IMPLEMENTATION OF ELECTRONIC SPECKLE SHEAR INTERFEROMETRY FOR NDE OF SPACECRAFT STRUCTURAL COMPONENTS

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ABSTRACT

Electronic Speckle Shear Interferometry (ESSI) system has been implemented for defects detection on spacecraft structural components made of honeycomb sandwich panels and in thin walled propellant tanks. ESSI has given in increased portability and also freedom from isolation platform requirement. Debond detection using dynamic excitation on Carbon Fiber Reinforced Plastic (CFRP) face skin with metallic core is presented. Application of this technique for in-plane strain measurements, using a dual laser beam setup, over a small area of CFRP Cylinder is also presented.

INTRODUCTION:
The laser based optical technique Electronic Speckle Shear Interferometry (ESSI) [1] is whole field, non-contact, high sensitivity is a powerful inspection tool for monitoring the integrity of the spacecraft structural components after fabrication and Non Destructive Evaluation (NDE) of thin walled propellant tanks. ESSI is integrated with a compact shearing optics, portable and also gives freedom from isolation platform requirement. This system can be used for detection of debonds in honeycomb sandwich constructions like deck plates and central cylinder with metal and composite face sheet. ESSI system with dual laser beam set-up can also be used on CFRP cylinder component for measuring in plane strain distribution. However, before the system can be used on flight hardware, its operational characteristics must first be standardized. This process involves acceptance testing of the instrument to determine its capabilities and limitations. After completion of the acceptance tests, it is implemented on the spacecraft structural components.

PRINCIPLE OF ESSI:
It works on interferometric principle, which permits whole field observation of surface strains. The object to be tested is illuminated by an expanded laser beam. The light reflected from the object surface is focused on the image plane of CCD (charge coupled device) camera where a Michelson interferometry is implemented in front of its lens. By turning one of the mirrors in the Michelson interferometry by a very small angle, a pair of sheared images of the object is generated on the image plane of the CCD camera. The two shearing images interfere with each other and produce a speckle interferogram. Due to the shearing function on the CCD, this technique is called Electronic Speckle Shear Interferometry.

EXPERIMENT: SE3 Shearography (isi-sys Germany) system was used for experiments, which consists of an array of laser Diodes (4x100 milli watts), related optics, CCD camera, image card and software. In Non Destructive Testing of propellant tank the first image (intensity distribution) corresponds to the non-deformed state (initial pressure of tank was kept at 4.0bars) of the test object is stored in the PC. This stored frame (image) is called reference frame. After the object is stressed (tank pressure is increased by 0.5 bars, i.e., 4.0+0.5 = 4.5bar) a second image (intensity distribution) corresponds to the deformed state of the test object is registered by the CCD camera again and is stored in another frame. The stressing (increase in the internal pressure) causes change in phase distribution and different in the intensity distributions of the two speckle interferogram. Digital subtraction between the two intensity distributions gives a visible fringe pattern of the object deformed. Due to the shearing function, the relative phase change gives the displacement derivatives instead of the displacement itself. The software is capable of carrying out the real-time subtraction, controls the PZT-driven mirror, transmits the values of the CCD array to the signal processor and calculates the phase distribution of the speckle interferogram at each pixel point automatically. This program generates the phase map, by filtering operation smoothens phase map, phase demodulation is done by a phase unwrapping algorithm, to display it in a three-dimensional plot and evaluate the phase map.

RESULTS AND DISCUSSION:
ESSI system identifies defects such as pores and cracks in thin walls of the propellant tanks by Non destructive testing and the tank with ESSI set-up is shown in Figure 1. The test was done on a qualification model propellant tank with simulated defects by internal pressure loading. The defect are simulated with a ratio of depth to length of the defect is not more than 0.1 and also depth of the defect is not more than 30% of the wall thickness of the tank. The simulated defects are identified by ESSI system and shown in Figure 2.
ESSI system provides non-contact way of watching an entire object vibrating and identifies its various resonance frequencies and amplitude. A real time vibration sweep will allow mapping out all the responses and mode shapes of the object. The time averaging shearogram is taken while the object is being excited with low amplitude vibration. The nodes will appear as brighter areas and antinodes will appear as darker fringes. The CFRP composite test coupon (size: 200x200x15mm) with simulated debonds between face skin and aluminum core was excited using piezoshaker, which is attached to the object with a vacuum suction cup. Time averaging technique was used for real time observation in order to localize the resonance of debonds which are seen very clearly and shown in the Figure 3.

Dual laser beam setup was used for in plane strain measurements in a small area (100 x100mm) of CFRP Cylinder and 2 strain gauges (S1&S2) are mounted in the test area, which is monitored by ESSI System. The differential load applied on the cylinder was 457Kgs. Measured strain gauge reading is 11 & 12 micro strains and ESSI results shows around uniform strain field (12 micro strains) as shown in Figure 4. The in-plane strain is obtained by subtracting two shearogram, which contain both in-plane and out-of-plane components. The larger the out-of-plane component, the smaller the measuring ranges of the in-plane strain. It should be emphasized here that the measuring range and the measurement accuracy are also affected by digital techniques, such as the spatial resolution of the CCD camera, the smoothing algorithms and so on, which have been described in detail [2].

CONCLUSIONS: This paper describes implementation of ESSI for NDE of spacecraft structural components like CFRP honeycomb sandwich panel and thin wall propellant tanks. The test carried out on qualification tank has shown that ESSI System could identify the simulated defects with a ratio of depth to length of the defect is not more than 0.1 and also depth of the defect is not more than 30% of the wall thickness of the tank. ESSI was implemented on the flight hardware. The ESSI system was also used for in plane strain measurement on CFRP cylinder. The strain distribution near the strain gauge bonded area is found uniform and matching with measured strain gauge reading.


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