A MULTIPLE SPECIMEN METHODOLOGY FOR CRACK GROWTH UNDER FATIGUE LOADING OF DOUBLE CANTILEVER BEAM SPECIMENS

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Abstract

High-cycle fatigue tests require long time periods to achieve the required number of cycles. In addition, the accurate evaluation of the fatigue life is a challenging process due to experimental complications such as crack length monitoring. In order to reduce the large test times and to develop a set-up which can be implemented in an industrial environment, a multi-fatigue set up for mode I DCB tests has been developed. The tool is capable to test 6 specimens at a time. The aim of this work is to illustrate the test methodology and to investigate onset and crack growth rate propagation using the multi-fatigue test set-up. To prove the test method, an onset curve and crack growth rate curve are obtained in a single test from a batch of 6 specimens. This study evaluates the sensitivity to pre-bond moisture of bonding agents for composite repairs.

1. Introduction

The prediction of the fatigue life of a structural component is a challenge due to the complexity of characterizing the material behavior and the usual uncertainty of the loading spectrum. In the design of composite materials, a particular attention has been devoted to the fatigue behavior of interlaminar cracks and bonded joints [1-4]. These studies are addressed in two potential directions: the identification of the number of cycles required to cause damage at the crack tip (the corresponding onset test is normalized by ASTM [5]) or to determination of the crack growth rates as a function of the loading intensity (expressed in terms of the energy release rate or the stress intensity factor).

Due to the heating of the composite materials if high loading frequencies are applied, tests are often performed at frequencies below 10 Hz. Such low frequencies, in turn, leads to tests that can last for a fraction of a week if information at a high number of cycles is desired. An additional experimental complexity of fatigue testing is related to the need to monitor the crack length in order to deduce crack growth rates, da/dN.

In this communication we present an experimental setup devised to perform a batch of fatigue tests over up to 6 specimens simultaneously. This fixture is used in combination with an experimental procedure based on the real time monitoring of the specimen's compliance. With both developments, fatigue testing becomes a more robust and objective procedure as compared to the traditional approaches.

The proposed methodology is used to analyze the fatigue behavior of bonded joints for composite repairs. The sensitivity and reproducibility of the technique is clearly illustrated with the crack growth rate curves obtained for those interfacial failure modes.

2. Experimental

Mechanical tests were performed in a 25 kN MTS hydraulic testing machine equipped with a bedframe capable to test 6 specimens at a time. Each test station was equipped with a load cell of 1.25 kN. Each specimen was mounted into the fixture system using a mechanical clamping device. Through the use of this clamping system it was possible to test at different levels of energy release rate and load ratios in one single-shot test. The parameter that had to be coincident for all specimens of the batch is the amplitude of displacements, $\Delta\delta$, not the minimum displacement, δ_{min}, nor the maximum, $\delta_{max.}$

In this work, the frequency was kept constant at 5 Hz for all specimens, with a load ratio of 0.1. The only varying parameter was the maximum energy release rate; it was decreased from 90% to 10%. All tests were carried out under displacement control. In order to determine the location of the crack tip during the test a compliance calibration was performed. Besides, this compliance calibration allowed to set-up the maximum energy release rate for each specimen before the cyclic test. This was achieved by increasing the distance between the load application point and the crack front.

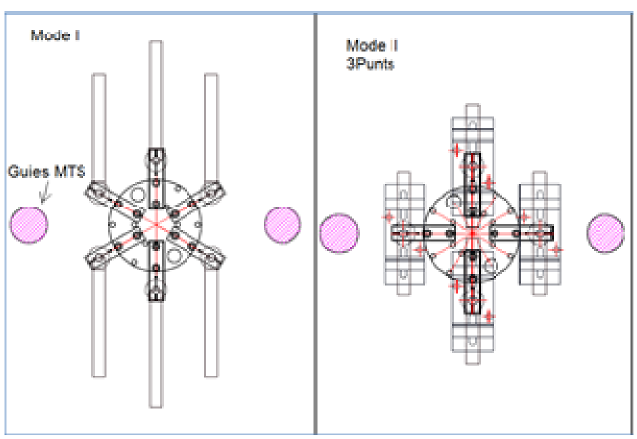

Figure 1. Specimen distribution for Mode I and mode II fracture tests in the multispecimen testing rig

