ULTRASONIC INSPECTION OF GRAPHITE-EPOXY SOLID ROCKET MOTOR CANISTERS

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INTRODUCTION

Thick filament-wound composite materials are particularly attractive for use in solid rocket motor structures. However, these materials are difficult to inspect because of the scattering losses associated with multiple fiber layers. Damage caused by either low or high velocity impact which results in matrix cracking, delaminations and broken fibers cannot be tolerated because of the possibility of catastrophic system failure. American Research Corporation of Virginia has performed a 2-year Phase II Small Business Innovation Research contract to develop an ultrasonic inspection system for graphite/epoxy rocket motor canisters [1]. This paper details the experimental apparatus and testing of rocket motor canisters, presents testing results and discusses observations and detection thresholds.

EXPERIMENTAL

Single sided ultrasonic scanning was performed on 300 mm square sections cut from a 2.1 m diameter Trident rocket motor stage. The specimens were 14 mm thick and were backed by a 3 mm thick rubber liner. These specimens were mounted on a two-dimensional scanning table and moved relative to an ultrasonic transducer. The transducer was mounted in gimbals to insure proper physical coupling with the irregular surface of the specimens. Acoustic coupling was aided by a combination of Sonotrace gel and water. The transducer was excited by a high-power Matec pulser-receiver, and the transducer response was digitized by a high-speed analog-to-digital converter capable of digitization rates up to 200 MHz. These digitized readings were acquired at each spatial point of a 2-D scan and stored in an IBM AT compatible computer. These stored time traces were later examined to extract signals resulting from material defects. A system schematic is shown in Fig. 1.

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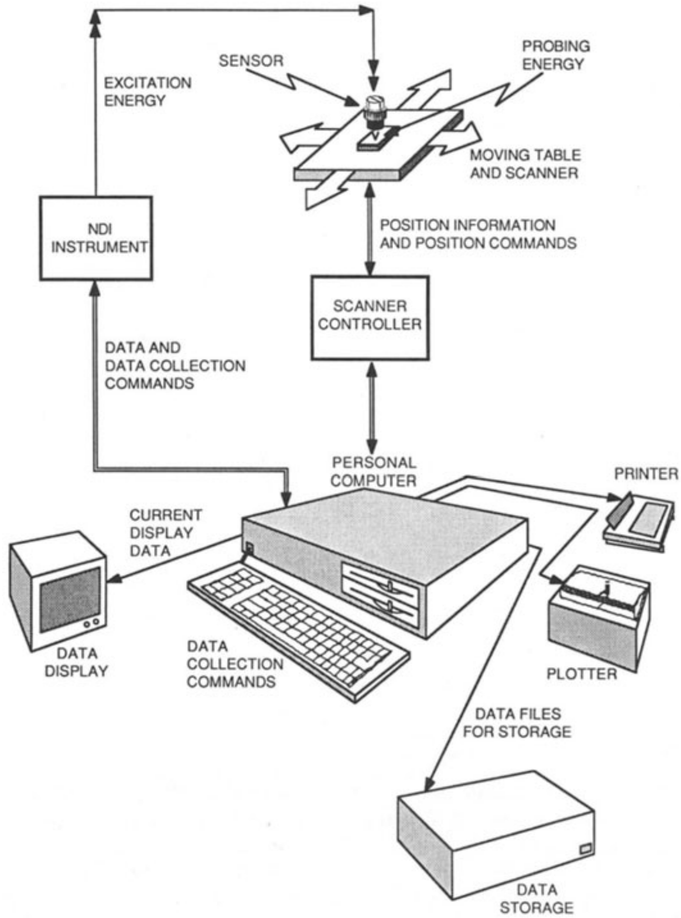

Fig. 1. Nondestructive Inspection System Schematic

The system was controlled by menu-driven software on an IBM AT compatible computer. Several signal processing techniques were explored to extract signals caused by defects. Digital filters were used in conjunction with an optimal linear detector [2]. To detect defects at all depths within the canister, the time trace was interrogated in three sections: the front surface, the middle region, and the back surface. These distinctions prevented strong front and back surface reflections from obscuring weak signal returns from defects.

RESULTS AND DISCUSSION

The ultrasonic scanning and signal processing system described above was used to examine thick graphite/epoxy specimens for composite-liner disbonds, delaminations and impact damage. The results of these tests are described below.

Composite-Liner Disbonds

The sensitivity of the ultrasonic test system described above was tested on a disbond specimen. The disbonded region was fabricated by peeling the rubber liner from the back of the composite canister and

