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INSPECTION TECHNOLOGIES

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1.0 INTRODUCTION

Regular maintenance of airframe is an important aspect of assuring flight safety of aircraft structures. One technology area, which plays an important role in proper maintenance and assuring the flight safety of aircraft, is the inspection at regular intervals. Reliable visual and nondestructive inspection (NDI) methods are needed to assure the airworthiness of these aircraft and at the same time keeping maintenance costs to a minimum. Commercial aircraft maintenance programs are shown in Figure 1. For military aircraft the inspection requirements are generally defined by Integrated Logistic Support (ILS) organization for non-critical components. For critical components, the inspections are defined by damage tolerance analysis.

1. Corrosion Inspection Program

Level 1- Local corrosion that can be removed within allowable limits.

Level 2- Local corrosion that exceeds allowable limit. This requires repair or partial/complete replacement.

Level 3- Potential urgent airworthiness concern requiring expeditious action.

Note- Airline's existing maintenance programs must control all primary structures to level 1 or better.

2. Periodic Maintenance Inspections

A Check- Visual inspection of interior and exterior every 65 to 75 hours.

B Check- Access panels removed for inspection and engine servicing every 30 days.

C Check- Heavy structural and maintenance check after every 5,500 flying hours.

D Check- Interior stripped to fuselage walls every 20,000 to 25,000 flying hours.

Figure 1. Commercial Aircraft Maintenance Programs

For in-service military aircraft, the inspection requirements may be defined by the usage (e.g lead-in-fighter, dissimilar air combat, air training command, etc.). Using the stress analysis and loads data, it is possible to predict the life of a structural component with durability and damage tolerance analyses techniques. From the crack growth analysis of a critical area of a structural component under actual spectrum, experienced by a structural component, it is possible to identify initial inspection and subsequent inspection requirements as shown in Figure 2. The crack growth curve for a critical location is obtained from assumed initial flaw a_0 , based on damage tolerance requirements, to critical size a_c at which the flaw grows to be catastrophic at N_f flight hours. If the inspection capability of the Non-Destructive Inspection (NDI) equipment to be used in field or depot is a_i , then the cycles to grow the crack from a_0 to a_i are determined to be N_i . The initial inspection requirement is given by $N_i/2$ and subsequent inspection requirements are given by $(N_f - N_i)/2$.

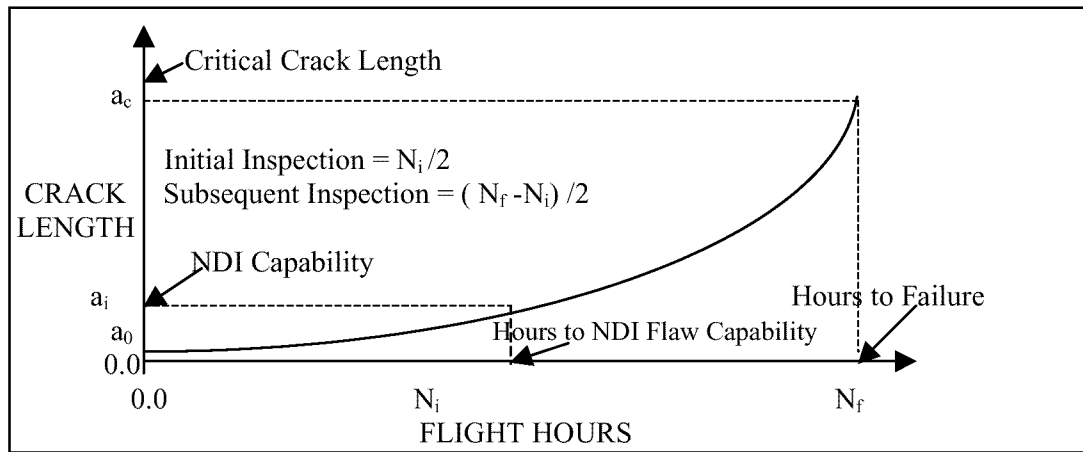


Figure 2. Initial and Subsequent Inspection Requirements from Crack Growth Life

The procedure outlined in Figure 2 is used to zone an aircraft structure for inspections depending on the severity of loads and structural details such as thickness, presence of substructure, fastener diameter and type, etc. Typical zoning of a wing structure for Air Training Command (ATC) usage is shown in Figure 3 (Reference 1). The wing in the figure has been divided in 5 zones, namely A, B, C, D, and E. The fasteners in each zone have different inspection requirements depending on the structural details and stress levels. The fasteners in zones D and E are in an area where the stresses are rather small and crack growth life is very large. The zoning and inspection requirements depend on the usage of an aircraft, as the load spectrum will change with the usage. For usage other than ATC the inspection requirements will be different from those shown in Figure 3, however, the inspection zones may still be the same. Analytical techniques provide tools to define inspection requirements based on usage and structural details to reduce inspection cost.

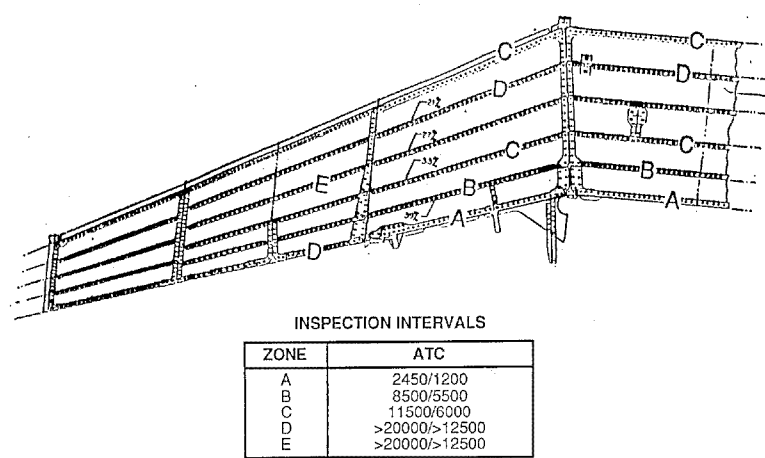


Figure 3. Zoning of Military Aircraft Structure for Inspection

This paper discusses currently available techniques for detecting damage in structures and their limitations. Inspection of cracks in substructure and hidden corrosion has always presented a nightmare for NDI engineers. Some recent advances made in the NDI technology to solve these problems are discussed.

2.0 COMPARISON OF NONDESTRUCTIVE INSPECTION (NDI) METHODS

A number of visual and nondestructive inspection methods are available for inspection. However, their application to detect flaws depends on the type of structure, access, desired degree of accuracy, and inspection time. The comparison of conventional NDI methods is shown in Figure 4.

NDI Method	Ultrasonic	Eddy Current	Radiography	Penetrants	Magnetic Particle
Flaw Type	All	Cracks, Corrosion	All Except Small Cracks	All	All
Sub-surface	All	Shallow	All	Surface only	Shallow
Area of Scan	Small	Small	Large	Large	Medium
Flaw Sizing	Fair	Poor	Good	Very Good	Good
Test Time	Slow	Slow	Very Slow	Varies	Fast

Figure 4. Comparison of NDI Methods

The advantages and disadvantages of various NDI methods (References 2-3) are shown in Figure 5 along with their applications. Some of these techniques are discussed in the following paragraphs.

