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Mapping with the Image Processing Method of Damage Regions with Respect Composite Laminates Subjected to Low Velocity

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Abstract

In this study , uni-directionaly reinforced laminates that arranged e-glass / epoxy composite samples in the form [+ 45 / -45 / 90/0 $]_s$ and [+ 45 / -45 / 90/0 $]_{2s}$ was applied low-velocity impact tests at impact energies of 10, 20 and 30 J has been obtained 8 and 16 laminated sample. Low-velocity impact tests were performed with the drop weight test device. Low-velocity impact damage was created on the samples depending on the different impact energies as a result of experiments conducted with hemispherical various impactor. The impactor mass was 6.350 kg. Digital imaging process method was applied images of the samples subjected to impact damage and damage maps for each damage zone were extracted. Also, change graph of damage area depending on the impact energies has been omitted. Changing damage zones were extracted. Also, change graph of damage area depending on the impact energies has been omitted.

Key words

Image processingmethod, Low-velocityimpact, Failureanalysis

1. INTRODUCTION

Composite materials have been used as a valid advantageous alternative for structural materials, replacing not only steel but even light alloys in the construction of some parts of vehicular body, spaceship, and aerodynamic structures and so forth. These materials are subjected to a wide spectrum of loadings during in-service use. Dynamic impact loadings, particularly in impact type events, represent a serious design condition for use of laminated composites for in-service applications, for example, dropping of tools during maintenance of the aforementioned industries. One of the properties of the laminated composite structures is that they are more susceptible to impact damage than similar metallic structures. If a composite laminate is subjected to normal low-velocity impact, invisible damage consisting of internal delamination might be induced [1]. Understanding the damage involved in the impact of composite targets is important in the effective design of a composite structure. For these reasons, numerous experimental and analytical techniques have been developed to study the dynamic response of composite structures subjected to transient dynamic loading. Some of the prominent work in this area is briefly mentioned in the following [2]. Damage mechanisms in composite materials are fairly complex, involving the interaction of matrix cracking, fiber matrix debonding, fiber pullout, delamination and fiber breakage. Generally, they occur simultaneously making the stress and failure analysis more difficult [3]. Impact failure in composites consists of various fracture modes which combine giving rise to a quite complex three-dimensional pattern [4–6]. Due to thecomplex features of damage mechanisms, more than one method is usually required for a complete non-destructive evaluation of impact induced damage. Advantages and disadvantages of different available techniques depend on the type of damage to be detected and on the test conditions in which sophisticated laboratory techniques can give highly accurate results, but may not be able to assess the state of the structure under in-service conditions [7]. There are various investigation techniques for determination of damages on composite materials. These are acoustic emission, thermography, dye penetrant, stereo X-ray radiography and ultrasonics. [8–10]. Unlike these methods, Image processing techniques are used in this study for determination of damages on composites. Delamination is observed to be the major failure mode. There for delamination areas are determined using image processing.

2. MATERIALS AND METHODS

2.1. Materials and specimens

In this study unidirectional E-glass/epoxy composite laminates were used. The laminates were cut into specimens of 140x140 mm in dimension with an average thickness of 1.6 and 3.2 mm. Stacking sequence of 8 laminated sample is $[+45/-45/90/0]_s$ and 16 laminated sample is $[+45/-45/90/0]_{2s}$.

2.2. Low velocity impact tests

The impact tests performed at impactor mass (6.35 kg) for three different impact energies (10, 20 and 30 Joule) were conducted with a drop weight testing machine (Figure 1). The radius of the impactors with a hemispherical nose was 6 and 12 mm. The composite specimen with dimensions of 140 mm by 140 mm was clamped on a fixture along a square circumference having a 100 mm side. The center of each plate was exposed to impact loading. The differences in the impact responses of specimens with varying width are characterized.

