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EFFICIENT NONDESTRUCTIVE EVALUATION OF PROTOTYPE CARBON FIBER REINFORCED STRUCTURES

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ABSTRACT

Thermography inspection is an optic based technology that can reduce the time and cost required to inspect propellant tanks or aero structures fabricated from composite materials. Usually areas identified as suspect in the thermography inspection are examined with ultrasonic methods to better define depth, orientation and the nature of the anomaly. This combination of nondestructive evaluation techniques results in a rapid and comprehensive inspection of composite structures. Examples of application of this inspection philosophy to prototype will be presented. Methods organizing the inspection and evaluating the results will be considered.

INSPECTION IN SUPPORT OF A PROTOTYPE SHOP

Nondestructive inspection can be a powerful tool in the development of methods to manufacture composite parts. The verification of the quality of parts, before structural testing, can lead to selection of the best and most cost effective methods of manufacture. Prototypes often push the capability of manufacturing, design, analysis, and materials such that a small inherent defect can drastically alter the outcome of a project. Frequently the cost of inspection can be recovered by ensuring efficient manufacture of production parts.

Inspection of new designs ensures that components are manufactured as designed. This base line inspection may in the event of component failure during prototype tests rule out manufacturing defects as the cause of failures. Without the initial inspection, manufacturing is usually a prime suspect in the failure. So efforts can be concentrated on improving the engineering analysis and design of the component.

INDUSTRY STANDARD INSPECTION

Ultrasonic methods are most commonly used to inspect composite structures. However, ultrasonic inspection can be expensive and labor intensive especially with limited run parts. The programming of automated inspection equipment for a one-time job can be very inefficient. Also, tooling for automated systems is costly and may require submersion in water or at least contact with water. If inspected by hand using A-scan methods, extensive highly skilled labor is required and a high probability of missing defects is likely due to human error.

Radiography is also commonly used to inspect aerospace composites. Because most polymer composites are almost transparent to X-rays; radiography often will not detect defective material unless the X-ray beam is aligned parallel with any crack-like defect. Delaminations usually are parallel with the outer surface and alignment of the beam parallel to the delamination may be difficult of require many shots. X-ray opaque penetrants may be used to enhance the detectability of damage that is open to the outside of the part but these penetrants may be caustic and damage the part or contaminate the part. Many common foreign materials, i.e. bagging film, release cloth, paper tape, and bag sealing material, that may be accidentally included in the part may have similar density to the part and hence will be undetectable with radiography.

EFFICIENT INSPECTION OF PROTOTYPE STRUCTURES

Relatively rapid inspection of composite components can usually be accomplished using thermography inspection for screening and ultrasonics to verify the condition of anomalies. Flash thermography can perform inspection with single sided access to the part using a hand held inspection head as seen in Figure 1. The inspection head contains a set of high intensity flash lamps and a high sensitivity video infrared camera. The flash lamps are similar to lamps used in portrait photography. The flash is started and timed acquisition of thermography images are performed by a computer. The infrared camera detects the temperature change on the surface as the heat input from the flash lamps flows into the part. The infrared camera is capable of detecting temperature changes of less than 0.02 degrees Celsius. Areas of different microstructure will conduct heat differently and show up as gray or color scale variations. Image manipulation and enhancement using image processing makes identification of anomalies quick and deterministic. For the inspection head shown, an area eleven inches by eleven inches is inspected at a time.

Using a grid and multiple flash thermography interrogations the entire structure can be inspected. Figure 2 shows the grid used to inspect a 72-inch diameter graphite epoxy prototype tank. At the nodes in the grid a small square of reflective tape is placed on the structure. This tape is visible to the infrared camera and allows correct placement of the inspection head within the grid. These foils can also be used to pinpoint the boundaries of a suspect region by successively moving a set of reflective markers close to an anomaly and reinspecting the area until the exact location can be identified on the part. A-scan ultrasonic inspection can then be used on the anomaly to further determine the microstructure.

