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Effect of Conductivity
Between Fasteners and Aluminum Skin
On Eddy Current Specimens

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Abstract

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The Federal Aviation Administration Airworthiness Assurance Nondestructive Inspection Validation Center (FAA-AANC) and Boeing Commercial Airplane Group are currently developing a study pertaining to the detection of cracks in multi-layered aluminum sheets. The specimen panels model pertinent aspects of the lap splice joints for Boeing 737 aircraft, Line Numbers 292 - 2565. Upon initial characterization of the specimen panels, it became clear that signals produced from a sliding probe at fastener sites were not representative of an in-service lap splice, and therefore, could not be used in a probability of detection experiment. This paper discusses specimen characterization and steps taken to make the specimens useful for nondestructive technology assessment.

Background

The FAA-AANC was established at Sandia National Laboratories by the FAA William J. Hughes Technical Center, Atlantic City, N.J. in August 1991 and is housed in a hangar at the Albuquerque International Airport. AANC's major role is to the study and validate nondestructive inspection techniques and assess advanced inspection technologies.

During a fleet survey of a Boeing 737 aircraft in September of 1994, cracks were found in the lower fastener row, lower skin (Figure 1) in a high cycle time aircraft. Because the primary crack location was covered by tear straps, a low frequency eddy current procedure was developed to detect this type of cracking from the exterior of the aircraft. On November 8, 1994 Boeing Commercial Aircraft Group issued Service Bulletin 737-53A1177 which specified the inspection of the lower fastener row of 737 lap splices for line numbers 292 through 2565. During a 1995 NDI Reliability Workshop sponsored by the FAA, the AANC was asked to assist the Seattle Aircraft Certification Office in developing Probability of Detection (PoD) curves for primary inspection called out in the Service Bulletin.

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Design and Production of Lap Joint Specimens

The specimens were designed to model pertinent aspects of an in-service 737 lap splice. Each test specimen consists of one mock doubler, four mock tear straps and two aluminum skins riveted together with a 76.2 mm (3") overlap (Figure 2). Programmed fatigue cracks were grown in aluminum sheets and placed as the lower skin. The spacing of the tear straps was varied to simulate manufacturing tolerances. Since the tear straps create a major source of noise for the eddy current inspection, the number of tear straps per unit length of lap splice was doubled. This gives an inspector a larger number of tear strap inspection sites with a minimum number of samples. The eddy current inspection is also effected by the skin thickness of the lap splice. Therefore, the top two layers of the specimens (upper skin and doubler) had two thickness values - 1.83 mm (0.072") and 2.03 mm (0.080"). The programmed fatigue cracks were created from starter notches at select locations. The lower skin panels were then cycled until the desired length of fatigue crack was reached. Starter notches were removed by drilling the final holes for fastener installation.

In an attempt to create the relatively low electrical conductivity between the specimen skin and fastener which is observed on aged in-service lap joints, at least eight hours were to elapse between drilling and countersinking the fastener hole and fastener installation. A petroleum base lubricant was also applied to each hole prior to fastener insertion.

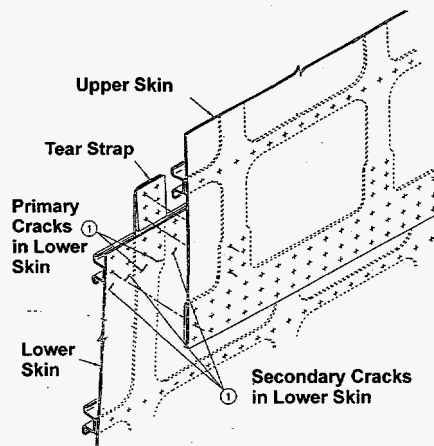


Figure 1. Crack locations in the Boeing lap joint.

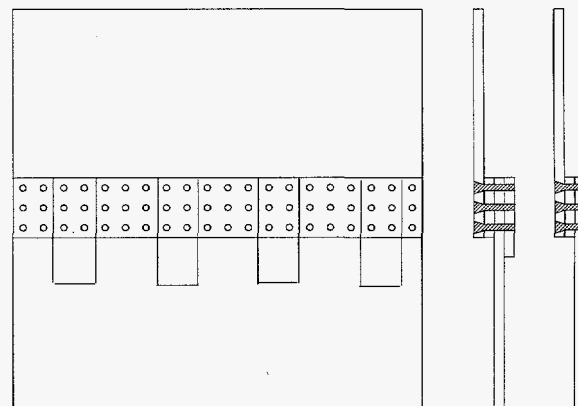


Figure 2. Panel design to simulate Boeing lap joint.

