Fast Infrared imaging of static and dynamic crush tests of composite tubes

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ABSTRACT

We describe fast infrared imaging of both static and dynamic crush tests on glass-fiber composite tubes. The results are compared with video images of the same tests.

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1. INTRODUCTION

In general, active infrared imaging has been used as a powerful NDE/NDI (non-destructive evaluation/non-destructive inspection) tool for various structures and characterization of materials. Ordinarily, NDE methods use external heating. However, passive infrared imaging can be used in situations where the temperature of the target changes as the result of deformation or stress. In this paper, we present the application of passive thermal wave imaging to the study of fracture of composite structures.Fast infrared (IR) imaging techniques are used to quantitatively study the energy absorption capabilities of composites, using different glass fiber composite tubes, and at different crushing speeds. A block diagram of our experimental arrangement is shown in Fig. 1.

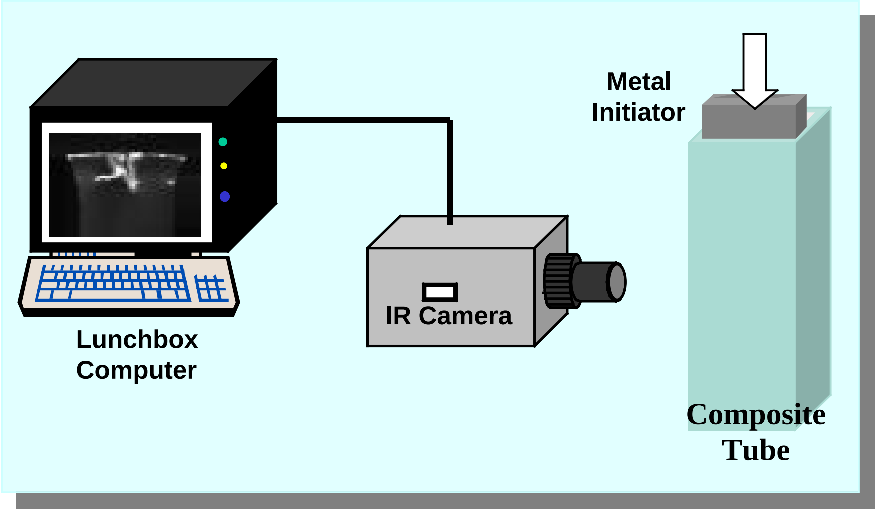


Fig. 1 Schematic drawing of Experimental setup

The composite tube is fractured by wedging open one end of the (square cross-section) tube with a servo-hydraulic press pushing on a metal wedge (the crack initiator). As the fracture begins, the release of mechanical energy causes the temperature to rise locally in the vicinity of the resulting cracks. The IR camera shown in Fig. 1 was used to image the resulting temperature patterns sequentially as the fracture proceeds. The camera contains a 256 x 256 focal plane array IR camera, operating in the 3µm - 5µm spectral range of the IR, and the camera was run at full frame rates up to 140 Hz, and at frame rates up to 500 Hz for a 128 x 128 sub-window of the array. A study of the details of the temperature changes in the material can be used to determine the energy absorbing properties of the composite, and thereby to obtain insight into such important structural properties as fracture toughness.

2. EXPERIMENTAL RESULTS

In Fig. 2 we show a sequence of thermal images of continuous strand mat (CSM) glass fiber composite taken with system shown in Fig. 1, being crushed at a constant speed of 2 inches/min. The tube is 8 inches long, with a 2 inch square cross section. The crack initiation in the closest corner is clearly evident in the first image in this sequence (top left). In the third image (top right), the appearance of lateral cracking is seen. As time progresses, more cracking appears and the sides of the tube curl over, and these sides are heated both from friction of the wedge and from delamination and plastic deformation of the matrix.

