Automation of Pulsed Thermography using Computer Numerical Controlled Manipulator for CFRP Circular Parabolic Honeycomb Structures

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ABSTRACT

Pulsed Thermography (PT) is a non-contact nondestructive testing (NDT) technique which is suitable for testing of circular parabolic Carbon Fiber Reinforced Plastic (CFRP) honeycomb sandwich structures. Commercially available PT systems have smaller coverage area in a single exposure which is mainly constrained by the number of heating elements required for providing near uniform surface heating. Automation facilitates repeatability and precise location of defects especially for testing of large structures is essential. Compared to other C-scan systems, automation of PT system is easier as it is an area interrogation method and does not need precise alignment of the imaging hood (enclosure with heating system and infrared camera). In this paper, the attempts made in programming the path of the PT imaging hood for covering the surface of circular parabolic structures are given.

Keywords: Pulsed thermography, Nondestructive testing, Carbon Fiber Reinforced Plastic, Honeycomb sandwich

1. INTRODUCTION

High specific stiffness, specific strength and tailorability of composite materials makes designers prefer them for weight critical applications. Sandwich construction of these materials provides improved stiffness and it is preferred structural configurations for many applications. NDT plays a major role for assessing the quality of these products especially for aerospace applications.

Automated water coupled C-scan Ultrasonic testing (UT) is a well proven test method for doing Nondestructive testing (NDT) of composite honeycomb structures. If the coupling medium adversely affects the properties of the composite products during service, water coupling cannot be applied for testing of these structures. Air coupled ultrasonic testing [1], laser ultrasonics [2], laser sherography [3], pulsed thermography [4], lock in thermography [5] are non-contact test methods. Air coupled ultrasonic testing can avoid coupling medium however proper assessment at edges and cut out locations is difficult because the bending of ultrasonic waves at these locations. Laser ultrasonic system has got the advantages of testing the products from a larger distances compared to the other ultrasonic methods however is very costly. Laser sherography directly measures the surface strain anomalies in the component, however discrimination between debond and delamination is difficult. Pulsed thermography like laser sheorography system is area interrogation method which can differentiate debond and delamination based on the characteristics of cooling curves. The schematic of PT facility is shown in fig.1.

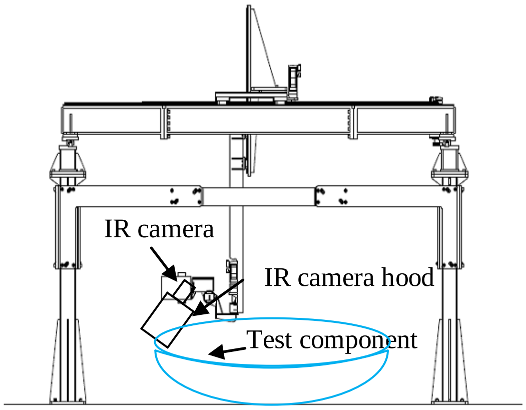

Fig.1. Schematic of PT facility

1.1. System configuration

In current study PT system (EchoTherm) (fig.2.) is supplied by Thermal Wave Imaging with IR camera from M/s FLIR. This is integrated with an indigenously developed 5 axes (3 linear axes : X, Y, Z and 2 rotary axes :1 & 2) Computer Numerical Control (CNC) manipulator as shown in fig.3. The imaging hood (fig.4) is mounted on the end effecter location (second rotary axis) with an offset of 330 mm from the z-axis.