NDI Method	Detection Application	Advantages	Disadvantages
Visual	Large Surface Defects or Damage in all Materials	Simple to use	Reliability depends on experience of user
Optical	Surface defects/structural damage in all materials	Rapid large area inspection Good for bonded and cored structures	Accessibility required for direct visibility
Penetrant	Surface cracks in metals	Simple to use, accurate, fast, easy to interpret	Surface defects only, access required, defect may be covered
High Frequency Eddy Current	Surface defects, cracks, intergranular corrosion, pits, heat treat	Useful for detecting cracks at holes not detectable by visual or penetrant, fast, sensitive, portable	Trained operators, special probes for each application, reference standards required
Low Frequency Eddy Current	Subsurface defects, corrosion thinning	Useful for detecting cracks under fasteners or substructure without disassembly	Trained operator, time consuming, special probe for each application
Sonic	Delaminations, debonds, voids, and crushed core in composites, honeycombs	One side access, does not require paint removal or surface preparation	Difficult to interpret results, loses sensitivity with increasing thickness
X-Ray	Internal flaws and defects, corrosion, inclusions and thickness variations	Eliminates disassembly requirements, permanent record, high sensitivity	Radiation hazard, trained operators, crack plane must be parallel to x-ray beam, special equipment
Magnetic Particle	Surface and sub-surface defects in ferromagnetic materials	Simple, portable, easy to use, fast	Trained operator, parts to be cleaned before and demagnetized after check Magnetic flux must be normal to defect plane
Ultrasonic	Surface and sub-surface defects, cracks, disbonds in metals and composites	Fast, easy to operate, accurate, portable	Trained operator, test standards required, electrical source needed

Figure 5. Relative Advantages and Disadvantages of NDI Techniques

3.0 PROBABILITY OF DETECTION (POD)

Probability of detection (POD) is a statistically based quantitative measure of inspection capability. The POD is different for different inspection equipment and even for the same NDI equipment is affected by a number of factors such as: material properties, structural details, defect shape, inspection conditions, etc. Another parameter generally associated with POD is the confidence level with which a flaw can be detected. A 95% confidence level is considered acceptable for flaw detection. An NDI equipment capability is generally designated as 90% probability of detecting a flaw with 95% confidence level. The POD of various NDI equipment for through the thickness damage (Reference 4) is shown in Figure 6. Figure 7 shows POD for sub-surface and internal defects. These figures indicate that the probability of detection varies significantly with each NDI equipment.

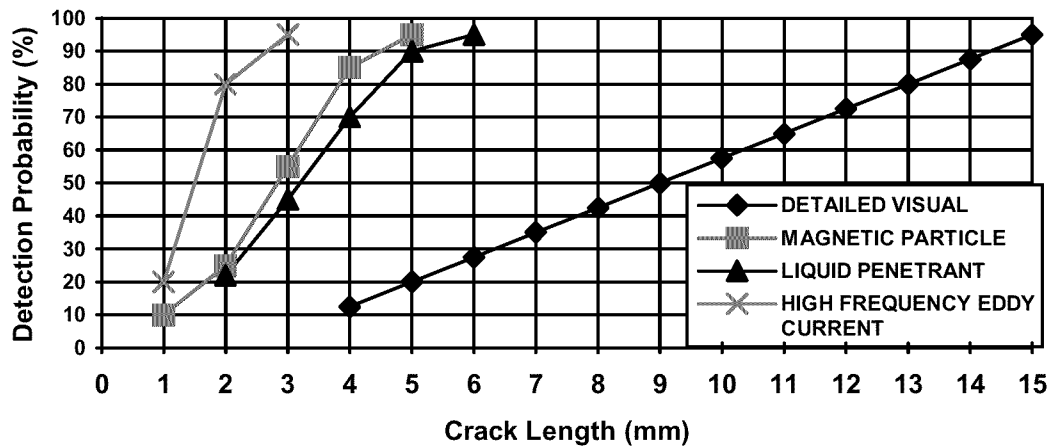


Figure 6. Probability of Detection for Through the Thickness Defects

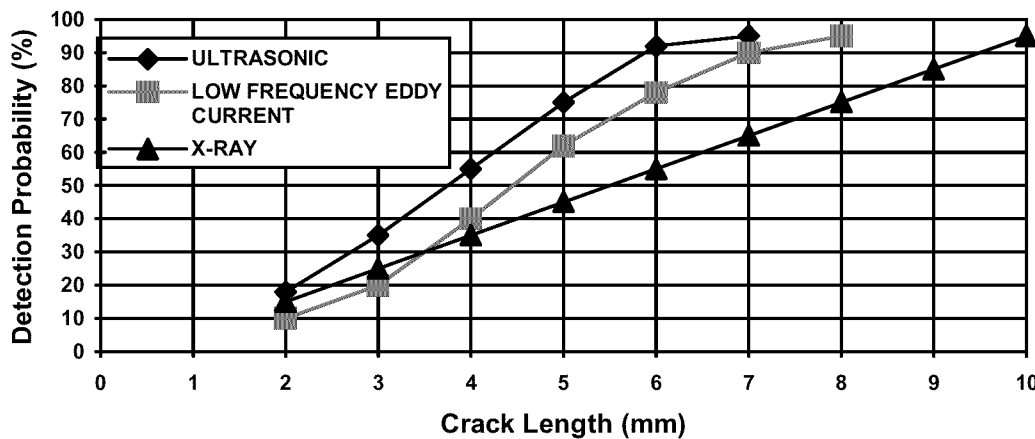


Figure 7. Probability of Detection for Sub-Surface and Internal Defects

4.0 VISUAL INSPECTION

Visual inspection is a sensing mechanism in which eye alone or in conjunction with other aids is used to judge the condition of a component being inspected. Visual inspection is an integral part of airplane maintenance and is considered as a component of NDI. Over 80 % of the inspections on large transport aircraft are visual inspections. On small aircraft the percentage of visual inspection is even higher. Typical defects found by visual inspection are cracks, corrosion and disbonding. Detection of disbonding due to corrosion is generally difficult; however, disbonding may be accompanied by local bulging due to corrosion or entrapped moisture and may be easily detectable.

Visual inspection is perhaps the simplest, most economical and most efficient method of assessing the condition of an aircraft. A large number of defects are generally found by visual inspection and the operators depend highly on the visual inspections to ensure the airworthiness of an aircraft. Hence, visual inspection plays an important role in the safe operation of an aircraft. The details of visual inspection are given in References 5-6.

4.1 Factors Affecting Visual Inspection

The manufacturer or regulatory authorities in the maintenance or overhaul manuals generally specify visual inspection procedures. A number of factors affect the results of visual inspection. Some of the important factors are:

- 1) **Qualifications and Training of Inspection Personnel-** Inspection should be done by qualified personnel or under the supervision of qualified personnel. These personnel should have knowledge of the structural details being inspected, types of defects which are commonly found and the causes of these defects.
- 2) **Inspection Area Access-** Proper access to the inspection area is an important factor in the reliability of visual inspection. An easy access to the component to be inspected will assist in the decision making process and ability to interpret results.
- 3) **Lighting-** Proper light without glare is essential for a quality visual inspection. Poor lighting can mask the defects and cause fatigue to the inspectors there by affecting their judgment.
- 4) **Pre-cleaning-** The part to be inspected should be free from dirt, contamination, and any foreign material that will obscure the detection of defects.
- 5) **Working Environment-** A proper working environment is necessary for the visual inspectors. Presence of excessive temperature, wind, rain or any other adverse condition can influence the interpretation capability of operators and increase the potential for errors.

4.2 Levels of Visual Inspection

Visual inspection is divided in four categories (Reference 5), namely: 1) Walkaround Inspection, 2) General Visual Inspection, 3) Detailed Inspection, and 4) Special Detailed Inspection.

Walkaround Inspection-The purpose of a walk around inspection is to serve as a quick check to detect any obvious discrepancies that would affect the performance of an aircraft. Most maintenance manuals specify a walkaround inspection on a periodic basis. Flight or maintenance personnel may do this inspection from the ground. This inspection includes: fuselage, left and right wings, leading edges, control surfaces, propeller or fan blades, exhaust areas, pylons and gear well. The walkaround is done twice to make sure that nothing was missed the first time. The inspector looks for any major dents in the skin, missing fasteners, corrosion, leaks etc.