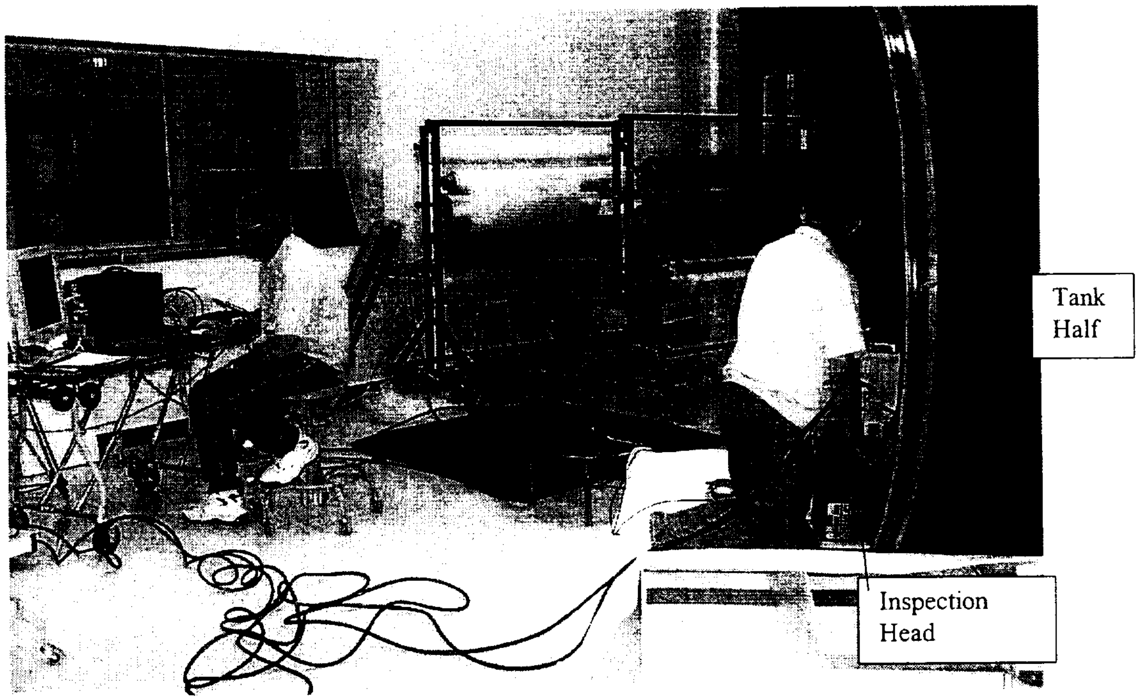


Figure 1. Flash Thermographic Inspection of Composite Tank Half

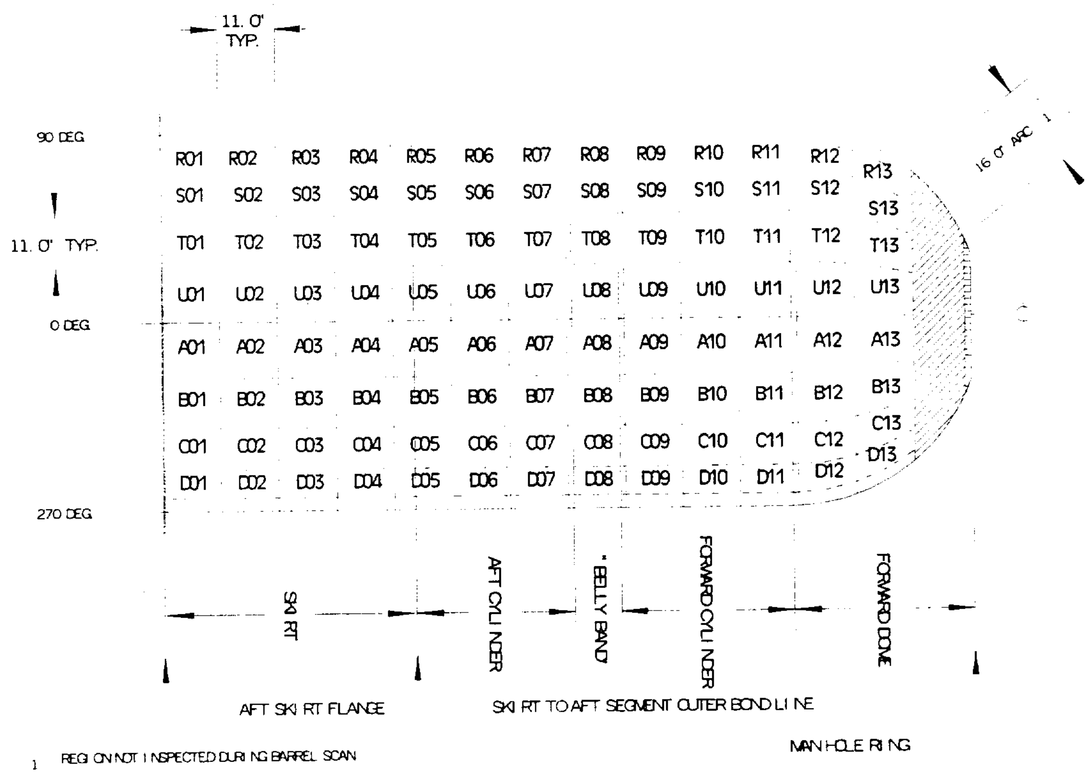
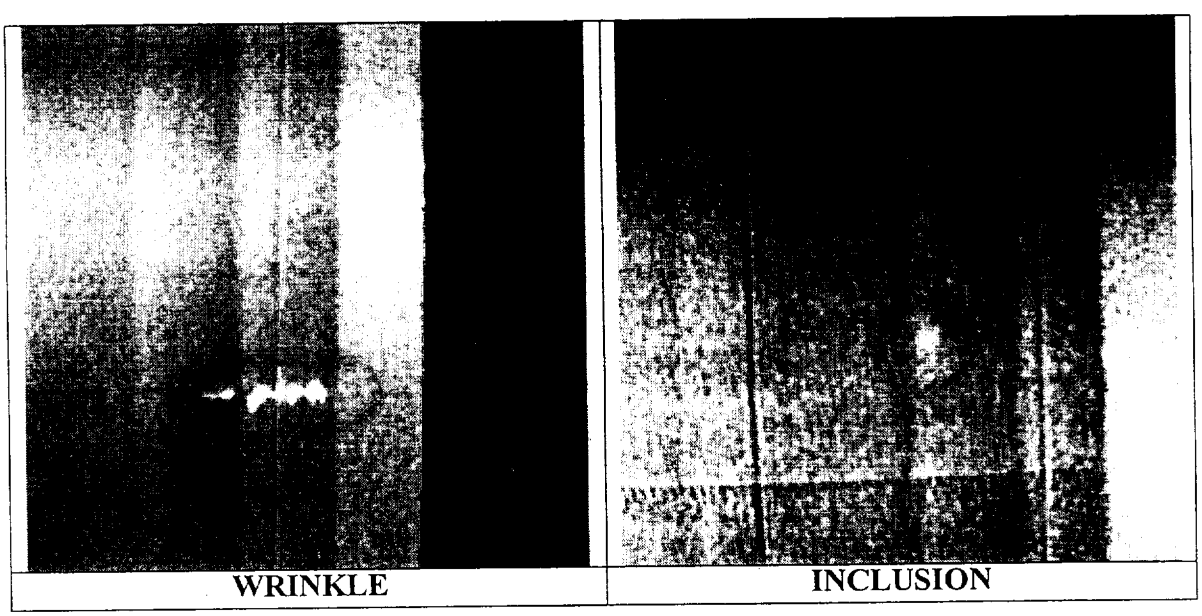


Figure 2. Image Map from Inspection Plan for 72 inch Diameter Composite Tank

Figure 3 shows thermograms of regions of a manufacturing processing prototype tank containing defects. The material was sectioned through the defects and microscopic examination revealed the microstructure was as expected. Figure 4 is a thermogram of a region containing slotted holes with machining damage. The system easily identifies loose fibers or missing fibers. Delamination and microcracking due to machining would be detected if present.



