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Analysis of PVT Composite Structure Images Using a Search Through Algorithm

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Abstract: - An effective NDT (Non-Destructive Testing) image analysis technique for detecting materials damage and defects existence has been developed successfully and applied to PVT images of composite structures. The developed technique is based on converting an image to its equivalent pixel values and then applying Search Through (ST) algorithm to the converted image such that the presence of damage in the composite structure and its extent can be easily verified.
The technique has a novel approach to data analysis by employing intensity, RGB signal re-mix and wavelength variation of a thermally generated IR-beam onto the specimen under test which can be sensed and displayed on a computer screen as an image. Specimen inspection and data analysis are carried out through pixel level re-ordering and shelving techniques within a transformed image file using a sequence grouping and regrouping software system, which is specifically developed for this work.

Key-Words: - Non-Destructive Testing, Defect Detection, Thermography, Image Reconstruction, Intelligent Systems, PVT.

1 Introduction

The layered composites are presently are among the most widespread advanced materials in use, such as fiber reinforced composites with polymeric matrices and polymeric sandwich materials, with thin laminate faces and foam or impregnated cores. The structural design and maintenance of composite structures involving these materials need comprehensive evaluation and characterization of mechanical properties and behavior under different loading conditions, in both undamaged and damaged states.

The marked inhomogeneity and anisotropy of these materials make them vulnerable different types of damage. For this reason, reliable composite structures need adequate NDT/NDE methods along the maintenance activities and knowledge of residual strength/stiffness or service life estimation linked to certain damage patterns. In the end, development of damage tolerant materials may be considered a goal towards further increasing the attractiveness of composite materials in building high tech reliable products. Many NDT methods were proposed and are in use for evaluating the structural integrity of composites, from simple visual inspection to laser shearography, with various sensitivity, versatility and affordability. In order to have a versatile NDT inspection method, ready to be used in industrial applications, not merely for laboratory research, the prime requirement is to need access on only one side using Pulse Video Thermography (PVT) assisted by computer and intelligent software specifically designed for this purpose.Thermal imaging information can be obtained regarding the following parameters [1, 2, 3, 4, 5, 6, 7,]:

- Thickness variation.
- Material content homogeneity.
- Porosity.
- Defect dimensions.

PVT is aimed at the discovery of subsurface features (such as subsurface thermal properties, presence of subsurface anomalies/defects) due to relevant temperature differences observed on the surface with an infrared (IR) camera.

Most NDT techniques available at present suffer from limitations imposed by detecting hardware, interpreting software or both. These limitations such as accuracy, resolution, depth of detection, type of detected defect, instrument portability, data repeatability, and material properties have been under investigation for some considerable time. The efforts were mainly directed towards sophistication of the detecting devices and the processing system. In addition, the most successful NDT systems are extremely costly and time consuming in the detection and analysis [8, 9, 10, 11, 12, 23, 24, 25].

In this paper a new technique in detecting and analyzing the presence of damage in a composite structure is presented. The technique employs an intelligent algorithm that searches and locates defective part of the damaged composite making use of boundary transitions in three dimensions. Such differentiable transitions are used to clearly indicate the presence of damage in the tested structure.

2 Experimental Setup

The chosen composite was a laminate made by resin injection molding (RIM) to produce 5mm thick samples that contain five layers of U750/450 Vetrotex continuous mat glass fiber impregnated with 65.4% 1153/72/A epoxy resin from SHELL mixed with 50g of 1153/172/B hardener at 4:1 ratio.

The equipment used comprised a heat source rated at 2000 watts with an AGEMA Infrared Camera. Images are captured in real time and analyzed using our ST algorithm.
Fig.1 illustrates our PVT testing system. The automated image capturing system possesses the following main characteristics:

- The ability to extract important information from a background of irrelevant details.
- The capacity to learn from experience and apply its knowledge to new situations.
- Capable of correlating and predicting from distorted or lost data files.