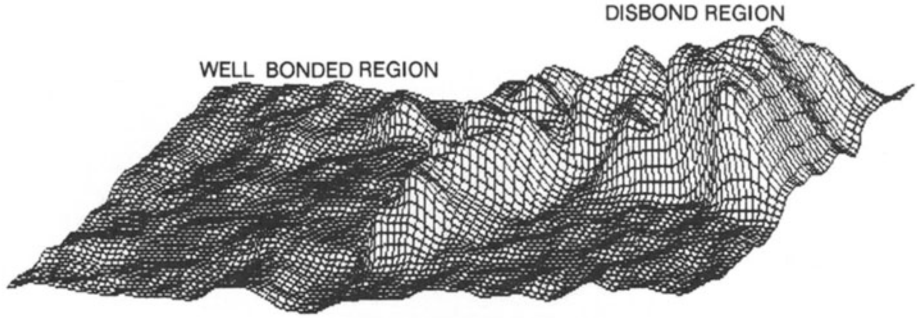

Fig. 2. Ultrasonic Amplitude Image of Disbond Region

refastening the liner with contact cement. Although the liner was in good physical contact with the composite, this system represents a weakly bonded, but still attached, interface which is often referred to as a "kissing" unbond. The back surface reflection amplitude is large and varying for the "kissing" unbond region, as shown by the mountainous regions in Fig. 2, while the reflection is small and stable for the strongly bonded region, as shown in Fig. 2. This technique is sensitive to disbonds of 13 mm in linear extent.

Flat Bottom Holes

To determine the detection thresholds for delaminations, several flat bottom holes of varying depths and diameters were machined in the samples. These flat bottom holes reflect ultrasonic waves in a manner similar to actual delaminations, except that the reflection coefficient is somewhat higher. One typical scanning result is shown in Fig. 3 where the detected amplitudes are lower for deeper and smaller diameter holes. Six mm diameter holes were reliably detected for all depths, establishing the threshold for flat bottom holes. Smaller diameter holes were detected, but not with the same consistency and reliability as the 6 mm holes.

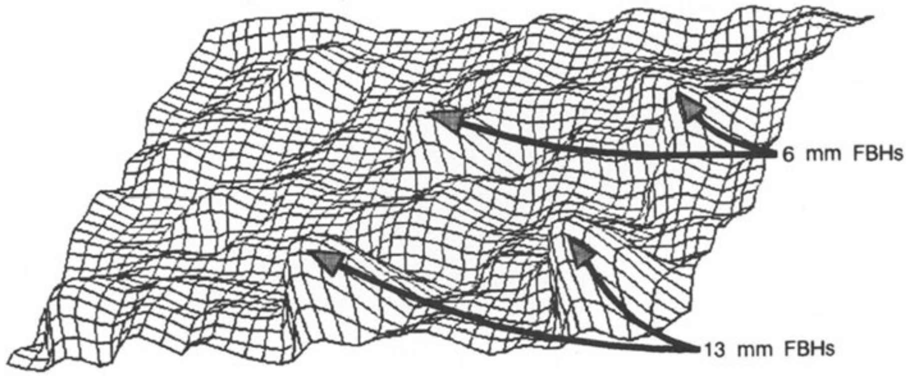

Fig. 3. Ultrasonic Amplitude Image of Flat Bottom Holes

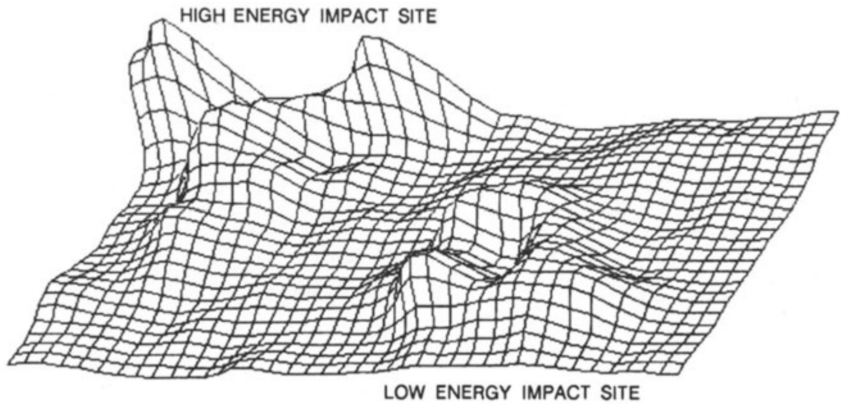

Fig. 4. Ultrasonic Amplitude Image of Two Impact Damage Sites

Impact Damage

Although reflections from flat bottom holes are similar to reflections from actual delaminations, the return amplitude is smaller for actual delaminations. Therefore, the detection threshold for actual delaminations should be higher than for flat bottom holes. Ultrasonic scans were compared to X-ray radiographs to determine the minimum detection size for impact damage. The spatial extent of ultrasonically detected damage regions was estimated with X-rays. Since the X-ray technique relies on the flow of dye penetrant into the damaged region, isolated damage may not be detected. Therefore, the ultrasonic images show larger damage sites than the X-ray radiographs. One typical ultrasonic image is shown in Fig. 4 for two impact-damaged sites. The minimum detected impact damage site was 10 mm diameter, a higher threshold than for the flat bottom holes.

SUMMARY

Single-sided ultrasonic inspection techniques have been applied to thick attenuative graphite/epoxy rocket motor canisters for defect detection and characterization. These tests required a high energy pulser and transducers with good coupling characteristics with the composite. Detection thresholds for composite-liner dibonds, flat bottom holes and actual delaminations were found to be 13 mm, 6 mm and 10 mm diameter, respectively.

ACKNOWLEDGEMENTS

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