DEVELOPMENT OF ULTRASONIC REFERENCE STANDARDS FOR DEFECT CHARACTERIZATION IN CARBON FIBER COMPOSITES

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Abstract *- This paper mainly focuses on how to produce realistic and repeatable test samples that can be used to access advanced inspection methods. Computed tomography (CT) is the optimal technique used to detect cell wall crushing within the full thickness of the honeycomb structure. This method also determines if the disbonds between the core and skin have been successfully produced. By deploying a high frequency ultrasonic probe to a mobile scanner, ply to ply variations can be detected. Comparison between ultrasonic inspection methods, computed tomography and active infrared technologies are examined. Finally, the results of using embedded Teflon inserts and water trapped in honeycomb cell wall to simulate in-service damage of a solid laminate to honeycomb composite structure will be summarized.*

Keywords: ***C***omputed tomography, Active infrared technologies, vacuum assistant resin transfer molding.

1. INTRODUCTION

For centuries composite material have been used in many form in many application. From the 1970's onwards polymer reinforced composite materials became increasingly popular especially in aerospace and defense due to its light weight and excellent strength and stiffness characteristics. composite materials typically consist of relatively strong, stiff fibers in a tough resin matrix. While fibers are the main contributors to strength and stiffness, the matrix serves as binding agent and medium for transferring stresses between adjacent fibers. Composite materials are particularly attractive to aviation and aerospace applications because of their exceptional strength and stiffness-to-density ratios and superior physical nature of composite materials makes it susceptible for defects, which limits the full exploitation of its potential.

The internal quality of every composite detailed part, subassembly and assembly must meet the basic quality criteria established by design. Prior to installation, potential defects must be detected (type, size and location) using the various non-destructive evaluation techniques. NDT plays an important role in helping to assure the integrity, reliability and safety of industrial and defense structures. The most common method of NDE for composite materials is ultrasonic inspection. In a composite, the defects are planar i.e. the defects are present in between the plies of the laminated structure. As the ultrasonic beam travels perpendicular to the plane of the defects, the ultrasonic NDE can detect the defects easily and effectively. The factor of safety of the bearing structures is reduced drastically by the presence of defects. Hence, there should be specific parameter settings while scanning for potential defects. such settings are to be experimentally arrived, such that no defects goes undetected.

The artificial detects can be characterized in the reference panel based on the ultrasonic behavior and can be compared with the defect in the original component. The instrument can be calibrated to the appropriate settings in order to detect the known artificial defects and characterize them. By repeating the resting of the reference standards, optimum settings can be achieved to detect all defects. Thus, by comparing the ultrasonic behavior of the artificial defects in the reference panel with that of the component, the defects in the component can be identified easily. The panels are used to calibrate the sensitivity and /or resolution of ultrasonic equipment and to aid with the detection of defects. The ultrasonic and radiographic reference standards are essential quality assurance tools of the composite manufacturing process. Without these tools it would be difficult to accurately evaluate the internal quality and structural integrity of the part with repeatability / consistency. This information is used to evaluate the component for its quality and acceptability. This present work is to fabricate NDT standards for sandwich components and arrive at optimum instrument settings to detect the potential process induced defects.

2. LITERATURE SURVEY

[1] For centuries, relevant material properties have been determined through a number of destructive test methods in order to provide comprehensive information on material behavior. Unarguably, the advantage of a destructive test is given by the fact that materials can be exposed to a variety of load conditions without the necessity to remain functional upon completion of a test. While this methodology has long served in optimal design of structures, it can rarely be applied to evaluation of civil structures.

[2] Recent composite technology research and development efforts have focused on discontinuous carbon fiber/epoxy molding systems derived from chopped aerospace-grade unidirectional tape prepreg. This study analyzes in detail the meso-structure of this class of materials, which exhibit point-to-point variations associated with the random chip distribution, by means of destructive and non-destructive inspections, in the attempt to identify characteristic traits that can yield insight in its quality and performance. Results show that several types of defects can be encountered within the molded panel, such as macrovoids, fiber kinking and swirling, or resin-rich areas. However, it is found that failure may or may not occur in proximity of these hot spots, independently from their size and location, even for specimens containing the circular hole. Therefore it appears that for this class of materials conventional ultrasonic inspection and defect classification may not be suitable as criteria for part acceptance or rejection.

[3] Advanced inspection techniques are currently being assessed to determine if embedded Teflon inserts, epoxy core potting, skin-to-core separation and water ingress in honeycomb composite materials can be detected and characterized. This paper will describe how to produce realistic and repeatable test samples that can be used to assess advanced inspection methods. Computed tomography (CT) is the optimal technique used to detect cell wall crushing within the full thickness of the honeycomb structure. This method can also evaluate through the thickness of the honeycomb material and determine if disbonds between the core and skin have been successfully produced.

3. OBJECTIVE

The main objective of this project is to detect the naturally occurring potential defects in the reference panel using ultrasonic reference standards.

