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ScienceDirect

Procedia Technology 19 (2015) 307 – 312

Procedia Technology

8th International Conference Interdisciplinarity in Engineering, INTER-ENG 2014, 9-10 October 2014, Tirgu-Mures, Romania

Aluminum Foil Based Fatigue Sensor for Structural Health Monitoring of Carbon Fiber Composites

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Abstract

For the development of a technique for cyclic deformation assessment using aluminum foil sensors glued onto the specimen surface the fatigue tests of carbon fiber reinforced polymer (CFRP) specimens were carried out. The DSLR camera mounted onto an optical microscope was used for capturing the images of sensors to reflect strain induced relief, which than was numerically estimated using various informative parameters in order to obtain the cyclic deformation assessment of composite. The results are discussed in view of application of this method for the development of Structural Health Monitoring (SHM) approach.
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Peer-review under responsibility of "Petru Maior" University of Tirgu Mures, Faculty of Engineering
Keywords: aluminum foil sensor, fatigue, mesomechanics, structural health monitoring

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Peer-review under responsibility of "Petru Maior" University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2015.02.044

1. Introduction

Carbon fiber reinforced polymer, with their superior properties are widely used in the industry, especially in aerospace. Unlike metals composites have complex heterogeneous structures with various reinforcement directions, different properties of binder and filler. Due to the complexity of structure, with many fiber/matrix interfaces, there are a lot of defect types that might nucleate during operation (matrix cracking, fiber breakage, delamination, fiber pull-out, etc.).

However, during the in-service life the structures are loaded mainly cyclically with applied stresses below yield strength that can give rise to fatigue failure. The fatigue failure of composite materials is an extremely complicated process because of a lot of heterogeneities and non-uniformities: complex multilayer heterogeneous structure to vary mechanical response in each ply; sudden brittle failure that can occur at a variety of structural levels due to the accumulation of integral material damage (cracks, chips, delamination and fiber breakage). In this regard it is relevant to develop new techniques for strain evaluation under different loading schemes and conditions. Besides development of the method itself it is of importance to find out numerical parameters to be extracted during surface images processing to correctly characterize deformation and fracture processes occurring in a loaded material.

Many recent papers on the subject of NDT are devoted to Structural Health Monitoring (SHM) systems. Such systems can provide information as the damage occurs and significantly improve the safety of operation, as well as expand the time intervals between the scheduled full-scale diagnostics events.

In the literature an approach described to the monitoring of materials under fatigue is related to the application of thin single crystal foils referred to as “smart sensors” [1,2]. This method is based on optical registration of images of foil (sensor) glued onto the specimen surface. Due to the cyclic loading the strain relief on the foil is formed and it is captured by digital camera. Digital processing of images allows one to calculate the informative parameters to assess the damage state of the material. In [3] “smart sensors” made of single crystal aluminum films were used to evaluate the mechanical state of AA2024 specimen during cyclic tension tests. In [4] the possibility of thin metallic foil sensors application in aeronautics is discussed. There are three fundamentally different functions of such sensors: load path detection, fatigue life sensing and crack assessing. Support to comply with the Airbus directives and airworthiness rules was given. Expectations in terms of performance and user interface were suggested in the paper.

However, in the above-mentioned papers “smart sensors” are offered to apply at fatigue damage evaluation of metals. The aim of the present study is to evaluate the possibility of application of such sensors for composite fatigue evaluation, as well as to develop a set of informative parameters for image processing. Early in [5], we developed a technique to study the deformation of composites under static loading based on the data of digital image correlation and acoustic emission.

2. Material and methods

Carbon fiber reinforced polymer used for investigation is pseudo-isotropic composite made of unidirectional carbon fiber layers with lay-up $[0^o, 45^o, -45^o, 90^o]_{2S}$ with epoxy matrix. Fig. 1,a presents the drawing of the specimen with two edge notches and glued Al foil sensor.

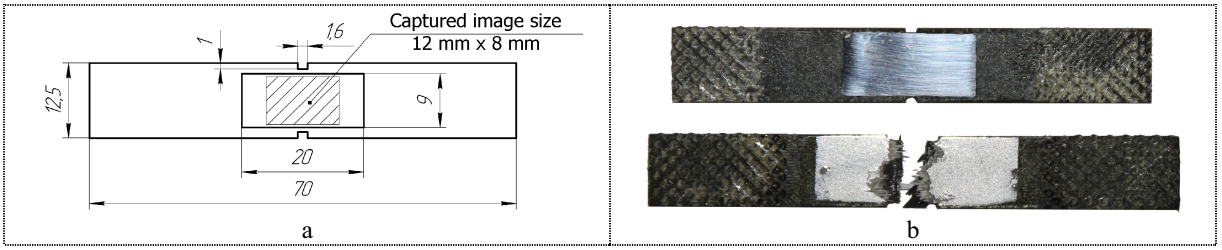

Fig. 1. a) Drawing of the specimen with glued sensor;
b) Images of untested and fractured specimens.

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