Fig.2. Photograph of pulsed thermography system

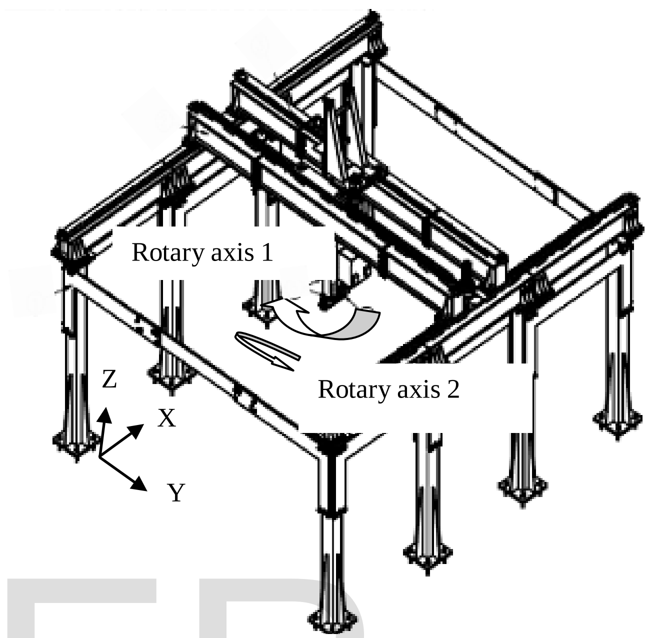

Fig.3. Schematic of CNC manipulator

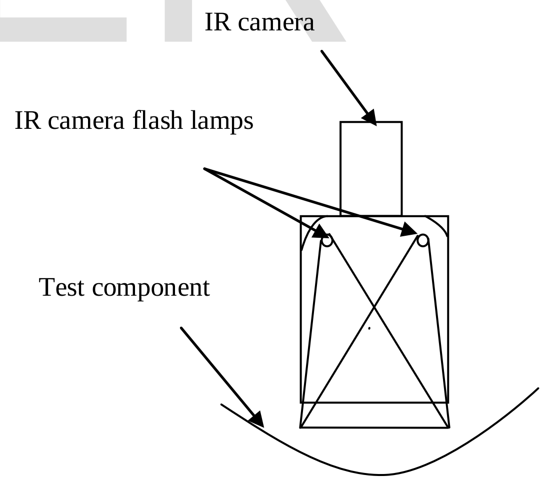

Fig.4. Schematic of PT imaging hood

The opening of imaging hood is 270 mm x 370 mm which limits the area that can be covered at an instance. Large parts are to be divided into smaller sections corresponding to the image hood

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opening. EchoTherm system has software called MOSAIC which can stitch the images for viewing the entire component in a single screen. It has got a feature to preselect the scan path (the path that imaging head has to move to cover the entire component surface). According to the scan path the movement of the imaging head has to be done using CNC program which also has to incorporate dwell time (the time required for capturing PT image sequence), external trigger command for PT system. For different shapes and sizes of the products, independent CNC program incorporating the above features need to be written considering the standoff distance (distance from component to imaging hood).

Programming has been done using Matlab [6] to create the CNC code required for testing CFRP circular parabolic honeycomb structures and results are presented in the next section.

2. PULSED THERMOGRAPHY OF CIRCULAR PARABOLIC HONEYCOMB STRUCTURES

2.1. Experiment on specimen

Based on the depth of parabolic dish, specimen is placed and captured the IR images for setting the parameters. It will ensure the detection of defect at various distance and curvatures. Photograph of specimen is shown in fig.5. Corresponding IR images (fig.6 & fig.7) of specimen are taken from both sides and log plot shows the variation of temperature profile between good and defective location is shown in fig.8. Size of the inbuilt defect on the specimen depends on the probable defects could be present in the actual test component.

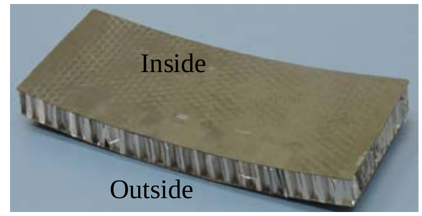

Fig.5. Photograph of specimen

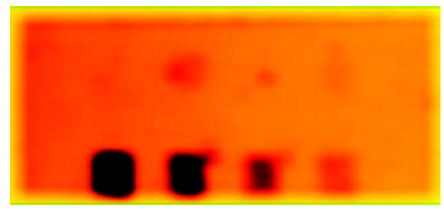

Fig.6. IR image of specimen (Inside)

