INTRODUCTION

Composite materials are being increasingly used for civil and military structural application owing to its good structural properties. These composites structures have laminates made up of multidirectional lamina stacked up to build the desired thickness. These materials have good strength to weight ratio, high stiffness and are corrosion resistant. However fragility of composites to impact damages is a concern, which if left undetected may drastically affect the laminate strength properties in flexure and compression. This necessitates for an inspection system at various stages during fabrication, after the component is fabricated and during usage of structure.

Non Destructive Evaluation (NDE) is a non-invasive technique for carrying out qualitative and quantitative inspection of components to assess their integrity without affecting functionality and useful lifetime [1]. There are various techniques established for carrying out NDE inspection of metallic structures. Metals being isotropic in nature, most of the NDE techniques can be applied quite easily. For inspection of composites same techniques can be adopted with slight modifications by studying the behaviors and features of the signals being analyzed for particular NDE technique.

Ultrasound based techniques have emerged as suitable and reliable method for NDE inspection of composites. These techniques are based on propagation of ultrasonic waves in composite materials and their interaction with anomalies in the material due to damage in structure. Propagation of ultrasonic wave depends on the material’s elastic properties hence provide useful information about integrity of the structure [2]. Bulk waves, longitudinal and shear, and guided waves, particularly Lamb waves are extensively used for ultrasonic inspection.

Damage detection methodology utilizing A-scan and C-scan concept for detecting flaws for composite structure has been presented. Ultrasonic bulk wave has been used for non-destructive testing of the composite specimen. Carbon fiber composites have been tested for different types of damages using longitudinal waves. Two sample specimens consisting of a de-lamination, a through hole, and resin rich region have been made using vacuum assisted resin transfers molding (VARTM) process. Signals from various regions of sample specimen have been acquired and processed for studying the features/patterns for various types of damages. A-scan based code for visualizing damage has been developed to qualitatively identify damage in the structure. Various features such as peak amplitude, energy, and time of flight in the selected time window of A-scan signal have been used to assess damage. Reference signal from healthy region can be selected by the user for quantitative analysis. Damage detection methodology is to manually A-scan the structure with the developed software so as to ascertain damage location qualitatively and then perform complete C-scan around selected region. Inspection is carried out using contact testing. By using developed A-scan software it is possible to identify damaged region in the least possible time.

Keywords: Non destructive testing, ultrasonic, A-scans, wavelet analysis

PACS: 43.35 Zc, 81.70 Cv, 78.20 Ci

ABSTRACT

Damage detection methodology utilizing A-scan and C-scan concept for detecting flaws for composite structure has been presented. Ultrasonic bulk wave has been used for non-destructive testing of the composite specimen. Carbon fiber composites have been tested for different types of damages using longitudinal waves. Two sample specimens consisting of a de-lamination, a through hole, and resin rich region have been made using vacuum assisted resin transfers molding (VARTM) process. Signals from various regions of sample specimen have been acquired and processed for studying the features/patterns for various types of damages. A-scan based code for visualizing damage has been developed to qualitatively identify damage in the structure. Various features such as peak amplitude, energy, and time of flight in the selected time window of A-scan signal have been used to assess damage. Reference signal from healthy region can be selected by the user for quantitative analysis. Damage detection methodology is to manually A-scan the structure with the developed software so as to ascertain damage location qualitatively and then perform complete C-scan around selected region. Inspection is carried out using contact testing. By using developed A-scan software it is possible to identify damaged region in the least possible time.

Keywords: Non destructive testing, ultrasonic, A-scans, wavelet analysis

PACS: 43.35 Zc, 81.70 Cv, 78.20 Ci

INTRODUCTION

Damage detection methodology utilizing A-scan and C-scan concept for detecting flaws for composite structure has been presented. Ultrasonic bulk wave has been used for non-destructive testing of the composite specimen. Carbon fiber composites have been tested for different types of damages using longitudinal waves. Two sample specimens consisting of a de-lamination, a through hole, and resin rich region have been made using vacuum assisted resin transfers molding (VARTM) process. Signals from various regions of sample specimen have been acquired and processed for studying the features/patterns for various types of damages. A-scan based code for visualizing damage has been developed to qualitatively identify damage in the structure. Various features such as peak amplitude, energy, and time of flight in the selected time window of A-scan signal have been used to assess damage. Reference signal from healthy region can be selected by the user for quantitative analysis. Damage detection methodology is to manually A-scan the structure with the developed software so as to ascertain damage location qualitatively and then perform complete C-scan around selected region. Inspection is carried out using contact testing. By using developed A-scan software it is possible to identify damaged region in the least possible time.