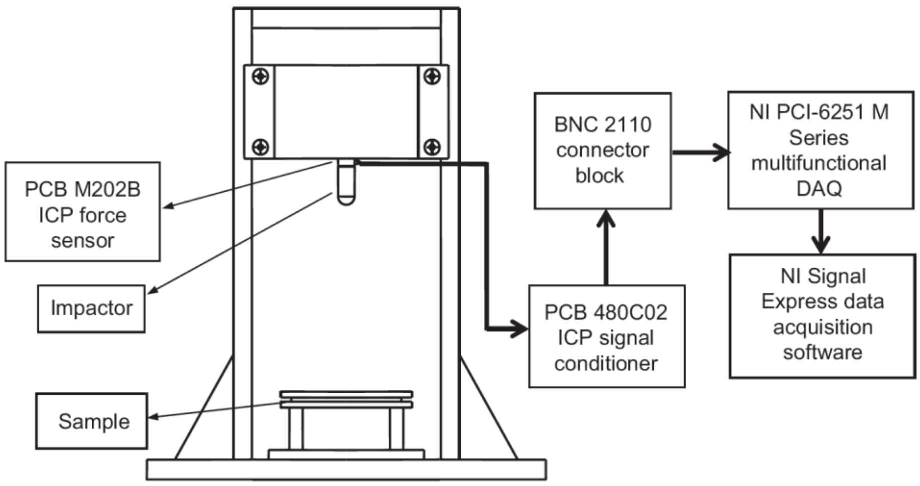


Figure 1. The Test rig [11]

2.3. Image Processing

Image processing involves processing or altering in an existing image. An image consists of a two-dimensional array of numbers. The color or gray shade displayed for a given picture element (pixel) depends on the number stored in the array for that pixel. The simplest type of image data is black and white. It is a binary image since each pixel is either 0 or 1. The next, more complex type of image data is gray scale, where each pixel takes on a value between zero and the number of gray scales or gray levels that the scanner can record. Most gray scale images have 256 shades of gray. The most complex type of image is color. Color images are similar to gray scale except that there are three bands, or channels, corresponding to the colors red, green, and blue. Thus, each pixel has three values associated with it [12].

Edge detection is one of the fundamental operations in image processing. The edges of items in an image hold much of the information in the image. The edges tell you where items are, their size, shape, and something about their texture.

Image segmentation is the process of dividing an image into multiple parts. This is typically used to identify objects or other relevant information in digital images. In segmentation, the computer attempts to find the major objects in the image and separate or segment them from the other objects [13].

Color mapping is a function that maps the colors of one (source) image to the colors of another (target) image [14]. A colormap is matrix of values between 0 and 1 that define the colors for graphics objects such as surface, image, and patch objects. MATLAB draws the objects by mapping data values to colors in the colormap.

3. EXPERIMENTAL STUDY

In this study, an image processing approach to detect damage regions with respect composite laminates subjected to low velocity impact was proposed. The process steps of the proposed approach are given bellow;

Colormaps can be any length, but must be three columns wide. Each row in the matrix defines one color using an RGB triplet. An RGB triplet is a three-element row vector whose elements specify the intensities of the red, green, and blue components of the color. The intensities must be in the range [0,1]. A value of 0 indicates no color and a value of 1 indicates full intensity. For example, this is a colormap with five colors: black, red, green, blue, and white [13].

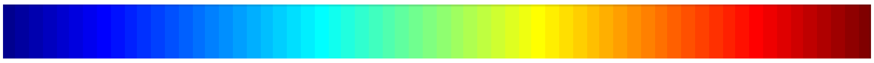


Figure 2. Colormap(jet) function used in the study

To create a custom colormap, specify map as a three-column matrix of RGB triplets where each row defines one color. An RGB triplet is a three-element row vector whose elements specify the intensities of the red, green, and blue components of the color. The intensities must be in the range [0,1].

It basically represents a walk on the edges of the RGB color cube from blue to red (passing by cyan, green, yellow), and interpolating the values along this path [13].

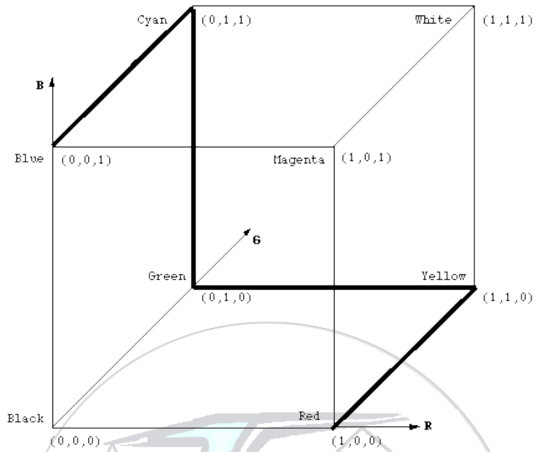


Figure 3. RGB color triplet cube

The RGB triplet values for common colors are shown in Table 1.