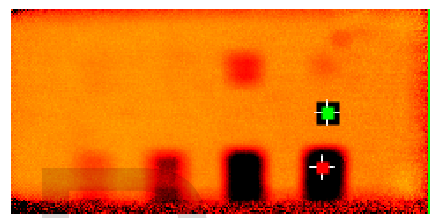

Fig.7. IR image (Outside) showing the log plot

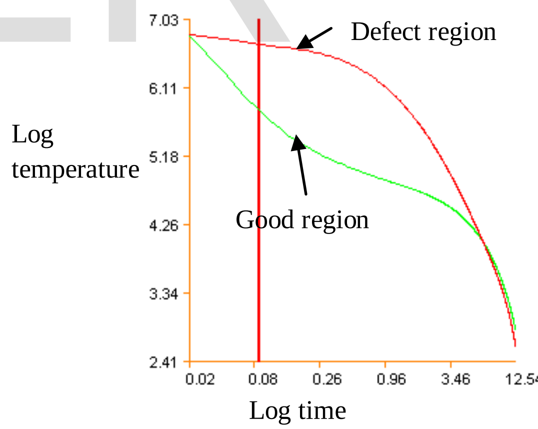

Fig.8. Log plot

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2.2. Experiment on component

Diameter of component is fed as input to the Matlab program. The output of Matlab program is the CNC program with all the necessary coordinates and commands for manipulator movement and IR camera triggering. The overlap between two adjacent scans is taken care by the coding. This ensures the complete scanning of components. Same CNC program can be utilized for testing of both sides of components. Based on the trails carried out on specimen corresponding to the test component, acquisition time [7] will be estimated and it will be considered while coding. Scanning profile for a typical circular parabolic component is shown in fig.9. Photograph of circular parabolic structure is shown in fig.10. This method is suitable for longer focal distance honeycomb structures. Initial values of the coordinates of the camera hood are set based on the profile of the structure. Grid size on the component surface is decided by the field of view of the camera.

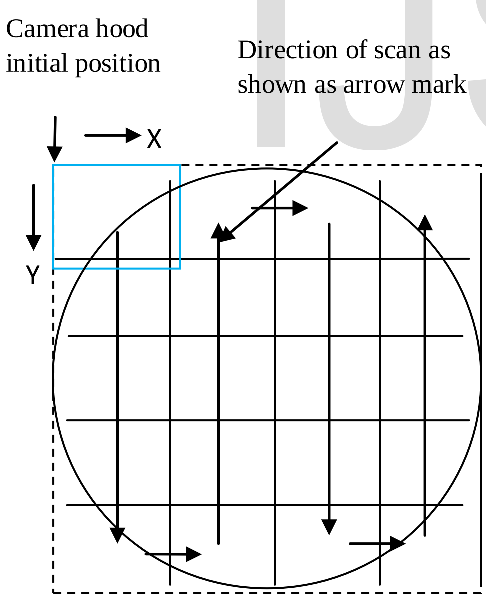

Fig.9. Scanning profile for a typical circular parabolic honeycomb structures

Fig.10. Circular parabolic honeycomb structure

3. RESULTS

The thermographic images corresponding to each frame has been interpreted separately for finding the presence of defects. All thermographic images are stitched together to form the entire component surface. Stitched images of circular parabolic honeycomb structure are shown in fig.11. The location of defects can be traced from the reference position. Using the log plot, temperature variation on the surface of component is identified and defect size is characterized. Detection of types of defect is done by comparing the IR image and log plot of inbuilt defect specimen and tested component.

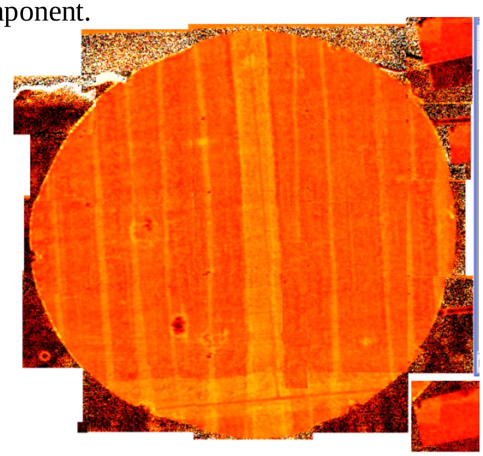

Fig.11. Stitched images of circular parabolic reflector

4. CONCLUSION

As part of scan path generation for different product configuration using CNC 5 axis machine, a Matlab code has been used for generating CNC code required for circular parabolic honeycomb structures. The code is being extended for the generation of CNC programs for conical and other generic shapes. Shorter focal distance honeycomb structures need separate Matlab program and scan pattern differs from longer focal distance.

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