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High Velocity Fragment Launcher and Impact Initiation of Munitions- A Numerical & Experimental Study

Bhupinder Sewak, Rajnish Gupta, Ritu Khurana, Anil Kumar, Akhilesh Sharma*
Terminal Ballistics Research Laboratory, Chandigarh-160030, India

*Corresponding Author: akhileshh@yahoo.com

Abstract

This paper presents a design of a fragment launcher which uses high explosive to launch fragment at more than 2000m/s. Detonation products are focused onto the projectile with the help of curved explosive which then propels it to the desired velocity. Dimensions of the launcher were finalized with extensive hydrocode simulation. Consistent impact velocities were obtained with aiming within acceptable limits. Separate simulations were carried out to understand the transmission of shock to the acceptor explosive of a warhead through the casing material. It is shown that transmitted shock through the casing material can initiate the acceptor even though the projectile is not able to fully penetrate the casing. In parallel several simulation were done to understand initiation mechanism due to impact. Experience gained from experiments and numerical simulations can be utilized for design of better mitigation systems.

Introduction

A number of science and engineering applications require understanding of high velocity impact of fragments and bullets on various types of targets. This requires launchers which can be used to propel fragments of desired shape and weight at required velocities. Traditionally propellant and gas guns have been used extensively in the study of impacts at high velocities as well as fundamental studies of material response at high pressures. Although guns provide well characterized and repeatable launches but there is a limit on the projectile mass and geometry. Another problem arises when impact on targets enclosing energetic material is to be investigated. Possible detonation in target material or warhead due to impact means that elaborate protective measures need to be taken to safeguard the gun.

Explosive launching provides another method in which detonation products propel the projectile to the desired velocity [1], [2]. However when projectile is in direct contact with explosive, the loading results in hydrodynamic deformation of the fragment. This paper presents an alternate design of launcher in which the fragment or the projectile is decoupled from direct contact with the explosive. Instead detonation products are focused onto the projectile with the help of curved explosive which then propels it to the desired velocity. Dimensions of the launcher were finalized with extensive hydrocode simulation. Experiments were done to launch a 10gm steel cube and 18.6gm STANAG projectile up to a velocity of 2400±50m/s. Consistent impact velocities were obtained with aiming within acceptable limits. The projectile was soft recovered and it showed no appreciable deformation in shape.

Furthermore understanding the transmission of shock in the target is very important. In this paper response of a cased munition having energetic material against impact is studied. A typical problem in many applications is to establish whether the munition will detonate or not at a particular impact velocity of a fragment or bullet. Both bullet and fragment attack represent a serious threat and are applicable for a wide variety of munitions both during storage and transportation. Protective measures against these threats have to be incorporated in the design of the munitions itself. They can be introduced by using suitable explosives which are less sensitive and/or use of proper packaging. Mitigation measures try to reduce the probability of an unintentional reaction in the munition. At the same time they reduce the severity of the event and also the amount of possible collateral damage.

Separate simulations were carried out to understand the transmission of shock to the acceptor explosive through the casing material. It is shown that transmitted shock through the casing material can initiate the acceptor even though the projectile is not able to fully penetrate the casing. In parallel several simulation were done to understand initiation mechanism due to impact. It is shown that for detonation to start, peak value of the transmitted pressure as well its duration are important. All the numerical simulations were carried out using Ansys AUTODYN hydro-code [3]. Experience gained from experiments and numerical simulations can be utilized for design of better mitigation systems.

Fragment Launcher

Figure 1(a) shows schematic diagram of the fragment launcher used for launching a cubical fragment. Simulation was used in finalizing various dimensions of the launcher. To increase computational efficiency of long simulation, just half of it was modeled by using the axial symmetric configuration around y-axis. Material models in-built in Ansys Autodyn were used for various parts [4]. High explosive RDX/TNT (60:40) was modeled with JWL equation of state while Shock equation of state was used for steel fragment. Cylindrical container of mild steel was used to confine high explosive. One face was kept as flat for initiating HE, while the other end was kept concave to create air gap. Calculation of curvature and air gap was carried out after carrying out multiple runs of simulation to ensure that the metal cube is propelled without deformation. A teflon sabot of 5mm wall thickness was used for projectile [5]. Figure

1(b) shows complete velocity history of fragment, casing fragments and front fragment holding plate vs time. It is clear that the projectile is propelled with much higher velocity than the debris of the casing material. It is much ahead of remaining fragments of the launcher and will impact the target cleanly. A partition plate with a hole can further be used as a debris trapper to stop the debris from impacting the target.

