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Abstract

The A320 aft fixed fairing is an advanced composite structure fabricated from laminate carbon woven and combines with honeycomb core which is externally mounted on the flap track fairing as a wing part of Airbus aircraft. These flaps are movable control surfaces to widen up the surface of the wing in order to increase the lifting. This paper discussed on the inspection of A320 aft fixed fairing by using shearography NDT technique. Shearography technique reveals the stress-affected zone due to additional loading that can be realized by the laser speckle correlation on the inspected composite panel. This A320 aft fixed fairing is identified as a scrap composite panel which having different sizes and orientations of defect. The results showed that the changes of shearing direction in laser shearography technique are an effective means to reveal the defects propagation in the composite component. The shearing at Y-axes direction is able to detect the cracks at horizontal orientation while shearing at X-axis has successfully detects the cracks at vertical orientation. Therefore, shearography could be utilized as an alternative inspection for other NDT method for inspection of

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PAPER

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Shearography Technique on Inspection of Advanced Aircraft Composite Material

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Abstract. The A320 aft fixed fairing is an advanced composite structure fabricated from laminate carbon woven and combines with honeycomb core which is externally mounted on the flap track fairing as a wing part of Airbus aircraft. These flaps are movable control surfaces to widen up the surface of the wing in order to increase the lifting. This paper discussed on the inspection of A320 aft fixed fairing by using shearography NDT technique. Shearography technique reveals the stress-affected zone due to additional loading that can be realized by the laser speckle correlation on the inspected composite panel. This A320 aft fixed fairing is identified as a scrap composite panel which having different sizes and orientations of defect. The results showed that the changes of shearing direction in laser shearography technique are an effective means to reveal the defects propagation in the composite component. The shearing at Y-axes direction is able to detect the cracks at horizontal orientation while shearing at X-axis has successfully detects the cracks at vertical orientation. Therefore, shearography could be utilized as an alternative inspection for other NDT method for inspection of composite material.

1. Introduction

Shearography technique is an optical measurement method among the new nondestructive testing NDT technique recently developed and introduced in the year of 1982 which has attracted considerable interest in a wide variety of industries including aerospace [1], oil and gas [2], automotive [3] and construction [2]. This laser based technique measures the derivative phase change difference that can be analysed with the introduction of the phase-stepping technique in the measurement system. Apart from being a non-contact and a relatively fast technique for wide area inspection [2], digital shearography have been shown to be considered reliable for detecting defects in metallic, non-metallic and also in composite materials[3,4] for qualitative inspection.

Based on Figure 1, the advanced composite of A320 aft fixed fairing component is located at wing at bottom portion, with the assembly of three main components where the upper one is known as top cover, lower is the A320 aft fixed fairing which attached in moveable fairing. Inspection of A320 aft fixed fairing component structure is increasingly important in the aerospace to make sure it is free from any manufacturing and/or service defects. At present, many NDT techniques [5,6] have been successfully employed for the detection and further analysis of the condition of advanced composite material. However, new techniques are still being explored to further improve detection and assessment capabilities in order to maintain and/or improving the quality control. Shearography could be considered as an attractive alternative for A320 aft fixed fairing inspection, since it can provide real-time inspection and visualization in a completely non-invasive way. The technique provides a highly sensitive integral measuring technique to record deformation and strain concentrations on the surface of the inspected samples or components. Therefore, with it has potential capability the application of digital shearography technique should be further explored and expanded to cater the growing needs of the aerospace industry.

