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Measuring and Modelling the In-Plane Bending Stiffness and Wrinkling Behaviour of Engineering Fabrics

Philip Harrison[1], Drew Anderson[1], Marcos F. Alvarez[1], Eshan Bali and Yuri Mateos

[1] School of Engineering, University of Glasgow, University Avenue, Glasgow, G12 8QQ, UK

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In this investigation two simple tests are conducted to characterise the shear, out-of-plane bending stiffness and in-plane bending stiffness of engineering fabrics and to investigate their wrinkling response during shear. A cantilever bending test [1] is first used to measure the out-of-plane bending stiffness while a modified version of the uniaxial bias extension (UBE) test is used to explore both the in-plane shear and the in-plane bending stiffness of the fabric (see Figure 1a). An estimate of the shear resistance of the fabric is obtained using normalisation theory [2]. In [3] it was shown that, for a given tensile stiffness in the two fibre directions, the in-plane deformation kinematics of the specimen are determined by the ratio between the fabric's in-plane shear stiffness and in-plane bending stiffness. Thus, by measuring the fabric kinematics together with the shear stiffness of the fabric, the in-plane bending stiffness of the fabric is inferred using an inverse modelling approach. This is the first occasion that the in-plane bending stiffness of an engineering fabric has been estimated based on experimental data.

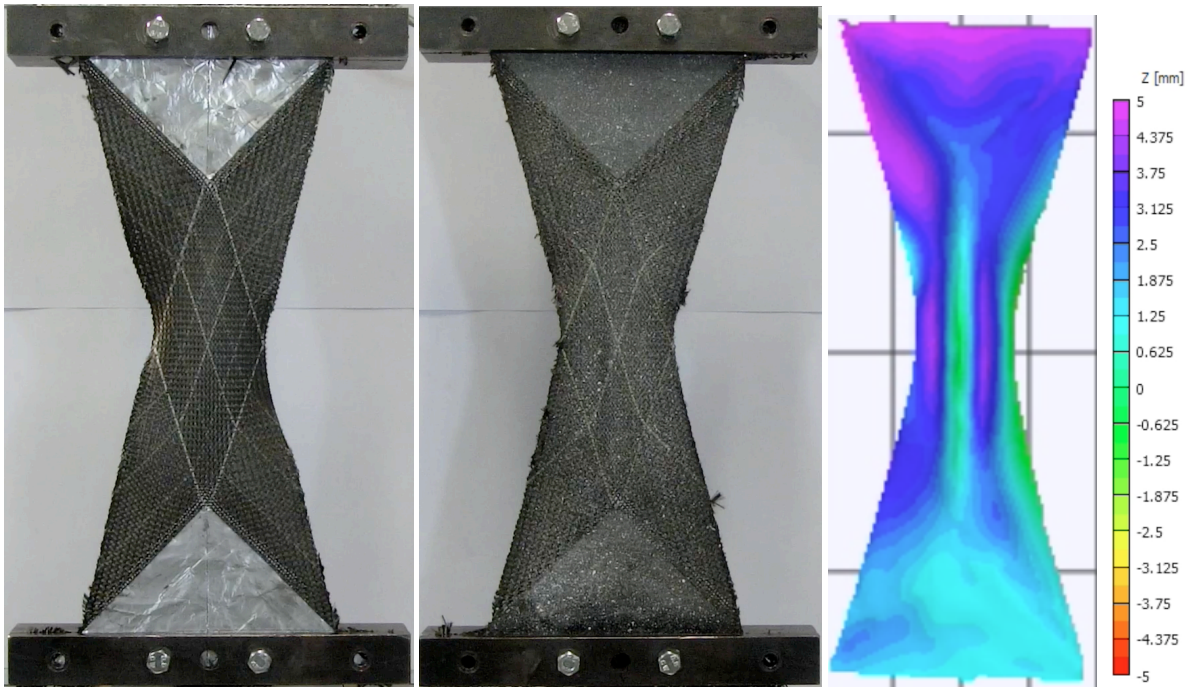

Figure 1. (a) Modified uniaxial bias extension test showing aluminium bonded to fabric to completely immobilise deformation in this region (b) modified uniaxial bias extension test specimen treated for digital correlation tests (c) typical digital image correlation result, the colour map indicates the out-of-plane displacement of the test specimen in mm.

Numerical results presented in [3] also suggested that the wrinkling onset angle in the UBE test is a function of the combined tensile, shear and bending properties of the fabric. Thus, each of these must be correctly modelled if the wrinkling behaviour of the fabric is to be accurately predicted. The ability to predict the wrinkling behaviour of a fabric in a UBE test therefore

provides a demanding criterion with which to evaluate the comprehensive forming predictions of fabric forming simulations. Thus, the aim of this investigation is to determine if, using the measured out-of-plane bending stiffness, shear stiffness and in-plane bending stiffness, the wrinkling behaviour of a fabric specimen of the UBE test can be predicted. A strong specimen size dependence of the wrinkle onset angle has been observed in experiments; consequently a goal is to determine if this size dependent wrinking behaviour is also observed in numerical simulations. In order to accurately characterise the wrinkling behaviour, digital image correlation tests have been conducted on carbon fibre a treated twill-weave fabric (see Figure 1b) to accurately measure out-of-plane displacement of the fabric during the test (see Figure 1c).

REFERENCES

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