Fig.1 illustrates the system used to acquire and process the obtained thermal image. The system consists of the normal PVT system with the addition of the innovated sampling and sequence reconstruction technique which is run under smart environment that provides the overall interpretation.

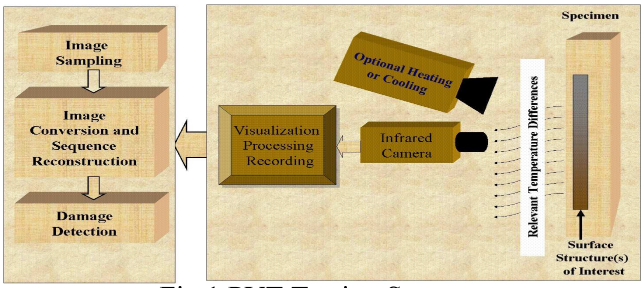

Fig.1 PVT Testing System

This system operates on the principles of image slicing and nearest neighbor classifier [17, 18, 19, 20, 21, 22]. Our classifier differs from other the known classifiers in that it in two dimensions on the converted image pixels and their intensities and statistically regrouped in comparison to intensity thresholds as shown in fig.2.

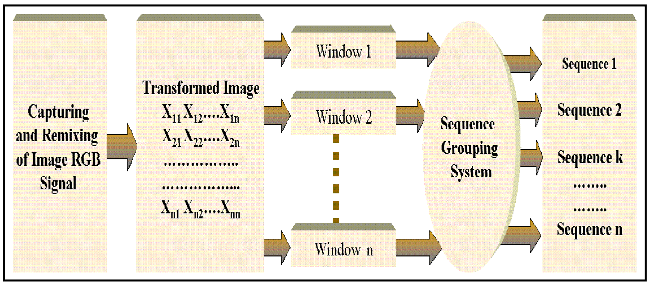

Fig.2 Search Through Algorithm

3. Testing Results

Thermal non-destructive testing can be employed to detect inclusions and flaws in polymeric composite laminates by demonstrating the difference in their heat transfer properties from the undamaged structure. When external heat is applied, the presence of defects affects the normal heat flow pattern of the structure. If this heat propagation is altered sufficiently, a temperature distribution profile can be realized. This distribution is then related to the existence of a flaw in the material. Infrared devices and sensitive coatings (e.g. liquid crystals) are two of the most practical temperature detecting systems that may be used in developing test devices [13, 14, 15, 16].

Thermography is essentially a technique whereby infrared radiation from the sample is captured and subsequently converted into an electrical signal generating a real-time thermal image.

Fig.3-6 shows the captured images for a composite structure over intervals of time.

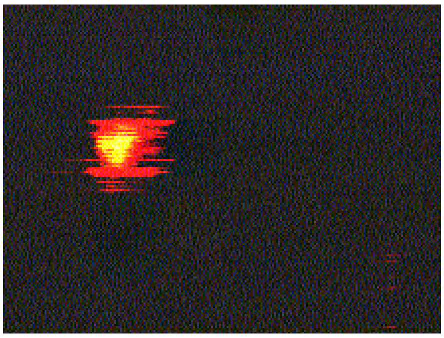

Fig.3 Component exposure to heat pulse (Stage 1)

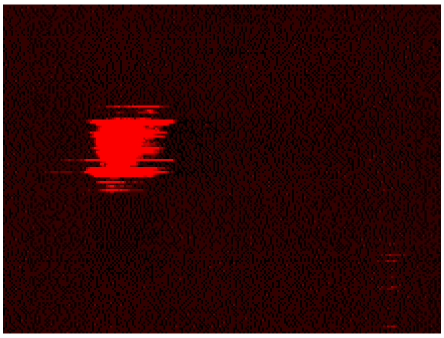

Fig.4 Component exposure to heat pulse (Stage 2)

