An Explosive Fragment Projector for IM testing

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Abstract

Fragment Attack (FA) testing, as described in STANAG 4496, calls for a specific fragment shape, material and velocity. Usually this is achieved by accelerating a fragment in a long barrel, powder or light gas gun. This method requires heavy infrastructure, binding FA tests to stationary facilities. At Rafael, the need for a mobile FA test apparatus had led us to use specially designed Explosively Formed Projectiles (EFP) as substitutes for the STANAG fragment. We call this method Modified Fragment Impact or MFI. In this method the EFP has the needed mass and velocity but is roughly spherical in shape and made of copper rather than steel. Another advantage of this method, besides being portable, is its accuracy both in velocity and in aim.

The objective of this work is to develop a new explosive charge and test set-up that will have the advantages of our EFP test method while projecting a fragment at the velocity, with shape, mass and material as required by the STANAG. The design process includes both hydrocode calculations and characterization of the performance through testing of selected designs.

Introduction

The Fragment Attack (FA) test is described in STANAG-4496 [1]. This procedure specifies a steel fragment of 18.6 g, made of mild steel, 14.30 mm in diameter and 15.56 mm in length, with a conical nose. The specified impact velocity is 2530 m/s. An alternate velocity of 1830 m/s is also specified in the STANAG. The means for accelerating the fragment to the desired velocity is usually a long barrel powder gun or a light gas dual stage gun. While this is a precise and common method, it requires a considerable investment in heavy infrastructure and maintenance. Typical setup time needs to account for activities such as sighting shots, propellant conditioning etc. [2, 3]. In addition, cost considerations require the gun to be protected from the detonation of the test item.

An alternate method which is relatively low-cost and mobile is the use of Explosively Formed Projectiles (EFP). This method was suggested for IM testing in the past for both copper and mild steel projectiles [4,5,6]. The disadvantage of this method is that the shape of the fragment differs from the STANAG requirements. At Rafael, the need for a mobile FA test apparatus has led us to use this method which we call Modified Fragment Impact or MFI [7]. In addition to its mobility, the tight manufacturing tolerances of the EFP charge yields consistent fragment velocity and shape thus reducing the need for a pre-test shot.

Several other designs were suggested as explosive fragment projectors such as the explosively driven light gas gun [8] or an explosive charge specifically designed for this purpose [9] which was based on the work of Held [10, 11]. These designs have the advantages of being portable and inexpensive but used a large explosive charge of ~4 kg and ~5-8kg respectively, resulting in an undesirable parasitic blast in the test arena.

The need to decrease the amount of high explosive incorporated in the test, served as motivation for the present work. By maximizing the effect of the charge confinement, we aimed to accomplish this goal. This approach, however, can decrease the explosive amount up to a certain physical limit. In order to decrease the explosive mass beyond this limit, we employed the Munroe effect by constructing a shaped charge like design. We will present the hydrocode simulations and experimental results achieved.

1830 m/s charge

This design aimed to maximize the use of the explosive's energy by placing a thick confinement around the charge. Thus one can utilize the detonation products' pressure on the fragment for a longer duration. The preliminary design was modeled, using The Autodyn© 2D Lagringian-Eulerian coupled solver, and had a charge of 1.2 kg of LX07 with an infinite rigid boundary condition, in order to achieve the standards' alternate velocity of 1830 m/s. Later on we replaced the boundary condition with a steel case (Figure 1).

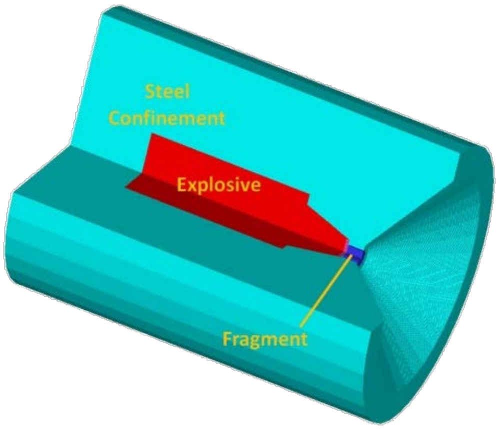

Figure 1 – Preliminary Autodyne model for a 1830m/s charge

The results of the simulation are shown in Figure 2: The fragment's shape after the acceleration process is unaltered and as can be seen from the time-velocity curve, the final velocity is ~1830m/s as required.

