ULTRASONIC C-SCANNING OF COMPOSITE METAL BARRELS FOR INTERFACIAL DEFECTS

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ABSTRACT. Composite wrapped gun barrels rely on a composite sleeve over a metallic barrel liner to reduce the weight of the gun barrel. Composite-overwrapped gun barrels are typically fabricated using the filament winding process. However, delamination damages in composites or between metal-composite overwraps either during production or in service can adversely affect performance or leading to catastrophic causality. This paper discusses a solution for inspection of a cylindrical steel/composite overwrapped structure using conventional NDE C-Scan immersion ultrasonic technique. This will help to identify and quantify the interfacial defects in the composite metal gun barrels.

Keywords: Ultrasonic, C-Scan, Gun barrels, Composites, Interfacial defects

INTRODUCTION

Metal matrix composites (MMCs) are composed of an element or an alloy matrix in which a second phase is embedded and distributed to achieve some property improvement. Based on the size, shape and amount of the second phase, the composite property varies. Particulate reinforced composites, often called as discontinuously reinforced metal matrix composites, constitute 5 – 20 % of these new advanced materials. The microstructure of the processed composites influences and has a great effect on the mechanical properties. Generally, increasing the weight fraction of the reinforcement phase in the matrix leads to an increased stiffness, yield strength and ultimate tensile strength. However, the low ductility of particulate reinforced MMCs is the major drawback that prevents their usage as structural components in some applications. In recent years, use of composite materials as a primary structural component for many industries like Space industries, military applications & Oil/gas industries has increased the need for corrosion resistance and strong lightweight materials respectively. The use of composite materials as a structural element allows for optimal design which is very difficult to achieve with metals. By combining the metals with composites we can get the complicate shapes and the analysis of the same is possible by a variety of softwares such as ABAQUS, COMSOL and ANSYS. Analysis of the composite models is itself is very difficult due to a large variety of variables involved in the process. By combining the composites with metals we can overcome the above problem. There is a variety of NDI methods are to inspect these complex structures such as Ultrasonic Immersion testing, Thermography, X-ray Radiography, Optical and acoustical Holography. Due to the complications involved in the manufacturing processes of the composite materials, there is a need to inspect them in between the manufacturing process. Ultrasonic testing is a common sub surface method for detection of laminar oriented discontinuities. Two techniques can be considered based on panel surface accessibility; pulse echo for one sided and through transmission for two sided. As used in this practice, both require the use of a pulsed
straight-beam ultrasonic longitudinal wave followed by observing indications of either the reflected (pulse-echo) or received (through transmission) wave. The general types of anomalies detected by both techniques include foreign materials, delamination, disbonds/un-bond, fiber de-bonding, inclusions, porosity, and voids.

This paper presents the detection procedures to evaluate the acceptance of gun barrels that have been fitted with attachments and made with composite wrapped on metal liners using Ultrasonic C-scan pulse echo method. The attachment regions were non inspectable due to the complex shapes. The gun barrel is coated with thick paint that attenuated the ultrasonic waves.

SPECIMEN PARTICULARS

The specimen used for this study is made of aluminium foil sheet on which a lot of CFRP layers in different orientations are put to achieve a required thickness. Two types of defects one type was Teflon insert and the other type was aluminium foil inserted for experimental study. This can be considered as a calibration sample to compare the experimental result to the real time problems/applications for characterization of the defects in the real time applications.
NDE SYSTEMS

The NDE System used with respect to this paper is as follows:

**Ultrasonic Immersion Testing**

This NDI system is comprised of the following components:

- Ultrasonic signal generator and an echo acquisition instrument called JSR DPR300 and a user oriented menu for I/O operations.
- 2.25 MHz probe for both transmitting and receiving the ultrasonic beam.
- Motion controller to control the motion of the specimen as well as the probe movement.
- A PC with Lab VIEW software that allows data acquisition and data analysis.

The block diagram of the above arrangement is shown in the Figure.

Immersion testing offers many potential benefits over its 'dry' alternative:

- Inspection over uneven surfaces
- Ultra-high resolution C-scan mapping
- Fast large area mapping area
- Inspection of complex geometry

The system is equipped with a dedicated ultrasonic data analysis system, together with integral scanner controllers.
Software for Data Acquisition and Data Imaging

The data acquisition software for data acquisition included motion control module, the signal digitization module, and the C-scan module. The region of scan is selected and the data is stored in the PC. The data imaging software consists of a front wall tracking algorithm, an envelope domain transform algorithm, and the ability to view the C-scan at any depth or view the scan over a time window.

Inspection Procedure

The ultrasonic inspection method uses a transducer to generate a short pulse of ultrasound (typically between ~2 MHz and ~10 MHz) into a component or structure, then analyses the reflected sound pulses. The photograph of the above set up is shown in the fig. Based on optimization studies, the frequency of 2.25 MHz was chosen. The focal length of 50 mm was also used providing a focal zone of approximately 1 mm. Pulse echo technique was adapted. In the future, a double-through transmission approach may also be used in addition to the Pulse echo method. The scanning was conducted at approximately 1 mm x 1 mm resolution. The x-axis is to be interpreted 1000 data steps represent 360 degree circumference of the barrel. Since the diameters are not uniform along the length of the barrel, 1 mm represents approximately 3 data steps and the total 1000 steps represents about 340 mm in the thick regions (firing region) and 304 mm in the thin regions (exit region). Due to variations in the thickness of the exterior polymer coatings (waviness) the signals from the internal layers were observed to show a wavy pattern. The B-Scans must be interpreted as an effect caused by the external layer thickness variation and not internal layer waviness. The ultrasonic transducer is scanned directly on the surface of the test part, by an operator. Immersion ultrasonics is a variation on the method whereby the test part is submerged in a water filled tank. The transducer is mounted in a multi-axis manipulator, a few cm distant from the component. Ultrasound then travels through water before entering the component.

Figure 4 Experimental setup of ultrasonic immersion testing
EXPERIMENTAL RESULTS

The resulting C-scan of gun barrel is shown in figure 5. The C-scan is the result of keeping the Gate in the A-scan in the defective region. The corresponding B-scan showing the depth of the flaw is also shown.

CONCLUSION

It was shown that the C-scan of immersion testing can be used to determine the location of delaminations even having access only from outer side of the barrel. By setting gates at different depths of the individual A-scan, features of different depths can be easily monitored.

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