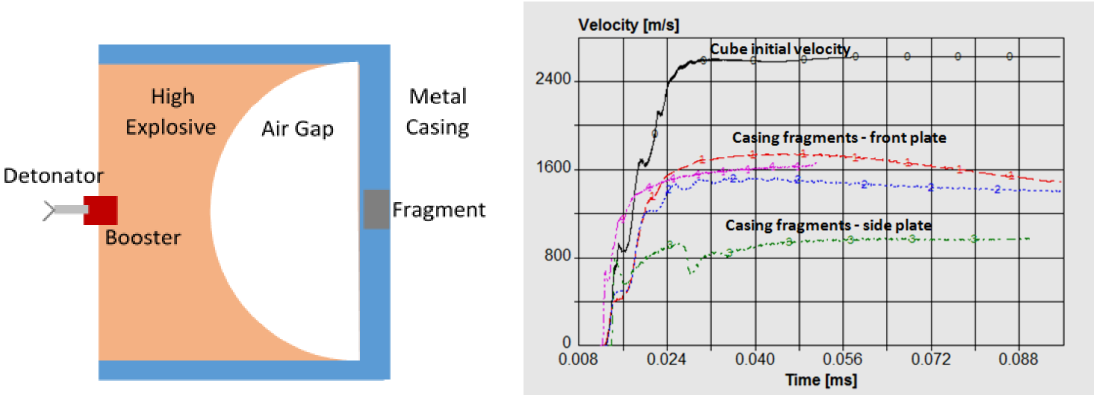


Figure 1(a): Schematic Diagram of Launcher (b): Velocity history of Projectiles

Figure 2 shows a particular experimental layout in which cubical projectile was launched. To record the velocity of projectile, number of velocity sensors were placed at a known distance from the launcher. Particle straw board along with sand filled bags were used to soft recover the fragment for post-trial analysis. The cube was soft recovered in straw board showing no deformation.

Figure 2: Experimental layout

A number of experiments have been carried out using this fragment launcher on warheads. This is especially useful when the target warhead contains large quantity of energetic material and conventional guns cannot be used because of safety considerations. Typically velocities of the order of 2500m/s are normally obtained very near to the muzzle end of the guns and keeping the warhead at this position can pose a safety risk for the guns in case the target warhead detonates.

Pressure Initiation- Simulation Case Studies

Separately a simulation study was carried out to study the detonation behavior of warheads because of shock initiation. Simulations were carried out to model impact of ogive tip and flat cylindrical projectiles on cased munitions with velocities varying in the range of 1700m/s to 2600m/s. Some of these simulation results were validated with experiments. Each simulation was done to see penetration of casing material and also to see weather detonation in the munition happens or not. Pressure history in the high explosive after the impact of projectile was also simulated. It is seen that shock transmitted through the metallic casing of the munition with sufficient pulse duration is the reason behind detonation. In some cases there was no penetration in the casing material even then shock initiates the detonation. Simulation results are compiled in table 1.

#	Velocity of projectile m/s	Pressure Transmitted in HE & Duration	Remarks
1. Flat Cylindrical STAGNAG 4496 Projectile (18.6 gm) Impact On Cased Warhead *No Penetration in target Plate (11 mm, steel 4340)*			
1	2000	123.2 KBar/ > 5 µs	Detonation started without Penetration
2	1800	100.1 Kbar/ 2.5 µs	Detonation started without Penetration
3	1700	88.8 KBar/2.1 µs	No Detonation
2. Ogive Projectile (8.8 gm) Impact On Cased Munition *Clear Penetration in target Plate (11 mm, steel 4340)*			
4	2650	107 KBar/ 5 µs	Detonation started before penetration
5	2250	52.6 KBar/2 µs	No Detonation