General Inspection-A general inspection of an exterior is carried out with open hatches and openings of interior to detect obvious damage. A general inspection is carried out when a problem is suspected or routinely when panels are open for normal inspection. The tools required for this inspection include: flashlight, mirror, droplight, rolling stool, ladder, stand and tools for removing panels.

Detailed Inspection- A detailed inspection is required when a specific problem is suspected or general inspection has identified some problems. This inspection is an intensive examination of a specific area, system, or assembly to detect any damage, failure or discrepancy. Surface preparation and special access may be required for this type of inspection along with special aids in addition to the tools required for general inspection.

Special Detailed Inspection- A special detailed inspection is a thorough examination of a specific component, installation or assembly to detect damage, failure or any discrepancy. Disassembly of sub-components and cleaning may be required for this type of inspection. Tools required for this type of inspection may include flashlight, mirror, borescope, image enhancement and recording devices, rolling stools etc.

4.3 Visual Inspection Equipment

Various aids are used for visual inspection. One of the most important aids in visual inspection is the proper lighting and illumination. Reference 5 describes the ideal lighting and illumination required for proper visual inspection. The reference describes various portable lighting aids. The other inspection equipment required include: mirrors, magnifiers and equipment to obtain images from inaccessible places being inspected.

Inspection Mirrors- These are used to look at the areas which are not in the normal line of sight. A number of different mirrors are available to inspect hidden areas (Reference 5).

Magnifying Devices- These are used in the visual inspection to expand the area being inspected for detecting damage and other anomalies. These devices include: simple magnifying glass, microscope and illuminated magnifiers.

Photographic and Video Systems- A photographic image of the area being inspected enhances the decision-making capability of an inspector to interpret what he sees. Photographic and video systems are available which can be attached to borescope, fiberscopes or any other visual equipment for documentation and interpretation of visual inspection images. The photographic images can be stored as permanent records for later viewing. A number of systems are available in the market.

Borescopes- A borescope is a tubular precision optical instrument with built-in illumination to allow remote visual inspection of internal surfaces. Borescope tubes may be rigid or flexible and are available in a wide variety of lengths and diameters. These are available in a number of designs and manufacturers can supply custom made borescopes to serve customer needs. The selection of a borescope depends on a particular application and is governed by factors such as- resolution, illumination, magnification, field of view, working length, direction of view, etc.

Borescopes are used in aircraft structures and engine maintenance programs to inspect the areas which are difficult to reach and thereby reduce/eliminate costly teardown inspections. These can be used to inspect the interiors of pipes, hydraulic cylinders, turbine blades and valves. They are also used to locate foreign object damage and verify the proper placement and fit of seals, bonds and gaskets.

4.4 Visual Inspection of Composite Structures

The in-service damage in composite structures is quite different from conventional metallic structures. In metallic structures detection of cracks and corrosion is of prime concern to the operators whereas in composite structures this kind of damage does not occur. The most common damage occurring in composites is impact damage which may result in internal matrix cracking, fiber breakage and delamination between plies without any appearance of external damage known as non-visible impact damage. Fortunately, all composite structures are designed for non-visible impact damage.

Any serious in-service damage that may affect the integrity of a structure has to penetrate, chip away or abrade the paint finish of the composite structure. Any damage caused by hailstorm, lightning or paint strippers will be easily visible on the surface and can be detected. Once the damage has been detected, the affected area needs to be inspected by other NDI methods for assessing the effect of the damage on structural integrity.

5.0 NONDESTRUCTIVE INSPECTION METHODS

As mentioned earlier a number of NDI methods are available and the use of a specific method depends on the type of structure being inspected, available access and the desired degree of accuracy in the inspection. Significant advancements have taken place in NDI methods recently. The methods and recent advancements are discussed in the following paragraphs.

5.1 Eddy Current

Eddy current is generally used to detect cracks and corrosion near the surface of metallic structures or in thin structures. Eddy current is also used for verifying and separating alloys by differences in their electrical conductivity. This technique has been gradually replacing x-ray. Hand-scanned eddy current probe coils can detect small cracks at fastener holes, however, the method is time consuming and tedious. As most conventional eddy current instruments display variations in the complex impedance, corrected for lift-off as seen by the probe coil, the flaw indications may be sometimes ambiguous. This generally requires trained and experienced operators to interpret the results. Also, the lift-off variations produced by surface roughness or paint thickness can result in false calls. The paint removal may be required prior to inspection with conventional eddy current equipment. Recent trends in eddy current technology have been towards the computerization, automation, improving capabilities to detect small flaws and flaws in multi-layer structures. Two NDI techniques which show significant promise in detection of corrosion and subsurface cracks without disassembly are Magneto-Optic/Eddy Current Imager (MOI) (References 7-10) and Low Frequency Eddy Current Array (LFECA) (References 11-14).

Magneto-Optic/Eddy Current Imager (MOI)- The MOI technique makes it possible to do faster, simpler and more reliable detection of cracks and corrosion in structures. This real-time imaging technology is based on a combination of magneto-optic sensing and eddy current induction. The images of holes, cracks or other defects are formed as the presence of these discontinuities in a material diverts the otherwise uniform flow of current near the surface of a structure as shown in Figure 8 (Reference 8). At eddy current frequencies of 25.6-102.4 kHz most through-the thickness fatigue cracks in aluminum are easily detected and imaged, whereas at lower frequencies (e.g. 6.4 kHz) hidden multi-layer cracks, corrosion and substructure (Reference 7) can be imaged. Figure 9 shows POD of sliding probe and MOI, indicating superior performance of MOI. Figure 10 shows typical cracks detected by MOI and Figure 11 shows corrosion detected by MOI.