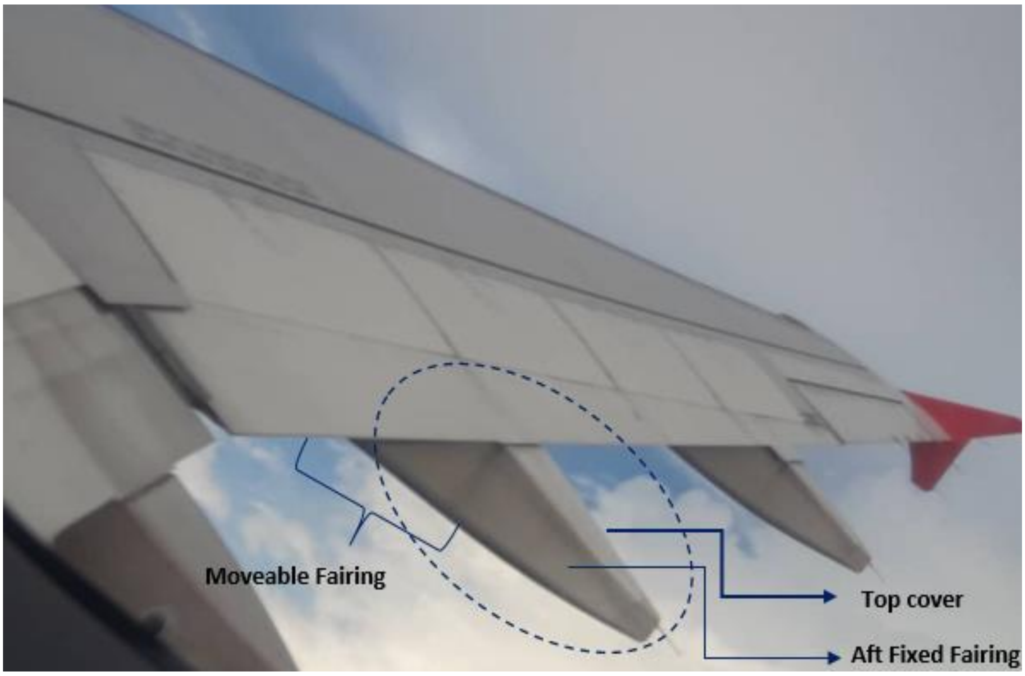


Figure 1. Wing portion of Airbus

2. Shearography: Principles of mapping, analysis and detection

The system setup of the digital shearography system used in this project work was illustrated in Figure2. It consists of a charge coupled device (CCD) video sensor as the recording media for data acquisition and digital image processing, and a Michelson shearing interferometer which employs a piezoelectric transducer (PZT) for optical phase analysis. An image processing package software, WiT7.2, is utilized with the system which assigns the intended voltage to the PZT for a four phase-stepping technique; and at the same time automatically captures and digitizes the fringe pattern image at each step. This setup is based on direct and automated measurement of phase change for phase maps representation of the displacement-derivative.

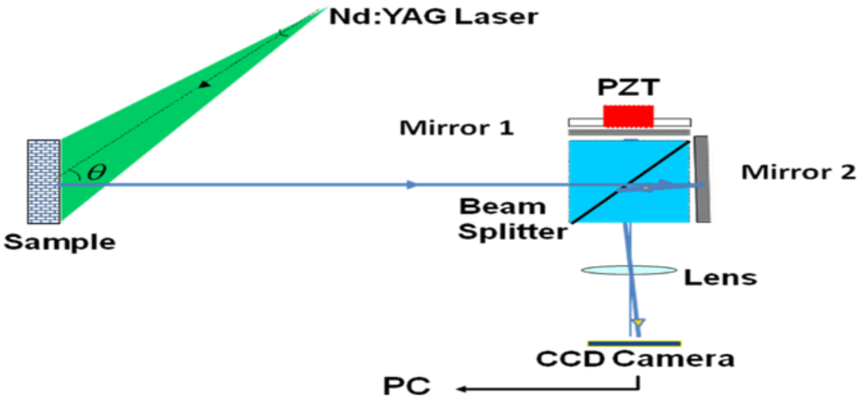


Figure 2. System setup diagram for digital shearography system

As illustrated in Figure 2, digital shearography requires the use of a laser point source for illuminating the test sample. In this project, an expanded light of Nd:YAG having a 10 mW power output and wavelength of 532 nm has been used. When the tested sample is illuminated by the expanded laser light, scattered wave fronts from an optically rough surface are sheared and interfered on the CCD sensor forming speckles as shown in Figure 3.