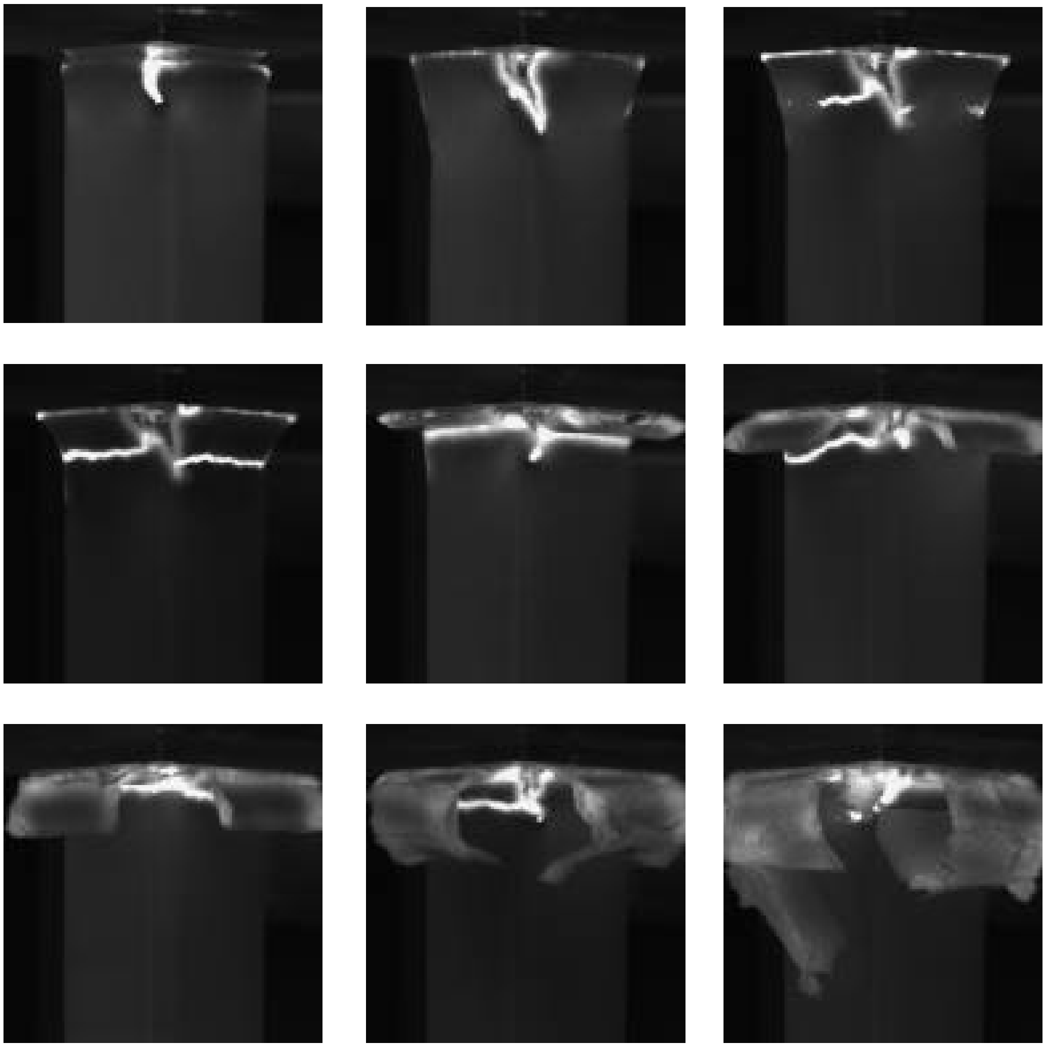


Fig. 2 Static crush: Time sequence of thermal images of csm13d thin composite specimen

In Fig. 3 we show two optical images which were recorded at the beginning and end of a crush test of a second tube of the same material as that of the tube in Fig. 2, taken with a normal video camera. The fracture and delamination are also readily apparent in these video images, but the information about energy absorption is not available from such images.

