APPLICATION NOTE

FAST Thermal Imaging: The New Way to Look at Ballistic Impacts

Abstract

For numerous years, soldier protection dedicated research groups have been using high-speed visible imaging systems in order to evaluate the level of protection offered by various ballistic materials. The main objective of these studies consists in evaluating the amount of energy absorbed by a given material, and how efficient this material is at spreading the absorbed energy to a large area. Obviously, the outputs lead to the commercialization of better and more efficient soldier protective gear.

This phenomenon can straightforwardly be measured very efficiently by a high-speed scientific grade infrared camera. This application note presents the results of measurements of ballistic impact using the Telops FAST-IR 1000 high-speed infrared camera.

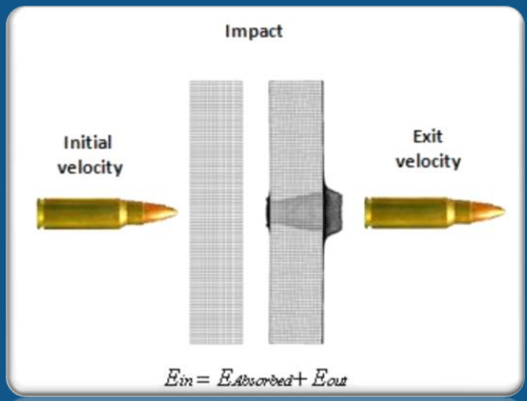

Figure 1: Ballistic impact – Absorbed energy quantification

Visible impact ballistic testing

The traditional way to study ballistic impacts is to perform two distinctive experiments using a visible high-speed camera. The first experiment consists in quantifying the total energy absorbed by a given material. To achieve this goal, the velocity of the projectile is measured before and after the impact (Figure 1). Then, using a simple energy balance equation, the absorbed energy is calculated.

The second part of the experiment is designed to monitor the surface area affected by the ballistic impact. To accomplish this work, scientists typically monitor the material deformation using a visible camera, coupled with human microscope observation following the impact (Figure 2).

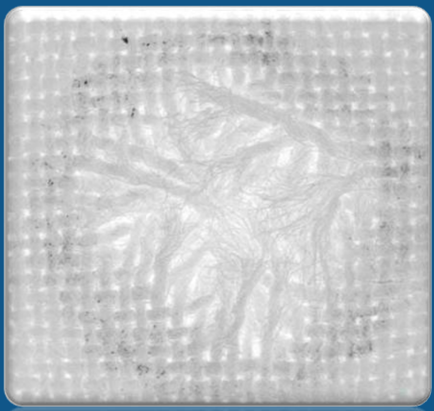

Figure 2: Ballistic impact – Total affected area by microscope analysis

Infrared Impact Ballistic Testing

Infrared cameras measure the radiosity of a given target, i.e. both the emitted and the reflected energy from the target (Figure 3). The Telops FAST-IR 1000 camera is sensitive to heat generation down to a 20 mK sensitivity. The huge amount of heat transfer resulting from a ballistic impact can thus be easily measured by a high performance infrared thermal imager. Based on this concept, one can understand that the high performance infrared camera directly measures the absorbed energy, and the impacted surface area caused by the ballistic impact.

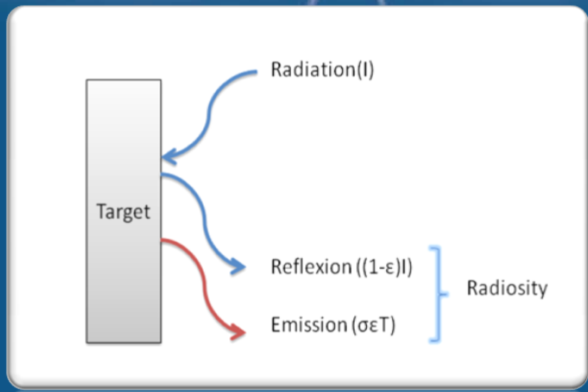

Figure 3: Infrared camera radiosity

Field Testing Experiment

Figure 4 presents the experimental setup used to demonstrate all the benefits of analyzing a ballistic impact with a FAST high performance thermal imager. In this study a M16 rifle using 5.56 mm caliber bullets was used to fire shots through a wooden laminate located at a distance of 10 meters in front of the firearm. The Telops FAST-IR 1000 camera is pointing at the target with a small angle of incidence at a distance of about 12 meters. Detailed test setup parameters are presented in table 1.

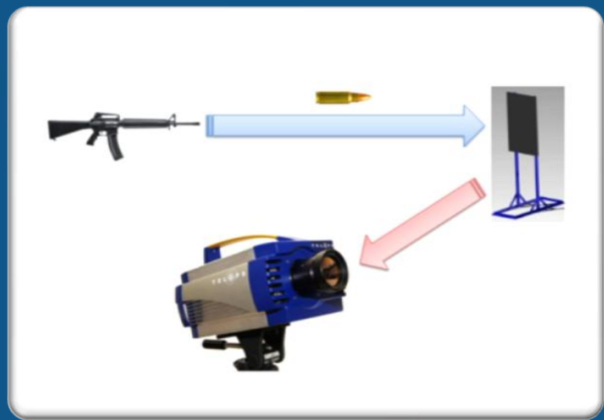

Figure 4: Field testing setup

Parameters	Unit	Value
Bullet diameter	mm	5.56
Bullet mass	g	4.1
Bullet entry speed	m/s	905
Camera frame rate	Hz	7000
Spatial resolution	Pixels	128x128
Camera FOV	° (HxV)	1.2x1.2
Camera sensitivity	mK	< 20
Distance to target	m	6