Table 1

In detailed simulations energy absorbed by the casing material and also the energy transmitted to the energetic material has been computed. These simulations can be used to plan mitigation schemes for warheads. Figure 3 shows simulation viewgraphs of impact of flat projectile at a velocity of 2000m/s (case no. 1 in table 1). Pressure history in the warhead casing and high explosive after the impact of flat face projectile is shown in figure 4. It is apparent that it is the shock pulse which is transmitted through the metallic casing of the warhead and has sufficient pulse duration is the cause of detonation. Thus detonation can take place even when there is no perforation in the casing of the warhead. Thus understanding of shock initiation is extremely important in the studies related to IM compliance.

Another simulation study further emphasizes it in which an investigation was carried out to see possible sympathetic detonation if one of the shell detonates in the launcher of a multi-barrel launcher. This is shown in figure 5. Simulation was done assuming two spherical shells as shown in the figure. Both the shells were assumed to have HMX/ TNT explosive while the shells were metallic. First shell was initiated from the center. Expanding metal casings of shells and partition plate ultimately hit the HE of the second shell. Lee-Tarver equation of state was used for the HE contained in the acceptor shell [6] [7]. Velocities of these casings and resulting pressure in the HE were calculated and are shown in figure 6(a) and (b).

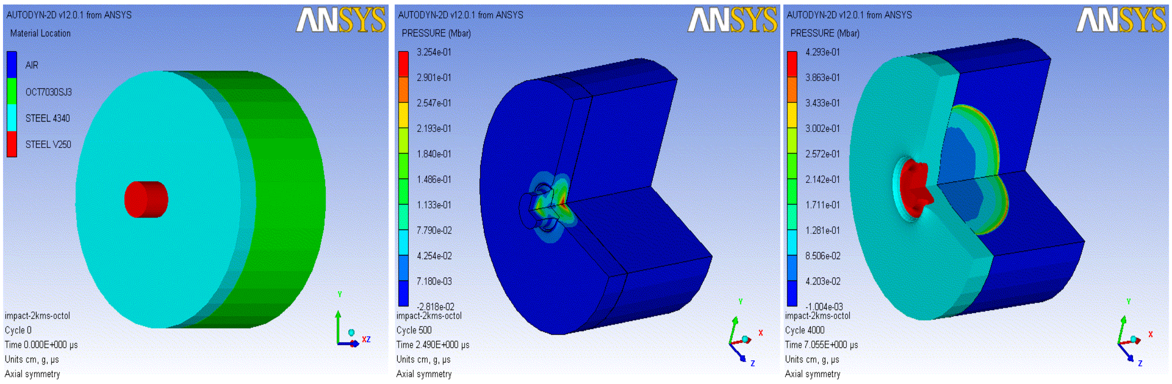


Figure 3: Simulation of Impact of Flat Cylindrical Projectile at 2000m/s

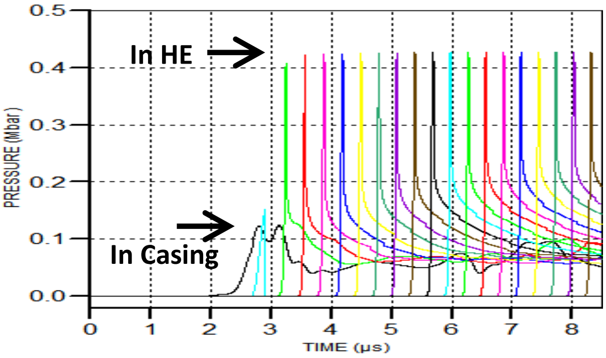


Figure 4: Pressure History in the Warhead Casing and High

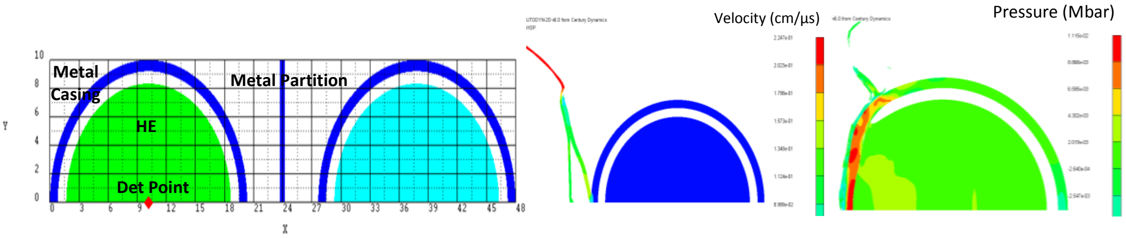
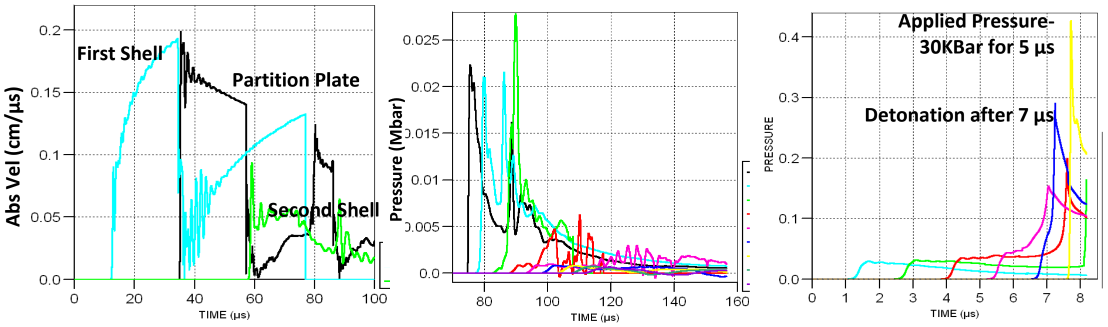


Figure 5: Problem Setup for Detonation due to Pressure Initiation



(a) **(b)** **(c)**

Figure 6: Velocity and Pressure Profiles

In the simulation maximum impact velocity of second shell on high explosive is less than approx. 1 km/s. - maximum values being nearer to the axis of symmetry. Peak impact pressure in second explosive varies from 22 to 29 Kbar at different locations in the explosive. The time duration of the peak pressure pulse is approx. 