ACCURATE CHARACTERISATION AND MODELLING OF THE NONLINEAR BENDING BEHAVIOUR OF NON-CRIMP FABRICS FOR COMPOSITE PROCESS SIMULATIONS

Peter H. Broberg[1], Esben Lindgaard[1], Christian Krogh[1], Adam J. Thompson[2], Jonathan P.-H. Belnoue[2], Stephen R. Hallett[2] and Brian L. V. Bak[1]

[1]The CraCS Research Group
Department of materials and production, Aalborg University, Fibigerstræde 16, Aalborg Ø, Denmark
Email: phb@mp.aau.dk, web page: www.cracs.aau.dk

[2] Bristol Composite Institute,
University of Bristol, Queens Building, BS8 1TR, Bristol, UK

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ABSTRACT

Simulation of the manufacturing processes of composite structures is being used increasingly to obtain defect-free manufacturing and investigate the effects of process parameters. The manufacturing of wind turbine blades (WTB) is considered in this work. The general trend in the industry is to form stacks of bindered non-crimp fabrics (NCFs) simultaneously to decrease the processing times. These stacks are referred to as preforms. On the other hand, forming of multi-layered fabrics may cause wrinkling (fibre waviness), which in WTBs can cause a knockdown in the strength of up to 66% for some wrinkle configurations [1]. To predict fibre wrinkling, the bending behaviour of the fabric materials needs to be accurately characterised and modelled [2]. Numerous methods for characterising the bending stiffness of fabric materials have been studied in the literature, but they all suffer from either expensive equipment or uncertainties in the data processing schemes [3]. Furthermore, most conventional models of fabric materials consider a constant bending stiffness, which causes the size of the wrinkles to be overpredicted [4], as shown in Figure 1. In the current work, an experimental methodology for automatic and reliable characterisation of fabric bending stiffness is presented together with a model that is capable of accurately simulating the nonlinear bending response of fabric materials.

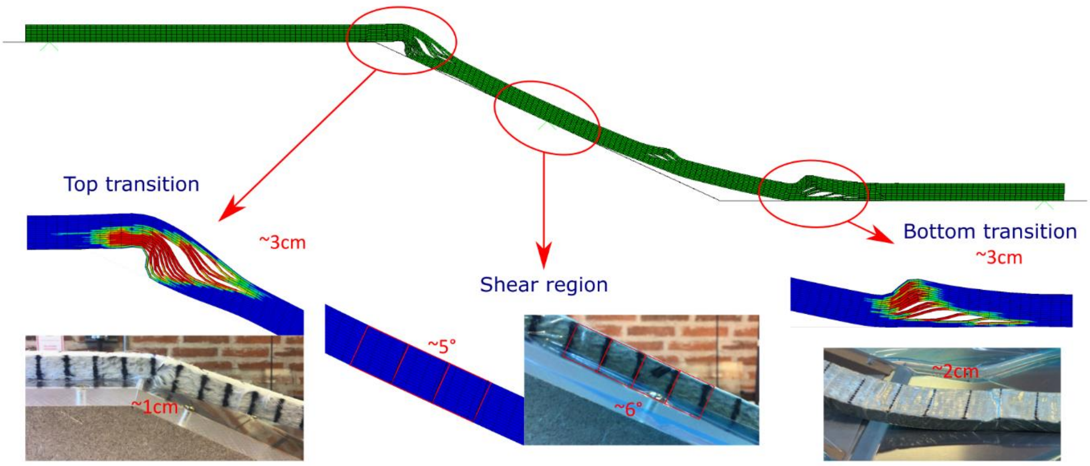

Figure 1: Simulation of the forming of a binder-stabilised preform over a z-transition [4].

