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Analysis of Ballistic Impacts on Composite materials by Infrared Active Thermography

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Abstract

This work focused on the assessment of the damaged area on composites ballistic plates subjected to high velocity impact. Active pulsed thermography technique was used for performing post-mortem analysis of the impacted specimens. The post-mortem analysis was combined with inputs of the velocity of the projectile, the absorbed energy to evaluate how efficient the material is at spreading the absorbed energy to a large area.

1. Introduction

Since the beginning of the last century the ongoing advances in materials engineering have led to an unrestrained development of new technologies. Composite materials are the ones attracting most attention because they have many advantages over their homogeneous counterparts. These include high specific stiffness and high specific strength combined with a significant reduction in weight [1-2] making them attractive for many industrial applications. One of the most important fields of application is the defense industry were the composites properties such as low weight, rigidity, strength and durability are of key importance. Composite materials made from artificially obtained high strength fibers [3] are particularly interesting. These composites are characterized by many fiber-reinforced properties that make them ideal for ballistic protection applications. The ballistic protection equipment should protect the user from for instance arms fire. The proper analysis strategy of the area of internal damage caused by the impact of bullets is very important in the research and evaluation of protective composite ballistic equipment. Damage to the internal structure of the composite coating material can only be assessed using non-destructive testing methods. Such methods, such as infrared thermography test methods, are particularly effective in the case of composite materials. This work focused on the assessment of the damaged area on composites ballistic plates subjected to high velocity impact. Active pulsed thermography technique was used for performing post-mortem analysis of the impacted specimens. The post-mortem analysis was combined with inputs of the velocity of the projectile, the absorbed energy to evaluate how efficient the material is at spreading the absorbed energy to a large area.

2. Experimental Information

2.1. Ballistic impact testing

In this study a M16 rifle using 5.56 mm caliber bullets was used to fire shots threw a wooden laminate located at a distance of 10 meters in front of the firearm. High speed visible cameras were used to measure the projectile velocity before and after the sample. The Telops high speed infrared camera was used pointing at the target with a small angle of incidence at a distance about 12 meters. Detailed test setup parameters are presented in table 1

Table 1. *Experiment parameters*

Parameters	Unit	Value
Bullet diameter	mm	5.56
Bullet mass	g	4.1
Bullet entry speed	m/s	905
Infrared Camera frame rate	Hz	7000
Spatial resolution	Pixels	128 x 128

2.2. Active thermography testing

Active thermography experiments were conducted with Telops new non-destructive testing solutions called TESTD. Flash lamp source with pulse energy of 6 KJ was used to excite the wooden laminate sample after the ballistic testing. Telops high definition Infrared camera was used to capture the sample cooling after the pulse heating and Fourier transform analysis were conducted to obtained phase images.

3. Results

The ballistic impact testing was conducted on 3 different materials (all composite type) with a total of about 80 shots. We analysed three different impact type: bouncing, perforation and partial perforation at different projectile speeds. The figure 1 a and 1b show phase images of the ballistic plate at 2 Hz and 0.03.Hz. Impact damage at the surface of the sample can be seen and quantified using the high frequency phase image, while the low frequency phase image is used to assess the subsurface damage. The impact radius was found to increase linearly with the projectile speed in the partial perforation case, while being independent of projectile speed in the total perforation scenario (see Fig 1.c)

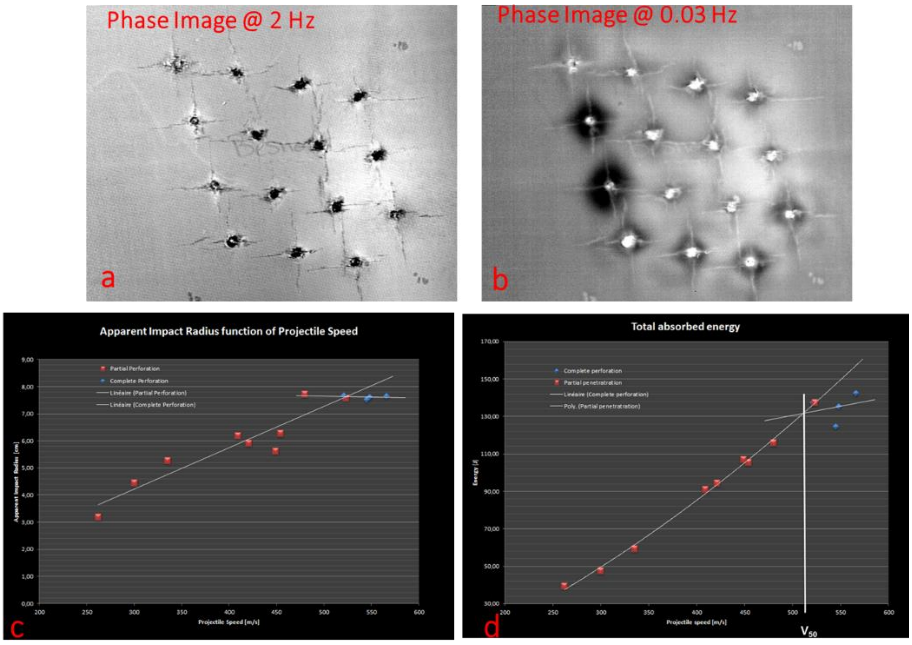

Fig. 1. *Phase images (a,b) and radius (c) and total absorbed energy (d) as a function of projectile speed.*

We also analysed the total absorbed energy in the material (Fig.1d) for the different projectile speed and impact radius. This was used to assess the limit of V_{50} ballistic protection which is a determination of the arithmetic mean of the three highest values of projectile impact speed in the test sample resulting in partial penetration, and the three lowest values of impact velocity causing total penetration.

4. Conclusion

When sample is impacted by the projectile, at the moment of impact the projectile is slowed by a large number of individual fibers. As a result of the impact, fibers in the sample stretch and break to absorb the kinetic energy of the projectile casing. This creates a subsurface defect in the composite structure with a much greater area than the caliber of the projectile. We showed in this work that it is possible to assess the degree of destruction of the internal material as more damaged areas generate more heat, and over these areas, the surficial temperature signal has a higher value. We also demonstrated the benefits of using high speed infrared camera for 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 behaviours are easily captured by the high-speed infrared camera.

REFERENCES

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