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Research paper

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Application of Non-Stationary Thermal Wave Imaging in Non-Destructive Testing of Carbon Fiber Reinforced Polymer (CFRP)

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ABSTRACT:

Infrared thermographic techniques show their potential usage for non-destructive testing and evaluation of various materials due to their inherent capabilities such as safe, full field, remote, qualitative, and quantitative defect detection capabilities. Frequency Modulated Thermal Wave Imaging approach is reported for detection of sub-surface defects in Carbon Fiber Reinforced Polymer (CFRP) sample for a given frequency modulated incident heat flux. Artificial flat bottom holes and metallic inclusions as subsurface defects are prepared for the experimental investigation. Matched filter algorithm is applied for detection of sub-surface defects by correlation coefficient images and compared the detection capability-es with convention-a conventional frequency domain phase images. The effect of spectral reshaping on frequency modulated thermal wave imaging is investigated. The results of the experiments show spectral reshaping is the most suitable selection for enhancing inspection capability and obtaining the highest Signal to Noise Ratio (SNR) for a given CFRP material.

KEYWORDS Thermal wave imaging, Frequency modulation, Matched filter, Signal to noise ratio

1.Introduction

Carbon Fibre Reinforced Polymer (CFRP) has emerged as a critical material in a variety of sectors due to its remarkable strength-to-weight ratio and corrosion resistance. Because CFRP is widely used in essential structures such as aircraft components, wind turbine blades, and automobile parts, it is critical to ensure the structural integrity of these materials. Non-

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Destructive Testing (NDT) procedures are critical for assessing CFRP components without causing harm.Traditional NDT techniques such as ultrasonic testing and X-ray radiography have been widely used for CFRP inspection. However, these technologies frequently confront issues with resolution, sensitivity, and adaptation to complicated systems. As a result of these constraints, there has been an increase in interest in investigating advanced NDT methods, with a particular emphasis on thermal wave imaging.

Non-stationary thermal wave imaging is a promising innovation in the field of non-destructive testing (NDT), with the potential to overcome the constraints of previous approaches. Non-stationary thermal wave imaging, as opposed to stationary thermal wave imaging, incorporates dynamic aspects, improving the capacity to identify and characterise flaws in CFRP structures. This dynamic technique adds a new dimension to the inspection process, improving sensitivity and accuracy.

Exploration of non-stationary thermal wave imaging for CFRP shows great potential for tackling the material's particular difficulties. Non-stationary thermal wave imaging is a leading option for the next generation of CFRP NDT due to its ability to identify concealed flaws, delamination, and other structural abnormalities with better precision.

2. Methodology

In Infrared Non-Destructive Testing (IRNDT), the surface of the test sample is exposed to a quadratic frequency-modulated optical stimulus. This stimulus initiates similar thermal waves in a very thin layer close to the surface, which then propagate into the object's interior through diffusion wave propagation. As a result, it creates a temperature contrast on the object's surface, highlighting subsurface anomalies. To extract fine details from beneath the surface, the captured thermal data undergoes various processing methods. These include phase analysis, pulse compression, Hilbert phase analysis, These methods are applied with the aim of defect detection using the recently introduced Quadratic Frequency Modulated Thermal Wave Imaging technique.

2.1 Fourier transforms (FT)

The phase picture has the benefit of being less susceptible to local fluctuations in light and surface emissivity. The thermal-wave signal in TWRI comprises variable frequency components. The amplitude and phase of the harmonic component of the thermal-wave signal

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were extracted using the Fourier transform (FT). The frequency domain phase details may be separated using FT, which offers phase information matching to the constituent frequency.

2.2 Hilbert Transform

The Hilbert transform makes it easier to create the analytic signal. The analytic signal is important in communications, particularly in the processing of bandpass signals. The Hilbert transform is computed for a real input sequence x by the toolbox function hilbert, which produces a complex output of the same length, y = hilbert(x), where the real portion of y is the original real data, and the imaginary part is the actual Hilbert transform. In regard to the continuous-time analytic signal, y is frequently referred to as the analytic signal. The discrete-time analytic signal's Z-transform is 0 on the lower half of the unit circle, which is an important characteristic.

2.3 Thermography with pulse compression

The heating time in conventional PT is much shorter than the cooling time, i.e. of the average timings of thermal diffusion events in the sample, therefore it may be modelled as a Dirac's Delta function. If the linearity and time-invariance criteria are met, the pixel's impulse response may be obtained by simply collecting a series of thermograms at different -sampling values using an appropriate IR camera. In fact, the excitement may be described as immediate.

3.Results and Discussion

A CFRP sample is modelled and simulated to validate the capabilities of the provided technique. Fig.1 depicts the sample's layout. The sample's thickness is 11 mm, with flat bottom holes of dimension 1.1 mm placed at various depths as sub-surface defects.

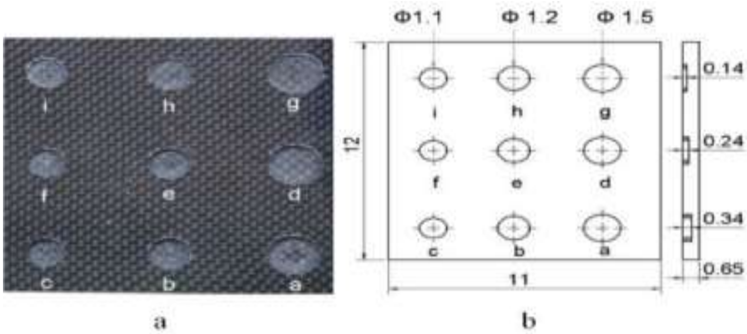

Fig.1 Layout of the experimental CFRP

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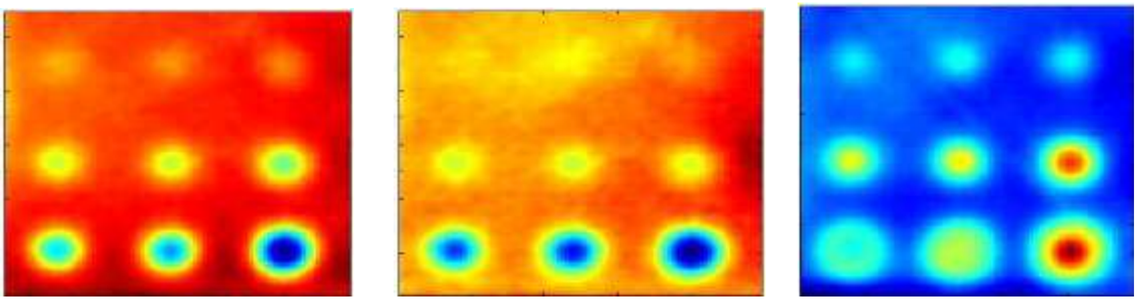

Fig.1 Fourier transform analysis, Hilbert Transform analysis,

Conclusions

The appearance of a new material is typically beneficial to the development of buildings. Carbon Fibre Reinforced Polymer (CFRP) is a novel high-performance composite material with several benefits, including a long breaking length and great strength. This report focuses on the ten extant CFRP cable constructions across the world. They are all CFRP cable bridges. Although these CFRP cable buildings were primarily developed for testing reasons, their successful construction and long-term use have thoroughly shown that replacing steel cables in cable structures with CFRP cables is achievable using current technology.

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