PULSE THERMOGRAPHY OF COMPOSITES USING WAVELET TRANSFORM

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Reinforced composites are widely used in various industries due to their low weight and high strength. In this regard, ensuring safe operating conditions for this composite is extremely important for research in the field of non-destructive detection and control. Impact damage is one of the most common types of mechanical defects associated with reinforced composites, which often leads to system failure [1]. There are quite a large number of experimental and analytical methods for detecting defects in reinforced composites.

Eddy current pulse thermography is one of the promising methods for non-destructive testing of composite materials. This method is characterized by improved spatial localization of defects in the volume of composite structures [2]. In experimental studies, a strong electromagnetic pulse is applied to the material under study. In this case, heat spreads not only along the surface of the sample, but can reach a certain depth, which is regulated by the depth of the eddy current skin layer. In addition, this thermography technique has the ability to adapt in terms of defect orientation and can improve the specific excitation direction to optimize the directional evaluation along the defect orientation, which is more effective for geometrically complex components and captures more defect features [3]. Pulse thermography has been applied in many studies, including the potential for detecting small defects with complex geometries, fatigue crack evaluation, and the investigation of temperature distributions around cracks with different penetration depths in composite materials.

However, identifying and localizing damage in the bulk of composite structures caused by low-energy pulses is a challenging task for detecting composite defects for many experimental techniques [4]. Impact damage information is difficult to identify due to the complexity of the composite structure, such as non-uniform and crossed fiber structure. In the pulse thermography method, the transient temperature response is a time-dependent signal, including the heating phase and cooling phase. Different time intervals contain different physical effects. Wavelet transform has been found to be effective for time, frequency and spatial analysis, and its function as a mathematical microscope of signal analysis can be used in image processing such as compression, noise reduction, etc. This study analyzes an automatic transition-spatial selective method based on wavelet coefficient energy data to enhance micro-impact detection and optimize transition interval selection.

The short-time Fourier transform method is often used in composite flaw detection. The Fourier transform has an equally spaced bandwidth across all frequency channels. Unlike the Fourier transform, the wavelet transform allows variable window sizes to be used when analyzing different frequency components within a signal. In this case, the reference signal is compared with a set of functions obtained by scaling and shifting the base wavelet. Since the thermal image signal is highly non-stationary and non-periodic, time-frequency analysis using the wavelet transform of image sequences is studied.

The method of thermography of defects in the bulk of composite specimens consists of several steps. In the first step, a set of raw thermal sequences is generated. In the second step, the scale is optimized by estimating the average energy of the multi-scale wavelet transform coefficient. Next, the scale is determined at which the set of several wavelet transforms allows maximizing the separability for fiber and impact thermal models. Then, based on the maximum energy criterion at the selected scale, the optimal wavelet is determined. The optimal transition frame of the wavelet window is determined by analyzing the change in low- and high-frequency components with time at the selected scale using the optimal wavelet. The combination of the optimal wavelet and the selected scale is used to wavelet transform the optimized transient pulse thermography image. At the final stage, information on impact damage and fiber texture is aggregated. The average energy of the first level wavelet transform decomposition coefficient was calculated to select the proper decomposition scale. The analysis of the decomposition results showed that the average energy of the approximation coefficient gradually increased with the increase of the decomposition level. However, the average energy of the detail coefficient (horizontal, vertical and diagonal) is very small in the first three levels, while the average energy of the coefficient at the fourth level is the largest among the five-level decomposition. The main frequency component corresponding to the scale of level four exists in the thermal image, then the wavelet coefficients at this level will have relatively high values. Therefore, the components associated with this scale can be extracted from the thermal image signal by wavelet transform. Thus, it can be stated that the fourth level of the discrete wavelet transform leads to a very good separation of the approximation of the impulse interaction and the details of the mechanical defect compared to other levels of decomposition.

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БЕЗКОНТАКТНЕ ВИМІРЮВАННЯ ЕЛЕКТРИЧНИХ ПАРАМЕТРІВ СОНЯЧНИХ ЕЛЕМЕНТІВ

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Сонячні елементи, які знаходяться в складі сонячної панелі, не мають доступних контактів для вимірювання їх електричних параметрів. Таким чином, дістатись до окремого сонячного елементу у складі панелі можливо лише безконтактним методом. Слід зазначити, що безконтактне вимірювання є актуальним при вирішенні таких задач:

- отримання оперативної інформації про стан окремих сонячних елементів з метою раннього виявлення їх дефектів і прогнозування процесу деградації сонячної панелі під час її експлуатації;
- тестова перевірка кожного сонячного елементу панелі перед її монтажем у малодоступних і недоступних місцях: на дахах хмарочосів, на фасадах будівель, у космосі тощо.

Основою безконтактного вимірювання є два принципових моменти:

- через сонячну панель пропускають змінний вимірювальний сигнал;