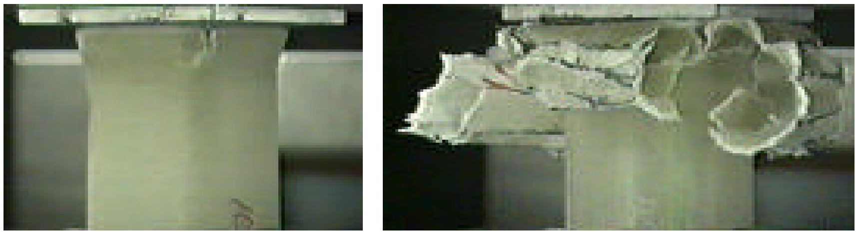
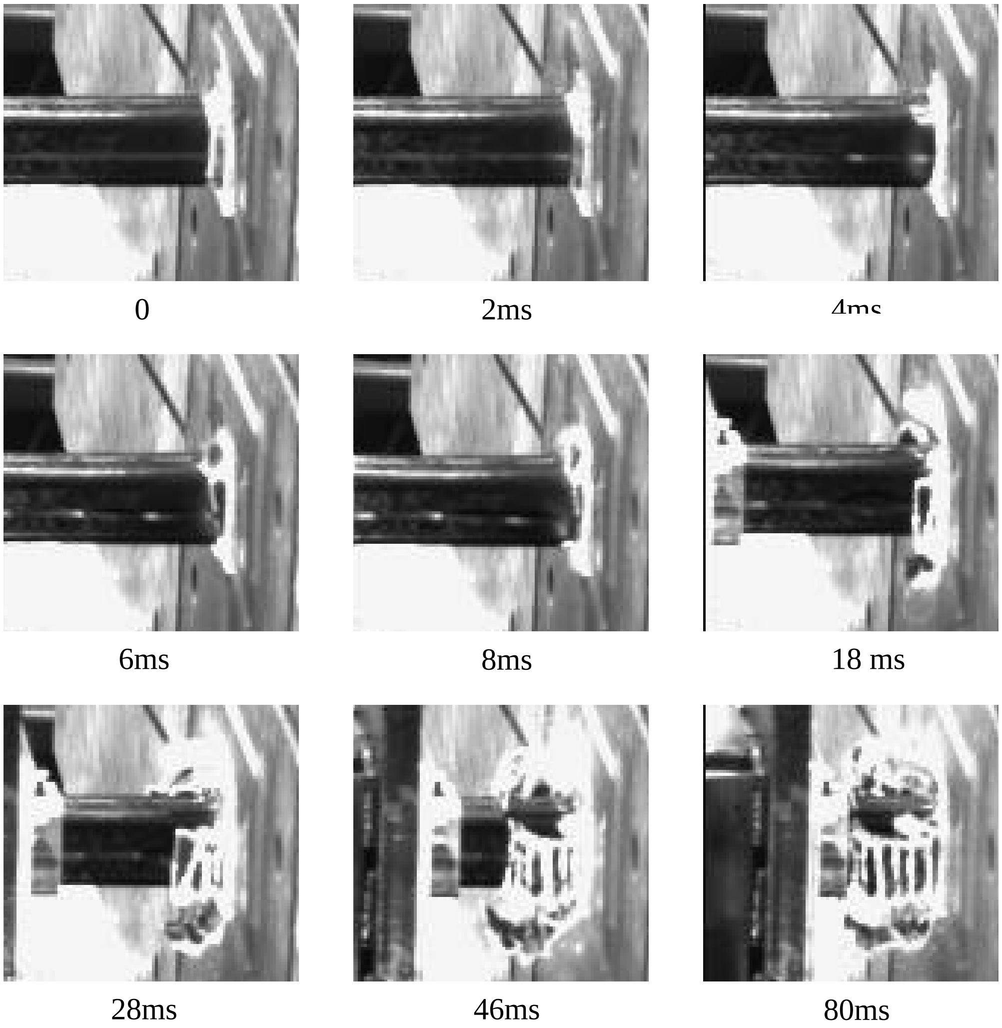


Fig. 3 Dynamic crush: Time sequence of thermal images of csm10d thin composite specimen.

In Fig. 4, we illustrate the high speed capability of the IR imaging system. A tube of similar structure to that used in the slow crush experiments of Figs. 2 and 3 was crushed in a crash sled test at a speed of 2.9 m/s. The details of the fracture are different, and can be used to study dynamic energy absorption.



0 2ms 4ms

6ms 8ms 18 ms

28ms 46ms 80ms

Fig. 4: Time sequence of thermal images of a fast fracture experiment on a composite tube of similar structure to that imaged in Figs. 2 and 3.

To show how IR imaging can be used to study the differences in thermal and mechanical properties of different composite materials, in Figs. 5 and 6 we show IR images during static and dynamic crush experiments on a composite tube of similar dimensions, but different fiber orientation and ply lay-up.

