification not applicable to an IED threat.

PROPOSED TESTING METHOD

A new model for the simulation of IED fragments is needed and should be based on a multi-tiered approach involving two distinct types of FSP: the 20 mm FSP representing the design fragment and a single large projectile shaped fragment (the non-design fragment). Two failure mechanisms are the basis for these two separate approaches. The first type of failure results from multiple design fragments either impacting and penetrating a panel, or impacting the panel and causing it to act as a secondary fragment. The second failure is a local penetration by the large non-design fragment.

For the smaller design fragments and accompanying blast wave, a two staged approach is warranted. The first tier would involve gun firing of the design fragment based on the existing 20mm FSP at velocities greater than the 960 m/s specified in STANAG 4569. The fragment could be fired as a single FSP or as a cluster of several FSPs contained in a sabot carrier. This concept would require practical design work and subsequent tuning.

The second essential stage of design fragment testing would involve a combined blast wave and impacting design fragments. This is required to find failures such as hatch or door failures due to blast or multiple strikes of fragments. The blast wave is critical in soft skinned vehicles where tests have shown that blasts can cause lethal injuries to personnel in the vehicle whereas troops in the open were not killed. In addition this blast and fragment generator would be usable in ganged arrays to simulate the multiple cased munition IED threats. Based on work carried out at DRDC Suffield (Figure 2, [5]) it is thought to be feasible to employ a dense fragment generator using 2.5 kg of explosive and 2 kg of 15 mm diameter and 50 g mass steel ball bearings.

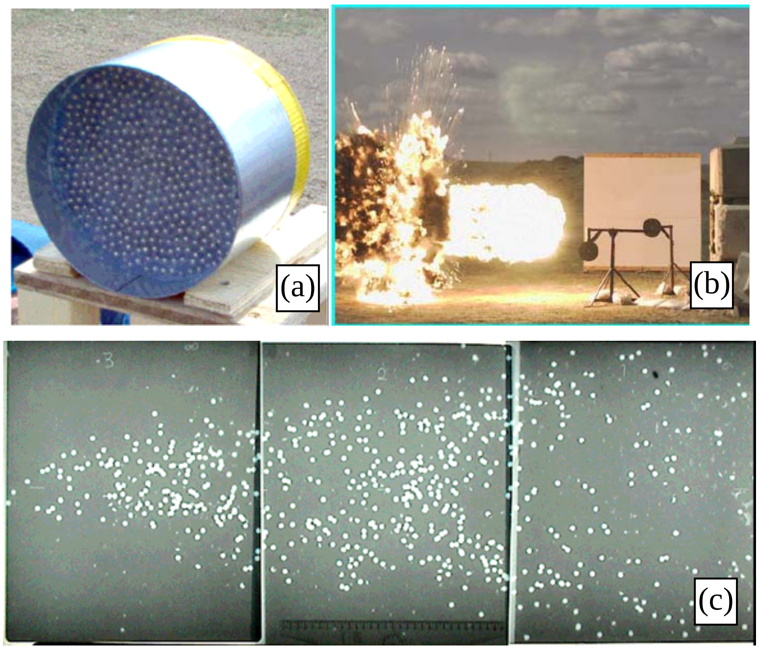

Figure 4. (a) Combined Blast and Fragment Generator (b) Resulting Blast, and (c) Flash Radiograph of Fragment Cloud [5]

The quantity of explosive used is representative of the fraction of the 7 kg of explosive in the artillery shell that is not consumed in fragmenting the case. Strike velocities of cloud centres have been measured at 1750 m/s. Velocity and aerial density of the fragments would be tune-able to reflect observed strikes.

A gun-fired elongated FSP on the order of 250g is needed for the large non-design fragment. This fragment would need to impact at around 1500 m/s and its dimensions would be based on calculations and experimental validation. It could be achieved with a 40mm Bofors cannon firing a sabot-encased FSP. Additional trials would be needed to show similar penetrations to representative non design fragments

RECOMMENDED FURTHER WORK

The statistical data of the velocity of a fragment produced by a 155mm shell at rest at ground level is currently limited. Additional trials using another type of instrumentation such as break screens, light screens or radar needs to be conducted to obtain additional data points for the determination of fragment velocity.

The size and shape factor of the fragments produced by a 155mm shell need to be evaluated to determine the size and shape the projectile shaped fragment. Once this fragment configuration was determined testing will need to be conducted in order to determine the similarity between the effects of the fragment simulator and the impact and damage effects of the 155 shell.

REFERENCES

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