Automated Double Cantilever Beam test system – A two-axis moving camera setup controlled by image analysis for crack recognition

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Composite materials are increasingly being used in structural components in industries where weight and demanding mechanical properties are important design criteria. To meet these high industrial standards the research and development in composite materials is a significant part of the industry. With the development of new materials and production methods, the need for mechanical testing will be inevitable to define the mechanical properties of the composite material. The most common type of failure in laminated composite materials is the separation of individual layers; delamination or interlaminar fracture. The experimental determination of the interlaminar fracture toughness is generally done by the Double Cantilever Beam (DCB) test, for laminated composite materials first developed by Wilkins et al. [1].
The standard configuration of DCB specimen is shown in fig. 1. Load blocks are bonded onto the surface of the unidirectional laminated specimen, to secure the application of the load in a straight line. The initial delamination is introduced in the specimen by positioning a thin film at the mid-plane of the composite laminate during the production process. On one side edge of specimen a white paint is applied to ensure a high optical contrast between the laminate and the growing crack front.

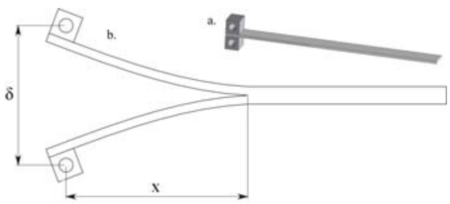

Figure 1: *Three dimensional view (a) and schematic diagram (b) of a DCB specimen.*

When executing a DBC test, following the common standard ISO 15024 [2], multiple parameters have to be recorded for the determination of the fracture toughness, GIc. Two data lines for the load and displacement of the specimen are directly extracted from the tensile testing machine and are relatively easy to record during the experiment.

A third parameter is more complex to determine, this is the distance from the load line to the crack tip, the delamination length, x (fig. 1). This research is focused on the identification and position of the crack tip.
The delamination length is currently determined at a limited number of points (typical 10-15) on the specimen by an observer moving a microscope along with the crack tip during the experiment. In the situation where no moving microscope is available the delamination length is measured in a post process at multiple pre-marked points on the specimen. Both manual methods have disadvantages; in the accuracy of the determination of the crack length, require a skilled observer and are time-consuming. To exclude the manual observation of the delamination length and thereby increase the accuracy and repeatability

of the test an automated test system is designed.

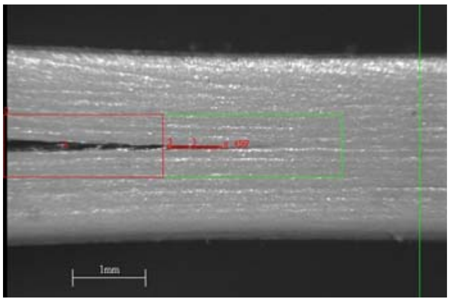

Figure 2: *Acquired and processed image of a DCB specimen at the crack tip.*

The hardware of the system consists of a CCD camera mounted on a two-axis linear actuator controlled by a stepper motor for each direction. This setup is mounted behind the tensile tester perpendicular to the mounted specimen. With the macro zoom lens fitted on the camera a meso-scale image of the side edge of the specimen is acquired with an image size of approximately four millimeters in height, see fig. 2 for a typical acquired image.

The processing of the acquired images is done real-time in the NI Labview platform at a rate of one frame per second. In this cycle the individual image is converted to a binary image by a threshold operation and a Region Of Interest (ROI) is defined. Within the ROI an object detection is executed, combined with the set boundary conditions for ia. minimal object size and contrast ratio, multiple dark objects are identified. In fig. 2 the red objects are numbered within the green ROI square. The object with the largest x-coordinate is selected as the location of the crack initiation. The coordinates of the crack tip are used to update the camera position every cycle. The delamination length is obtained by the current camera position and the crack tip coordinates in the acquired image.

Experiments with the operational system have been performed with thermoplastic composite (CF/PEI) laminates with good results. A significant improvement is made compared to the manual analysis; the interlaminar fracture toughness is determined at every data point (1Hz) and is not limited to a number of manual observations. The automated system has been compared to a manual analysis for a single specimen, first automatically tested and post-processed manually. The automated system has a tendency to underestimate the delamination length, caused by the conversion to a binary image in the first step of the process. This is related to the limited number of available pixels of the used camera compared to the height of the crack opening at the tip. The height of the crack-opening near the crack tip is possibly less than one pixel and therefore information is lost by the threshold operation.

Continuous research will involve performing automated DCB experiments on thermoplastic laminates, the acquired data will be used to improve and quantify the system. The automated DCB test system should contribute to the reliable and time efficient execution of delamination toughness experiments in academic and industrial environments.

References

1 D.J. Wilkens, J.R. Eisenmann, R.A. Camin, W.S. Margolis, and R.A. Benson, ASTM STP-775 (1982)

2 ISO 15024, ISO Central, (2001)