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INFLUENCE OF SMALL ARMS AMMUNITION ON TARGETS MADE OF GRANULAR MATTER

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Abstract: *The behavior of granular matter under the impact of projectiles with varying calibers is examined in this work. Different granulations were used to make the samples - targets, which were then assembled differently. The samples were created using a variety of sand kinds with varying moisture contents and densities. Two cameras were used to investigate the behavior of the tested substrate following the projectile impact: a thermal camera and a high-speed camera. The state of the samples after the action was also reviewed. When it comes to evaluating the effects of a projectile striking a granular substrate as a target, these experiments may be of ballistic significance. Examining the granular materials' physical characteristics and their importance for use in the development of materials for the manufacture of military-grade protective materials is the main goal of the test.*

Keywords: *granular matter, new military materials, projectile's impact*

1. INTRODUCTION

This paper presents a thorough analysis of the impact of projectiles on grannular matter [1] with many possible applications. It is an experiment to see how ammunition affects a particular target or surface in an open space. This influence is determined in different ways that will be described in the text of the paper, but additional types of analysis can also be included. As this is a very fast or short process, an ultra-fast and thermal camera were used for observation. In this specific case, a sandy substrate of different granulations was examined as well as some solid materials. As `for the ammunition, the most typical calibers were used in real shooting conditions. The benefits of utilizing this kind of material for a military protective material were discussed with keeping on mind the significance of this kind of test in the broader ballistic context.

2. EXPERIMENTAL

A new, very similar experiment with rifle ammo was carried out, based on the air rifle experiment previously reported elsewhere [2]. Calibers 7.62 mm and 5.56 mm were used. The 7.62 mm caliber [3] is very widespread and is used by famous rifles such as the AK-47 and the SKS Carbine. It is also predominantly used in weapons of the Serbian Zastava brand and many others. An alternative to this caliber is the 5.56 mm bullet [4], which was developed in the USA. This refers to the standard NATO caliber that is utilized, for instance, in M16 rifles. The characteristics of the described calibers is shown in table 1.

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Table 1. Bulet characteristics

Bullet characteristics			
Bullet	**Mass**	**Length**	**Diameter**
7.62	7,9 g	24 mm	7,62 mm
5.56	4,0 g	23 mm	5,56 mm

During shooting, speeds of approximately 700 m/s were measured for caliber 7.62 mm, while for caliber 5.56 mm, a speed of approximately 895 m/s was measured.

Three types of sand of different granulations and densities were used as the first test substrate. The first type of sand is coarse sand with a density of 1770 kg/m^3, the second is fine sand with a density of 1700 kg/m^3 and the third is absorbing sand with a density of 1340 kg/m^3. In the main experiment, all three kinds of sand were mixed with water and placed on the base according to a predetermined scheme. The base is constructed as a box on the bottom of which there is an armor plate.

Second type of material for target was a construction cement. This is a solid target and is investigated in the same way as the sandy target on the same base. It is made with same types of sand mixed with a cement to get greater strength. As a reference, the testing was additionaly done on the box with an armor plate with no extra substrate.

In the experiment, no weapon was used during the actual firing. Instead, a stationary block for experimental investigations was used. The block measures 900 mm in height by itself, and 1100 mm when the barrel is added.

The FLIR SC620 24° Package thermal imaging camera and the Phantom v9.1 ultra-fast camera were the two types of cameras used in the experiment. Data processing is performed in the program FLIR ResearchIR Max ver 4.40.12.38.

3. RESULTS AND DISCUSSION

The temperature profile of the granular substrate as well as the target made of construction cement and armor plate were observed during and after the impact of the projectile. Temperatures at characteristic moments were measured and compared. It was also easier to observe the splattering of granular matter on the thermal images, as well as some additional analysis in that direction.