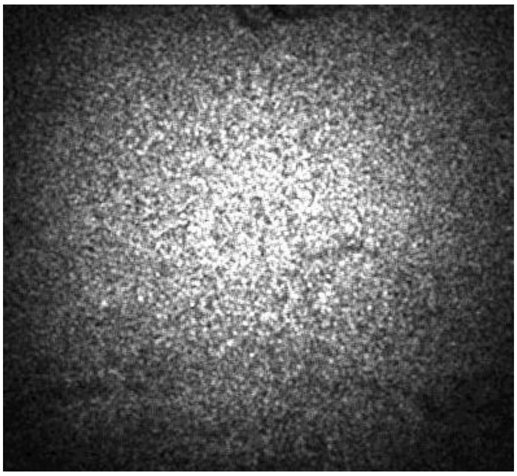


Figure 3. Laser speckle obtained by the CCD camera

The simplified mathematical equation of the intensity of the laser speckle detected on every pixel of the CCD is [5]:

$$I = A + B\cos(\phi) \quad (1)$$

Where ϕ represents the random phase difference between scattered wave front from two points on the sample surface, A is the background brightness and B is the modulation term of interference.

When the sample is applied with stress which cause it to deform slightly, both A and B could be regarded as constants. Furthermore, a relative change of surface displacement from the two points will produce a relative change of optical phase difference Δ, while the rest of Eq. (1) remains unchanged. Therefore, image intensity function after applying stress can be written:

$$I' = A + B\cos(\phi + \Delta) \tag{2}$$

With the subtraction of Eq. (1) and Eq. (2) of the two digital images and displaying the absolute value, visible fringes embedded with random speckle will be displayed. Figure 3 illustrates an example of the fringed pattern obtained by the subtraction of Eq. (1) and Eq. (2) for a pressure vessel sample deformed due to a central point load conducted in our previous work [5].

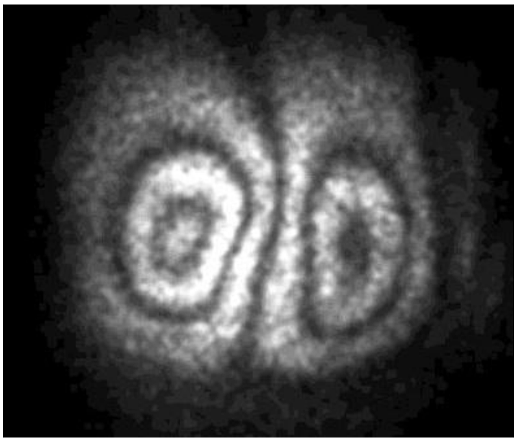


Figure 4. The fringe pattern of a pressure vessel with deformation due to a central point load

With the introduction of the phase-stepping technique, automated fringe-phase interpretation becomes feasible and the displacement derivative for the deformation can be represented by phase maps. Eq. (1) and Eq. (2) contain four unknowns A, B, ϕ and Δ, while I is the digitized pixel intensity recorded by the camera. The intention of applying the phase-stepping is to superimpose known phases using whatever means to generate a system of equations to solve for the unknown Δ. For practical reason, phase-stepping of four steps are introduced as 0, $\pi/2$, π, $3\pi/2$ between four separate frames, hence Eq. (1) becomes [6]:

$$\left.\begin{aligned} I_1 &= A + B(\cos\phi + 0) \\ I_2 &= A + B\left(\cos\phi + \frac{\pi}{2}\right) \\ I_3 &= A + B(\cos\phi + \pi) \\ I_4 &= A + B\left(\cos\phi + \frac{3\pi}{2}\right) \end{aligned}\right\} \tag{3}$$