Characterization of Lap Joint Specimens

Three criteria were used to judge how well the test specimens modeled the eddy current response of an aged in-service lap joint. First, does the eddy current signal from unflawed fastener locations on the specimens compare to similar sites on an aircraft? Second, is there a similar amount of variation in eddy current signal strength from a sample of unflawed specimen sites as compared to a similar sample of aircraft sites? Third, does the eddy current signal strength at flawed fastener sites in the test specimens match the signal strength from aircraft sites with similar length flaws? In making these comparisons it was found that some flawed and unflawed sites in the specimens did produce eddy current signal strengths comparable to aircraft sites.

However, most sites produced a smaller than expected signal. Of course this meant that the amount of signal variation among similar sites on the specimen panels is much greater than found on an aircraft. It was concluded that the specimen panels had not been properly lubricated. Therefore, the generation of artificially aged fastener sites was not obtained on the test specimens. Figure 3 documents the characteristics of a rivet site with an abnormal conductivity between the rivet and hole. This impedance plane signal is not representative of sites found on aircraft.

Remanufacturing of Lap Joint Specimens

To remedy the signal response discrepancy found during the initial characterization, each top and bottom row of rivets was removed. Following is the removal process developed for these specimens: 1) remove the back side of the rivet using an air powered metal shaver and 2) drive out each rivet using a rivet press. After this process is complete, the specimens were re-inspected. Each hole and rivet was then coated with Sharpie® permanent marker. Petroleum lubricant was applied to each site and rivets were then driven back into the existing holes. The specimens were re-inspected using the low frequency eddy technique and data acquisition software. The re-inspection data was compared to the original data. The purpose of this comparison was to document that removal and re-installation of rivets does substantially change the impedance plane signal and the most significant factor affecting original response in the lap joint specimens was the result of poor lubricant during rivet installation. Figure 4 displays the results of the re-manufacturing process (removing the rivet, applying permanent marker to the hole and rivet, adding petroleum lubricant to the rivet hole and re-installing the rivet). The impedance plane signal is representative of fasteners found on actual aircraft.

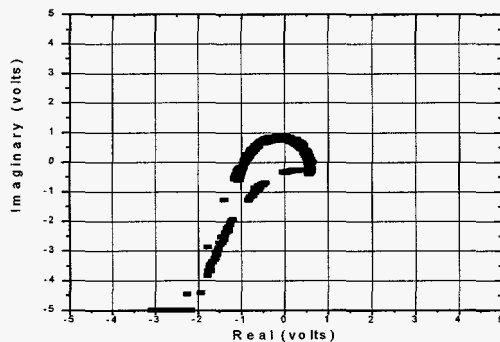


Figure 3. Signal from rivet that exhibits high conductivity between the hole and rivet.

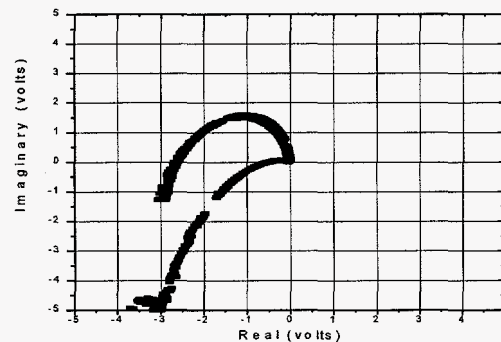


Figure 4. Signal from the same rivet site after remanufacturing.

Conclusions

To successfully implement a probability of detection experiment, specimens must simulate the response of an in-service aircraft inspection. The electrical conductivity between the fasteners and skin in a high cycle aircraft are different from newly manufactured ones, thus, lap joint specimens must be artificially "aged" to model the eddy current response of an in-service aircraft. The remanufacturing steps described in this paper are one method to approximate the correct electrical conductivity between the fastener and skin of an in-service lap joint.