Keywords: Non destructive testing, ultrasonic, A-scans, wavelet analysis

PACS: 43.35 Zc, 81.70 Cv, 78.20 Ci

INTRODUCTION

Composite materials are being increasingly used for civil and military structural application owing to its good structural properties. These composites structures have laminates made up of multidirectional lamina stacked up to build the desired thickness. These materials have good strength to weight ratio, high stiffness and are corrosion resistant. However fragility of composites to impact damages is a concern, which if left undetected may drastically affect the laminate strength properties in flexure and compression. This necessitates for an inspection system at various stages during fabrication, after the component is fabricated and during usage of structure.

Non Destructive Evaluation (NDE) is a non-invasive technique for carrying out qualitative and quantitative inspection of components to assess their integrity without affecting functionality and useful lifetime [1]. There are various techniques established for carrying out NDE inspection of metallic structures. Metals being isotropic in nature, most of the NDE techniques can be applied quite easily. For inspection of composites same techniques can be adopted with slight modifications by studying the behaviors and features of the signals being analyzed for particular NDE technique.

Ultrasound based techniques have emerged as suitable and reliable method for NDE inspection of composites. These techniques are based on propagation of ultrasonic waves in composite materials and their interaction with anomalies in the material due to damage in structure. Propagation of ultrasonic wave depends on the material’s elastic properties hence provide useful information about integrity of the structure [2]. Bulk waves, longitudinal and shear, and guided waves, particularly Lamb waves are extensively used for ultrasonic inspection.

Damage detection methodology utilizing A-scan and C-scan concept for detecting flaws for composite structure has been presented. Ultrasonic bulk wave has been used for non-destructive testing of the composite specimen. Carbon fiber composites have been tested for different types of damages using longitudinal waves. Two sample specimens consisting of a de-lamination, a through hole, and resin rich region have been made using vacuum assisted resin transfers molding (VARTM) process. Signals from various regions of sample specimen have been acquired and processed for studying the features/patterns for various types of damages. A-scan based code for visualizing damage has been developed to qualitatively identify damage in the structure. Various features such as peak amplitude, energy, and time of flight in the selected time window of A-scan signal have been used to assess damage. Reference signal from healthy region can be selected by the user for quantitative analysis. Damage detection methodology is to manually A-scan the structure with the developed software so as to ascertain damage location qualitatively and then perform complete C-scan around selected region. Inspection is carried out using contact testing. By using developed A-scan software it is possible to identify damaged region in the least possible time.

Keywords: Non destructive testing, ultrasonic, A-scans, wavelet analysis

PACS: 43.35 Zc, 81.70 Cv, 78.20 Ci
FABRICATION OF COMPOSITE TEST SPECIMEN

There are many processes for fabrication of composite structures. Resin Transfer Molding (RTM), Vacuum Assisted Resin Transfer Molding (VARTM), and autoclave processing of prepreg systems are some of them. For fabrication of large composites structures VARTM is a cost effective method. In the current work, development of NDE technique is intended for inspection of carbon fiber reinforced plastic (CFRP) bridge structures, which are fabricated using VARTM. Two CFRP test specimens have been fabricated using VARTM process. The layup sequence and orientation selected for test specimen was same as that of the web section of the composite bridge girder. Different types of damages have been purposefully introduced in test specimen during fabrication. These are delamination, resin rich region (through hole) and blind hole from one side of specimen. The specimen is used to develop and evaluate software for detection and identification of different damages.

EXPERIMENTAL SET UP

Experimental set up consists of Panameric’s ultrasonic contact probe of 2.25MHz central frequency, pulser receiver model PR5058, National Instruments digitizer card 5102 and developed LabVIEW based data acquisition and visualization software. Contact testing using water as couplant in pulse-echo mode has been carried out. Figure 2 shows schematic of experimental set up.