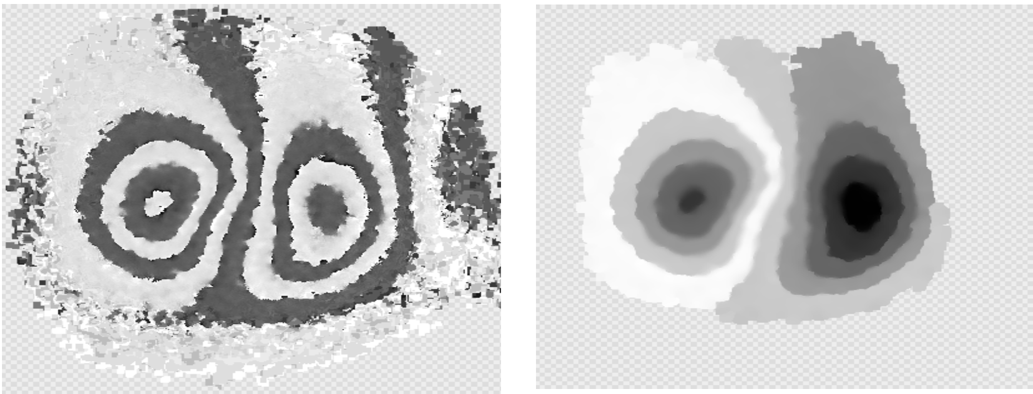
The initial random phase ϕ is determined using the following equation:

$$\phi = arctan\frac{I_2 - I_4}{I_3 - I_1} \tag{4}$$

The same process is repeated for the deformed speckle image using Eq. (2)

$$\phi + \Delta = arctan \frac{I_2' - I_4'}{I_3' - I_1'} \tag{5}$$

The phase change distribution due to displacement-derivatives is subsequently obtained by subtracting Eq. (4) from Eq. (5). Since the phase-step was introduced between each captured frame separated in time, the phase change Δ is wrapped in the range of $-\pi$ to π . However phase unwrapping is necessary to recover the true phase map. Both wrapped and unwrapped phase of Figure 3 is shown in Figure 4. Localized out-of-plane displacement anomalies will manifest itself as fringe condensation and can be further analyses for defect detection and characterization. The main benefit and purpose of presenting and analysing the phase images is that it can verify the obtained images from digital shearography inspection are from the stressed area and not from background noise during the test. Furthermore, quantitative evaluation is possible with further analysis of the displacement-derivatives of the unwrapped phase images; though knowledge about fringe pattern and wrapped images are essential for accurate analysis



(a) (b)

Figure 5. Phase images obtained by the phase stepping technique for the pressure vessel sample shown in Figure 4, (a) wrapped phase image, (b) unwrapped phase image

3. Inspection Investigation of A320 Aft Fixed Fairing

Based on the investigation by shearography for inspection of A320 aft fixed fairing in an advanced composite sample, a 500 Watt spotlight was used as the stress mechanism applied at the front surface of A320 aft fixed fairing sample. The distance between the spotlight and the aft fixed fairing sample during the heating (5 and 20 second) of the sample was position at 300 mm; the distance and heating period where the whole surface of the sample can be optimally heated as shown in figure 6. In this inspection, shearography shows the effect of a local strain concentration due to stress loading if a crack present, on the visible surface of this sample. The A320 aft fixed fairing to be inspected is externally loaded by heating the A320 aft fixed fairing, this will produce the external stress of the A320 aft fixed fairing surface. In the areas of weakened surface caused by flaw, the rear surface of the sample is deformed more than the areas of without flaw. The phase change difference of a stress loaded and unloaded state provides information about the deformation of the rear surface of the A320 aft fixed fairing.