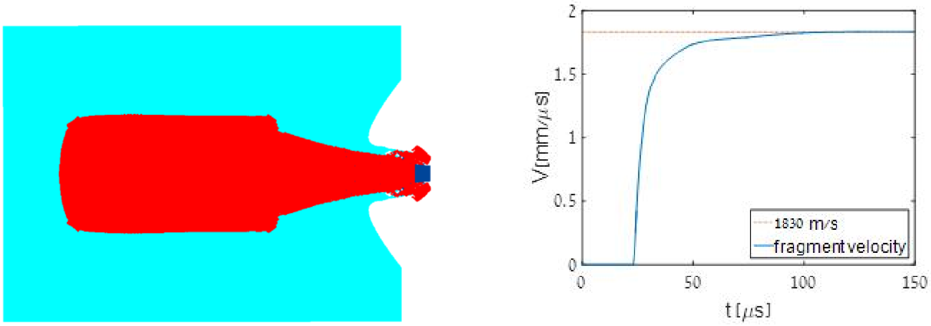

Figure 2 – 1830 m/s charge simulation result

This design performance was evaluated in a live test. In the detailed design we replaced the explosive fill from LX07 to a cure-cast explosive– PX91 (a formulation similar to PBXN110) and added the required features needed for the detonation chain and handling (Figure 3).

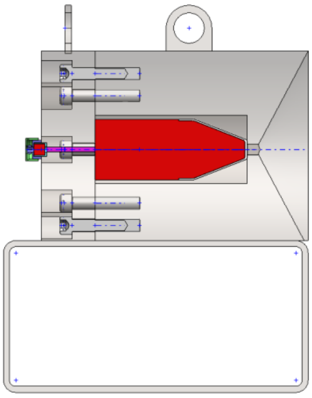

Figure 3 – 1830 m/s charge design

The test setup consisted of water containers placed around the charge due to safety requirements. Two flash x-rays were used to evaluate the shape and velocity of the fragment (see Figure 4).

Figure 4 – 1830 m/s charge test setup

The fragment velocity measured from the x-ray image was only 1650m/s. It is presumed that the front part of the confinement came apart sooner than predicted and as a result the pressure was released earlier. However, as can be seen in Figure 5 the fragment kept its shape.

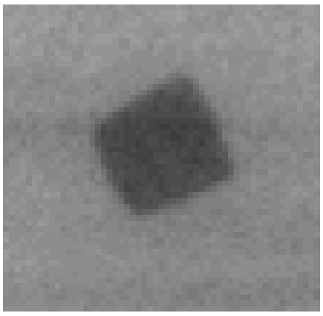

Figure 5 – 1830 m/s fragment test X-Ray image (1650m/s measured velocity)

This design shows a proof of concept regarding the efficiency of thick confinement in reducing the mass of explosive in the charge. Even though the velocity was not fully achieved, a high velocity was achieved with much less explosive than was done previously.

The fact that the fragment’s shape was preserved is also a positive sign, since it already suffered its maximum loading at the beginning of the acceleration process. Further refinement of the confinement should achieve our design goals.

2530 m/s charge

The second effort we took was to achieve the standard velocity of 2530 m/s. First attempts of doing so with the same basic configuration did not achieve the desired velocity and an increase of the charge diameter (and mass) seemed necessary. We decided to take a different approach and instead of enlarging the charge we thought on using the Munroe effect to “focus” the detonation products’ effect on the fragment. The preliminary design was modeled as before and showed the desired velocity with a charge of 0.8 kg of LX07 under the same boundary configuration as the previous design. The efficiency of this approach is evident when we compare the explosive mass 0f 0.8 kg to 1.2kg needed to achieve the lower velocity described above, and more so compared to ~8 kg in [9] or ~4 kg in [8].

The preliminary model is shown in Figure 6.