Figure 1 shows the thermograph of the moment of penetration of the projectile into the sandy substrate. The point of impact, i.e. impact area, is easy to see, as well as trajectories of granulation particles. The trajectories show the end points where the particles are at the moment the image is taken, while the paths of those particles are seen as slightly brighter, more precisely slightly cooler lines. As a whole, the entire area within which the energy transfer occurred, that is, the area within which the movement of granulation particles occurred due to the impact of the projectile, is singled out.

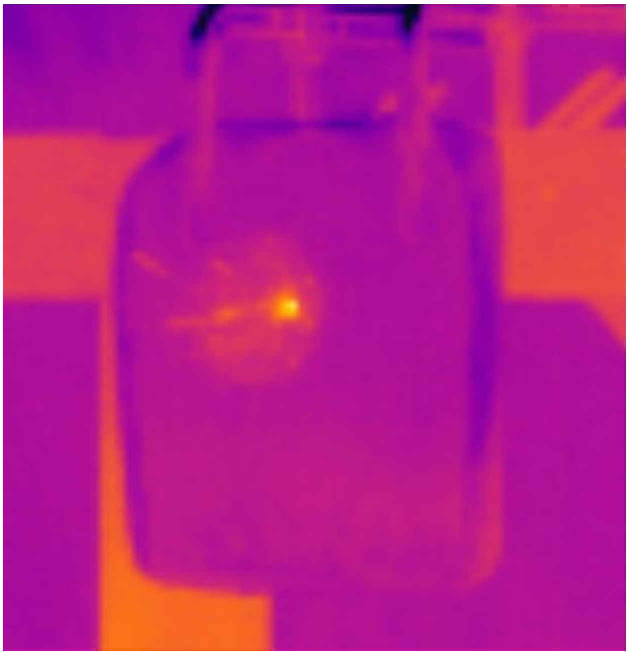

Figure 1. Thermograph of the moment of penetration of the projectile into the sandy substrate

Thermal analysis showed an increase in temperature in the area of impact and scattering of the grains.

Below are the results of the thermal analysis, i.e. temperature change diagrams. Shots of the impact of the 7.62 mm x 39 projectile with an initial velocity of 740 m/s and a velocity measured at the target of 700 m/s were selected. An area of 20 pixels where the impact of the projectile was registered was observed. The diagrams show the maximum temperature in the given area.

The first diagram (Figure 2) shows the change in temperature at the moment of hitting the armor plate. An increase in temperature of about 37 degrees is observed.

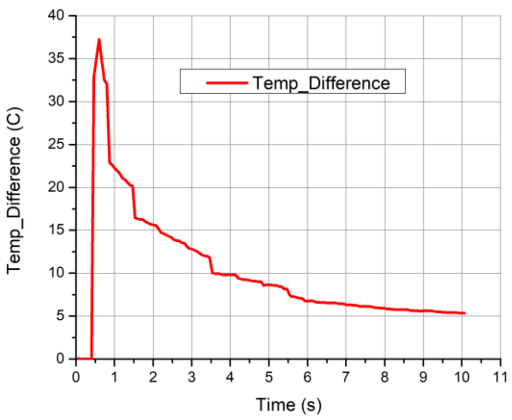

Figure 2. Temperature change diagram for armour plate hitting

Figure 3 represents the moment of hitting the sandy substrate which measures a bit higher temperature change than for armour plate, the increase of 40 degrees.

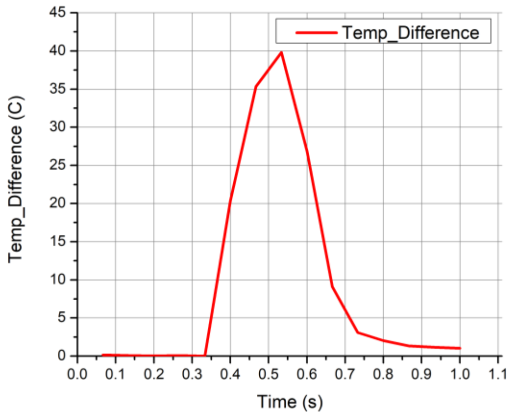

Figure 3. Temperature change diagram for sand substrate hitting

The last diagram (Figure 4) is for a target made of construction cement. In this case, a much smaller temperature change was recorded. The increase was about 22 degrees.