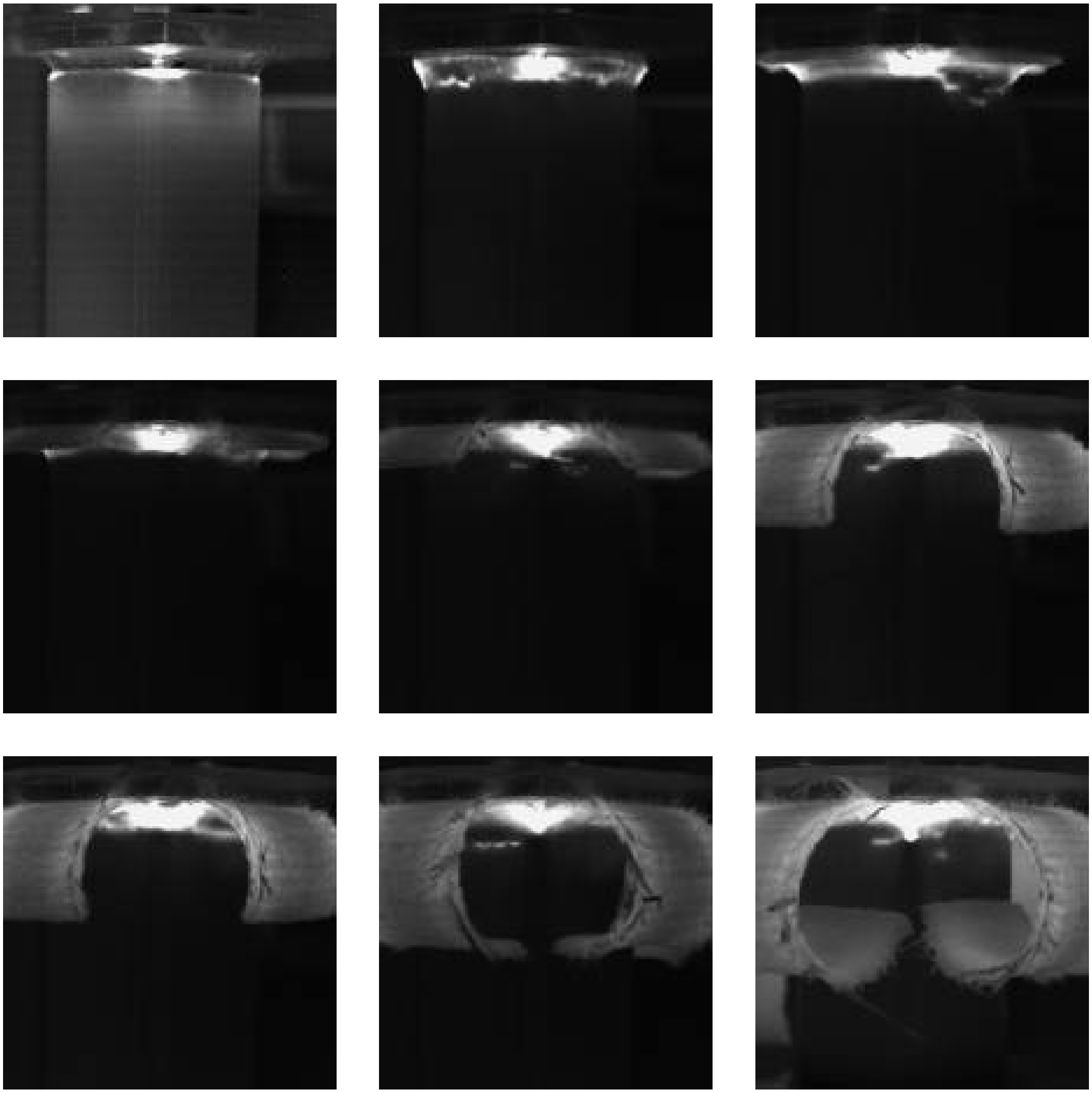


Fig. 5 Sequence of IR images taken during a static crush experiment of a composite tube similar in dimension to that imaged in Fig. 2, but with a different fiber orientation and ply lay-up. Clear differences can be seen in the fracture energy dissipation between the two materials (compare with Fig. 2).

0

2ms

4ms

8ms

18ms

28ms

46ms

70ms

84ms

Fig. 6 Sequence of IR images taken during a dynamic crush experiment of a composite tube similar in dimension to that imaged in Fig. 4, but with a different fiber orientation and ply lay-up. Clear differences can be seen in the fracture energy dissipation between the two materials (compare with Fig. 4).

3. ACKNOWLEDGMENTS

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