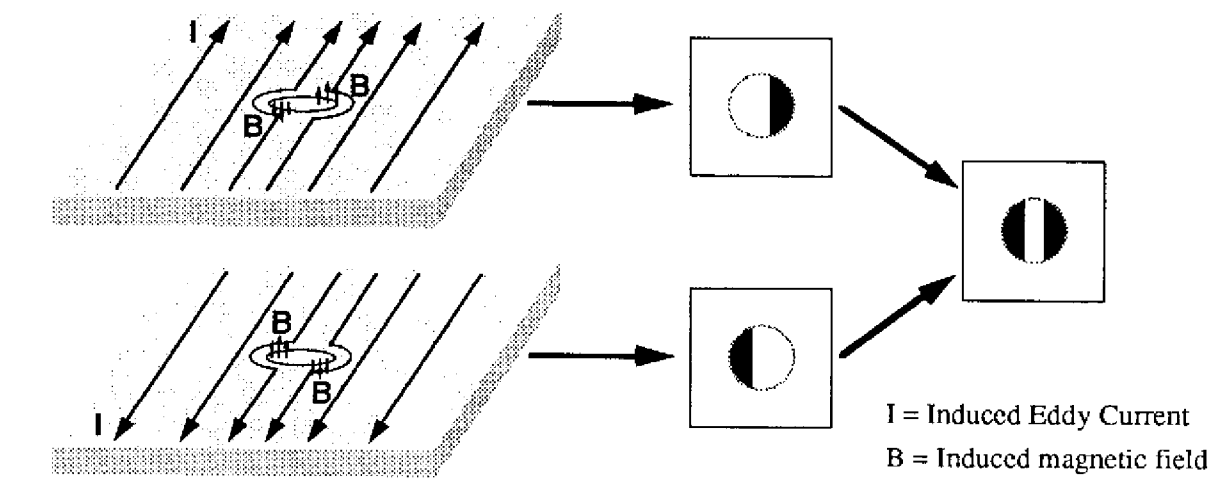


Figure 8. Formation of Images with Magneto-Optic/Eddy Current Imaging

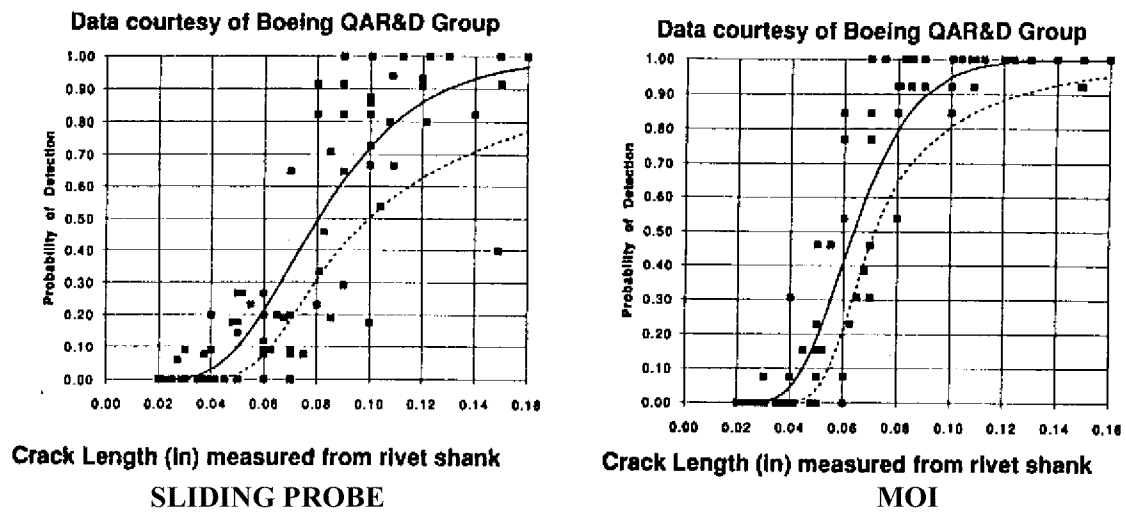


Figure 9. Detection POD for Sliding Probe and MOI

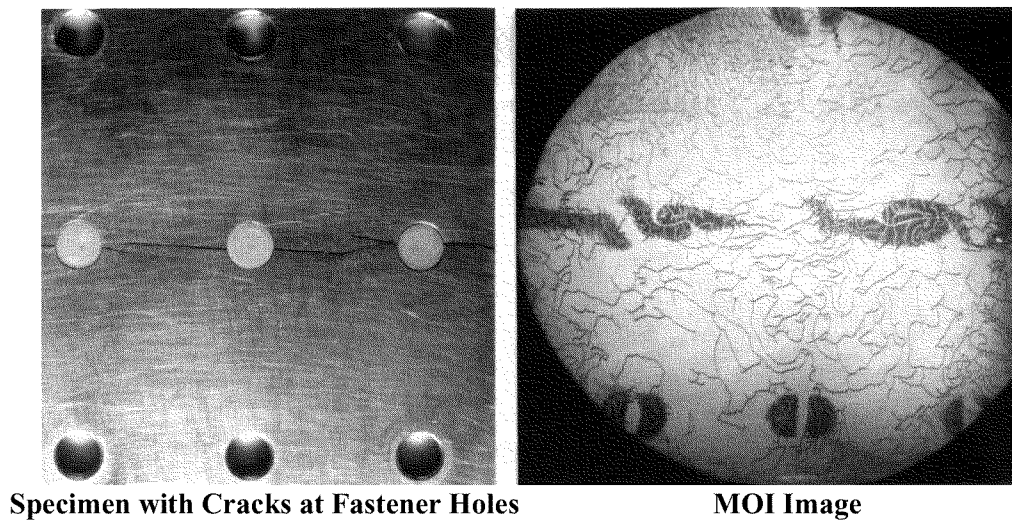


Figure 10. MOI Image of Cracks at Fastener Holes

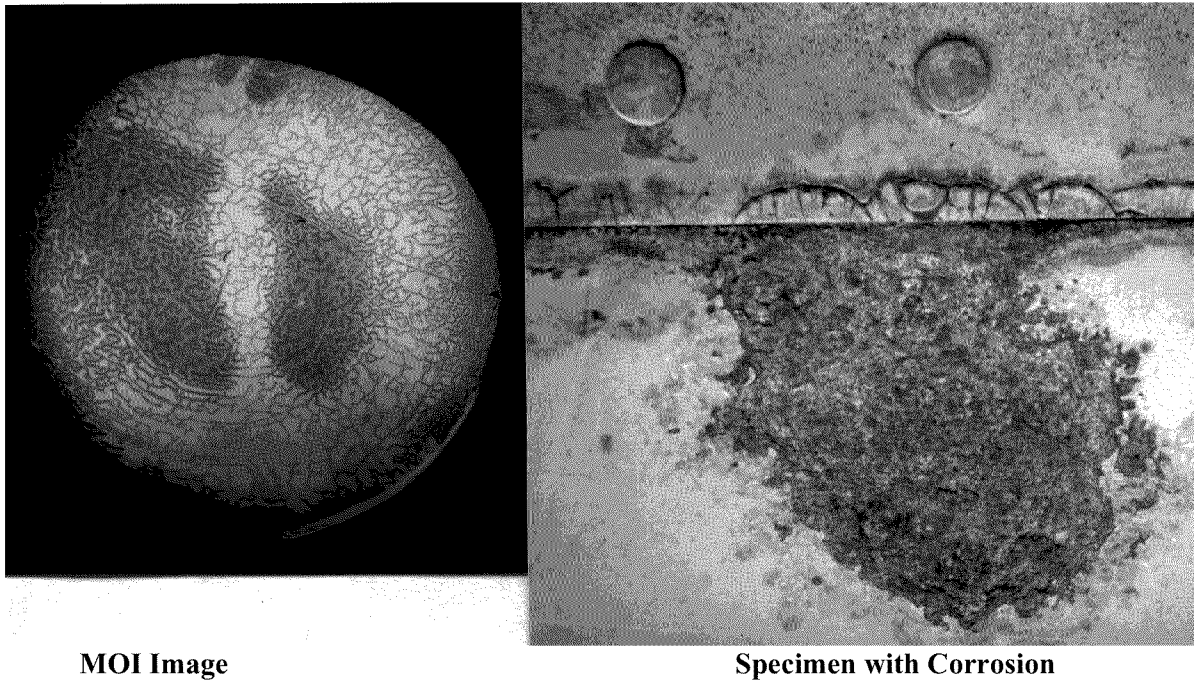


Figure 11. MOI Image of Corrosion

The key advantages of MOI are (Reference 7): 1) Speed of operation 5 to 10 times faster than conventional eddy current, 2) Easy to interpret image formation, 3) No false calls, 4) Elimination of paint or decal for inspection, 5) Easy documentation of results on video or film, and 6) No operator fatigue.

Low Frequency Eddy Current Array (LFECA)- The LFECA system, developed by the Northrop Grumman corporation, is a portable eddy current inspection equipment to detect subsurface cracks under installed fasteners in multi-layer aircraft structures (References 11-14). The inspections can be performed in near real time without the removal of fasteners. The LFECA system can detect cracks, determine crack length and also give crack depth and orientation. The system consists of a LFECA probe for inspection, shown in Figure 12, three printed circuit boards, a cable and software all assembled in a portable personal computer. The LFECA probe consists of a cylindrical core made from ferrite material with a drive coil located on the center post of this core to generate an eddy current distribution that encircles the fastener being inspected. An array of 16 sense elements, spaced evenly around the outer rim of the core, measures the spatial distribution of these eddy currents. The presence of a crack causes a disruption in the eddy current distribution and is measured by the sense element array. The outer drive coil is used to measure the response due to the adjacent structural features independent of the features at the structural hole. A typical response obtained from the LFECA system is shown in Figure 13 (Reference 11) for various crack sizes along with the probability of detection. The horizontal tick marks in the figures indicate the 16 angular positions around the fastener hole such that going from left to right will indicate going around the fastener hole once. The horizontal location in the response indicates the orientation of the crack and the magnitude of the peak indicates the crack length.