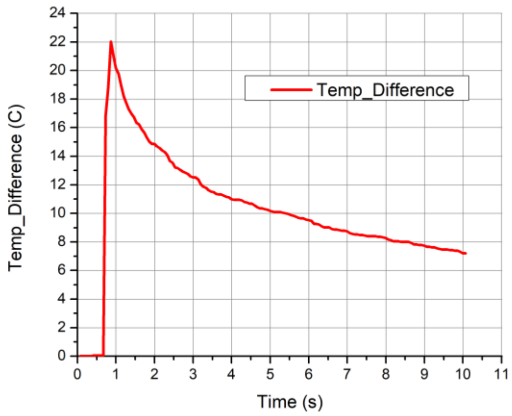

Figure 4. Temperature change diagram for construction cement hitting

From the diagrams obtained, it is evident that the temperature increased for all three cases. In the diagrams shown (Figures 2-4), only the curves of temperature changes of the specific substrate are isolated.

Figure 5 shows a diagram of the temperature change during the entire experiment with a sandy substrate. Here, the temperature is measured not only during the interaction of the projectile with the sand substrate, but also the next moment when the projectile hits the bottom of the base, that is, the armor plate. In this case, it can be observed that after a huge increase in temperature, there is an extremely fast cooling of the substrate, and then reheating when it hits the plate at the back. Such rapid cooling of the granular substrate is a very interesting feature and can represent a great advantage for use when constructing protective materials.

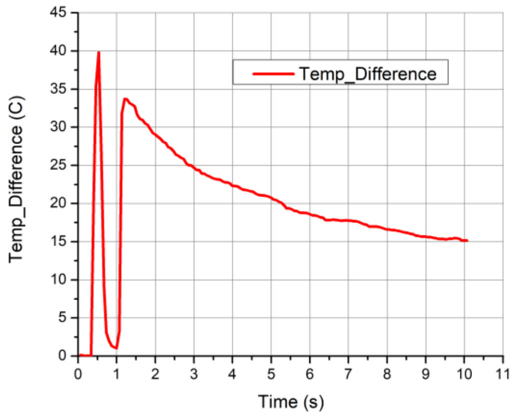

Figure 5. Temperature change diagram for both the sand substrate and armor plate hitting

The analysis of the solid substrate shows heating in a smaller range, which is favorable when viewed as a single material. For a combination of materials in which a significant temperature jump measured with sand could be a signal for some behavior of another material from the combination, this profile is already much more interesting. Looking at it this way, the first advantage for using granulates in protective materials is precisely this big jump in temperature. Especially important is the moment of cooling at a high speed, which is not observed with a solid surface. In this way, the overall material does not overheat. The third advantage refers precisely to the phenomenon observed when comparing the diagram in Figure 2 and the diagram in Figure 5. It can be seen that when shooting only the armor plate, there was a noticeably higher heating of the plate than in the case when the bullet first hit the sandy substrate. This is explained by the loss of kinetic energy during the transfer of heat to the sand, and therefore less heat energy is transferred to the plate itself (which then heats the cooled sand again). This is important because sand, as a very loose material, although it has no stopping power, definitely reduces the kinetic energy. Therefore, granular materials can be used in the construction of protective ballistic materials to create a redistribution of energy that ultimately leads to stopping the projectile in combination with other hard or more resilient materials.

4. CONCLUSION

Bearing in mind that granular substrates that have no stopping power were investigated, this research was based on the examination of impact energy transfer through the granular substrate. The obtained results firstly suggest that granular matter is an excellent structure for use in protective ballistic materials in combination with other materials. This research also showed that it is very important to apply optical methods to examine the effect of projectile on the substrate, more precisely the target. The possibility of obtaining the temperature profile, the impact energy distribution profile, but also the very distribution of the grains of the substrate is of great importance for ballistics and many other applications.

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