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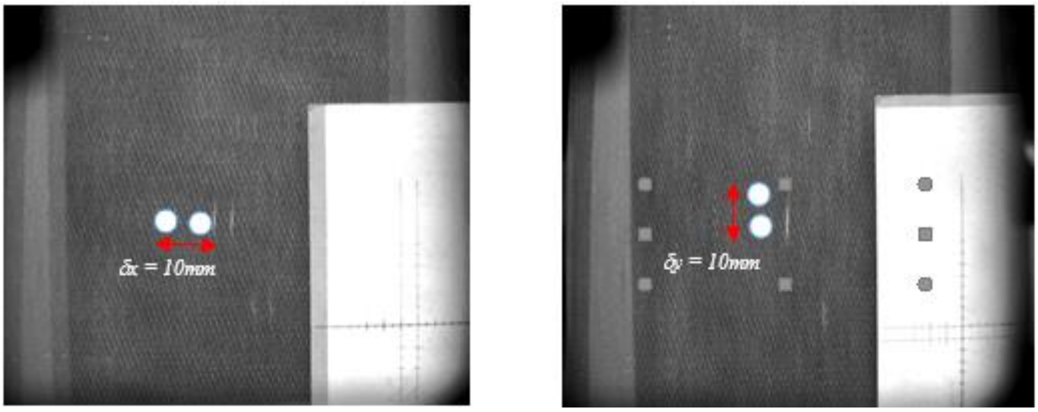
Figure 6. Arrangement of 500Watts infrared spotlight during heating of A320 Aft Fixed Fairing sample

The inspection is done at X and Y-axes shearing direction of shearography. Shearing produced by the Michelson configuration, leads to two image shearing, originated from two mirrors that are fixed orthogonally with the beam splitter. The shearing direction is changed by tilting or moving these two mirrors to the different angle. In this case two images interfere with one and the other by given 10 mm amount of shearing on the image plane as shown in figure 7. These two images should have the same intensity distribution provided that the light division by the beam splitter is an equal amount to each mirror.



(a) (b)

Figure 7. Two images interfere with one and the other by 10 mm amount of shearing at (a) X- Axes shearing and (b) Y-Axes shearing of A320 Aft Fixed Fairing sample

The A320 aft fixed fairing sample has the thickness of 30 mm lamination of carbon woven with honeycomb structure inside the sample, as shown in Figure 8. As it can be seen in Figure 8(a) front surface and Figure 8(b) back surface with multi direction cracks in honeycomb structure of A320 aft fixed fairing Sample. The presence of the crack is intended in the inspection as a reference defect of A320 aft fixed fairing location. The schematic illustration of cracks size measurement is shown in figure 9. The measurement indicates that the higher size of crack is 3.0 cm while the lowest size is 0.8 cm.