The probability of detection of cracks with the LFECA system was obtained at Federal Aviation Administration (FAA) NDI validation center at Sandia National Laboratories in Albuquerque, New Mexico, USA (References 11-13). The POD process consists of a blind test of eddy current equipment to inspect a lap joint typical of a commercial airline fuselage shown in Figure 14. The process involves inspection of 43 specimens with each specimen containing 20 fastener holes.

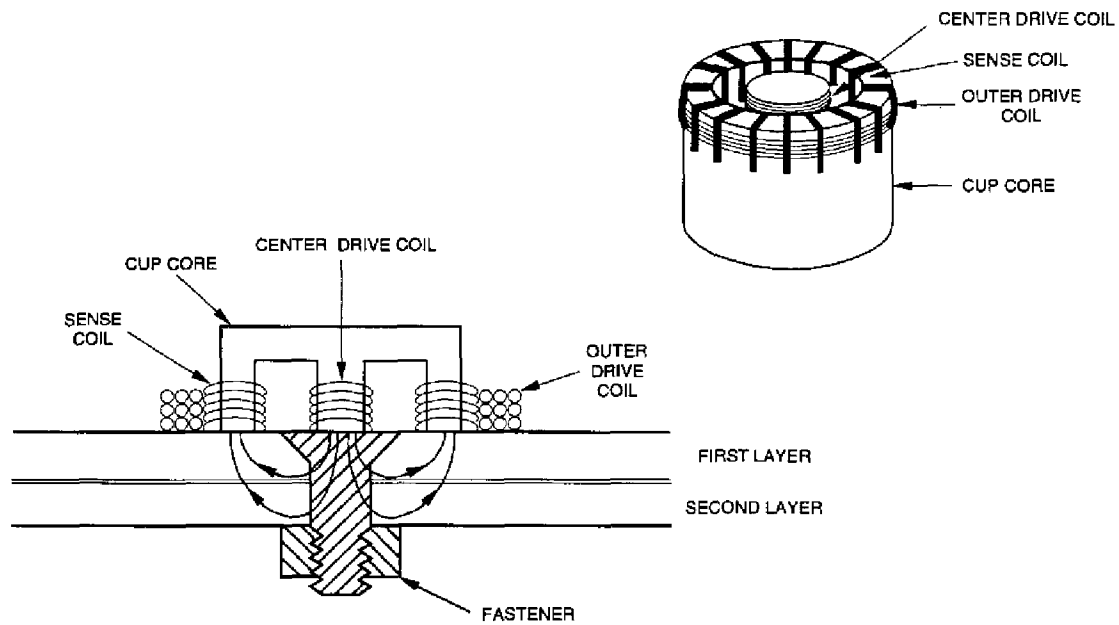


Figure 12. Low Frequency Eddy Current Array Probe

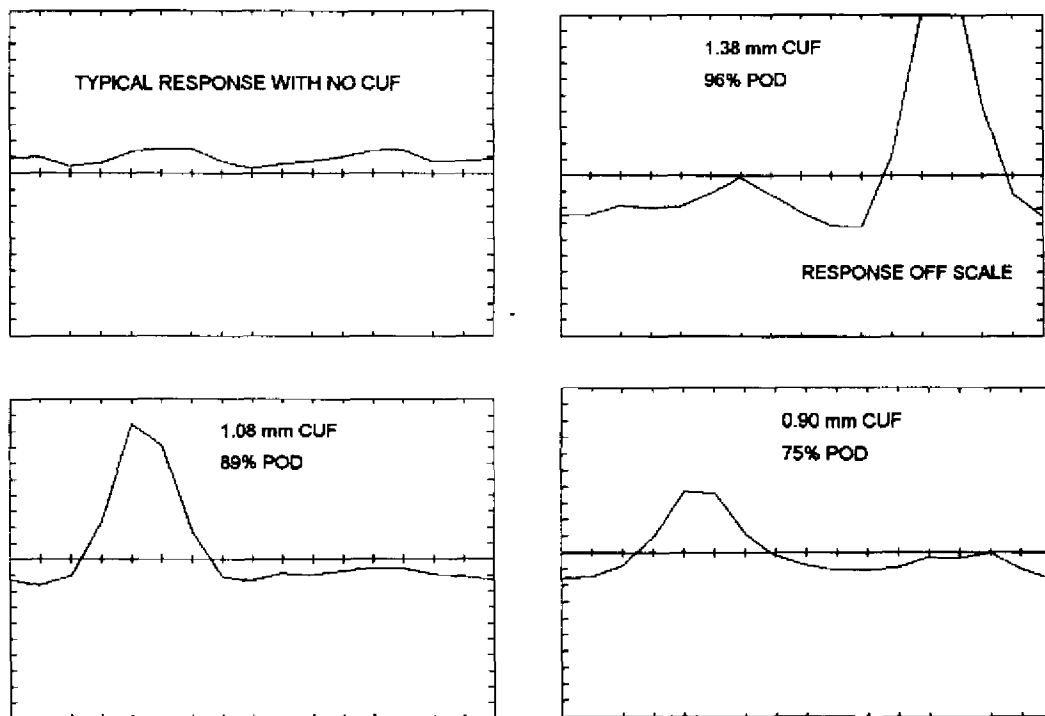


Figure 13. LFECA Response for Cracks of Various Lengths Under Fasteners

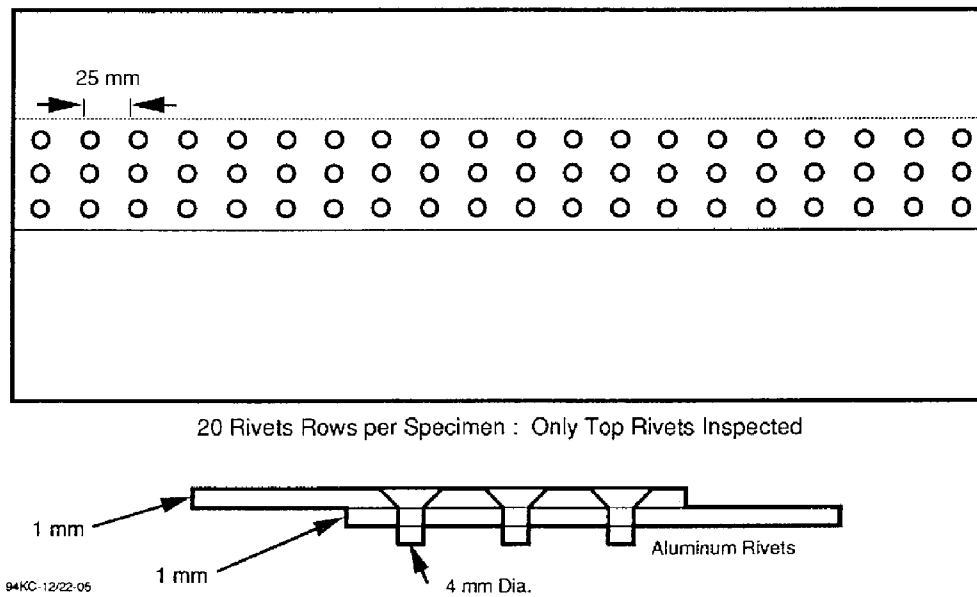


Figure 14. Boeing 737 Lap Splice Specimen Configuration

The specimen were constructed using 1 mm thick 2024-T3 aluminum sheets which were fastened together with three rows of 4 mm diameter aluminum flush head rivets. Fatigue cracks were grown in the first layer of selected holes prior to riveting the panels. A range of crack sizes from 0.3 to 25 mm (a hole to hole crack) were grown within +/- 22 degree orientation (0 degrees being the direction from hole to hole). Holes with cracks on one and both sides were present. Specimens contained either none, a low, a medium or a high number of cracks. A total of 860 holes were inspected with 708 being unflawed holes. The validation exercise contained only the first layer cracks under installed fasteners. Figure 15 shows the POD for the LFECA system and conventional eddy current techniques. It is seen that POD obtained with the LFECA system far exceeds that obtained with the conventional system.

