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NDE Studies on Spacecraft Structural Components Using Air coupled Ultrasonic and Thermography Techniques

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Abstract

The two Non-Destructive Evaluation [NDE] techniques viz., Air Coupled Ultrasonic [ACU] and Pulsed Thermography [PT] find many applications in aerospace industry . These NDE techniques can be used for debond detection in spacecraft structural components like honeycomb sandwich deck plates, shear web panels and central cylinder made of aluminum core and composite face sheets. The Air coupled ultrasonic NDE techniques, because of its non contact and non couplant nature and thermography because of it's non contact and whole field nature are very much useful for NDE of honeycomb sandwich components especially made of carbon fiber reinforced composite [CFRP] face sheets which are hygroscopic in nature for couplants . Air coupled ultrasonic and pulsed thermography were used for the calibration studies and actual application of honeycomb sandwich panels made of aluminum core and CFRP face sheets . Different debonds were simulated by adhesive missing in the honeycomb panels between the face sheets and the honeycomb core. Also the debonds were simulated for some test coupons by inserting the Teflon sheet between the layers in the CFRP composite face sheet. These two techniques were also used for the actual testing of few spacecraft structural components for the NDE purpose.

Key words: Air coupled ultrasonic, pulsed thermography ,debond detection ,composites

1.Introduction

The spacecraft components viz., central cylinder, deck plates, shear panels, solar panel substrates, antenna reflectors are made of aluminum / composite honeycomb sandwich construction. Defects in these components can severely limit the performance and in some cases cause the failure. Defects like debonds in these honeycomb sandwich components are likely to occur either during fabrication process or testing. Detection of debonds in the above honeycomb components is important to assess the integrity of the spacecraft structure.

The two Non-Destructive Evaluation [NDE] techniques viz., Air Coupled Ultrasonic [ACU] and Pulsed Thermography [PT] find many applications in Aerospace industry [1-6]. These NDE techniques can be used for debond detection in spacecraft structural components like honeycomb sandwich deck plates, shear web panels and central cylinder made of aluminum core and composite face sheets.

The Air coupled ultrasonic NDE techniques, because of its non contact and non couplant nature and thermography because of it's non contact and whole field nature are very much useful for NDE of honeycomb sandwich components especially made of carbon fiber reinforced composite [CFRP] face sheets which are hygroscopic in nature for couplants. In this paper, both NDE techniques viz., Air coupled ultrasonic and pulsed thermography were used for the calibration studies and actual application of honeycomb sandwich panels made of aluminum core and CFRP face sheets . Different debonds were simulated by adhesive missing in the honeycomb panels between the face sheets and the honeycomb core. Also the debonds were simulated for some test coupons by inserting the Teflon sheet between the layers in the CFRP composite face sheet.

2. Air coupled ultrasonic technique

When sound passes across an interface between two materials only a proportion of the sound is transmitted, the rest of the sound is reflected. The proportion of the sound that is transmitted depends on how close the acoustic impedance of the two materials matches. Water is a fairly good match for most commonly used materials - for example typically around half the sound energy is transmitted at the interface between water and a carbon laminate. After four solid- liquid interfaces (from the probe, to the couplant, to the test piece, and then back again) there is still a few percent of the original energy left so accurate measurement is possible .

If the sound has to move between the test piece and air (which has very low acoustic impedance) only around 1% of the sound energy is transmitted. Thus after four transitions very little sound energy is left - Typically the overall path loss may be 100 dB higher using air as a couplant than when water is used. The path loss is significantly higher with metals, which have a high acoustic impedance compared to plastics which are lower in impedance **[1,2].** Hence few techniques were tried to maximize the performance of the Sonda 007CX system. The performance was achieved by using an un-damped Resonant Ceramic transducer possible the receive and transmit transducers are 'paired' to match the resonant frequency.

A sinusoidal transmitter excitation signal was used rather than a single rectangular or 'spike' pulse. In the Sonda 007CX a 500V peak to peak tone burst of up to 15 cycles is used, rather than a single pulse. Thus the pulse contains much more energy, and by matching the tone burst frequency to the transducer resonance, maximum energy transfer is obtained. A lownoise preamplifier is mounted directly adjacent to, or incorporated in, the receive transducer, so as to minimize.