A-scan signal is a time history captured at a particular point on the sample specimen. Figure 3 shows typical A-scan signal. Visualizing changes in amplitude or wave pattern from A-scan signal is complex and difficult as the signal is in time domain. To overcome this problem, visualization code has been developed in LabVIEW. In this program, user has to first fix the window in time domain in A-scan signal and then select feature, which is to be extracted and used for imaging. Currently three features are available viz peak amplitude, energy and difference in time of flight between two wave group
in user selected time window. The user has to set reference value either from A-scan signal or by fixing constant value with which other A-scan signals can be compared.

A-SCAN BASED GUI SOFTWARE

The aim of the post processing exercise is to classify healthy region and damaged region. Next, attempt has been made to identify type of damage. Damage in sample specimen has been classified into three types of damages viz. de-lamination, through-hole (epoxy rich), blind hole (half epoxy region). Fabricated sample specimen has been tested with developed software for studying waveform of ultrasonic bulk waves with these three damages. Figure 3 to figure 6 show A-scan waveform signals from healthy region as well as different damage regions on the sample specimen. It also shows wavelet coefficients extracted using Morlet mother wavelet at frequency where maximum peak value in A-scan signal appears. Energy of wavelet coefficients provides information about integrity of structure [3].

As seen from figure 3 to figure 6 it is observed that peak magnitude in A-scan signal as well as magnitude of wavelet coefficients is reduced in case of damaged regions as compared to healthy region. The amplitude reduction is from 1.5V to .5V approximately in time plot and from 9 units to 3.5 units in wavelet coefficient plot for healthy to various damages regions. Similarly if we consider first wave group it is clearly seen that there is reduction in energy in the damaged region wavelet coefficients signal as compared to that of healthy region signal. Hence these two features, peak value and energy, clearly give qualitative identification for damage region. Similarly on closer look it can be seen that difference in time of flight between two wave group changes for different type of damages. Therefore these features have been used to classify damages. Also there is slight reduction in peak frequency from healthy region signal to damaged region signal. Figure 7 shows front panel of the software program.

The GUI consists of three waveform display regions along with some data acquisition parameter control settings as seen in figure 7. It displays A-scan received and filtered signal, time window selected signal and A-scan image of current inspection region generated using healthy region signal. Thus blue color in display has been set by making healthy region signal as reference and black at center indicates damaged region where contact transducer is currently held and A-scan signal is being acquired. In absence of damage, display is completely blue in color indicating no damage. Thus A-scan signal has been exploited for quick qualitative scan. This will further identify if any detailed C-scan inspection is necessary. With the developed program, ultrasonic NDE of a CFRP structure about 18 mm thick has been successfully evaluated for three different types of damages.

Fig. 5: Through hole (full epoxy) A-scan signal and its wavelet coefficient plot

Fig. 6: Blind hole (half epoxy) region A-scan signal and its wavelet coefficient plot
DISCUSSION

Propagation of bulk wave in thick high attenuating medium such as glass fiber reinforced plastic based materials is difficult. Hence through thickness inspection in pulse echo mode is challenging for such materials. Through transmission technique can be used with the same A-scan software in such cases. Also weak reflecting signals from damages such as 

insitu 
cracks etc are difficult to identify. For such damages appropriate method with appropriate instrumentation would be necessary to obtain meaningful signals. The present study has not covered investigation of such damages.

CONCLUSION

Damage detection approach utilizing A-scan based software has been presented. In a bridge like structure, performing complete bridge C-scan analysis is time consuming and tedious, moreover the data acquisition is extensive. Therefore manual A-scanning with the post processing and visualization program has been developed for quick qualitative non-destructive inspection. It provides qualitative information about damage and broadly gives its locations. Thus only selective area around probable damage location can undergo thorough C-scan inspection using contact or immersion type set up. Manual A-scan provides qualitative information whereas C-scan provides quantitative information about damage extent, type of damage etc.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Dr S Guruprasad, Director R&DE, Shri A K Patel, Group Director Advanced System Group, for all the encouragement and support to carry out this work. Also support and assistance from entire CRC team is deeply acknowledged.

REFERENCES

3. Seth S. Kesseler, Piezoelectric based 

insitu 
5. www.ndt-ed.org