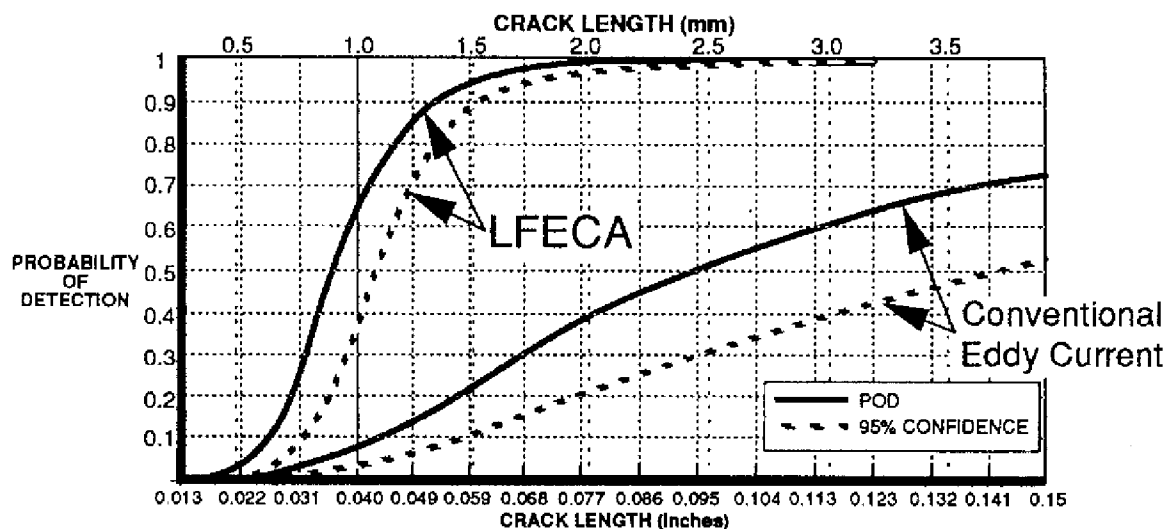


Figure 15. Probability of Detection with Low Frequency Eddy Current Array and Conventional Eddy Current NDI System

5.2 Ultrasonic Methods

Ultrasonic inspection techniques are widely used for quick and relatively inexpensive evaluation of flaws in composite structures. Portable inspection devices are used for on-site inspection of areas with suspected damage. Two methods, namely pulse-echo and through-transmission, are used. In the pulse-echo method, a transducer transmits the ultrasound and the same transducer receives the reflected signal after the signal has been reflected from the back surface of the composite part being inspected. The attenuation of the reflected pulse is influenced by the presence of the internal defects, and the time delay of the reflected pulse is related to the depth location of the defect. This method is generally used in contact mode of testing and only one side access is required. Inspection of honeycomb structures will require access from both sides for inspection of both face sheets. Ultrasonic inspection using through transmission method is generally conducted with water as a couplant by two methods- 1) Immersion, and 2) Squirting. In the immersion method the part and transducer are immersed in water whereas the squirting method employs dynamic water column that is squirted and the transducer and the part are suspended. In both methods water acts as the medium that transmits the ultrasound into and out of the part. The images of the defects may be recorded as B-scan, C-scan or 3-D scan. Scans for typical impact damage in a composite part are shown in Figure 16.

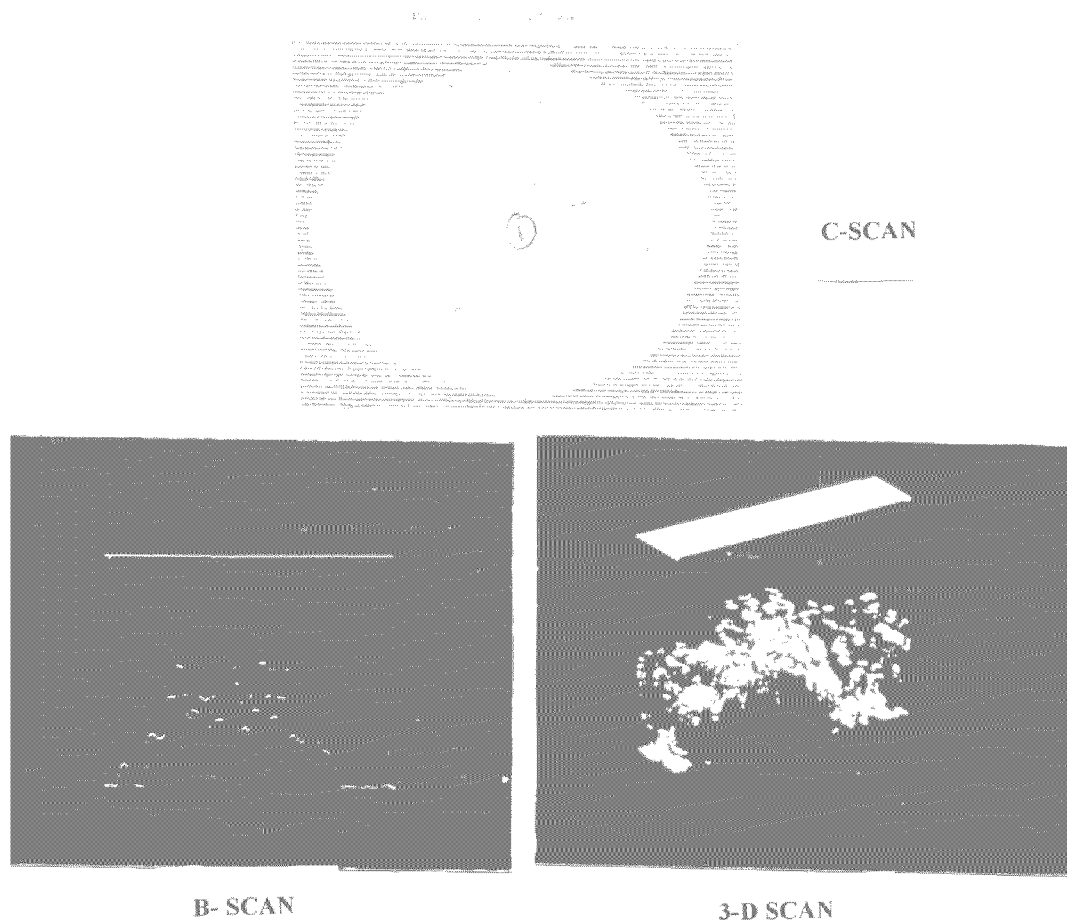


Figure 16. B, C and 3-D Scans of Typical Impact Damage in Composite Laminate

An ultrasonic technique to detect corrosion in a wing box has been developed in Reference 15. The technique has been successfully used to detect corrosion in DC-9 wing box substructure. The current method of inspection is to enter the wet wing box for corrosion inspection. The technique of Reference 15 eliminates entry in the wing box for the inspection and will result in significant savings in the inspection costs.