3. Air coupled ultrasonic NDE tests

The air coupled ultrasonic system was operated with two transducers at frequency of 120 KHz for calibration study in the transmission mode. The test part is kept between the transmitter and the receiver transducer which were mounted in a single yoke type fixture. The yoke along with the transducers was moved in the c- scan mode and the air coupled measurements were made .The x-y plot of the measured signals show the debond areas differently compared to the good areas in the honeycomb sandwich . The basic Sonda 007CX system is shown in the figure 1. The sample test results by the Air coupled system on the honeycomb sandwich test coupons are presented in figures 2a and 2b. Figure 2a shows a single debond [size : 12mm dia.] as red colour.Figure 2b shows number of debond areas of different sizes ranging from 25mm x 25mm to 5mm x 5mm as white paches by the ACU system.

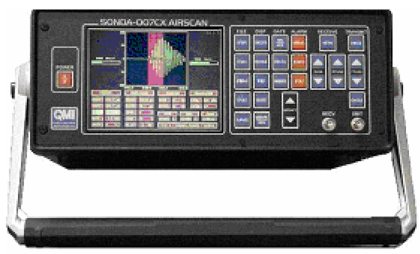


Fig 1 .Sonda 007CX System

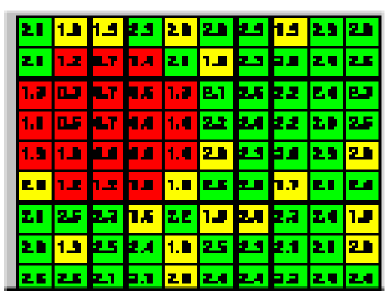


Fig. 2 a : A debond in honeycomb panel [Red colour]

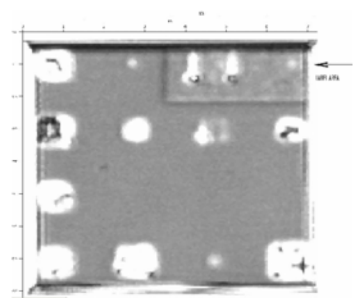


Fig. 2b : More debonds in honeycomb panel [white patches]

4. Thermography

4.1 Thermography Techniques

Thermography makes use of the infrared spectral region [3 to 10 micro meters of wave length in the electromagnetic spectrum] for imaging a structural part using a special type infrared camera mostly sterling cooled and connected to a PC with a suitable image processing software. Various techniques of active thermography viz., pulse thermography

(PT), lock-in thermography (LT) and pulse phase thermography (PPT) etc., and their merits and demerits were very well discussed in the references [3-7]. In PT, a short-duration high peak power excitation pulse is applied to the test sample and the thermal response is recorded by an IR camera. The resultant sequence of infrared images indicates defects in the material at different depths to some extent. This technique requires high-power heat sources and has an additional drawback of being sensitive to surface in-homogeneities. In contrast, lock-in thermography uses mono-frequency sinusoidal thermal excitation. From the recorded infrared image sequence, information about the phase and magnitude of the reflected thermal wave is derived. The phase angle has the advantage of being less sensitive to local variations of illumination and surface emissivity. However, the mono-frequency excitation in LT limits the depth resolution [4,5,7]. In our study only the PT was used since the honeycomb sandwich test coupons are made of thin [t = 0.3 to 1.2 mm] CFRP face sheets. The PT shall detect the debonds between the face sheet and delaminations within the face sheet [CFRP]

4.2 Pulsed Thermography Test Results

Two test coupons of honeycomb panels of size 200mm x 200mm with CFRP face sheets of thickness of 0.3 & 1.2 mm with simulated debonds were tested . Since the face sheet thickness of our specimens are small [t = 0.3 and 1.2 mm] test results for debond detection by PT are very clear. Figure 3 and 4 show the test results by both PT on honeycomb panels with CFRP skins.