Table 1: Experiment parameters

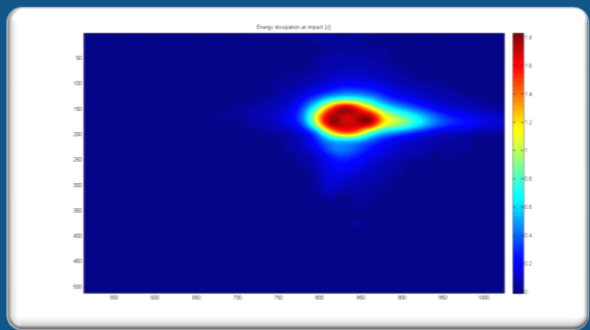

Figure 5: Energy distribution at ballistic impact (7000 Hz)

Results & Discussion

The results from the measurements reveal a quasi circular shape energy distribution with a main energy propagation line toward the right corner of the target. Figure 5 introduces the spatial distribution of the energy (Joule) at t = 0.00014 second following the ballistic impact. The energy propagation preponderance toward the rigth direction is explained by the angle of incidence of the bullet not being perfectly perpendicular to the target. This result shows the true and incredible sensitivity of the Telops FAST-IR 1000 infrared imager. Figure 6 presents the after impact dynamic energy proliferation sequence. Images were taken at a time interval of 0.00014 second. It can be observed that the energy distribution quickly resorbs following the impact. An appealing feature appears at t=0.00056 second whereas a plastic deformation (crack) propagating toward the bottom left section of the target is noticable.

Another interesting way to analyze the performance of the FAST-IR 1000 infrared camera in this high dynamic and high energy application is to look at the dynamic progression of the energy over the entire images and surface area affected by the ballistic impact. As shown in Figure 7, the user has direct access to the total absorbed energy occurring during the impact. In fact, the total energy absorbed peaks around 1193 Joules after approximately 60 ms. More than 40% of the total energy absorbed by the ballistic material occurred within the first (1) ms following the impact. Considering that the ballistic kinematic energy [1/2 mv^2] of the bullets before the impact is about 1679 Joules, it was calculated that more than 71% of the bullet kinematic energy has been absorbed by the wooden laminate. Moreover, the total affected surface area is approximately 400 mm^2. The ratio between the absorbed energy and the total surface area indicates the maximum energy density never exceeded 0.2 Joules/mm^2.

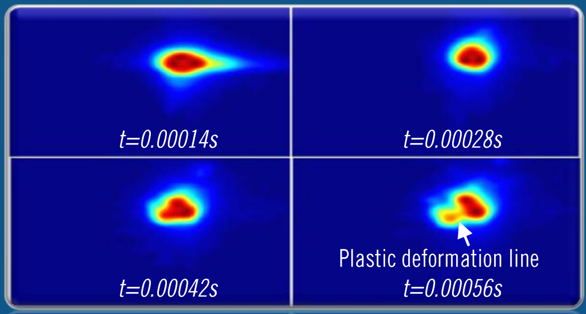

Figure 6: Energy distribution at different time intervals

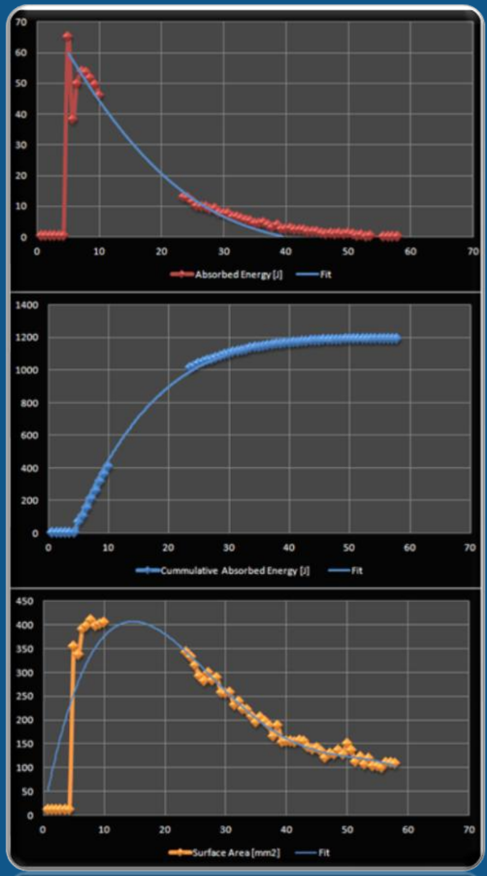

Figure 7: Ballistic impact - Absorbed energy (top), cummulative energy (middle), and surface area affected by the impact (bottom).

Conclusion

The benefits of obtaining a passive direct FAST energy measurement to the characterization of ballistic material are numerous. The most obvious of them is it's allowing the user to see beyond the visible deformation limit the real surface area affected by a ballistic impact. Heat is generated not only by the plastic mechanical deformation but also by the stress induced by the impact. These thermodynamic behaviors are easily captured by the unique Telops FAST-IR 1000 infrared camera. The Telops FAST-IR 1000 is the perfect infrared camera for soldier protection ballistic analysis. Its unique speed combine with best in class NETD makes it the perfect tools to push the soldier protection research to the next level.

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