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EDDY CURRENT ARRAY INSPECTION OF DAMAGED CFRP SANDWICH PANELS

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ABSTRACT

The use of eddy current (EC) arrays to detect damage in sandwich panels, such as disbonding of the face-sheet to the core, is investigated. It is shown that the array is very sensitive to slight core crush and can readily find small dents and disbonds. At the same time, the eddy current array can look much deeper into the honeycomb to detect defects such as tears. The phase map of the EC signal can be used in some cases to distinguish between different types of damage. EC arrays offer the ability to rapidly scan large areas

Keywords: eddy current, sandwich panel, disband, damage

1. INTRODUCTION

Composite honeycomb panels have become widespread, especially in the aircraft industry because of their excellent weight-to-stiffness ratio. There is concern, however, about the ability to detect barely visible impact damage (BVID). With aluminum face-sheets, impacts that have sufficient force to crumple the honeycomb typically also result in a permanent dent in the aluminum skin. Slight impacts typically do not result in separation of the skin from the underlying honeycomb. With composite face-sheets, separation of the face-sheet from the underlying core has been shown to happen. In these case there is little or no sign of damage on the face-sheet, but the strength and stiffness of the panel has been compromised because the face-sheet is no longer attached to the core. There is further concern that what started out as small invisible disbonds may grow under fatigue loading into large disbonds, which lead to failure of the part.

A number of NDT techniques have been used to investigate the integrity of sandwich panels. One of the earliest of these was the tap test[1] which has since evolved into specialized instrumentation [2].

Ultrasonic inspection of sandwich panels is common and a very basic ASTM standard practice guide (ASTM E2580) for inspection of flat panels has been developed. Guided wave inspection appears to be particularly suitable for detecting disbonds in BVID, partly because of its ability to inspect large areas at once. Major issues with ultrasonic inspection are that it requires skilled operators to set up and run the equipment and to interpret the data and can be relatively slow when compared to methods like thermography[3].

Thermography is a rapidly evolving non-destructive testing (NDT) technique that shows great promise for detection of defects in sandwich panels with composite face-sheets. There are a wide range of thermographic techniques available that vary how heat is generated and how signals are analyzed. Yang and He [4] have published a comprehensive review of various thermographic techniques as applied to composite panels. Duan et al. [5] compared pulsed thermography to ultrasonic C-Scan of panels and found that flash thermography could actually detect a smaller defect size at 90% POD. A major drawback in thermography is the requirement for an expensive infrared camera. However, Strugala et al. [6] have shown that equivalent results can be obtained using thermochromic sheets and a conventional camera.

A variety of other techniques have also been proposed for determining damage in sandwich structures. Interestingly, conventional eddy current is not usually considered. However, for sandwich panels with aluminum honeycomb cores, the advent of eddy current arrays offers the possibility of rapid scanning of large areas to detect dents and disbonds using the lift-off signal. This paper examines results obtained using eddy current array probes on CFRP sandwich panels with aluminum honeycomb cores. The results are compared with flash thermography on a number of CFRP sandwich panels with BVID. Advantages and disadvantages of the two techniques are discussed and their suitability for rapidly scanning large panels to find and characterize BVID is examined.

2. EXPERIMENTAL

Two array probes, an Olympus SAB-067-005-032 and an Olympus FBB-051-150-032 were used to examine the honeycomb panels. The first had coils 9.0 mm in diameter arranged in equilateral triangles (9.5 mm on a side) and was configured as a transmit-receive probe. It was operated at a frequency of 40 kHz (its maximum). The second array had coils 3 mm in diameter, arranged in a double row of equilateral triangles with a spacing of 3.2 mm. The probe was configured in absolute bridge mode. It was operated at several frequencies ranging from 100 kHz to 1.5 MHz. However, frequency had little effect on its performance. Both arrays were connected to an Omniscan MX. The phase angle of the arrays was set so that lift-off was vertical in the impedance plane display and was recorded in the C-Scan. As no reflection array was available, the performance of a reflection type array was simulated by using a reflection probe (Olympus 9222199.01) mounted on the arm of a Tecscan robotic system, which translated the probe and recorded both the horizontal and vertical components of the eddy current signal. The reflection probe had a diameter of 11.2 mm (the actual coil sizes are unknown). It was connected to an Olympus Nortec 600D eddy current system. The signal was set so that lift-off was vertical and the gain was adjusted so that 1 mm of lift-off corresponded to 4V (divisions). Frequencies of 10, 40 and 160 kHz were investigated. Signal-to-noise ratio improved as the frequency was increased; however, clear C-scans were recorded at all frequencies.

