DYNAMIC MODE I DELAMINATION OF COMPOSITE LAMINATES USING A DROP-WEIGHT TOWER AND OPTICAL DATA-ACQUISITION

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Abstract: Impact events can hardly be called quasi-static. To test for relevant properties with quasi-static test methods thus seems to make little sense, especially when materials with a rate-sensitivity are the subject of testing. Therefore, a test setup is developed to obtain the traction-separation behaviour and fracture toughness of composites in mode I delamination at impact rates of deformation. An optical technique is applied to obtain the load-deflection curve, allowing for contactless measurements.

1. Introduction

There is evidence for the variation of some mechanical properties of composites with strain rate [1]. Delamination characteristics could be experiencing the same variation. It is thus possible that material properties obtained using a standard quasi-static delamination test method are not representative for dynamic events.

The goal of this work is to develop a method to analyse composite dynamic delamination behaviour in mode I. A separation speed of the cantilever legs of at least 1 m/s is aimed for. A drop tower is modified to perform the delamination tests. The literature contains some records of other researchers' work to reach this specific goal [2], [3]; in this paper an alternative methodology is developed. To prevent unwanted influence of the measurement equipment on the movement of the specimen during the dynamic event or vice-versa, a contactless optical tracking technique is used to obtain the relevant experimental results.

2. Method

A support structure is designed where a block on the top leg of a double cantilever beam (DCB) specimen is connected to a rotating support, while a block attached to the bottom leg is allowed to move freely (see figure 1). The DCB specimen and top block are perforated, allowing a slender pin connected to the drop-weight to hit the bottom block without touching anything else. The perforation does increase the amount of specimen preparation, but it facilitates setup alignment and reduces the setup complexity.

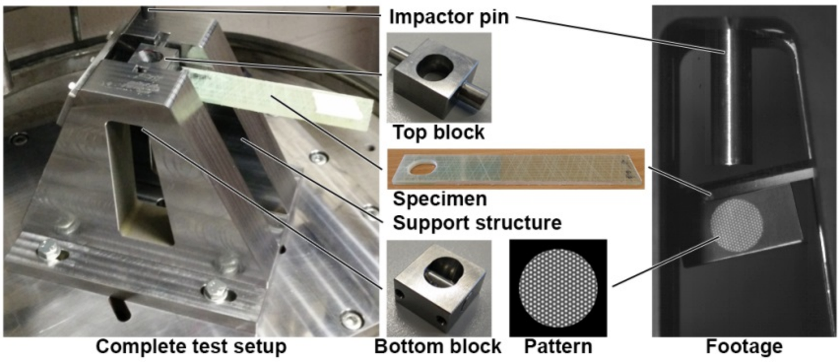

Figure 1. Overview of test setup and footage

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An optical pattern, which is a combination of three line sets, is attached to the impactor and bottom block on the specimen (see also figure 1). Each pattern is recorded by a high-speed camera, and a third camera records the delamination progression. A Fourier analysis of the spatial frequencies on the images allows for an accurate measurement of the position, which can be used to compute velocities, accelerations and forces occurring during a test.

Dynamic delamination tests are carried out by letting the drop-weight fall on a statically pre-cracked specimen mounted in the setup, whereby the pin hits the bottom block a single time, which in turn freely moves away downwards, only restricted by the bottom leg of the DCB specimen. The inertia of the bottom block then causes the delamination to propagate.

3. Results

Typical raw test results are shown in figure 2. The acceleration of the bottom block is depicted on the right, which has been calculated from the displacement signal shown on the left. Naturally, there is more noise in the acceleration signal, mainly due to dynamic effects of the experiment and possibly also as a result of the numerical differentiation, so some data smoothing might be necessary.

Delamination progression is recorded by analysing the footage of the side of the specimen and thus assuming the delamination front is straight. Delamination velocities between 2 and 20 m/s have been reached, with separation speeds between 2 and 4 m/s.

The next step is to connect the acceleration to the vertical end load on the DCB specimen, and relate this load and the corresponding displacement and crack length to the fracture toughness and traction-separation response.

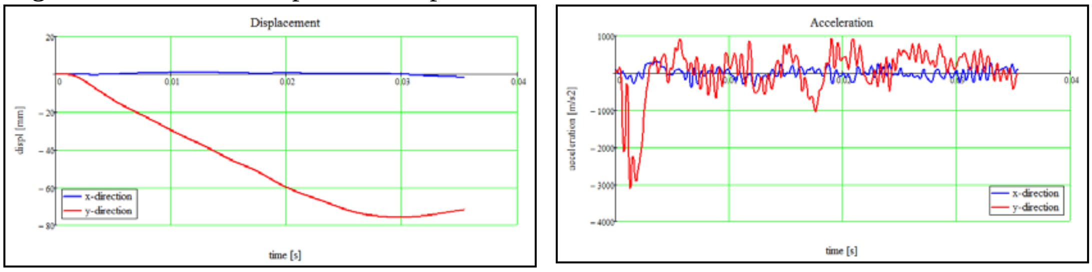

Figure 2. Typical raw test results: displacements and accelerations in x-direction and y-direction

4. Conclusions

The developed dynamic mode 1 delamination setup is capable of successfully delaminating composite DCB specimens, and the optical measurement technique provides the position of the specimen accurately enough to be used to compute the loads acting on the specimens.

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