

# Development of a tool for testing PPE under near simultaneous Triple Impacts

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## Abstract

The deminers are the backbone of Mine Action. Even though the incidence of accidents is limited, the risks involved may inflict a hit on the motivation of the endeavor. PPE serve this way a double purpose. The obligation of the scientific community is to provide with efficient tools to the manufacturers to tune the performance of their products and clear guidelines to the end users for selecting them. Current practices for assessing the performance of PPE have been proven significant but inaccurate. This has led to designs of PPE that overestimate (expensive, non ergonomic), or underestimate the threats deminers are dealing with.

This paper describes the development of a new tool for assessing the performance of Personal Protect Equipment against fragment impacts. This technique involves near simultaneous impacts of three projectiles in close proximity to one another. The interactions between the three impacts are analyzed to predict the resultant ballistic performance. An important factor for this assessment is the degree of simultaneousness of multiple impacts and its influence towards the ballistic performance. This setup was realized in order to simulate the conditions that are typically identified during an explosion of an AP blast mine. The development of the main tool for testing is described in detail and the results of its assessment through the steps of its development are submitted. Important diagrams of velocity as a function of powder mass and dispersion are analyzed.

## 1. Introduction

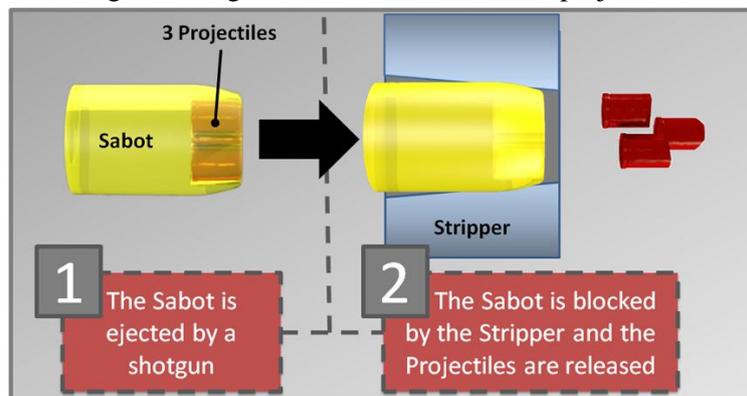
In the rare case of an accident, the life of the deminer depends on the personal protective equipment he wears. The performance of PPE is difficult to assess due to the complicated phenomena that take place in an event of an explosion. Two main methodologies are being used in order to certify the defensive performance of PPE. Ballistic impact tests assess the resistance to perforation from fragments usually generated in an explosion and blast tests provide an insight to the structural integrity of the PPE [1]. In order to introduce controlled testing procedures for these tests many assumptions are determined. One of these assumptions is that the interactions of near simultaneous multiple fragment impacts are negligible and can be simulated with single impact tests. This hypothesis has not been investigated in depth by the scientific community due to the technological difficulties in realizing such tests. However a few attempts have been made to examine the ballistic response of a protective material under near simultaneous multi-site impacts[2-5]. Qian et al investigated the terminal effects of fragment cluster impacts on a metallic plate[2-3]. Norris developed a five steel cube launcher for hazard assessments for non-nuclear munitions [4]. Deka et al, developed an air gun triple launcher for realizing near simultaneous triple impact tests against S2-glass/epoxy composite laminates [5].

In this article two methods for performing near simultaneous triple impact tests are presented. The first method concerns the use of an intermediate bullet-like structure called sabot on which the projectiles are loaded in order to accelerate them while maintaining a predetermined triangular formation. In the second method the three projectiles are loaded in three parallel barrels that are connected with a common combustion chamber.