Table 1. The RGB triplet values for common colors

Color	**RGB Triplet**
Yellow	[1,1,0]
Magenta	[1,0,1]
Cyan	[0,1,1]
Red	[1,0,0]
Green	[0,1,0]
Blue	[0,0,1]
White	[1,1,1]
Black	[0,0,0]

4. EVALUATION OF THE STUDY

The damages on glass/epoxy and Kevlar composite samples can be observed by directing light beam from the back of the damaged areas. The size and nature of layer separation together with the existing matrix cracks can be determined with naked eyes [15]. After impact at various impact energy levels, high-resolution photographs of the damaged areas at the front of the test samples were taken using a simple backlighting method [1]. Image processing approach was applied these high-resolution photographs to detect damage regions with respect composite laminates. Figures 4–7 just show damaged areas of the specimens obtained using backlighting for specimens and photographs which were applied image processing, respectively.

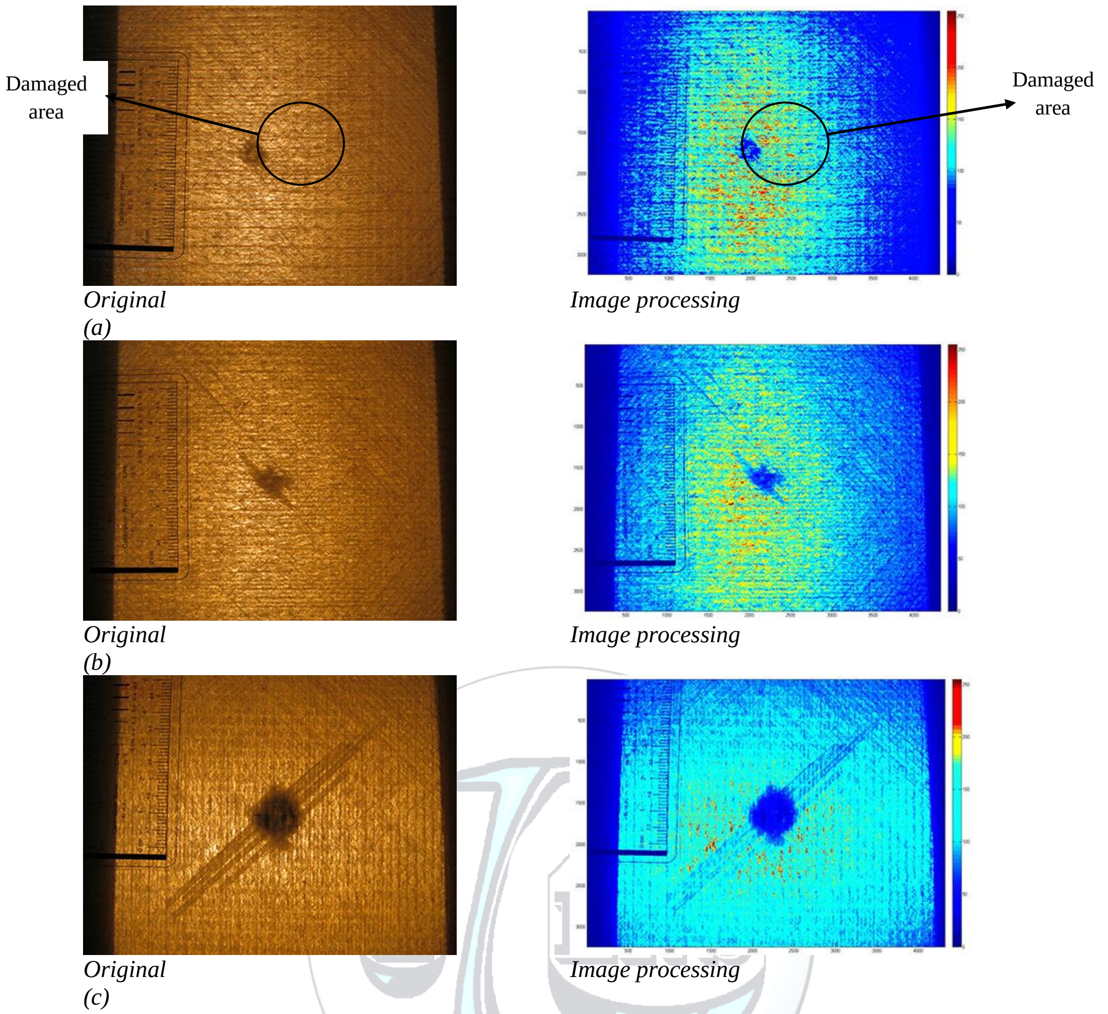
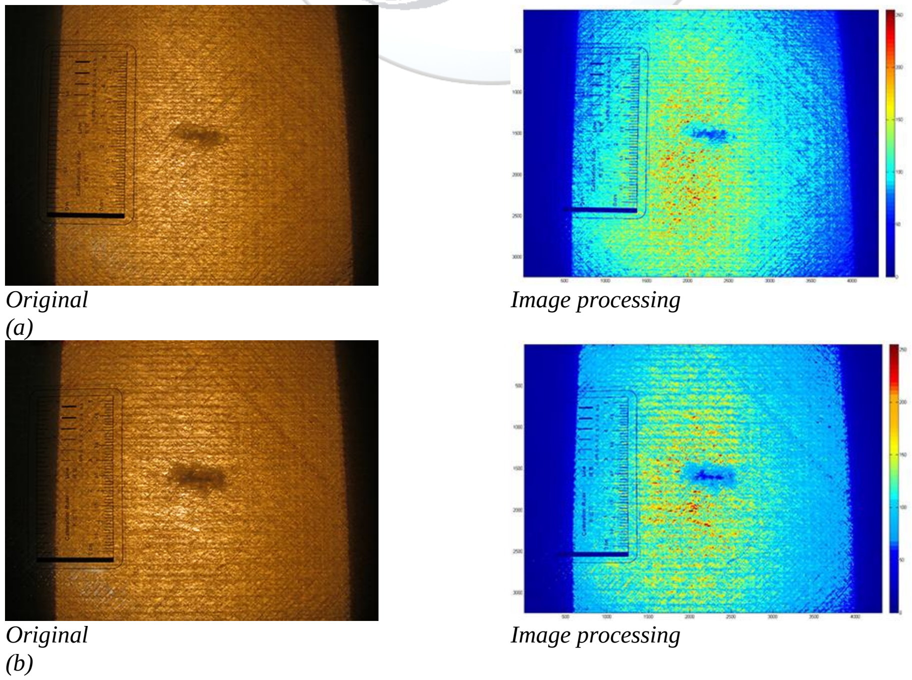
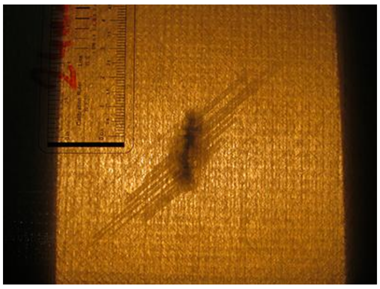
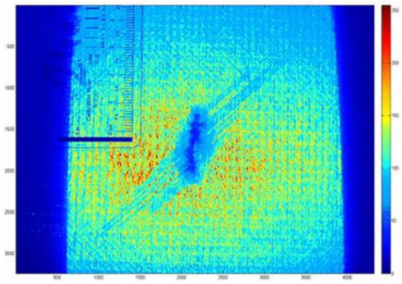