1.5 µs. The peak pressure rapidly decays to a value of 6 KBar at 104 µs. No sympathetic detonation of the second shell was observed. To further validate this a 30 KBar triangular pressure pulse was applied on the explosive for 2 µs. No detonation was observed. However 30 KBar pressure applied for a longer duration of 5 µs caused detonation. (Figure 6(c)). Similarly the explosive detonated when the pressure was increased to values of 50 KBar for 2 µs when detonation was observed to occur after approximately 47 µs. Detonation occurred after approx. 7 µs when the pressure was further increased to a value of 100 Kbar applied for 2 µs. These observations show that both peak values and duration of incident pressure are important.

Discussion & Conclusions

This paper has presented a design of a fragment launcher which uses high explosive to launch fragment up to velocities of 2400m/s. Detonation products are focused onto the projectile with the help of curved explosive which then propels it to the desired velocity. This work has demonstrated a method of projectile launch which can be used to simulate STANAG 4496 fragment impact on a full scale warhead and munition. A traditional difficulty with high-explosive launching systems is that severe loading generally causes hydrodynamic deformation of the projectile. In the present design, the projectile is cushioned from direct action of the explosives by an air gap. Fragments can be delivered at impact velocities in excess of 2400m/s with minimal deviation, good velocity control and accurate aiming. Dimensions of the launcher were finalized with extensive hydrocode simulation. Simulations were also carried out to understand the transmission of shock to the acceptor explosive of a warhead through the casing material. It is seen that transmitted shock through the casing material can initiate the acceptor even though the projectile is not able to fully penetrate the casing. Experimental and simulation results also verified the role of shock pressure and pulse duration, for initiating detonation in the energetic materials without perforation by the bullet or fragment. Design of presented launcher can be further modified to gain even higher velocities. The simulation offers an insight in the process of Impact initiation and sympathetic detonation and can be used as a useful tool for testing, designing and storage of Munitions.

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