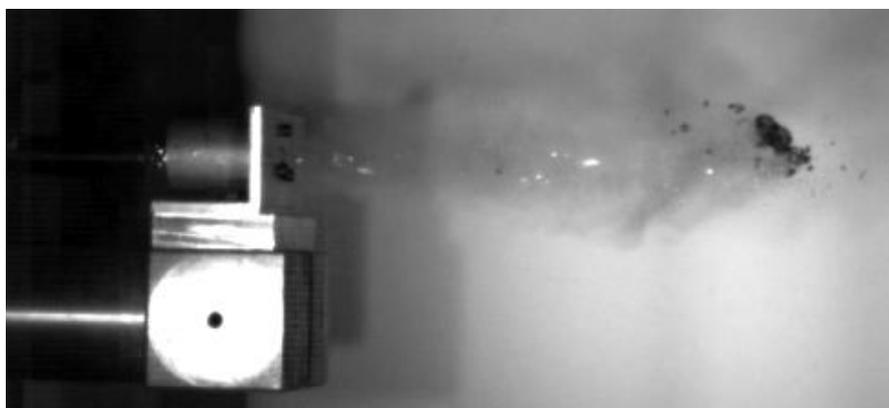
## 2. The Experimental Configurations

### 2.1 First Approach: “The Sabot”

In the first approach an intermediate bullet-like structure called “sabot” was used. This technique is widely used in the area of ballistics whenever unconventional projectiles need to be fired for which no specifically made barrels exist. Eight different sabot designs were examined to finally choose the most efficient taking in to account the means available. The sabots were made of nylon machined by a standard turning machine or ABS using a 3d printer. In this method three projectiles were loaded in the sabot which then was loaded in a shotgun with a barrel diameter approximately 19mm. After combustion, the sabot is accelerated till it exits the barrel. The sabot’s flight is stopped by a conical structure called “stripper” releasing the three projectiles, which would continue on their trajectories. In figure 1. the sabot’s function is illustrated. The velocity of the sabot was monitored by a high speed camera at 30000fps. With this method, the sabot reached successfully speeds from 350m/s to 650m/s with sufficiently stabilized flight. Unfortunately, due to the severity of the collision of the sabot on the stripper, the sabot was crushing into pieces in all tests, generating more fragments and disturbing the triangular formation of the three projectiles.



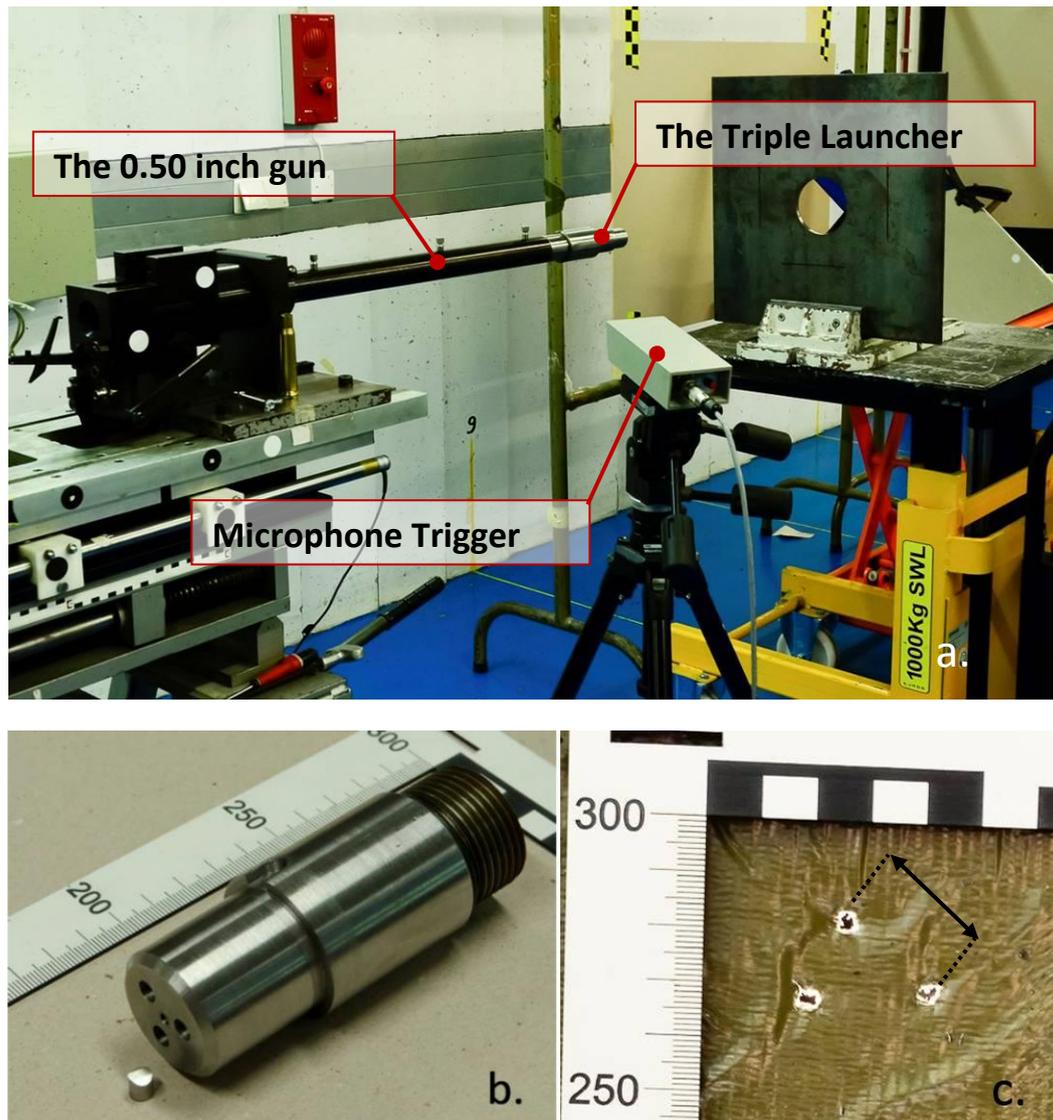
**Figure 1.** Sequence of events in a ballistic test with the “Sabot” method



