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Damage identification and assessment in composite structures

Wiesław M. Ostachowicz[a,b]*, Tomasz Wandowski[a], Paweł H. Malinowski[a], Paweł Kudela[a]

[a]*Institute of Fluid–Flow Machinery, Polish Academy of Sciences, 14 Fiszera Street, 80–231, Gdansk, Poland*
[b]*Faculty of Automotive and Construction Machinery, Warsaw University of Technology,*
84 Narbutta Street, 02–524, Warsaw, Poland

Abstract

The paper presents multidisciplinary methods and techniques oriented towards damage identification and assessment in composite structures. Two types of materials have been used: carbon and glass fibres reinforced composites. Particularly the paper is dedicated to elastic waves propagation phenomenon, scanning laser vibrometry, electromechanical impedance and terahertz spectroscopy. It also includes a variety of techniques being related to diagnostics (damage size estimation and damage type recognition) and prognostics. Selected numerical aspects of the phenomena related to the mentioned methods are addressed.

Moreover it covers the main disciplines which are related to above mentioned techniques as piezoelectric sensors and transducers, and signal processing. The signal processing approach is crucial allowing extracting damage related features from the gathered signals.

Investigated damage is in the form of mechanical failures as cracks, delaminations, debonding, voids. Also methods dedicated to thermal degradation, moisture and chemical contamination are shown. Presented methods are also suitable for performance of bonded joints assessment. Problem of external factors on investigated methods is also discussed in this paper. The characteristic of each method is summarized by a critical look.

The laser vibrometry is a non–contact technique that allows to measure vibrations of structure excited by shaker or piezoelectric transducer. In guided waves–based technique, the interaction of elastic waves with failures can be seen after appropriate signal processing.

The electromechanical impedance method is based on electromechanical coupling of piezoelectric transducer with a

* Corresponding author. Tel.: +48-58-341-1271 ext. 285
E-mail address: wieslaw@imp.gda.pl

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host structure. Damage in structures caused frequency shift of certain resonance frequencies visible in resistance characteristic.

The terahertz spectroscopy method is based on an electromagnetic radiation in the range: 0.1–3 THz. It allows for reflection and transmission measurements. Reflection mode is more feasible for real structures where access to the structure is only from one side. During current research time signals as well as sets of signals creating B–scans have been analysed.

Authors address also the problem of adhesive bonding in the case of CFRP samples. Techniques for detection of weak bonds are presented together with signal processing approaches. The reported investigations concern contaminated bonds caused by both manufacturing (e.g. release agent) and in–service contaminations (e.g. de-icer).

Promising combination of selected techniques should lead to an innovative approach to ensure safety operation of structures. Local and global methods have been applied and validated by experimental studies.

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Keywords: Composite structures; Damage identification

1. Introduction

Fiber reinforced composite materials are utilized in many branches of industry. They have large strength to weight ratio, they are chemical resistant and can be simply formed in complex shapes. Beside of many advantages they are vulnerable to barely visible mechanical damage like delamination. Therefore, problem of damage assessment in the case of composite materials is very important from the point of view of safety of its exploitation.
There are many non-destructive testing NDT techniques that can be utilized for damage assessment in composite materials. In this purpose such techniques like ultrasound testing [1], active infrared thermography [2], eddy currents [3], X-ray tomography [4], terahertz spectroscopy [1],[5], guided wave GW based technique as well as electromechanical impedance [5] are utilized.
In this paper authors focused attention on guided wave propagation method, electromechanical impedance method and terahertz spectroscopy.

2. Scanning Laser Doppler Vibrometry

Scanning Laser Doppler Vibrometry SLDV is non-contact technique dedicated to measurements of vibrations and guided wave propagation in structures. In presented research Polytec PSV-400 system was utilized for measurements of guided wave propagation. Measurements were taken at dense mesh of measuring points spanned over the area of investigated structure. Guided waves were excited using piezoelectric transducer in the form of disk with diameter 10 mm and thickness 0.5 mm made out. This transducer was made out of NCE51 piezoelectric material.

One of the full wavefield signal processing method is based on calculation of damage maps based on weighted root mean square (WRMS). As consequence map of energy distribution related to guided wave propagation in the structure is obtained. This map shows all forms of interaction of waves with any kind of discontinuities in the structure. This algorithm is extension of conventional RMS map algorithm. In WRMS algorithm a weight factor which decreases the importance of the time samples at the beginning when excitation is applied and increases the importance of the samples closer to the end of signal where waves amplitudes are small due to damping. The WRMS can be calculated as:

$$WRMS = \sqrt{\frac{1}{N}\sum_{k=1}^{N} w_k s^2} \tag{1}$$