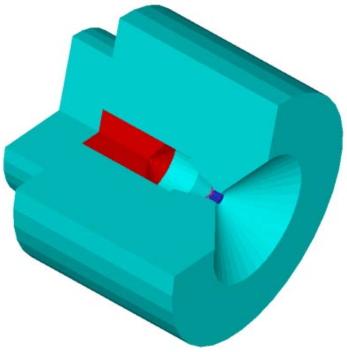

Figure 6 – Preliminary Autodyne model for a 2530m/s charge

The simulation results at two different times and the time-velocity curve as shown in Figure 7 demonstrate that the focused stream of detonation products on the fragment achieves the desired velocity.

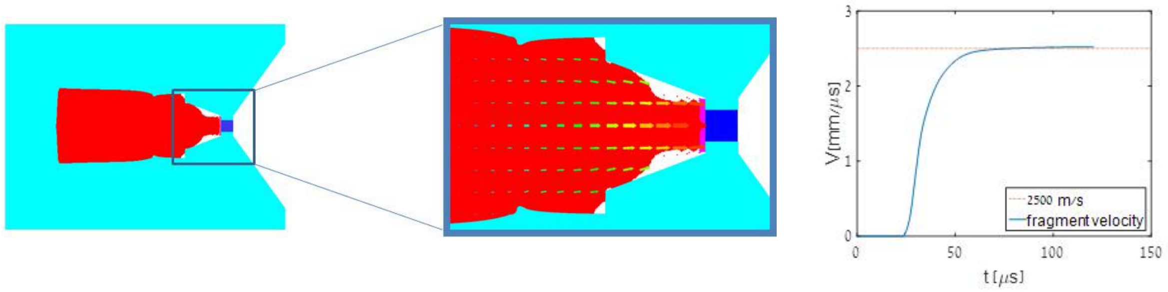

Figure 7 – 2530 m/s charge simulation result

This version was manufactured and tested after a detailed design process. We used PX91 explosive fill and redesigned the casting jigs to form the needed explosive shape. The design can be seen in Figure 8.

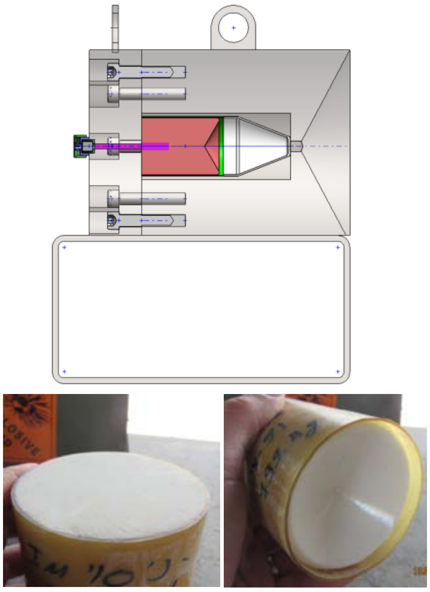

Figure 8 – 2530 m/s charge design

The charge's performance was also evaluated in a live test. The test setup was similar to the one used for the 1830m/s charge.

The fragment's velocity measured from the x-ray image was 2540m/s – well within the standard requirement. However, as can be seen in Figure 9, the fragment deformed beyond what could be regarded as an acceptable shape.

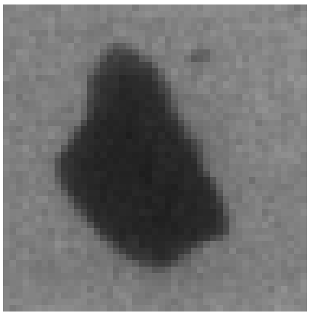

Figure 9 – 2530 m/s fragment test X-Ray image

Again this design shows proof of concept regarding the use of the Munroe effect in accelerating a fragment to the required velocity. With further refining of the design correct fragment shape could also be achieved.

Summary

Fragment Attack tests require test apparatus to accelerate the threat fragment. While a powder gun is the common way of achieving the fragment shape, velocity and accuracy requirements, it also has its limitations in terms of mobility and cost.

In this work we presented two designs aimed at achieving the STANAG requirements with an explosive charge using a much smaller charge than was demonstrated before. This was done by using the kinetic energy encompassed in the detonation products more efficiently. Two methods were employed: one based on heavy confinement and the other on a focused stream of detonation products (Munroe effect).

It was found that the second method has a greater potential for accelerating fragments for high velocities using relatively small amount of explosive (an order of magnitude smaller than previous attempts [9]). The challenge of preserving the fragment's shape in this method will be addressed in future work.

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