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# Low-Voltage Radiography on Aircraft Composite Doublers

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David G. Moore
Sandia National Laboratories
Federal Aviation Administration
Airworthiness Assurance NDI Validation Center
Albuquerque, New Mexico 87185
(505) 844-7095

John D. Murray
Sandia National Laboratories
Manufacturing & Rapid Prototyping
Department - Radiography
Albuquerque, New Mexico 87185
(505) 844-8822

**Abstract**

Composite doublers are gaining popularity for their ability to repair and reinforce commercial aircraft structures and it is anticipated that the potential cost savings may spur wider use of this technology. But before composite doublers can be accepted by the civil aviation industry, inspection techniques must be developed to verify the integrity of the doubler and the parent material under the doubler. The Federal Aviation Administration Airworthiness Assurance NDI Validation Center (AANC) is currently developing test methods to inspect aircraft structures under composite doublers using low kilovoltage radiography. This paper documents the radiographic techniques developed by the AANC which have been found to give the best contrast of the radiographic image with reduced image distortion.

## Background

The AANC was established by the FAA William J. Hughes Technical Center at Sandia National Laboratories to support nondestructive inspection (NDI) technology development and assessment. Since the number of commercial airframes exceeding twenty years of service continues to grow, Service Life Extension Programs are becoming more prevalent. These test and evaluation programs are presently being conducted to extend the "economic" service life of commercial airframes to thirty years. The use of bonded composites may offer the airframe manufactures and airline maintenance facilities a cost effective technique to extend the service life of their aircraft. Structural reinforcement doublers (or composite repairs) may offer numerous advantages over metallic patches. The advantages of corrosion resistance, light weight, high strength, elimination of fasteners, and time savings during installation all factor into the decision of designing a repair made of composite materials. The key to adding composites as an option for repair is to validate their design and add inspection techniques into the maintenance NDT manuals. The AANC has just completed a technology evaluation project with Delta Air Lines, Lockheed Martin, Textron, and the FAA. The focus of this project was to determine if a L-1011 door frame could be reinforced using composite technology and what changes in the current inspection procedure would be required to inspect the door frame corners.

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## DISCLAIMER

**Inspection Procedure Prior to Composite Doubler Installation**

Radiographic inspection is currently specified in the L-1011 NDT manual to inspect all passenger, galley, and cargo door frame corners located at the floor level for fatigue cracks during Heavy Maintenance Visits. The procedure specifies double loading with a high and low speed film. The equipment set-up and proper location for the X-ray source is also specified. The requirement for film density in the inspection area is between the range 2 and 3. To utilize composite repair technology in commercial aircraft the inspection techniques in the NDT manual must be modified and shown that composites will not interfere with existing radiographic inspection requirements.

**Development of Radiographic Technique for Composite Doubler**

Radiography is a very effective inspection method to interrogate the interior of the parent material covered by the composite doubler. This technique provides the advantage of permanent film record. However, it is more expensive than other inspection techniques and requires safety considerations due to the potential radiation hazard. This method utilizes a source of X-rays to detect cracks in the aircraft door frames covered by the composite doubler. Variation in density over the composite are recorded on the film and produce differential densities of X-ray absorption of penetrating radiation. Since composites are low absorbers of X-ray and high contrast on the film is needed, the inspection was performed at low kilovoltage ranges (50 kV to 80 kV). However, at 50 kV or less the radiation beam intensity decreases with distance more rapidly than calculations suggest. Therefore, exposure time correction factors are required to obtain the desired film density when the source-to-film distance is changed [1]. Two different types of test specimens were used to develop the radiographic procedure. The first test specimen was a 72 ply, multi-axial lay-up boron epoxy (B/E) composite coated with fiberglass placed over laboratory grown fatigue cracks (Figure 1). The second test specimen was a L-1011 door surround structure with a B/E composite lay-up (Figure 2).

