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Analysis Of Damage In Composite Laminates With Embedded Piezoelectric Patches Subjected To Bending Action

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Abstract

Smart materials offer the possibility of the integration of active functions into a composite primary structure. This work aim to investigate the impact of the incorporation of smart materials in a conventional composite laminate. Fiberglass specimens with and without PZT piezo elements embedded in the lamination stack are manufactured and then subjected to a four-point bending test. Together with the classical mechanical parameters, the operational behaviour of the piezo as sensor is monitored in terms of electrical capacity during test. Benefits and disadvantages of the embedment of a piezo element in a laminate are evidenced from a comparison of the experimental results. In parallel, numerical models of the experimental setup and test, with a finite element approach, allows to explore the mechanisms of damage of such kind of sensorized specimens.

Keywords: Advanced composites; smart materials; piezoelectric embedding; structural health monitoring

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1. Introduction

Structural damage is identified as the changes introduced into a system that adversely affect its current or future performance. With the aim to improve the resistance of materials, a better understanding of damage processes in structural and mechanical systems becomes necessary. The scientific process of nondestructively identifying damage for aerospace, civil and mechanical engineering infrastructure is referred to as Structural Health Monitoring (SHM) [1][2]. The economic motivation is stronger. For structures with SHM systems, the envisaged benefits are real time or continuous monitoring that reduces costs, enhance reliability by allowing on-condition maintenance, instead of increasing maintenance costs and decreasing reliability for classical structures without SHM. This process involves the observation of a structure or mechanical system over time using periodically spaced measurements, the extraction of damage-sensitive features from these measurements and the probabilistic analysis of these features to determine the current state of system health [3]. Damage identification [4] is related to disciplines that include SHM, such as condition monitoring (CM), non-destructive evaluation (NDE), statistical process control (SPC) and damage prognosis (DP). Hence SHM system is an attractive approach to solve problems that occur in degraded structures. Damage and intensity of degradation are monitored in real time providing useful information for predicting the service life. These methods would definitely increase safety, especially for hardly accessible hot-spots, but it could also save up to 50% of necessary inspections time depending on the aircraft type [5]. Composite structures are in the top demands list regarding SHM technology, they are precisely the structures that reveal both the safety and economic issues, because of complexities in predicting mechanical damage and fracture, which often lead to overestimated components. Therefore, a need for new kind of monitoring techniques has led to researches on embedded sensors or active layers of smart materials [6]. The most popular sensors suitable for embedding in structures are fibre-optic sensors and piezoelectric sensors. Piezoelectrics have become important in controlling the response of structures, for their potential as sensors and actuators [7][8]. In particular, piezoceramics such PZT family are interesting for being integrated as sensors and actuators since they can be found in form of small and thin patches and can be bonded to or embedded in laminates [9][10], leading to minor structural modifications combined to a relative high electromechanical coupling. However, the integrity of the host structure is compromised by the presence of the embedded device, as investigated in several works [11][12][13][14], and the overall strength of a composite laminate with an embedded sensor or actuator is sensitive to the method of lay-up used to embed the device [15]. Embedding can be necessary to protect a sensor from its surrounding environment or to create an integrated structure with smooth surfaces. PZT sensors can be effectively protected from environmental disturbance and impact damage, which would enhance the durability and feasibility of PZT patch in SHM domains. Different techniques used to introduce a