**Figure 2.** Screenshot of high speed video footage displaying the moment after the sabot is ruptured on the stripper

## 2.2 Second Approach: “The Triple Launcher”

The triple launcher is consisted of a 0.50inch barrel and attached at its end a custom made cylindrical piece approximately 100mm long and 35mm wide with three parallel holes along its length. The three independent holes determine the accelerating path of the three projectiles and their equilaterally triangular formation. The 0.50 inch barrel is loaded with blank ammunition and acts as a gas generator. After combustion the rapidly expanding gases are confined in the 0.50inch barrel due to pre-installed glass fiber reinforced membranes in order to build up pressure. After a critical value of pressure is reached, the membrane ruptures releasing the gases through the three parallel holes of the launcher.



**Figure 3.** *Experimental setup.*

*a. A general view of the 0.50 inch gun, the Triple Launcher, the microphone and a mechanical filter that was used during the tests.*

*b. The Triple Launcher loaded with Fragment Simulating Projectiles of 1.1g*

*c. The perforation marks on the witness plate*

### 3. Results

For evaluating the ballistic performance of the triple launcher, the velocity measurements of the three projectiles were coupled with the input powder charge used to accelerate them. A diagram of velocity as a function of powder mass was acquired. The velocities reached are in good agreement with the proposed International Mine Action Standards velocity values for testing PPE, around 450m/s. It was showed that increasing the input charge mass, the projectile velocities initially present little increase and at higher charges they remain constant. At lower powder masses, the projectile velocities are generally lower but seem to variant from test to test. This variation is caused by the limitations of the launcher's geometry. The large 0.50inch barrel engulfs high amount of volume which needs to be filled with high pressure gases. The powder in order to have high burning speeds must also be compressed. Low powder masses with such high barrel volume give weak deflagrations. Variations in powder fragmentation (powder grain size) produce variant results. This variation is confirmed by tests with powder masses lower than 4.5g.