Figure 4. Original and image processing view of 8 laminated sample subjected to (a) 10, (b) 20, and (c) 30 J impactenergy levels. (12 mm in diameter hemispherical impactor)

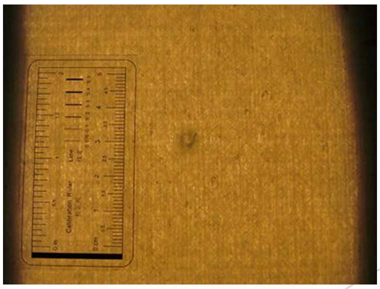
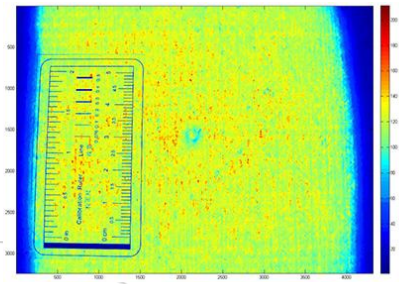


Original *Image processing*

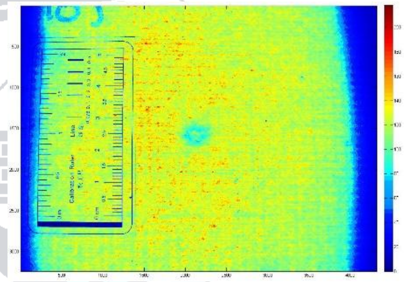
(c)

Figure 5. Original and image processing view of 8 laminated sample subjected to (a) 10, (b) 20, and (c) 30 J impactenergy levels. (24 mm in diameter hemispherical impactor)