4. EXPERIMENTAL WORK

The components containing the same core thickness and the same core were taken and grouped together. The grouped parts were examined for their contour shape and thickness. The component containing the deepest contour was selected as the reference standard. Each standard shall contain artificial defects that use as reference discontinuities in the laminate. The artificial defects are inserted during the standard manufacturing / lay-up process prior to curing. The reason is if the ultrasonic instrument is able to detect the defects in the maximum curvature part, then it will also be able to detect in the flat parts or less curvature parts.

The parts which were selected for fabrication are:

- Engine bay door-aft – The core used is a flex core and the core thickness is 27mm.
- Bottom panel assembly – The core used is a hex core and the core thickness is 6mm.
- Bottom door RH – The core used is a hex core and the core thickness is 12mm.
- Side cover RH – The core used is a flex core and the thickness of the core is 27mm.

The defects in the different component are shown below

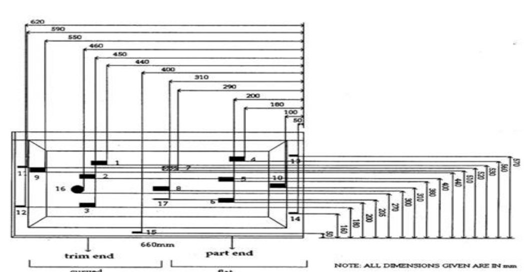

Fig 1.The location of the defects in engine bay door is given above

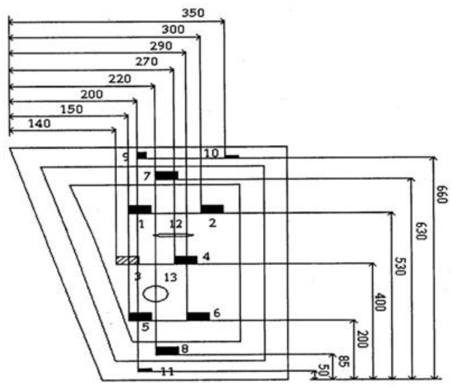

Fig 2 The location of the defects in the bottom panel assembly is given above

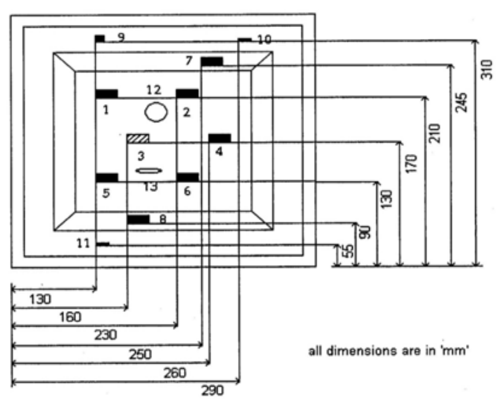

Fig 3 The location of the defects in the reference standard for bottom door is given above

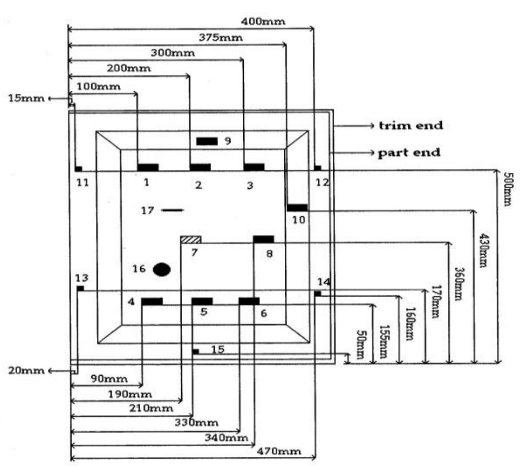

Fig 4 The location of the defects in the reference standard for side cover is given above

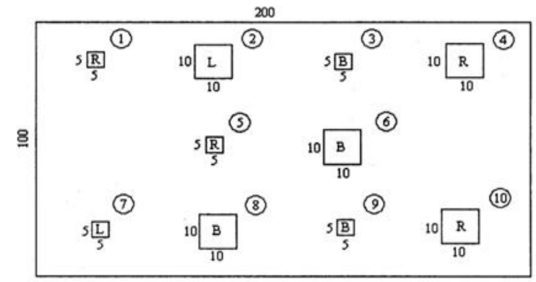

Fig 5 sketch showing the defects location in the reference laminate with different defects

The Mylar sheet for the particular part was taken and the template for the component was prepared using the above sketch in figures 1, 2, 3 and 4. The angle and the thickness of the core with the plies were considered for keeping the defect in the chamfered area. The defects were drawn in the appropriate locations and it was cut from the mylar. This mylar sheet was used as the template for placing the defects in the reference standards during lay-up

The reference standards were fabricated using the same lay-up procedure which was used for the original component of the reference panels. The defects were placed in the appropriate position as mentioned above in the figures 1, 2, 3, 4, and 5. The final vacuum bagging sequence was done and it was autoclave cured as per the cure cycle for the component. After curing, the laminate was taken for Non-destructive testing.
The ultrasonic scanning was done for the component once the curing was done. The A scan pulse echo and C scan through transmission were done

Engine bay door:

- C scan: Through transmission: the scanning was done using a 1 MHz probe with a gain of 70 dB in the sandwich area and 44 dB in the monolithic area
- A scan: the A scan pulse echo scanning was done using the 10MHz probe

Bottom panel assembly:

C scan: Through transmission: the scanning was done using a 2.25 MHz probe with a gain of 21 dB in the monolithic area and 67 dB in the sandwich area.