Figure 8. (a) front surface of A320 Aft Fixed Fairing sample

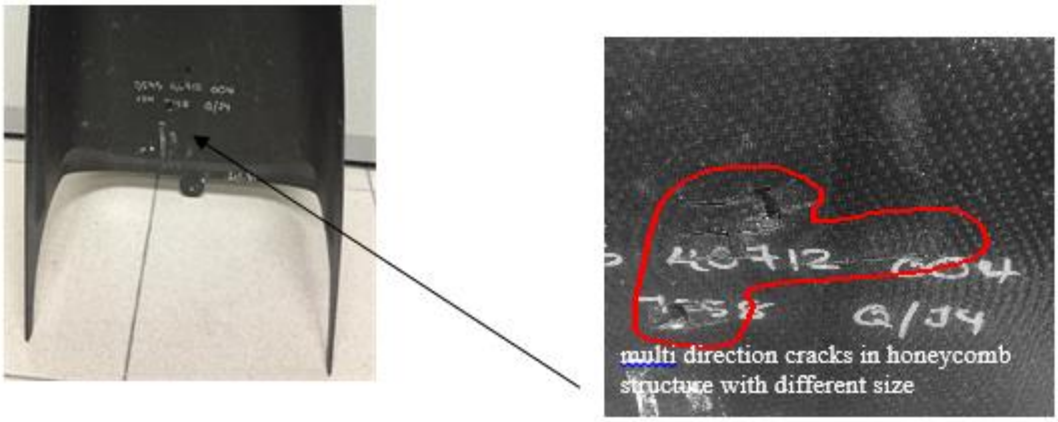


Figure 8. (b) back surface of A320 Aft Fixed Fairing sample

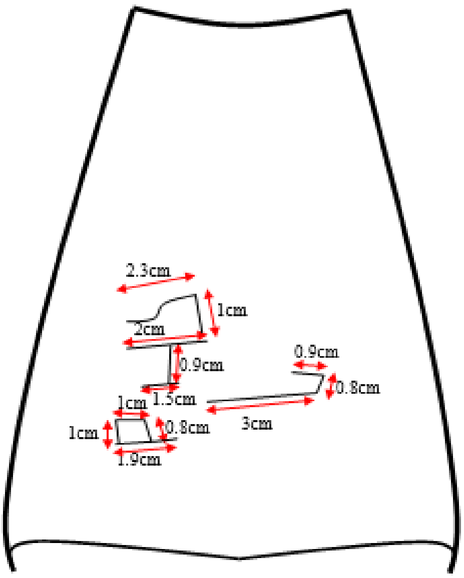


Figure 9. Schematic Illustration of cracks size in A320 Aft Fixed Fairing sample

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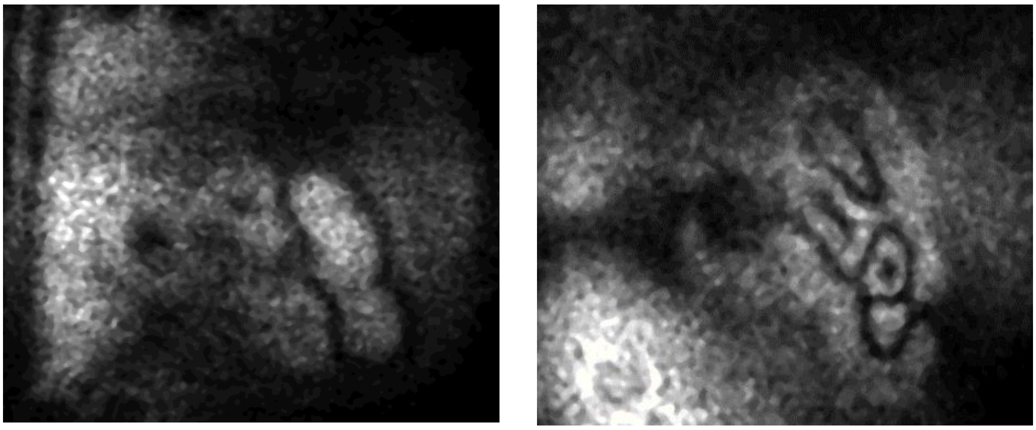
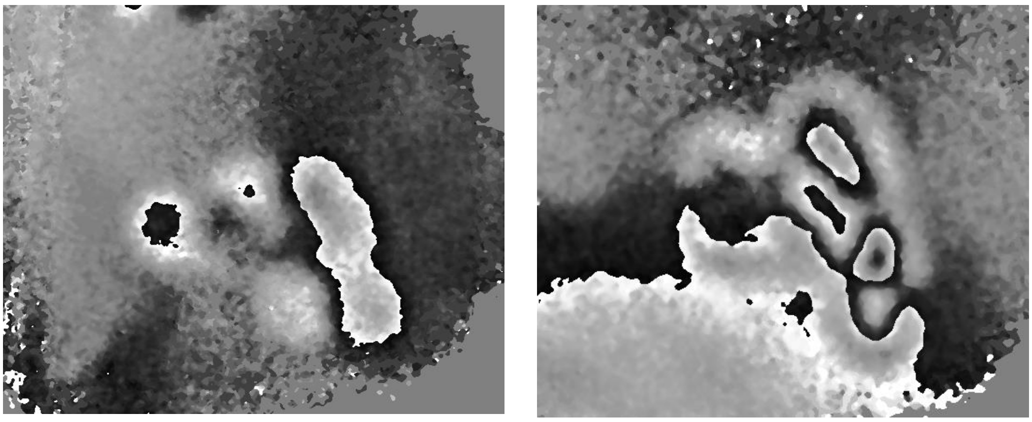
The shearography results for the deformation of the aft fixed fairing sample surface by the applied stress by the spotlight are shown in Figure 10. The figures show the fringe patterns obtained at X and Y-axes shearing direction of shearography inspection.