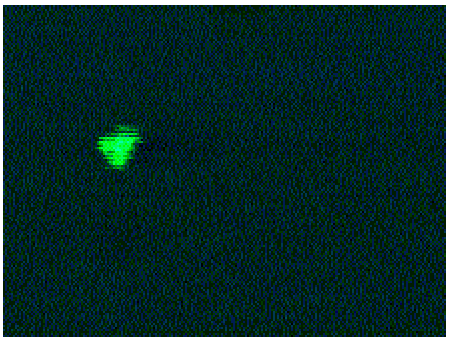

Fig.5 Component exposure to heat pulse (Stage 3)

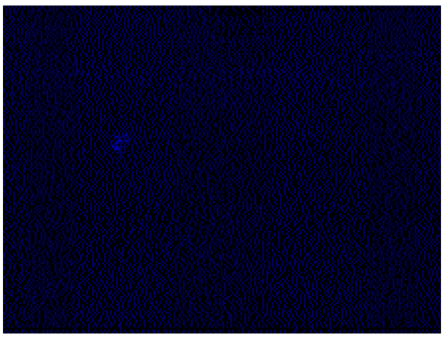

Fig.6 Component exposure to heat pulse (Stage 4)

4. Discussion and Conclusion

From the images and fig.7-9, we deduce that using sequence reconstruction can be very effective in determining the real existence of damage. Fig.7 illustrates the over all damage characteristics obtained using our ST algorithm. It is clear that there are two localized areas of damage, these areas are shown in fig.8 and fig.9, where the damage is detected in stages as a function of time and space. The separation between the peaks of the curves indicates boundary crossing and distance between Macrostates. The shown curves follow Gaussian distribution as expected, due to the nature of thermal charging-discharging cycle, which in general follows either a power law or an exponential law, and both are very much related to Gaussian distribution characteristics.

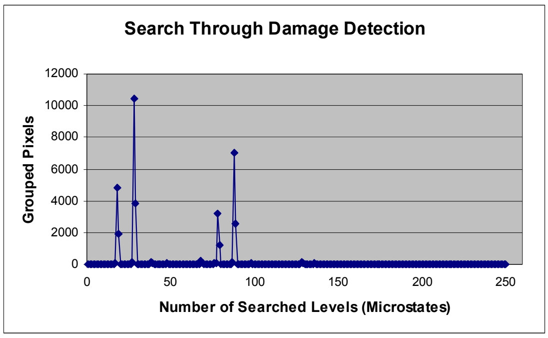

Fig.7 Overall characteristics of damage component

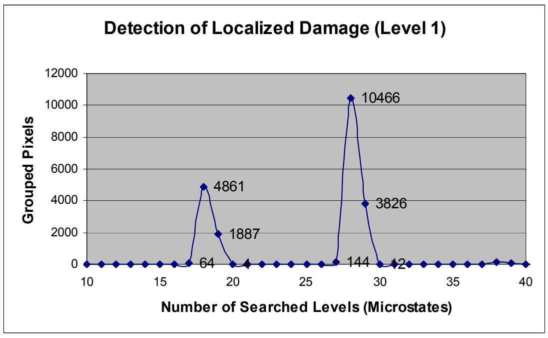

Fig.8 Lower level detected damage

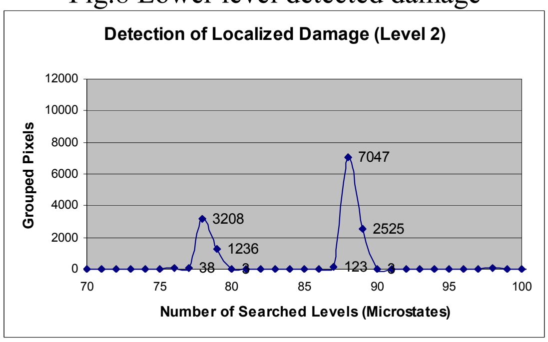

Fig.9 Upper level detected damage

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