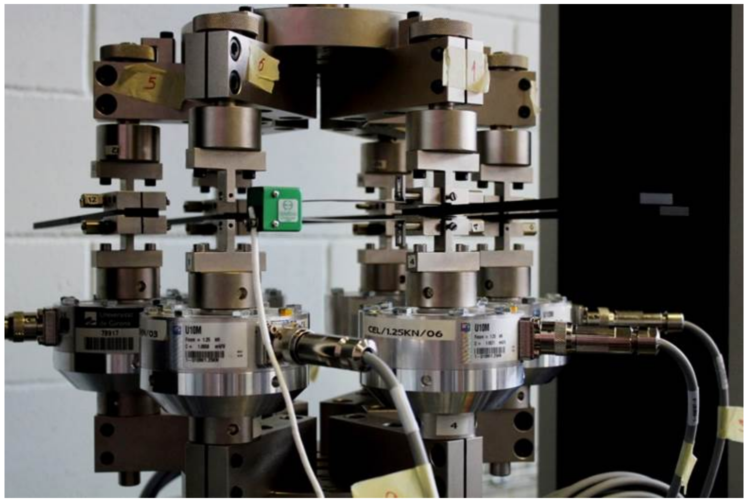

Fig.2. Experimental set up with a COD extensometer attached on pin.

3. Results

During the fatigue test the compliance was continuously monitored. As a criterion for the onset propagation, an increase of the compliance by 1%, 2% and 5% was taken into account, which could be determined with a precision of 1 cycle. By means of the compliance calibration a continuous relationship between the crack propagation against the number of cycles was obtained, and consequently a continuous crack growth rate curve.

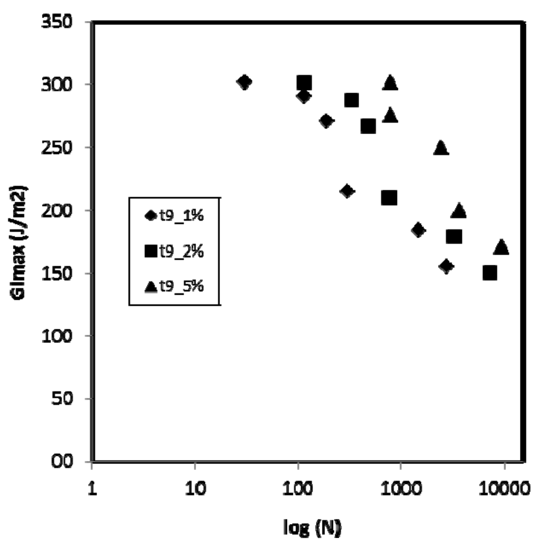

Fig. 3. Variation of onset life with G_{Imax}

Fig.4. shows the crack growth rate data, da/dN, versus G_{Imax} for six specimens tested with different energy ratio, from 90% to 40% of the static treshold.

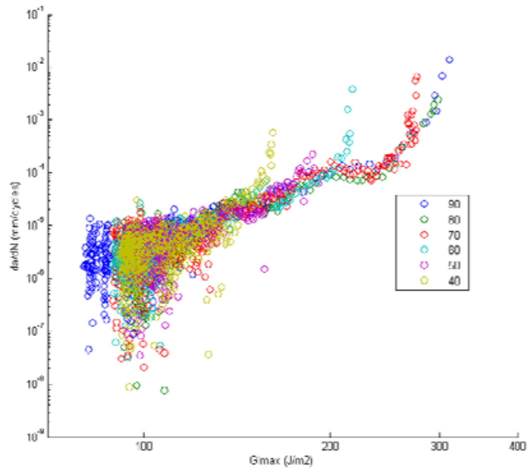

Fig. 4. Fatigue crack growth rate (da/dN) versus maximum strain energy (G_{Imax})

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