5.3 Radiographic Methods

The present trend seems to be getting away from using radiographic methods due to safety, cost and maintenance logistics. However, these methods are still being used to detect internal cracks and corrosion in aging aircraft structures. An advanced system known as COMSCAN, developed by Phillips, allows to form images of underlying structure and requires access to one side of the part only. It is currently being used to find corrosion in bulkheads under thin skins, and sonar dome inspections. The system is limited to finding defects near the surface and has the same detection capability as conventional x-ray. Digiray makes a system that has better resolution and better image quality than the conventional systems. The system is basically the reverse of a conventional digital x-ray imaging system as shown in Figure 17. The x-ray source is formed by a large scanned screen like a TV screen and the detector is a single point sensor as shown in the figure.

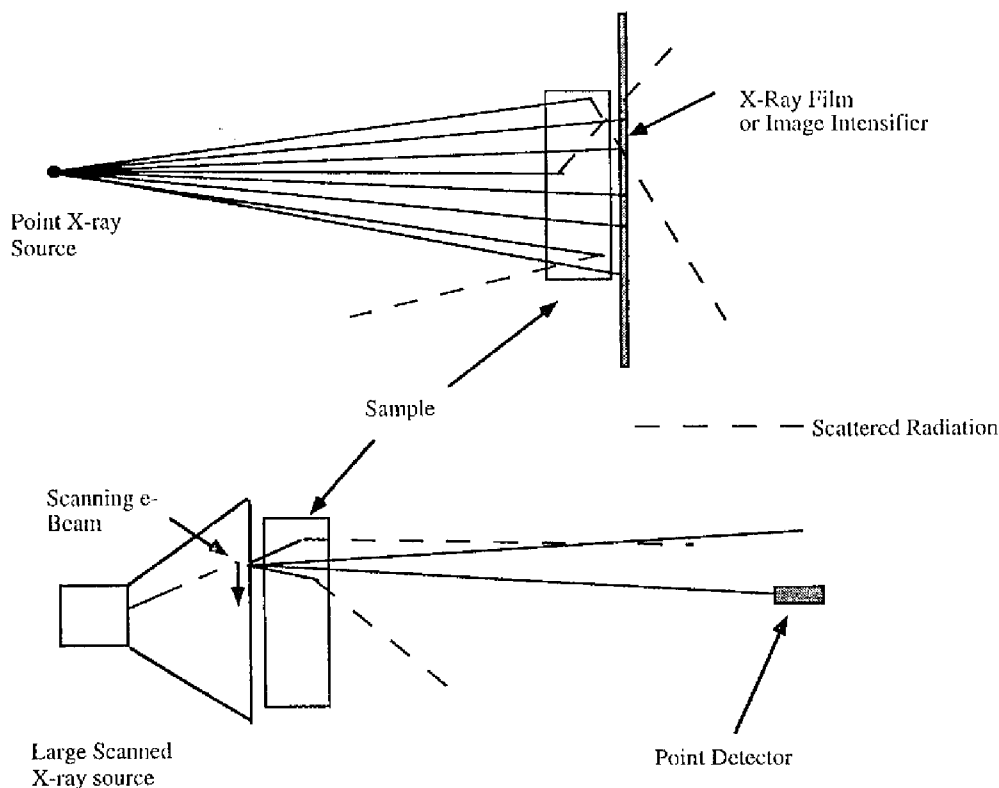


Figure 17. Conventional and Reverse Geometry X-Ray Radiography

5.4 Acoustic Emission

The acoustic emission (AE) technique is used to identify the flaw characteristics by change in acoustic emission signal. Acoustic emissions are transient waves that are generated by the rapid release of energy within a material when it undergoes deformation or fracture. This technique has been used to detect damage in composite materials and cracks in metallic structures. Various types of damages in composites such as matrix cracks, fiber/matrix debonding, fiber fracture and delaminations produce acoustic emissions that vary in magnitude, duration and frequency. Various damages in composite materials can be identified by the acoustic emission characteristics. Cracks in aircraft wing were located during ground test with AE technique in Reference 16 using AE sensors 20 inch (51 mm) apart. However, the source location of flaws could not be precisely predicted.

5.5 Optical Methods

Significant advancements have taken place in optical methods to detect damage in aircraft structures. Some of the techniques being- shearography, DIAS system and thermography.

Shearography- This is a field inspection technique which images internal defects as concentration of surface strain due to an applied stress. A reference image is stored electronically using the shearography video laser interferometer, then a uniform stress is applied in the form of vibration, pressure or thermal, and the subsequent images of the test part are compared with the reference image which will indicate flaws on video monitor (References 17-18). This is a cost-effective method for inspection of honeycomb and composite structures. Most of the other NDI techniques do point by point inspections whereas shearography provides a full field video image of flaws in real time. Defects such as disbonds, delaminations and impact damage can be detected with this technique.

D Sight Aircraft Inspection System (DAIS)- This is a fast and sensitive enhanced visual inspection system for detecting surface irregularities such as pillowing caused by corrosion (References 19-20). In Reference 19, DAIS system was used in the laboratory as well as in the field to detect corrosion in fuselage lap splices. The results of this reference showed that corrosion pillowing indicative of thickness loss as low as 2% is detectable. A typical D sight optical set-up is shown in Figure 18.

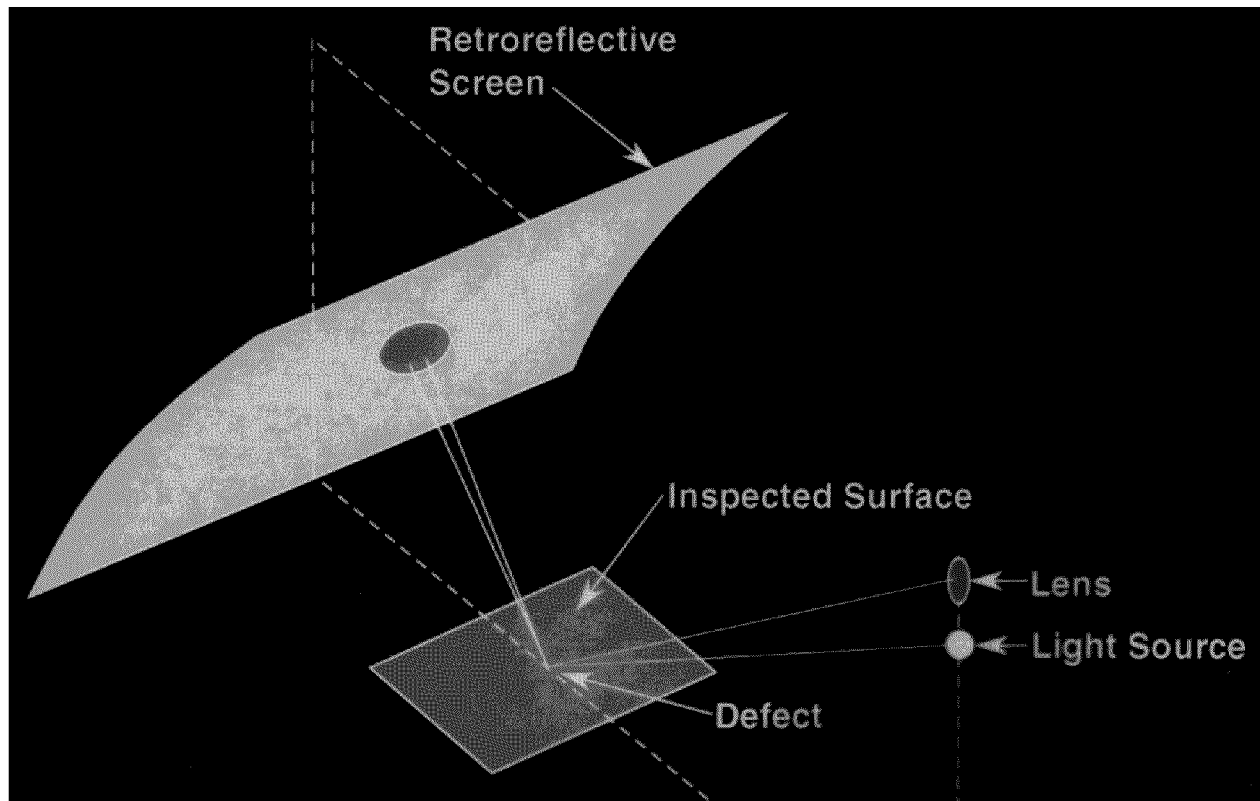
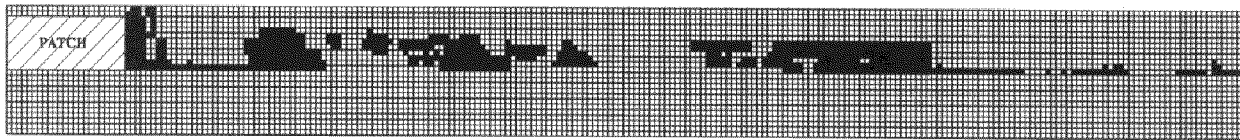
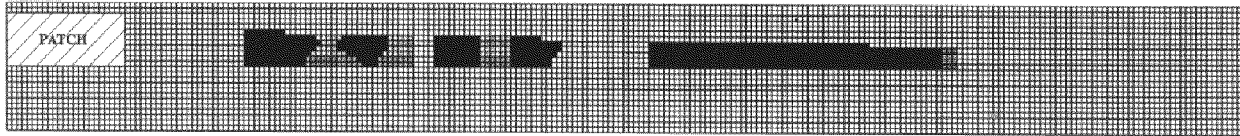