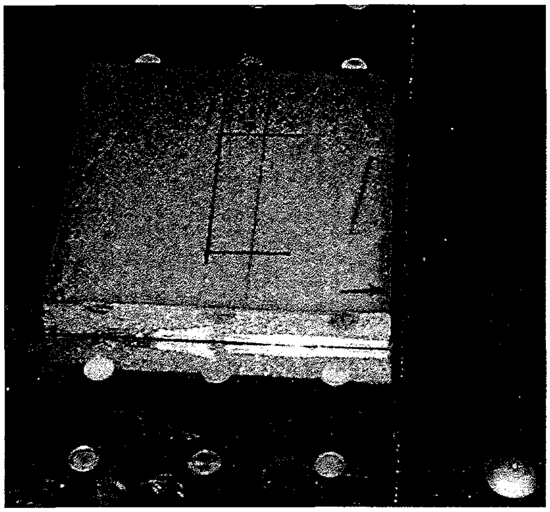

Figure 1. First test specimen 72 ply muti-axial lay up (7.62 x 8.26 x 0.953 cm) over laboratory grown fatigue cracks.

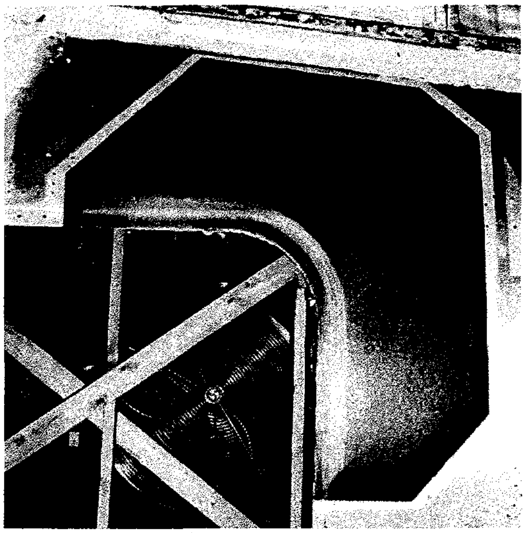

Figure 2. Full scale door surround structure with a 72 ply composite doubler (84.5 x 88.9 cm with 7 ply taper) installed.

## Inspection Results on Test Specimens

Several exposures below 50 kV were attempted on Specimen #1 in the laboratory setting. Since an actual aircraft has limited space to change the source-to-film distance (SFD), only exposure times were varied. Due to the SFD limitation, density ranges did not fall between 2 and 3 until long exposure times were employed. To optimize the film density between 2 and 3, the kilovoltage was increased and the exposure time was decreased. Table 1 displays the radiographic settings for Specimen #1 and the density value near fatigue crack locations.

Table 1. Equipment Settings for Specimen #1

| | | | |
|---|---|---|---|
| 80 kV | 12 mA | 30 sec. | 0.98 |
| 80 kV | 12 mA | 120 sec | 2.85 |
| 80 kV | 12 mA | 90 sec | 2.64 |

Note: the source to film distance is 1.52 meters.

To assist with the development of the radiographic technique on Specimen #2, Image Quality Indicators (IQI) were utilized. A number 2 penetrameter (per ASTM E801) containing different wire diameters was placed in the field of view behind the composite doubler and the aircraft skin. Table 2 displays the radiographic density values for Specimen #2. The equipment settings were: 80 kV, 12 mA, exposure time 90 seconds, SFD 1.52 m, and source offset 25.4 cm and 50.8 cm. Note: this test specimen does not have fatigue cracks.

Table 2. Density Values for Specimen #2

| | | | |
|---|---|---|---|
| Between Fasteners | 1.36 | # 2 Penetrameter | 1.18 |
| Full 72 Ply | 1.37 | 1st Taper | 1.37 |
| 2nd Taper | 1.54 | 3rd Taper | 1.62 |

Wires A and F (0.051 mm diameter) from ASTM penetrameter could be detected on the radiograph. Particle diameters G (0.381 mm) H (0.254mm) and I (0.203 mm) from ASTM penetrameter could be detected on the radiograph.

## Conclusions

Radiographic inspections of boron epoxy doublers are as practically effective as before the doubler was installed. Adding boron/epoxy composite material on an aircraft structure will change the film density and sharpness, however, kilovoltage and exposure time can be adjusted to achieve the required film density and contrast.

## References

1. R. H. Fassbender and D. J. Hagemaier, "Low-Kilovoltage Radiography of Composites", Materials Evaluation, Volume 41, June 1983, pp. 831 - 838.