All the sandwich panels used in this work were based on a 12.5 mm (0.5”) thick 5052 aluminum honeycomb with a 3.2 mm (1/8”) cell size and a 0.02 mm (0.0007”) wall thickness. Construction of the honeycomb meant that in one direction two walls were glued together producing a wall of double thickness.

3. RESULTS AND DISCUSSION

The transmit-receive array was used on a sample in which the honeycomb was indented with a spherical 50 mm diameter indenter to produce five defects ranging in approximate diameter from 6 to 13 mm, and depths of 0.2 to 0.8 mm. A 1.4 mm thick face-sheet was placed over the honeycomb. The array gave excellent results when scanned perpendicular to the double walls, easily detecting all the indents. However, when it was scanned in a direction parallel to the double walls, it failed to detect all but the largest indent. Similar results were obtained when it was scanned over a standard, which had 4.8 mm (3/16”) and 6.4 mm (1/4”) cell sizes. This strong directionality made it unsuitable for this application, since the orientation of the honeycomb in a real sample would seldom be known.

The absolute bridge array was scanned over several 150 mm x 150 mm sandwich panels with face-sheets containing different numbers of plies arranged in alternating 0/90 configurations. Defects were created by impacting the panels with a 50 mm diameter spherical indenter at a range of low energies. In some cases this produced barely visible dents in the panels and in other cases the face-sheet sprang back. The presence and size of the detached crushed core could be verified using flash thermography. Typical results are shown in Figure 1, below. A similar scan was obtained when the array was scanned at 90°, indicating that this probe did not suffer the directionality problem that the transmit-receive probe did.

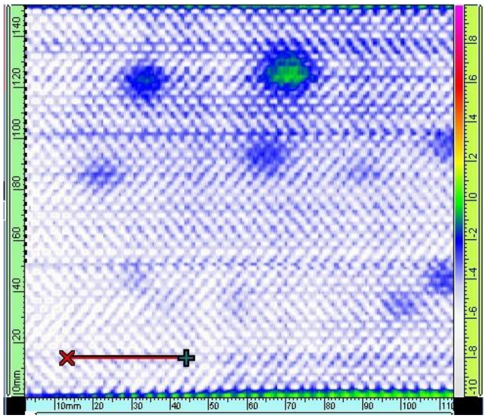

FIGURE 1: C-SCAN OF DAMAGED HONEYCOMB ARRAY THROUGH A 0.76 MM THICK CFRP FACE-SHEET.

Because the coils were smaller than the cell size of the honeycomb, a strong texture due to the honeycomb was superimposed on the image. The strength of the signal of many of the smaller defects is barely larger than that of the honeycomb and they can be most readily seen because they have a solid colour as opposed to the pattern produced by the honeycomb. The probe shows potential but is not ideal for the task because of the small size of the coils. A similar array with larger coils would be expected to work at larger lift-offs and show less sensitivity to the details of the honeycomb structure.

Figure 2 shows the Y component of a C-Scan of 150 mm X 150 mm CFRP panel with a number of defects. Figure 3 is from the same scan,but shows the phase component. It is interesting to note that there is a phase component as the system was set up to make lift-off strictly vertical. The round indications are from light impacts. They all look similar in the phase image.

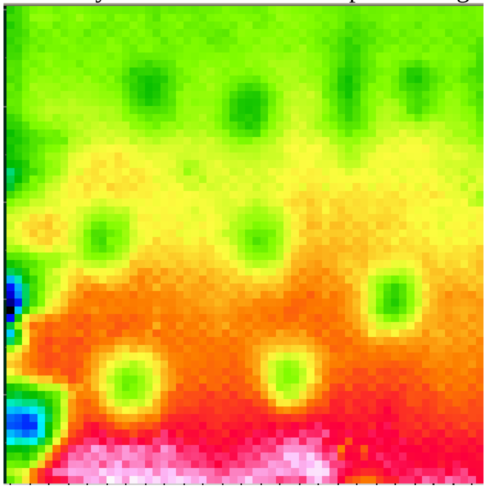

FIGURE 2: C-SCAN (Y COMPONENT) OF DAMAGED HONEYCOMB USING REFLECTION PROBE @ 40 KHZ.

