

Guided Wave Acousto-Ultrasonic (AU) Non-Destructive Evaluation (NDE) Technology for Composite Materials

Introduction

Multi-layer composite structural elements have many advantages over comparable metal designs. Among these are a very high stiffness to weight ratio, strength vs. weight and resistance to corrosion. However, in order to realize these benefits, the layers that make up the composite structure must be fully bonded to each other during the original manufacturing or repair process.

To determine the quality (integrity) of a bonded structure, inspection techniques have been developed which include various forms of ultrasonic inspection. Due to the nature of the material – including the bonding process itself – these techniques require sophisticated test set-ups that are typically available only in large laboratories or production facilities.

Once structures are actually put into place, in field applications, the same techniques that can be used in the production environment are often not usable in the field. For instance, the ultrasonic technique most often used for composite panel inspection typically involves a through-transmission setup in an immersion tank to enable ultrasonic waves to penetrate the difficult built-up structure.

The Guided Wave AU system uses oblique angle, pulse-echo, ultrasonic techniques to scan a thick-section composite with access from one side only (Figure 1).

Thus, once composite structures are in-service, returning to an “as produced” inspection environment can be very difficult, if not impossible. As a result, current field-based NDT (ultrasonic) inspection of multi-layer composite structures is difficult if not impossible.

Discussion

As a successful result of a recent SBIR (Small Business Innovative Research) project sponsored by the Lightweight Structures Team at TARDEC (Tank Automotive Research, Development and Engineering Center) and executed by Physical Acoustics Corporation (PAC), a portable, field-application technique to fully inspect multi-layer composite sections has recently been developed.

The unique portable nondestructive field-usable inspection system has been

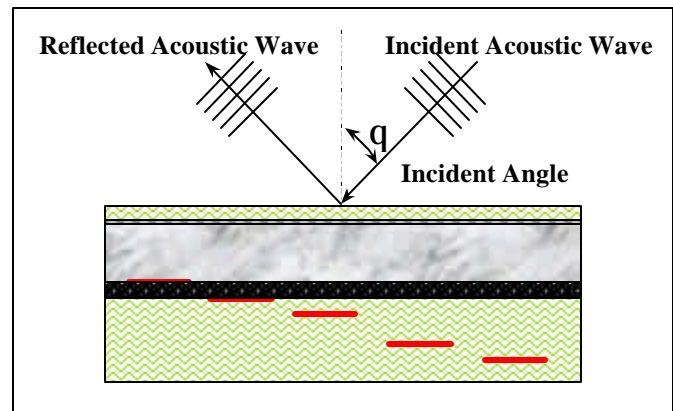


Figure 1: Principal of operation, showing one-sided inspection technique.

demonstrated on multi-functional lightweight composite armor, which is representative of many types of complex, difficult to inspect, multi-layer composite materials (Figure 1 shows the system technology).

Development Background

In order for the composite armor to be effective, it is important to make certain that the structural integrity of the armor is maintained throughout its life cycle, preserved through periodic inspection of the vehicle and repaired if defects are found. Multi-functional composite armor is very difficult to inspect nondestructively due to the presence of several materials through the thickness with different acoustic properties.

Typical materials used in the Composite Armored Vehicle/Advanced Technology Demonstrator (CAV/ATD) (Figure 2) are S/Glass toughened epoxy supporting layer, ceramic armor tiles, and rubber layers for multi-hit performance and top and bottom protective layers. The total thickness of multi-functional composite armor is just less than two inches.



Figure 2.: CAV/ATD.

Description of Guided Wave Acousto-Ultrasonic (AU) Technology

An oblique incidence angle, low frequency Guided Wave AU technique has been demonstrated to be capable of penetrating through the different layers of thick section multi-layered composites (in this case, armor) and has been used to detect the presence of primary defects. These defects include delaminations in the composite supporting layer, between rubber layers and ceramic tiles and between rubber layers and supporting composite layers (Figure 1).

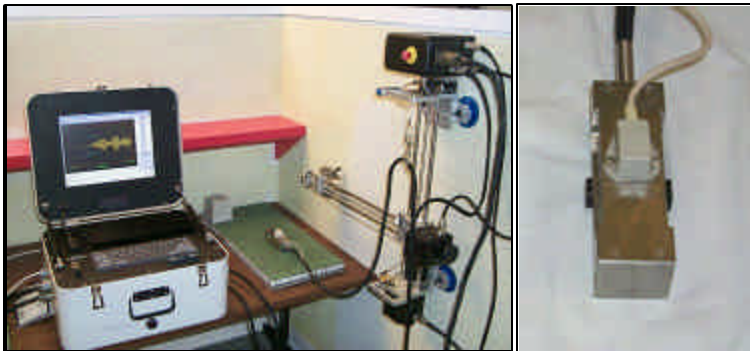


Figure 3.: Guided Wave Oblique Angle AU system. The prototype instrument and “free-motion” manual scanner head.

The initial system, as delivered to TARDEC, is portable, easy to transport, set-up and use (Figure 3). This system is capable of performing both fully automated and “free motion” manual scans with the scanners developed. The automated scans of a large, complex structure (like the CAV/ATD) can be performed in less than eight hours.