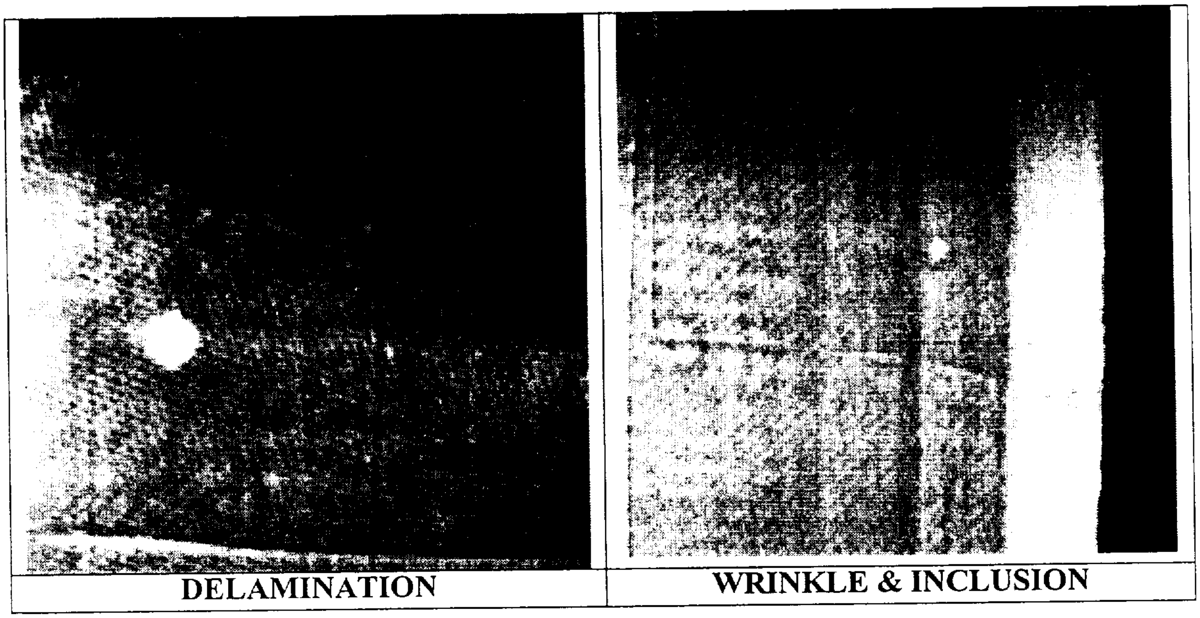


Figure 3. Thermograms of defects in manufacturing prototype tank.

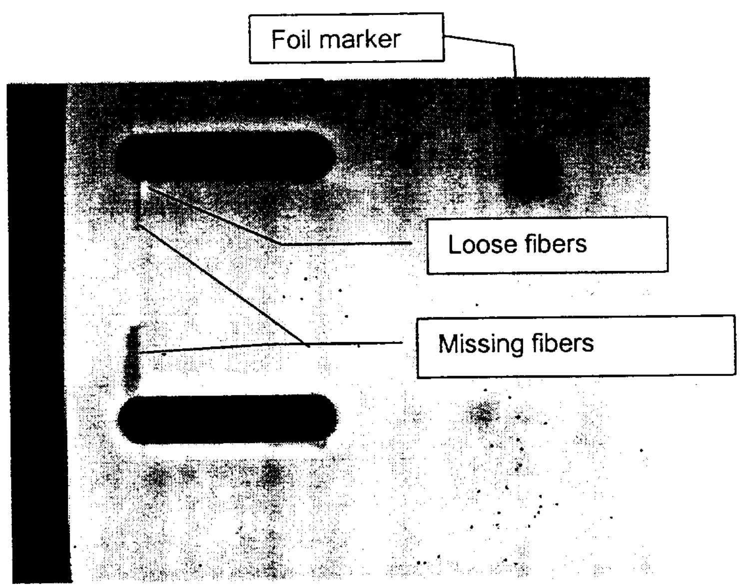


Figure 4. Thermogram of machined area of graphite epoxy tank.

A good test for the depth of inspection when performing single sided thermography inspection if defect standards are not available is to place a piece of adhesive backed metal tape on the opposite side of the composite skin from the imager. The size of the tape should be no larger than the critical flaw size. If the inspection detects the metal tape then the inspection is adequate throughout the thickness. Thicker composite parts may require heating one side of the part and observing the opposite side. Figure 5 shows such a test being conducted on a graphite epoxy duct. A quartz lamp is inserted into the duct and the outside surface is observed.

One of these composite ducts was manufactured with a piece of plastic film embedded in the laminate, see Fig. 6. Marker tape was used to map the location of this defect on the surface of the part. Also most thermography inspection software packages have a feature that will allow rapid and convenient sizing of anomalies.