The three indications down the left hand side and the thin indcation in the top right, show the opposite trend running from orange to yellow to green. The three defects on the left are from horizontal slits parallel to the face-sheet made in the side to represent tearing of the honeycomb due to fatigue after buckling. These slices were located at different depths from the face-sheet with one being very close to the opposite face. Their detection is a bit surprising as one would not expect the eddy current to be sensitive to cuts running parallel to the surface. Clearly, the sensor can be sensitive to defects quite deep in the honeycomb. The thin vertical feature in the top left is a vertical slit made in the honeycomb on the other face before the panel was constructed. The phase image indicates that it is possible to distinguish between tears and core compression.

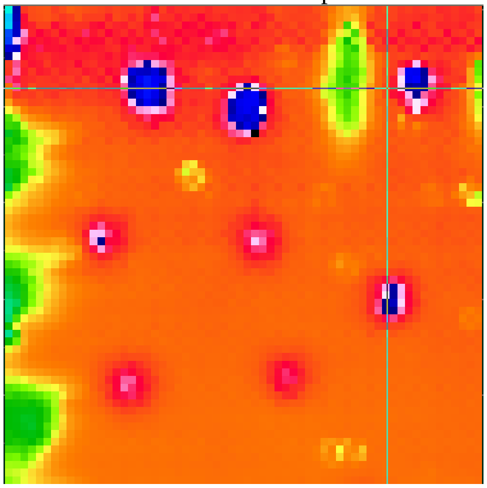

FIGURE 3: C-SCAN (PHASE) OF DAMAGED HONEYCOMB USING REFLECTION PROBE @ 40 KHz

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The eddy current images can be compared to the results from flash thermography (Figure 4) or from a laser scan, which gives depth of the face-sheet directly (Figure 5). The thermographic image is most sensitive to disbonds and so the round impact in the bottom left only shows up weakly in the thermographic image despite the fact that it is the largest and deepest dent. Conversely, the feature in the centre top shows up strongly in the thermographic image, but is not associated with any deflection in the face-sheet. The eddy current image shows both defects with very similar intensity because it does not see the face-sheet at all, just the top of the honeycomb.

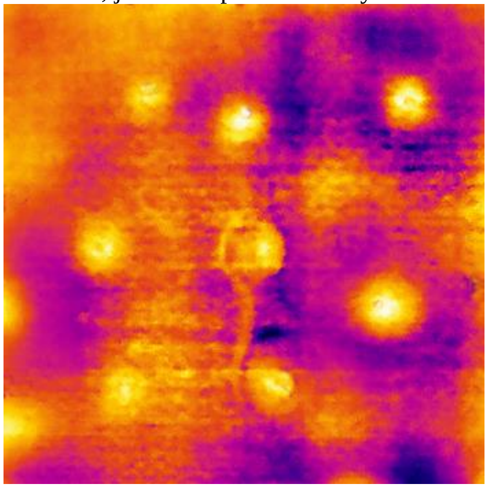

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FIGURE 4: THERMOGRAPHIC IMAGE

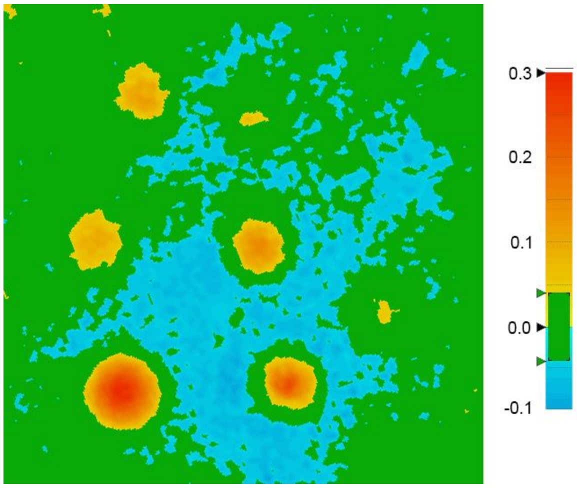

FIGURE 5: DEPTH IMAGE OF SAMPLE FACE-SHEET. DEPTH IN MM

4. CONCLUSION

The results indicate that eddy current array can be very useful for rapidly identifying defects in sandwich panels made with aluminum honeycomb cores and insulating face-sheets. It is very sensitive to core crush and can easily detect differences of 0.1 mm depth. At the same time, it has sensitivity to defects in the honeycomb that are well sub-surface.

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