Uni-directional NCFs are considered in this work. The cantilever bending test is used to characterise the nonlinear bending behaviour of the fabric, see Figure 2. In this test, a single image of a cantilevered fabric specimen can be used to compute a nonlinear moment-curvature relationship of the fabric. A novel automated image processing algorithm is proposed in this work to extract the deflection curve from the image of the cantilevered specimen, and a smoothing spline is fitted to this deflection curve. The smoothing spline only requires one parameter, which is chosen automatically through cross-validation. This makes the method independent of user-set parameters and allows accurate and automatic calculation of the bending stiffness with ***just one click***.

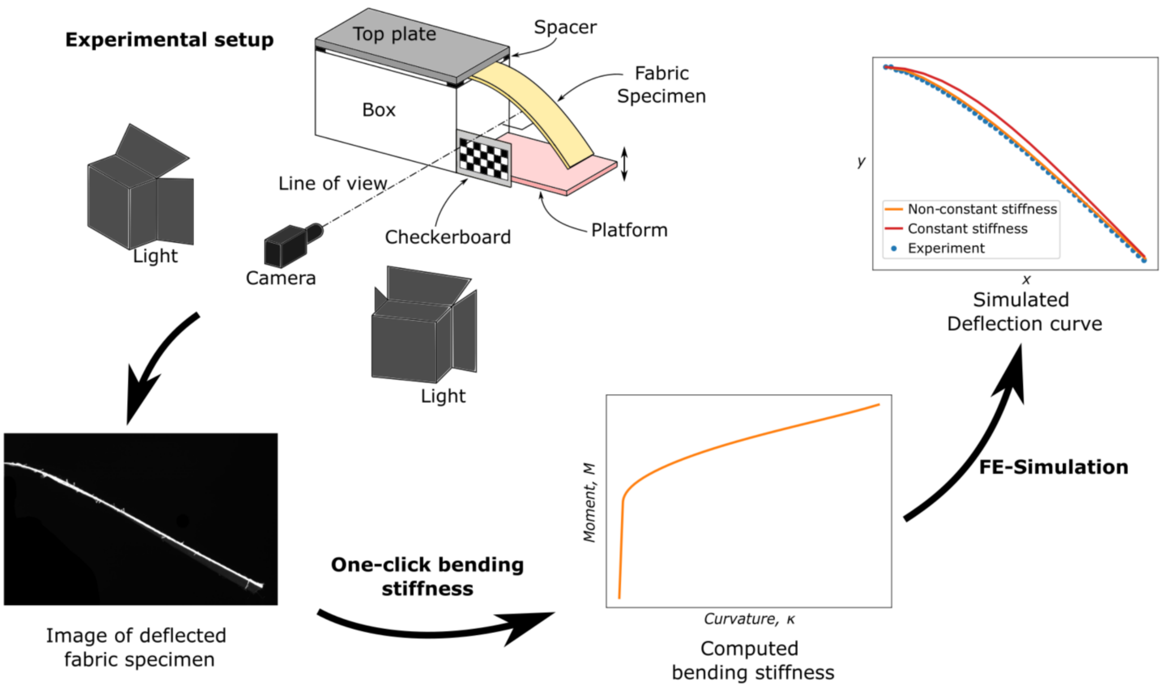

Figure 2: Experimental setup for the cantilever bending test. From an image of a deflected fabric specimen, the *one-click bending stiffness* algorithm calculates the bending stiffness automatically.

The computed bending stiffness is inputted in a finite element model of the NCFs. A comparison of the model using the non-constant and constant bending stiffness is shown in Figure 2. The bending model with non-constant bending stiffness is capable of accurately representing the cantilevered specimen, while the model with constant bending stiffness only estimates the deflection curve in an average sense. The model with non-constant bending stiffness is, thus, better suited for simulating wrinkles with high curvature, as is the case for the forming of binder-stabilised preforms in WTB manufacturing, see Figure 1.

In conclusion, the methods presented in this work can be used to accurately measure and simulate the nonlinear bending behaviour of fabric materials. At *CompTest* the novel methodology for characterising the bending stiffness will be presented in detail together with additional results on the use of the measured bending stiffness in process simulation models.

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