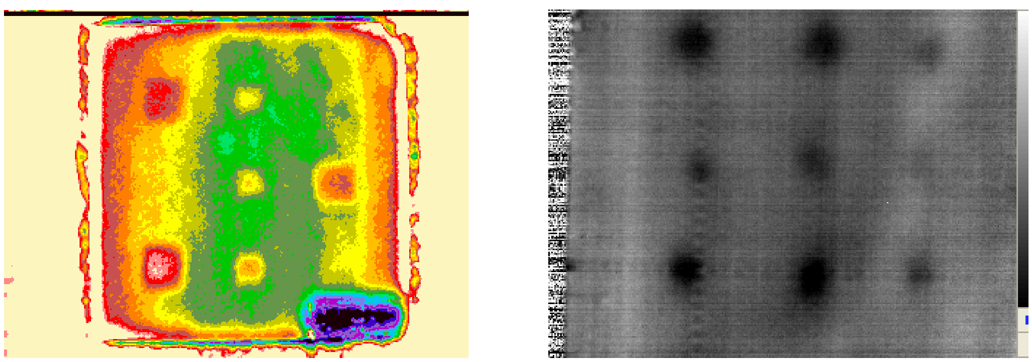


Figure 3 . Honeycomb panel with debonds between face sheet & core by PT

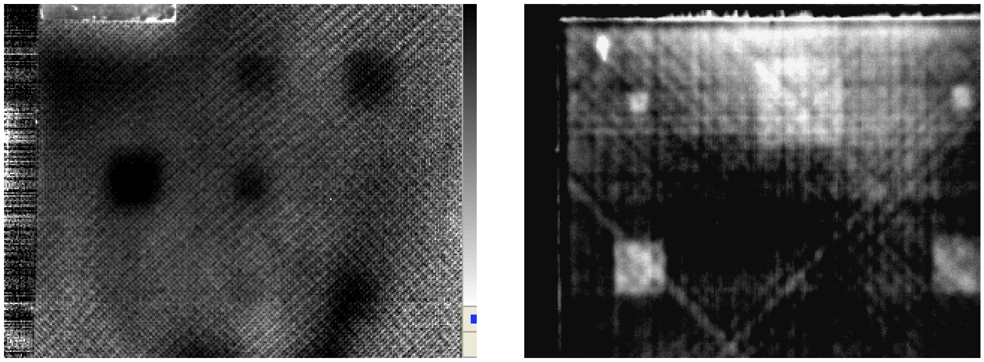
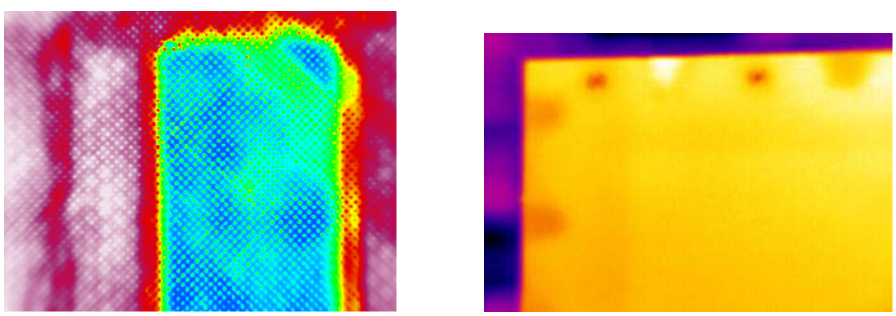


Figure 4 Debonds between the layers in the composite skins of a honeycomb panels by LT

The thermographic technique was also used for the actual testing of few spacecraft structural components for the NDE purpose. The test results using PT on a typical SAR antenna tile and shear web panel are shown in the figure 5. In the case of the shear web panel the number of inserts were bonded insitu along the edges for fastening purpose. One insert [white color] was detected clear a debond by thermography technique.



SAR Antenna Tile Edge inserts in a Shear Web panel

Figure 5 Debond s in actual spacecraft components

6. Conclusion

The two Non-Destructive Evaluation [NDE] techniques viz., Air Coupled Ultrasonic [ACU] and Pulsed Thermography [PT] were used for debond detection in spacecraft structural components like honeycomb sandwich deck plates, shear web panels made of aluminum core and composite face sheets. The pulsed thermography gives very good detection capability for the simulated debonds between face sheet and the honeycomb core in honeycomb panels made of thin face sheets [less than 1 mm thickness]. The Lock in thermography also gives good results and the depth of the defect should be analysed with a proper software. Some more work should done using LIT for the defect depth estimation.

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8. References

1 . Joe Buckley , Sonatest Plc "Air-coupled Ultrasound - A Millennial Review"

2. Jan O. Strycek and Hanspeter Loertscher "Ultrasonic Air-Coupled Inspection of Advanced Material"

3. Maldague X P V, "Theory and Practice of Infrared Thermography for Non-destructive Testing" Wiley-Interscience Publication, John Wiley & Sons, Inc.(2001).

4. Wu D and Busse G, "Lock-in thermography for nondestructive evaluation of materials" Rev. Gen. Therm, vol.37(1998), pp. 693-703.

5. Maldague X P V, Galmiche F and Ziadi A, "Advances in pulsed phase thermography, Infrared physics & Technology" vol.43(2002), pp. 175-181.

6. K.Jain, H. N.Bar, M.R.Bhat and C. R. L.Murthy "Infrared thermographic evaluation of defects in composites" NDE 2005--Kolkata

7 . Ravibabu Mulaveesala and Suneet Tuli "A New Approach To Thermal NDE: Frequency Modulated Thermal Wave Imaging" NDE 2005—Kolkata