Bottom door RH:

C scan: Through transmission: the scanning was done using a 2.25 MHz probe with a gain of 21 dB in the monolithic area and 57 dB in the sandwich area

Side cover RH:

C scan: Through transmission: the scanning was done only in the flat portion of the side cover component using a 1 MHz probe with a gain of 28 dB in the monolithic area and 64 dB in the sandwich area

Reference laminate with different defects:

C scan: Through transmission: the scanning was done using a 2.25 MHz probe with a gain of 22 dB and 24 dB.

5. RESULTS AND DISCUSSION

Detection of defects using ultrasonic scanning:

The reference panels were scanned in a similar way as it would be done for the component. The ultrasonic A scan and C scan was done in order to detect the implanted defects in the reference panel for the engine bay door, bottom panel assembly, bottom door RH and side cover RH.

Detection of defects using C scan:

The defects which are present in the sandwich area are clearly seen where as the defect present in the monolithic area is not detected in scan. The adhesive removed is not seen as a defect in the ultrasonic C scan. This might be because the adhesive which is nearby would have flown during the temperature rise of the curing process. The defect 2 i.e. the back-up film is also not clearly seen because it might contain some resin of the prepreg which would have bonded with the layers. Core crush and node separation is detected by the ultrasonic through transmission C scan. The other defects were detected in the appropriate locations. But the exact size of the defects is not clearly seen. Detecting the exact size of the defect is not possible with the current settings of the instrument. So, there need to be a change in the settings like scan index, frequency to detect the defects.

Table – 1 Detection of defects by changing setting parameters.

Engine bay door			
	Frequency	Sandwich area	Monolithic area
Trial 1	1 MHZ	70dB	40db
Trial 2	1MHZ	68dB	33dB
Trial 3	1MHZ	68dB	40dB
Trial 4	1MHZ	69dB	40dB
Bottom panel assembly			
Trial 1	2.25MHZ	67dB	21db
Bottom door RH			
Trial 1	2.25MHZ	57dB	21dB
Trial 2	5MHZ	70.8dB	11dB
Side cover RH			
Trial 1	1MHZ	64dB	28dB
Reference laminate			
Trial 1	1MHZ	22dB	24dB

The defects in the sandwich area are clearly detected when there is a change in the settings when compared to the previous scan report .The clarity of the defects has improved when there is a change in the settings. The change in the settings help in the confirmation of the defects to the exact size which were identified using the normal parameters used to scan the part

Detection of defects using A scan:

None of the defects in the monolithic area is detected in the scan. The reason might be because the teaching was not proper for the monolithic area when the 3D scanning was done. The defect size was also very small i.e. 8mm x 3mm. the scan index was 2mm. since the defect size geometry is almost equal to the scan index; the probability of detecting the defect is low. The other reason might be the folding of the release film would be improper letting out the air. This makes the detecting probability even less. By changing the scan index to 1mm, the detectability of the defect will be more. The A scan was done using the 10 MHz probe for the monolithic area in engine bay door since the defects were not detected properly in the C scan. The velocity of the material was set to be 3000m/s. The pulse repetition frequency was set to be 744 Hz. All the defects in the monolithic area were detected.

Table - 2 Gives the attenuation of the defects present in the monolithic area.

SL no	Defects in the monolithic area	Attenuation(dB)
1	Release film(top) and 12(bottom)	7dB
2	Release film (top)	6 dB
3	Release film (bottom)	9 dB
4	Release film (centre)	5 db

6. CONCLUSION

From the above paper it is observed that the reference panels were fabricated with different kinds of defects each simulating a naturally occurring defect and also with different defect sizes and these reference panel undergone to C scan through transmission and A scan pulse echo scanning. The adhesive removed is not seen as a defect in the ultrasonic C scan. core crush, node separation, the implanted defects and skin-core debond in honeycomb areas, The double folded release film simulation delamination were detected using the ultrasonic C scan by changing various parameters. The exact size and dimension of the various defects were found out using the A scan for the components.

7. FUTURE WORK

1) Fabrication of the remaining two parts to be done with the artificial defects implanted and the ultrasonic scanning C scan A scan must be done.
2) The sensitivity and the resolution characteristics of the ultrasonic equipment are to be found out by implanting defects at a closer proximity. This would help in knowing the efficiency of that equipment.
3) Frequency analysis and waveform analysis is to be done for the reference panels.

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BIOGRAPHIES

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