The system’s key components are: a multi-sensor probe, a specially designed arbitrary waveform generator board, a Peripheral Component Interconnect (PCI) digital signal processing board, a computer controlled scanning bridge, a position tracking system for manual “free motion” scanning and control and storage and analysis software. The A-scans and C-scans of multi-layer composite materials (Figure 4) demonstrate that the technique is

capable of penetrating (from one surface) multi-functional composite armor and detecting primary defects such as delaminations located in the deepest layers of the supporting inner composite shell.

In addition to the initially demonstrated application, this field inspection technology will find use in the inspection of many critical composite structures, such as aircraft inspection for military and commercial aircraft. Typical Air Force and Navy applications might be for inspecting thick-section polymeric composites. The

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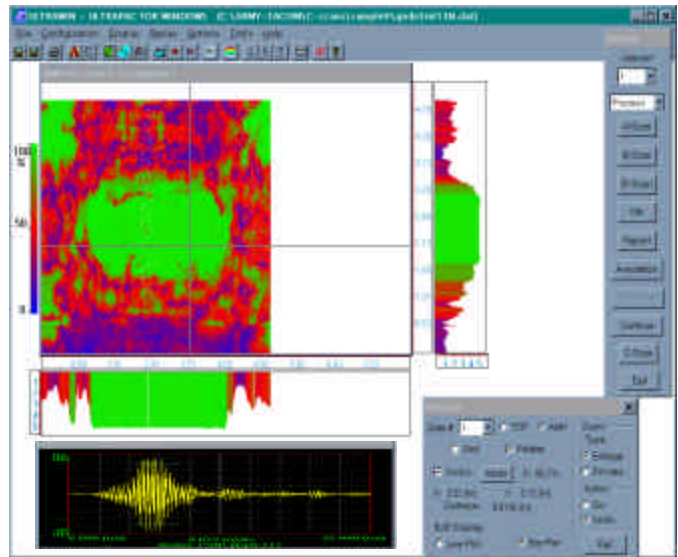
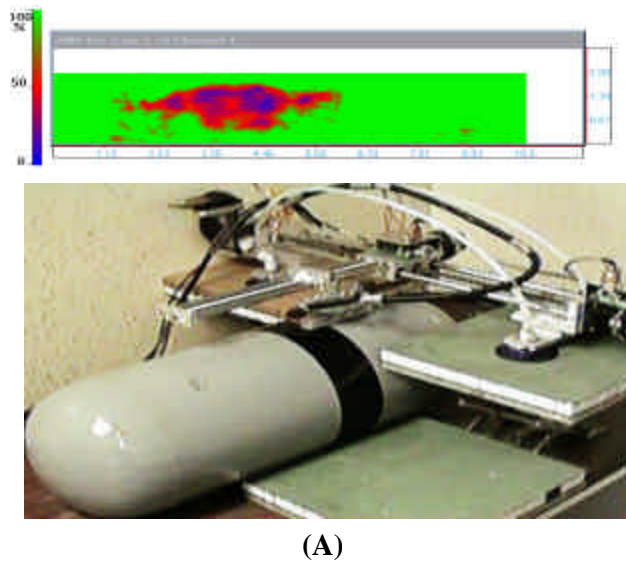
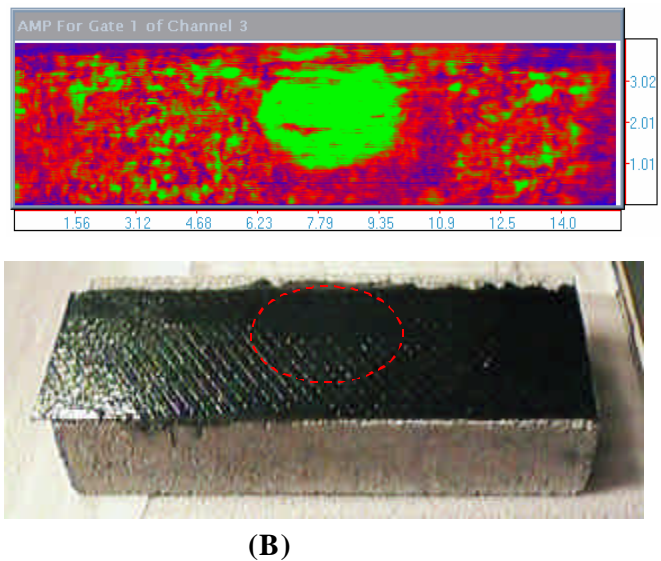


Figure 4.: A-scans and C-scans of multi-functional composite armor.

technology will be especially applicable where other technologies cannot be utilized, such as for inspecting thick section composites in aircraft fuselage, wings and tail sections, helicopter composite rotor blades and Navy ship hull structures. PAC has already demonstrated the technique for inspecting other composite structures, such as composite wrapped high-pressure bottles, composite structural members, and composite wrapped concrete columns (Figure 5).



(A)



(B)

Figure 5.: C-Scan images of damage in composite wrapped high-pressure bottles (A) and concrete (B).