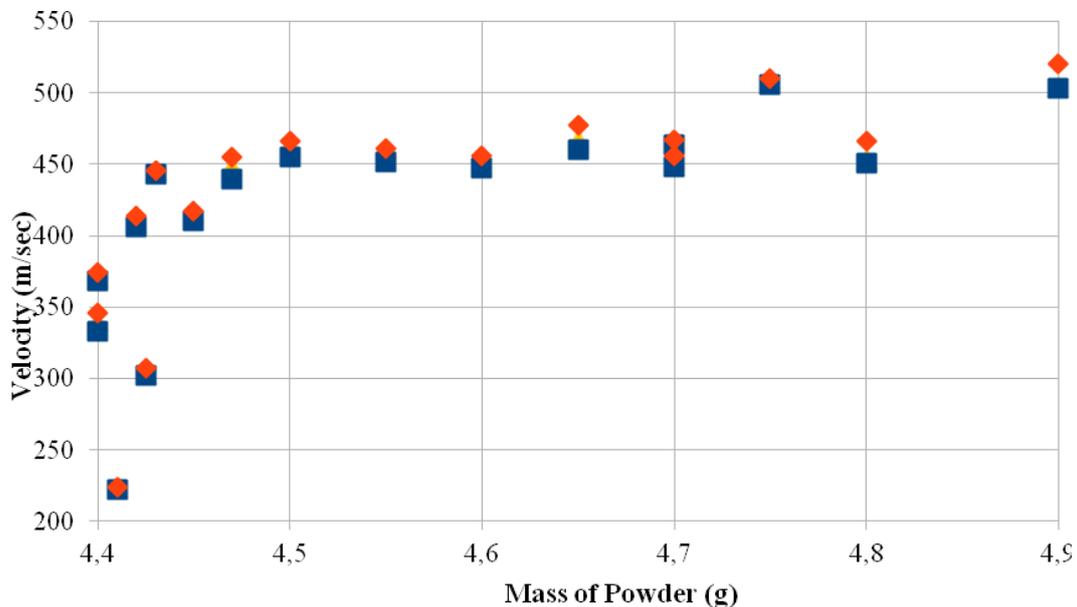


Figure 4. Velocities of the three projectiles vs powder mass

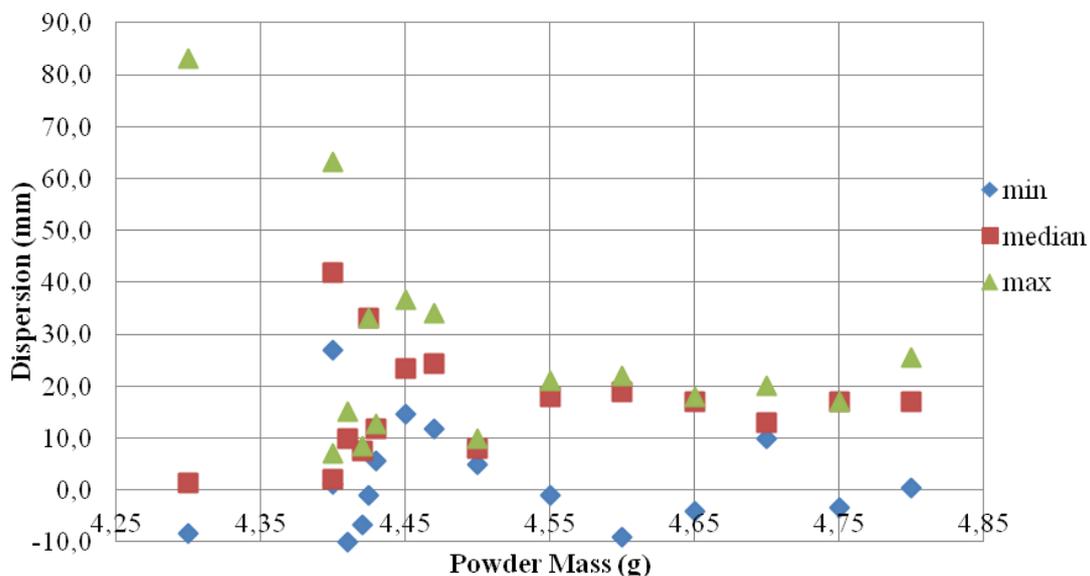
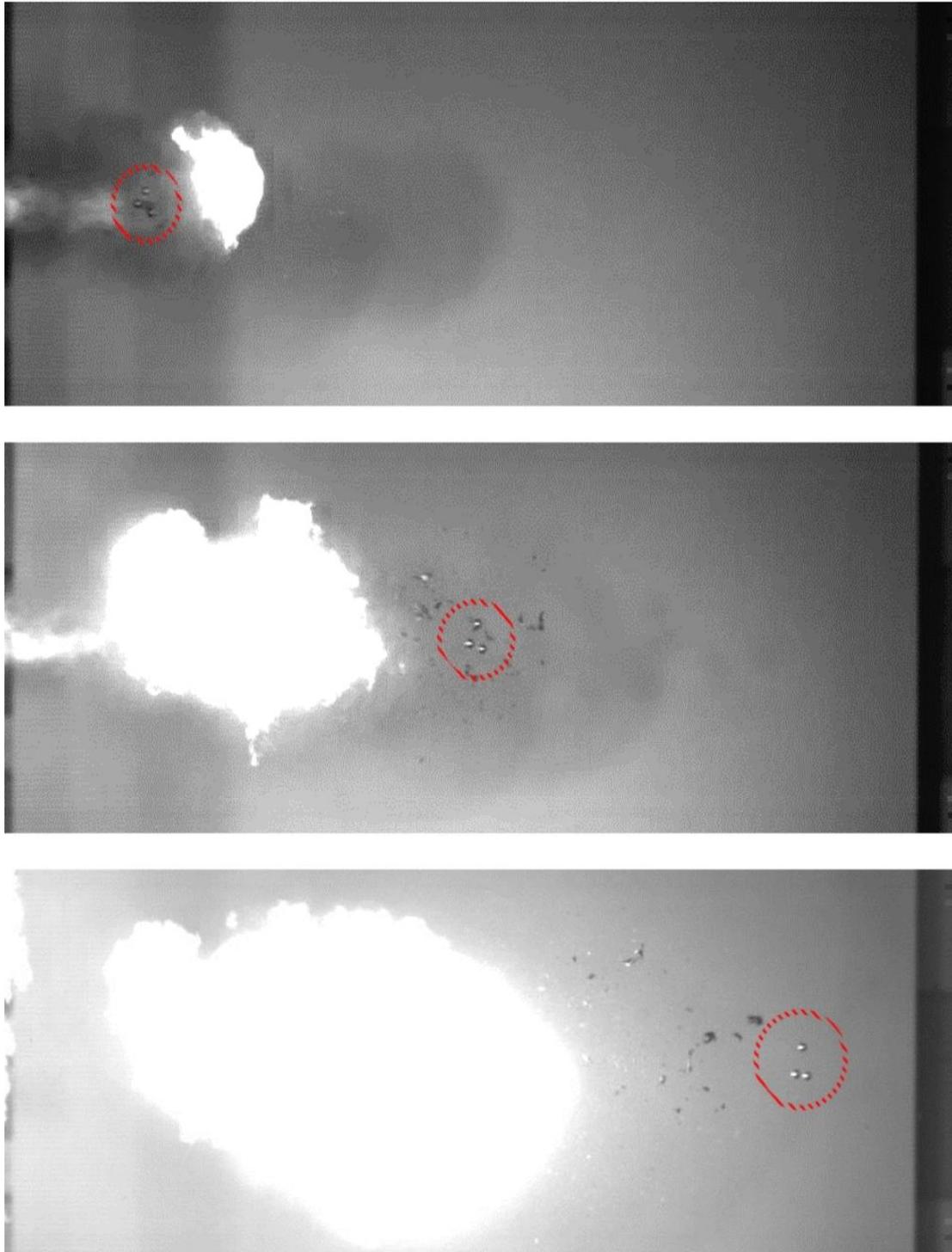


