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WAVENUMBER FILTERING FOR STRUCTURAL DAMAGE DETECTION

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Plate structures, which include laminar composites, are widely used in various industries. Quite difficult to detect damages, such as corrosion and delamination in composite structures, can occur in these components. Due to this, there is a need to implement methods for monitoring the condition of the structure, as well as non-destructive evaluation. Examples of cost-effective techniques that can help ensure safe and reliable operation of structures incorporating composite inserts include radiographic testing [1], eddy current testing, magnetic particle testing [2], and many others. The engineering implementation of these methods usually requires various precautions and time-consuming verification processes. The analysis of acoustic and guided wave propagation results underlies most methods for detecting damage in layered structures.

The vibration mode of the plate structure is provided by the propagation of mechanical waves in the form of Lamb wave packets. Wave characteristics such as attenuation, reflection, scattering coefficients, and time of flight are often used to detect and identify faults using various signal processing techniques. Guided wave propagation patterns are complex and difficult to analyze due to their dispersive and multimodal behavior [3]. Therefore, issues of improving damage detection efficiency require isolation of wave modes. This can be achieved based on wavenumber analysis. Wavenumber spectroscopy algorithm successfully localizes and visualizes thickness change caused by damage initiation [4]. Local wave number estimation can lead to efficient and quantitative assessment of the size and depth of delamination in composite plates. In addition, efficient quantitative assessment of damages occurring in the bulk of the composite structure requires the implementation of both instantaneous and local wave number filtering to the Lamb directed wave packet field data. A prerequisite for the analysis of multimodal directional wave fields is the ability to separate propagating, transformed and reflected wave modes using wave number filtering. In this case, energy wave mapping after processing consisting of wave number filtering is effective for damage visualization. It should be noted that in some cases the wave energy is insufficient to identify mechanical damage, especially in composite structures. This creates several problems, including the need to increase the number of sensors and actuators, as well as the averaging procedure, which is expensive in terms of numerical calculations.

The technique using the full stationary wave field is free from these drawbacks. The technique of acoustic wave spectroscopy uses standing waves to detect damage instead of guided waves. The results of these studies showed that different types of damage can be detected using wave number analysis. In particular, the wavenumber mapping method allows detection and visualization of small defects such as cracks. It uses a single excitation with a fixed frequency in a steady state. The advantages of such a technique include: efficient energy injection into the composite structure, which leads to the appearance of higher magnitude waves; the need to use only a few cycles of wave measurements to record the behavior of wave packets at each scanning point. The implementation of the wavenumber filtering technique involves a modification of the scanning process. The measurement of the full stationary wave field is performed using a piezoelectric transducer mounted on the surface of a composite plate. plate. The transducer generates a stationary excitation at a single frequency. Scanning is performed over a uniformly discretized two-dimensional grid M × N of the spatial scanning area, where M and N are the numbers of spatial points in the x and y directions, respectively. After the scanning process is complete, the measured response is reconstructed into an M × N × T 3D matrix v [x, y, t], where t represents the data in the time domain. The discrete Fourier transform allows processing the entire array of data on the response of the Lamb wave packet receiver.

The paper presents a modified 2D wavelet-based damage detection method based on wavenumber analysis. The wavenumber, the inverse of the wavelength, has a fixed value for a given frequency, thickness and material properties. Therefore, a change in wavenumber is an indication of structural damage in a composite. The wavenumber spectra of the steady-state response v [x, y, t] are a superposition of several propagating modes existing at the excitation frequency.

In a fixed frequency range, the response contains symmetric (S0) and antisymmetric (A0) modes of zero order. Isolation of the wave mode is of utmost importance for wavenumber-based damage detection. The reason is that the presence of several modes creates difficulties for automated analysis of wave number spectra. The method of laser scanning of the wave field of a stationary state used in the work allows focusing on one mode. The performance of the wavelet-based composite volume damage detection technique is determined by the mother wavelet function. The results of numerical calculations and their comparison with the available experimental data show that the structural damage can be clearly identified with higher accuracy by filtering the 2D wavelet wavenumber. It is found that the wavelet damage indicator function can accurately identify the wavenumber change in a much higher spatial resolution compared to the 2D Fourier transform.

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CALCULATION OF THERMAL CONDUCTIVITY OF GeBiTe SOLID SOLUTIONS BASED ON ZONE MODELS

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Solid solutions based on germanium telluride are considered to be among the most efficient medium-temperature p-type thermoelectric materials to date [1]. High thermoelectric figure of merit has been achieved for GePbBiTe solid solutions, where the figure of merit is approximately 2.3 at T = 700 K [2]. This value can be further increased, in particular by optimizing doping and further improving the material growth technology. Improving the composition and structural properties, such as grain size and dislocations, can contribute to increasing the efficiency of the material for thermoelectric applications over a wider temperature range.

In the study of hard GePbTe and GeBiTe solutions, an approximation was used to calculate the electronic component of thermal conductivity, in which it was assumed that a non-parabolic zone of light holes is located higher in the energy spectrum. As a result, important conclusions were obtained regarding the location of the Fermi level [3], on the basis of which an increase in the thermoelectric figure of merit ZT was explained when lead (Pb) and bismuth (Bi) atoms were added to GeTe.

Due to differences in the numerical values of the band parameters specified in [1-2] and used in [3], this work calculates the Fermi level and the electronic component of the thermal conductivity coefficient based on experimental data [3]. The main objective of the study was to identify possible differences in the numerical values of these parameters due to the choice of a specific model of the GeTe band