International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 07 | July 2019 www.irjet.net p-ISSN: 2395-0072

NON-DESTRUCTIVE DETECTION & CHARACTERIZATION OF DAMAGES IN HONEYCOMB COMPOSITE STRUCTURES

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Abstract –*This thesis discusses many existing methods of non-destructive evaluation used on honeycomb*

structures ranging from ultrasonic transduction to various low frequency techniques. The focus, however, is given to newly developed technique based on hysteresis effects in force-displacement curves. The area enclosed by the hysteresis loop represents the amount of energy absorbed by the sample during the loading and unloading phases. The great advantage of this method is that it only requires access to one surface of the structure to generate a force displacement curve. A mechanical testing machine could take up to 15 minutes to produce a single force-displacement curve, this method will produce the same curve in seconds. Much of this research was devoted to the testing and development of the techniques used to deduce a force-displacement curve from an accelerometer tap.

Keywords- Delamination, Micro cracking, Thermography, Shearography, Computer Aided Tap Test

1. INTRODUCTION

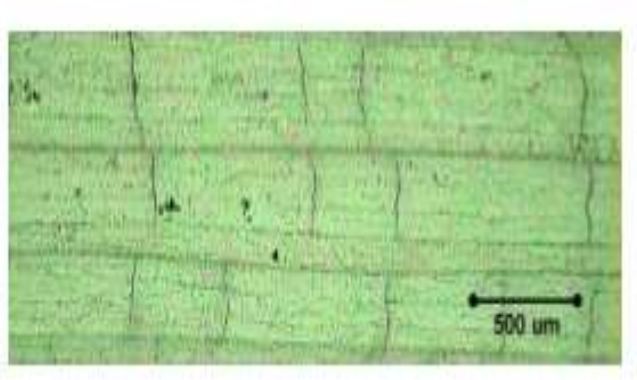
A honeycomb composite differs from a solid laminate in its structure. The honeycomb composite makes use of a light weight material fashioned into a honeycomb structure with a high load bearing ability in relation to its weight. The honeycomb is then sandwiched between two face sheets which are solid laminates. Composites, unlike aluminum, can have defects embedded within the material, ranging from delamination between plies to micro cracks and porosity in the matrix. Most cracks in aluminum propagate to the surface because they do not have to cross materials interfaces, making them easily detectable. Cracks in composites however are stopped by each ply interface, making them much more difficult to detect. As a result, structural uncertainties requires airplanes manufactures to over design composites aircraft, taking away much of the light weight advantages of the composite material. Non destructive evaluation gives manufacturers the ability to reduce or eliminate the over design of composite materials, allowing them to make full use of their lightweight advantage. For this reason the development of non destructive techniques is essential to the use of composites within any structure. A focus on honeycomb composites and their associated damages must be outlined in ordered to evaluate the new detection techniques developed throughout the course of this research. Various different detection techniques have been addressed, ranging from the tap test to air coupled ultrasonic.

1.1 COMPOSITE DEFECTS

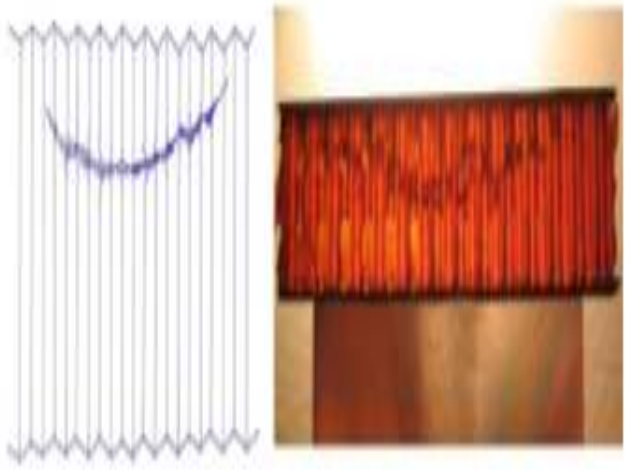
1.1 Defects In The Laminate-In a composite structure, the laminate constitutes a composition of materials made up of fibers and resin matrix. Several plies are built up to form the face sheet or laminate. The face sheet tends to be more resilient to damage than the core, though damage can still occur. Many times the damages can occur before the structure has ever entered service. Poor layup conditions or flawed fabrication can cause various types of defects in the face sheet. The majority of in-service damages in face sheets come from impact damages, which can cause various defects within the layup, some of which remain hidden to the naked eye.

1.2 Delamination-A delamination occurs when a gap forms between two plies of deferent fiber orientation. Due to the fact that these composites are usually assembled ply by ply, poor layup conditions can be a cause of delamination. If manufacturing conditions are not clean, unwanted particles, such as dust, can be introduced into the interface between the plies. Faulty bonding conditions will result, which leads to a delamination. There exist as resins rich areas which will be lacking in fibers. This section is the weakest point of the two ply region and as a result becomes a failure point when the structure is put under a load.

1.3 Micro cracking-In addition to delamination, matrix micro cracking also presents itself as a common defect in solid laminates. It is one of the many types of defects associated with impact damages, yet the damage can be caused by thermal cycling as well. This structure was thermally cycled from room temperature to cryogenic temperatures several times to induce severe matrix micro cracking.



1.4 Cracking Or Buckling-Cracking or buckling takes place when a sandwiched composite is put under an excessive compressive load. When the load exceeds the limit of the structure, the core buckles and leaves a fracture line in the core which often takes the shape of a "smile" centered below the impact site.