Figure 5. Dispersion vs powder mass



**Figure 5.** *Three frames of a triple shot, which were acquired by the high speed camera, and show the stable projectile flight formation.*

The deflagration that is followed after triggering is inconsistent and in many cases it continues after the projectiles have left the barrel, disrupting their flight augmenting their dispersion. What is more, the burning rate of the powder, due to the high design tolerances of the launcher, its short effective length and the light weight of the projectiles compared to the energy produced by the powder burn, the projectiles leave the barrel before the powder is burnt so tests with higher powder mass charges exhibit indifferent results in terms of

projectile velocity and dispersion. Results of the measured distances between the three impacts of each shot as a function of powder mass are presented in the figure 5.

#### **4. Conclusions**

Sabot speeds exceed the requirement of International Mine Action Standards of 450m/s with sufficiently good stabilized flight. Separation of the projectile from the sabot has been problematic due to the high impact velocity of the sabot on the stripper. Higher impact strength materials may solve this problem. Controlled separation of the projectiles from the sabot requires further investigation.

The projectile velocities attained by the triple launcher are within the spectrum of performance assessment of PPE but their range is limited and moderately controlled with the charge mass input. The dispersion of the projectiles is limited at speeds around 450m/s. At speeds less than 445m/s the dispersion of the projectiles is higher. Improvements of the triple launcher are possible by, reducing the length of the 0.50inch barrel, increasing the effective length of the triple launcher and tighten the tolerances. What is more, the use of rifled barrels will enable the firing of fragment simulating projectiles instead of spherical projectiles.

#### **5. Acknowledgements**

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