(a) (b)

Figure 10. shows fringe pattern result of A320 Aft Fixed Fairing sample (a) X- Axes shearing and (b) Y-Axes shearing

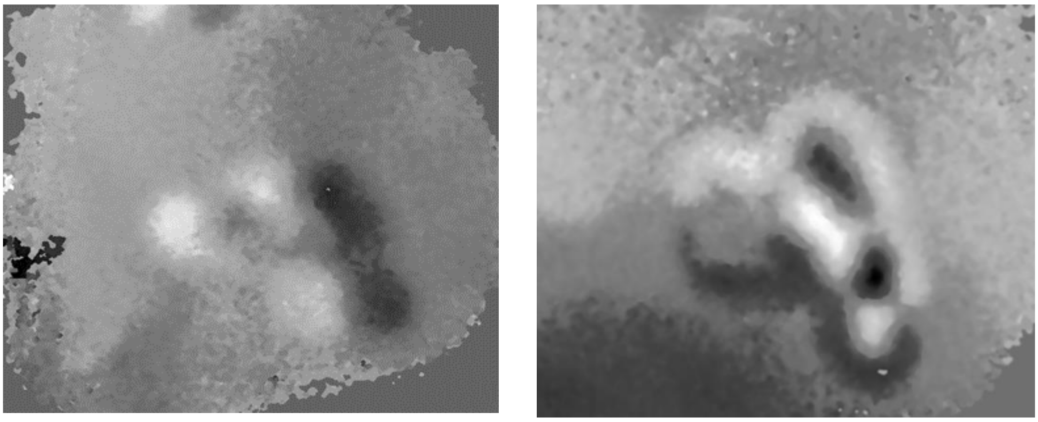
The consecutive wrapped phase representation of the displacement-derivative from the obtained fringe patterns is shown in Figure 11. The figure evidently shows a strain concentration indication due to the presence of cracks. This relatively high strain concentration is due to the higher expansion of the crack compared to the A320 aft fixed fairing the applied stress. Due to the unsmooth condition of the A320 aft fixed fairing sample surface, a smeared effect of the strain distribution can be observed with the obtained figure. However, as the strain concentration indication is obvious in the figure, the presence of the cracks can be instantaneously identified.



(a) (b)

Figure 11. shows wrapped phase result of A320 Aft Fixed Fairing sample (a) X- Axes shearing and (b) Y-Axes shearing

Analysis of the true phase map by the unwrapped phase image of the displacement-derivative presentation can be conducted to further verify the presence of cracks in the A320 aft fixed faring sample. Figure 11 shows the unwrapped phase representation at the A320 aft fixed faring sample surface. From the Figure 12, a clear and visible indication presence of crack can be observed.



(a) (b)

Figure 12. shows unwrapped phase result of A320 Aft Fixed Fairing sample (a) X-Axes shearing and (b) Y-Axes shearing

4. Conclusion

This paper has reported the application of shearography for the inspection of A320 aft fixed fairing of advanced composite material. Inspection investigation has been carried out using a spotlight as a stress mechanism and utilizing a four phase-stepping technique in producing the qualitative results of fringe pattern and wrapped phase results for the deformation of the cracks in A320 aft fixed fairing sample. The qualitative results have shown that the cracks in the A320 aft fixed fairing sample can be detected and instantaneously identified through the strain concentration indication of the displacement-derivative by shearography inspection technique. Future work will concentrate on further evaluation of the technique and the construction of image and data processing algorithm for crack evaluation in the composite structure via the digital shearography inspection technique.

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