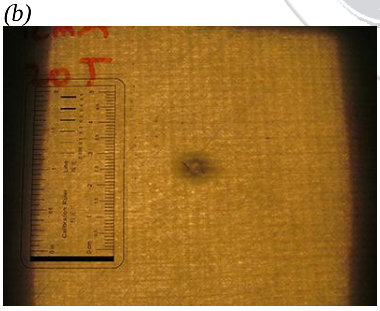
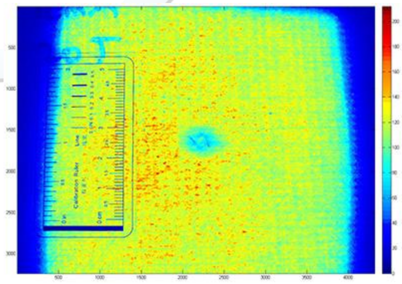
Original *Image processing*

(a)

Original *Image processing*

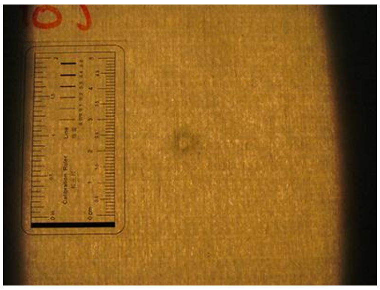
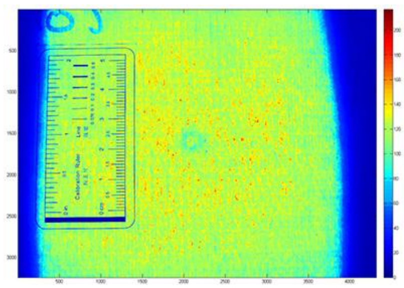
(b)

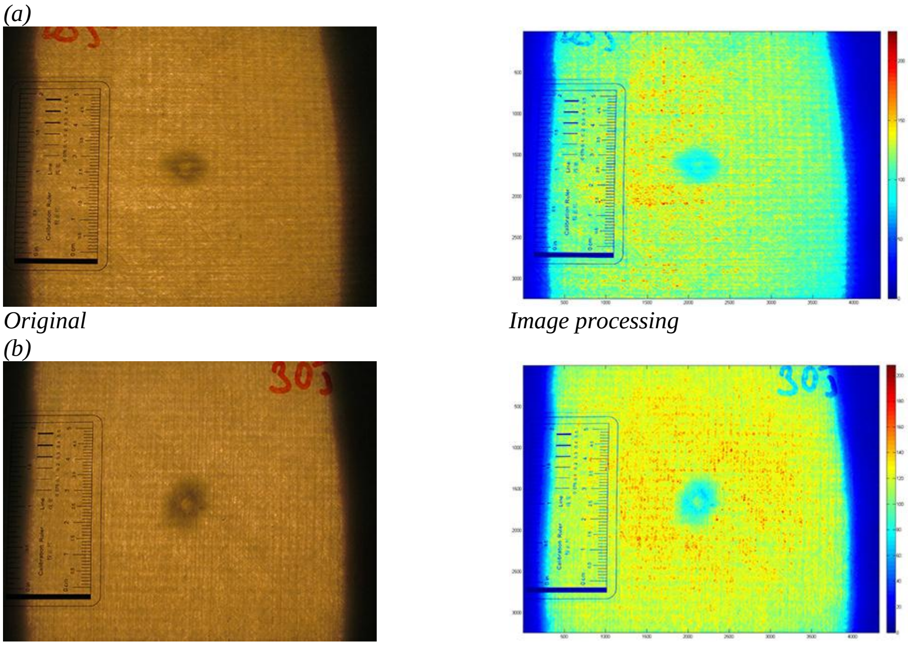



Original *Image processing*

(c)

Figure 6. Original and image processing view of 16 laminated sample subjected to (a) 10, (b) 20, and (c) 30 J impactenergy levels. (12 mm in diameter hemispherical impactor)



Original (a) — Image processing

Original (b) — Image processing

Original (c) — Image processing

Figure 7. Original and image processing view of 16 laminated sample subjected to (a) 10, (b) 20, and (c) 30 J impactenergy levels. (24 mm in diameter hemispherical impactor)

5. CONCLUSIONS

The Image processing technique was used to detect and map damaged area. Practical results obtained from this study;

- Using image processing techniques, it was possible to quantify the damage areas.
- The result shows that for low velocity impact tests, as the impact energy increased the damage in the composite laminated increased.
- Dimensions of sample, especially thickness of the specimen in this study, have significantly affected the damage area that increases as the thickness of the specimen increases.
- In the tests conducted with various hemispherical taps, as the radius of the tap increases the damage area increases for the same energy level.

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