SUMMARY

Thermography with assistance from limited ultrasonic inspection is a powerful and efficient way to inspect prototype components. Because prototypes are usually the only copy, manual manipulation is more cost effective than automating the placement of the inspection head. However, the inspection head can be mounted on a robot arm for complete inspection automation if the quantity of components makes it practical. Powerful software, cameras, and computers make the inspections practical and efficient. Thermography systems can detect most defects that result from manufacturing errors, handling, or use

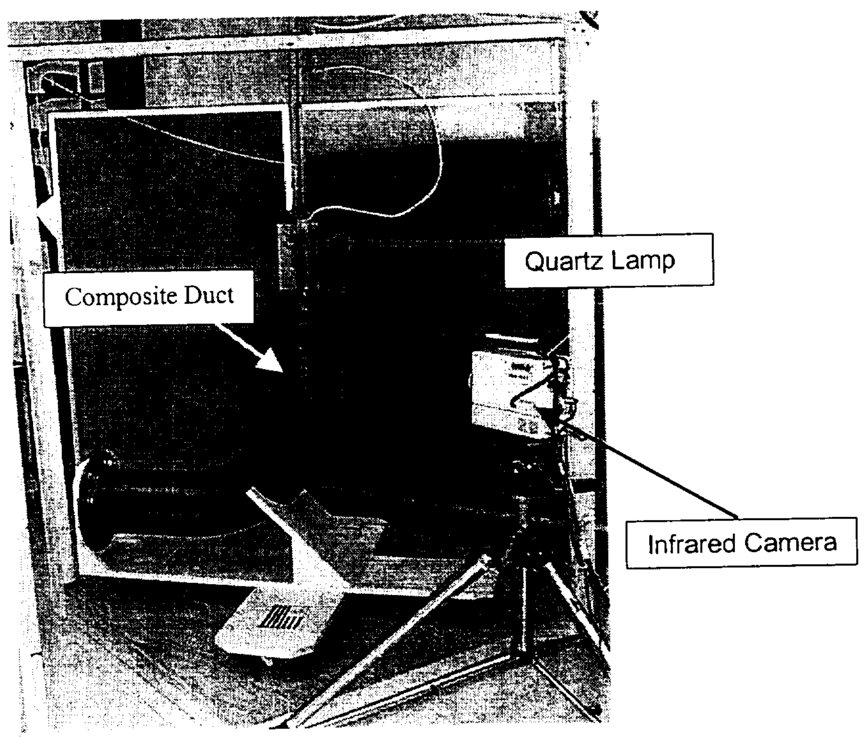


Figure 5. Inspection of Graphite Epoxy Duct

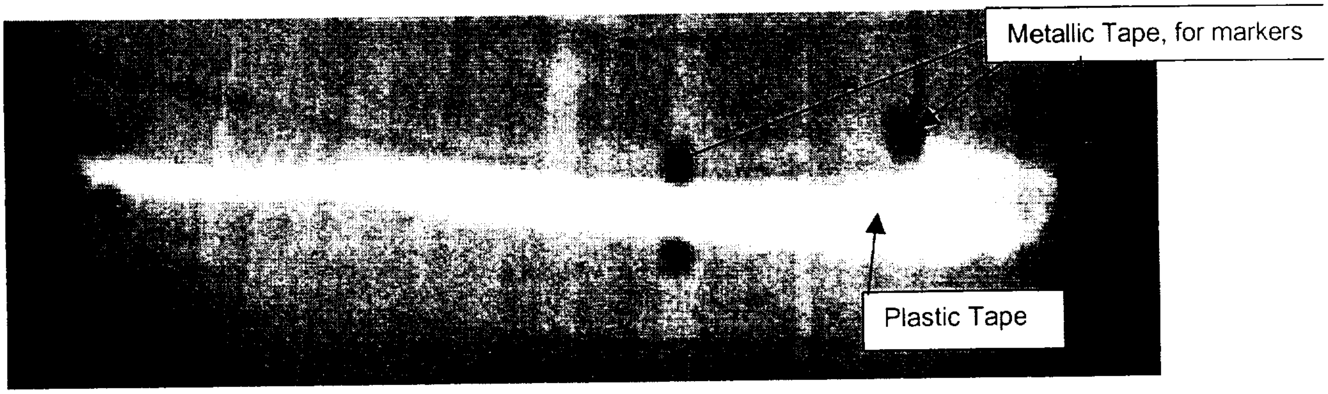


Figure 6. Thermogram of composite duct with embedded foreign material, plastic tape.