Figure 18. D Sight Optical Set-up

A comparison of fuselage joint corrosion detected by X-ray and D Sight is shown in Figure 19. The figure shows a very good correlation between the two techniques.



Boeing 727 fuselage lap joint corrosion, analyzed using X-Rays



Boeing 727 fuselage lap joint corrosion, analyzed using D Sight

Figure 19. Comparison of Fuselage Joint Corrosion Detected by X-Ray and D Sight Techniques

Thermography- This technique uses differential in the thermal conductivity of a defect free part and a part with defects as a basis for locating defects in a structure. A heat source is used to elevate the temperature of the structure being inspected and surface heating effects are observed through a radiometer. For example bonded areas conduct more heat than unbonded areas, the amount of heat either absorbed or reflected indicates the quality of the bond line.

A new technology known as “Thermal Wave Imaging” uses pulses of heat to examine the subsurface in solid objects (Reference 21). The pulses propagate in the structure being examined as thermal waves and are reflected from any defects, present in the structure, as surface “echoes”. These echoes are detected by the use of infrared video cameras, coupled to appropriate hardware and software. The patterns of the echoes on the surface of the structure are used to image subsurface corrosion and disbonds in aircraft structures. Thermographic inspection technique for detection of water ingress in sandwich structures is discussed in Reference 22. It is shown in the reference that this technique can be reliably used to detect water in sandwich structures.

6.0 NONDESTRUCTIVE INSPECTION OF METALLIC STRUCTURES REPAIRED WITH COMPOSITES

Nondestructive inspection of composite patch repair of metal structure involves two inspection issues- 1) inspection of bondline for disbonds, and 2) inspection of cracks underneath the repair patch. Bondline inspection has been reliably carried with Kraut Kramer Branson bond tester. Other bondtester such as Fokker bondtester have also been used.

Application of eddy current procedure to detect cracks underneath a composite repair has been investigated in Reference 23. A comparison of measured crack length using eddy current and anticipated crack length is shown in Figure 20. The figure shows the actual crack length when the crack was visible outside the patch and dotted line represent the anticipated crack length when the crack was not visible. A comparison between NDI measured crack length and anticipated length is good.

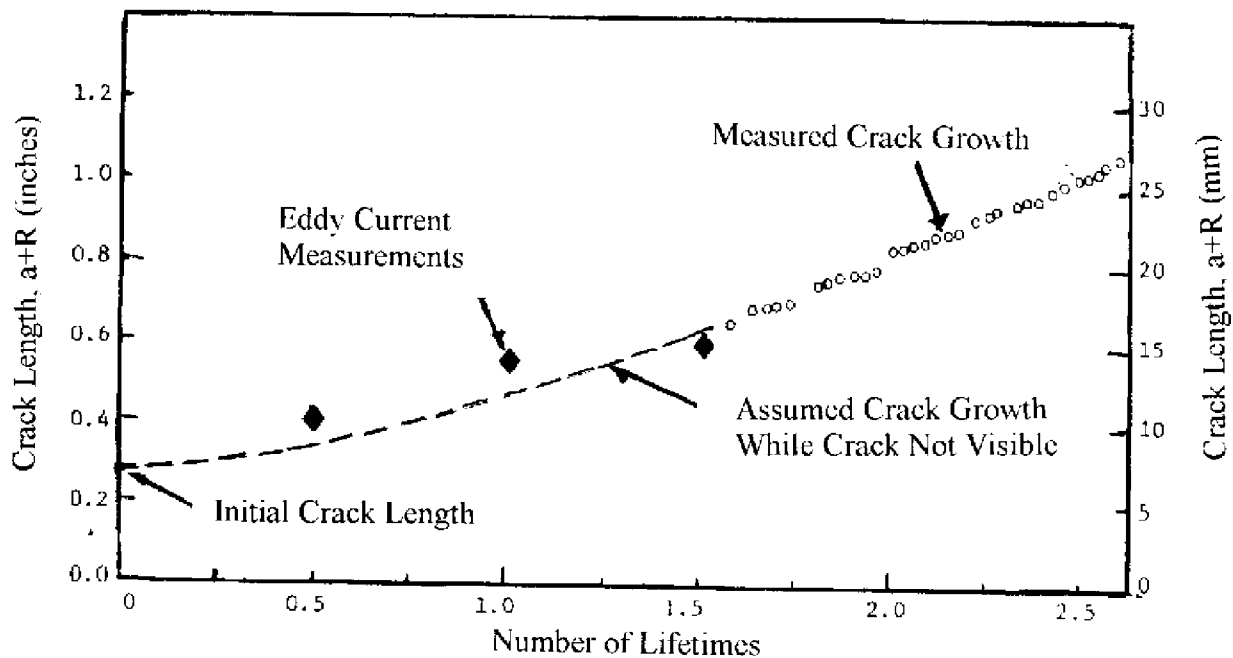


Figure 20. Comparison of Measured, Using Eddy Current, and Anticipated Crack Lengths

Conventional eddy current seems to be effective in detecting crack lengths of 0.25-inch or larger. However, for smaller crack lengths Low Frequency Eddy Current Array (LFECA) system, discussed earlier, has shown promise.

7.0 CONCLUDING REMARKS

Significant advancements have been achieved in NDI technology in the recent past. Some of the advancements are discussed in this paper. The use of a particular NDI method is highly dependent on the type of structure being inspected, structural material, desired accuracy, the size of the flaw to be inspected, type of damage, time available, and the labor skill. NDI and structural engineers have to make proper choices to assure the reliable detection of the damage with desired accuracy. Structural engineer can work together with NDI engineers to identify the requirements. Reliable inspection techniques are available for detection of damage in metallic structures underneath composite repair patches.

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