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EXPERIMENTAL INVESTIGATION ON THE EFFECT OF CREEP ON THE DAMAGE EVOLUTION OF CFRP STRUCTURES DURING FATIGUE LOADING

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Abstract: This paper presents an experimental investigation on the effect of creep on the damage evolution of Carbon Fiber Reinforced Polymer structures during fatigue loading. A new experimental campaign is proposed where unidirectional CFRP specimens are tested under the combination of fatigue and constant compressive load. The tests represent the loading that the lower part of an air-wing faces during the flight and parking process. Acoustic Emission technique is employed in order to monitor the damage progression and accumulation. The results of the acoustic emission are compared with reference tests where only fatigue loading is used and it is found that the acoustic emission patterns in terms of number and distribution of events over the duration of tests and energy accumulation is different for these two types of tests. The results indicate that the damage process on CFRP structures is different when creep is present.

1. Introduction

Fiber Reinforced Plastics (FRP), known as polymer composites, are widely used nowadays as primary structures (air-wings, fuselage, etc.) in commercial aircrafts. The most recent example is the Airbus A350, which is in service since January 2015, and more than 50% of its structural weight made of composites. Despite the fact that aerospace industry promotes the use of composite materials, a comprehensive understanding of their mechanical behavior in terms of fatigue and damage analysis is missing. As a consequence, the aircraft is not optimally designed. A framework that combines a generalized physics based model, sophisticated real time monitoring strategies and realistic loading scenarios should be developed in order to fortify our confidence about composites materials.

This study deals with the fatigue loading during the testing procedure of polymer composites and proposes a more representative loading scenario. Up until now, researchers and engineers investigated the fatigue behavior of composites by performing experimental campaigns where they tested composite structures continuously until failure. Dedicated fatigue loading spectra were developed and the structures were loaded continuously until failure [1]. However, an aircraft is not loaded continuously under fatigue loading but the fatigue loading is interrupted, i.e. due to parking or downtime periods. During these periods the aircraft faces only dead loads caused by its own weight. This type of constant loading promotes creep which may affect the strength and stiffness of the polymer composites due to their viscoelastic nature or, on the other hand, give the time to the structure to rest expanding its fatigue life [2].

2. Experimental procedure

An experimental campaign is proposed where constant load is added before and after of each fatigue loading block. This way, creep phenomena can be investigated and a more realistic

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loading scenario is taken into account, especially for midrange flights where the parking time of the aircraft is significant in comparison to the flight time.

Unidirectional (UD) Carbon Fiber Reinforced Polymer (CFRP) coupons are tested. Figure 1 illustrates schematically the loading of the specimens, which represents the loading scenario of the lower wing of an aircraft. The red line highlights the constant compressive load.

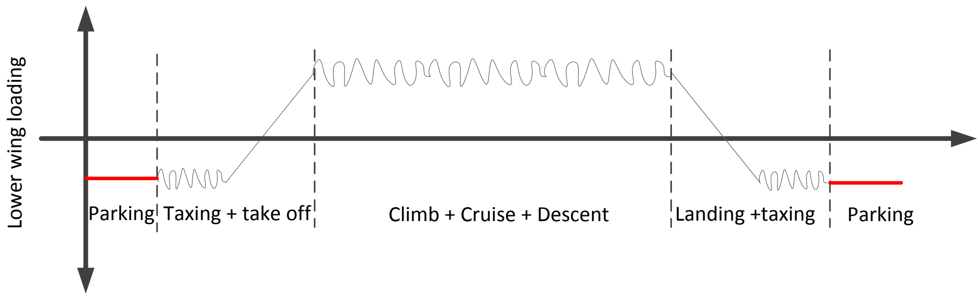

Figure 1. A schematic of the loading for the lower wing of an aircraft

The campaign consists of two testing phases:

- N number of blocks until failure where each block has the following loading sequence: constant fatigue C-C, constant fatigue T-T, constant fatigue C-C.
- N number of blocks until failure where each block has the following loading sequence: constant compressive loading, constant fatigue C-C, constant fatigue T-T, constant fatigue C-C, constant compressive loading

Table 1 presents the testing parameters; frequency, R ratio, maximum load and duration of each sequence.

Table 1. The testing parameters.

Loading sequences	Frequency	Ratio	Maximum load	Duration
Constant fatigue C-C	f=5 Hz	R=10	10% of the ultimate strength	6000 Cycles
Constant fatigue T-T	f=5 Hz	R=0.1	80% of the ultimate strength	54000 Cycles
Constant compression loading			5% of the ultimate tensile strength	20 min

Acoustic Emission (AE) technique is employed in order to monitor the damage progression and accumulation during the two different type of tests. It is found that the acoustic emission patterns in terms of number and distribution of events over the duration of the tests and energy accumulation is different for the two types of tests. The results indicate that the damage process on CFRP structures is different when creep is present.

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