2. EXISTING INSPECTION METHODS

2.1 Ultrasonic Transduction

Ultrasonic transduction is a very popular technique used to inspect composite structures. It is able to detect delamination, micro cracking, porosity, skin-to-core disbands, and a host of other defects common among composite materials. A selected frequency is dependent upon the medium used and the thickness of the material, where lower frequencies are able to penetrate further into the material. Ultrasonic transduction is also hampered by very expensive and complex scanning systems needed to collect the data and generate an image.

2.2 Thermography

While ultrasonic makes use of sound waves propagating though a material thermography makes use of thermal waves propagating from the surface into the material. These waves are outside the visible spectrum of light, having longer wavelengths than those contained within the visible spectrum of light. This section will outline three types of methods involving infrared thermograph which are actively being used as nondestructive techniques; they include: Traditional Thermograph, Flash Thermograph or Thermal-Wave Imaging, and Vibro Thermography.

2.3 Shearography-Another popular optical, non-contact method is shearograpy; digital speckle shearography is starting to make its way into non destructive evaluation. It is an inter Ferro metric method which uses images obtained from a structure while at rest and while loaded. When the surface of the structure is illuminated by the laser, the camera produces two sheared images which interfere with each other producing a speckle pattern. These images are obtained while the structure is at rest and loaded using the same high resolution film, where the speckle pattern will change while the structure is loaded. The two speckle patterns interfere with each other, revealing a macroscopic fringe pattern which correlates to the stiffness of the material.

2.4 Development of Tap Test Method-Aside from visual inspection, manual, hearing-based, tap test is arguably the most practiced inspection technique on composites, especially on bonded sandwich structures. Because of its wide use, a real improvement of the tap test method will have a significant impact on the NDI(Non Destructive Inspection) of composites.

2.5 Computer Aided Tap Test-The Computer Aided Tap Test (CATT) is a method which makes use of an accelerometer and electric circuit to capture the impact duration, τ, of the tap. The CATT system is able to store these τ values and plot very informative contour maps over the surface of the structure. Fig shows all components of the CATT system as well as an example of a CATT image produced on the computer screen. The photo also shows a magnetic cart in the foreground, which provides a quick, semi-automatic method of obtaining all the τ values over the surface of the structure.

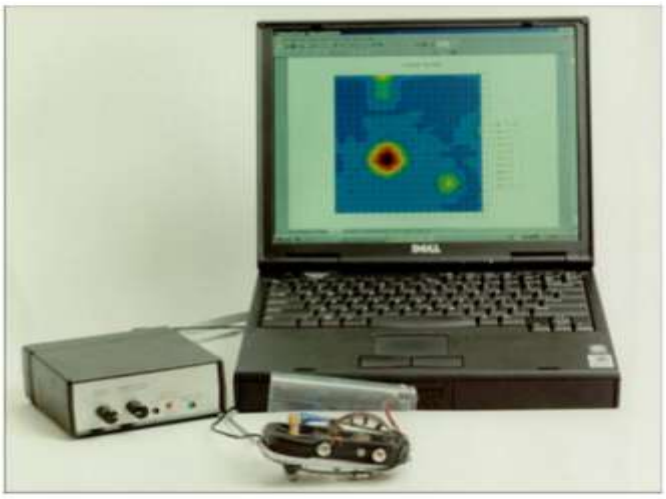


Fig 1. A stiffness image of a Boeing 747 outboard spoiler generated by tap test

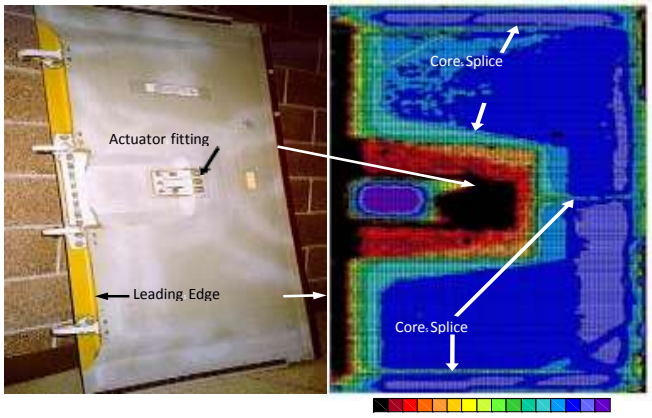


Fig 2. B747 outboard spoiler (left) and its resulting tap test image(right).

2.6 Image-Based NDI for Composite Inspection

Ultrasonic inspection, when implemented with mechanized automated scanners generates scan images and is widely used in the laboratories and for the inspection of manufactured composite products. When used in the field or in a maintenance hangar, ultrasonic inspection is typically carried out with a flaw detector. Low frequency bond testing and tap test are not imaged-based techniques. In the inspection of composite structures the advantage of an image-based technique cannot be over emphasized By having the inspection results presented in an image forms a complete coverage of the inspected area is ensured.

A recently developed approach for making manual, image-based "C-scans" using ultrasound, eddy current, and low frequency bond testing (mechanical impedance analysis) exploits the existence of off-the-shelf, low cost, commercial products with position encoding capability. The NDI output, such as the amplitude or time-of-flight of an ultrasonic signal, is combined with the position information by software in the generation of the scan image.

3. CONCLUSIONS

As the use of composite increases, especially in the next generation of airplanes, there will be a greater need for nondestructive inspection procedures for quality assurance by the manufacturers. The challenges will include efficient inspection of thick primary structures' Specific field inspection needs of the new generation of composite-intensive airplanes may not arise until they are in service for a number of years. More bonded structures are now classified as primary structures and will receive more inspection attention. The use of foam-cored sandwiches are also on the rise, with the accompanying NDI needs. These two techniques were discussed in detail, although no real developments were made to these techniques during the course of the research; they were simply used as a reference.

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