SIMPLIFIED APPROACHES TO
BUCKLING AND ULTIMATE STRENGTH OF COMPOSITE PLATES

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Summary. Plates of fibre-reinforced composite materials are widely used in wind turbine blades and in certain types of ships. The work reported here concerns the ultimate strength of simply supported plates subjected to uniaxial in-plane compression load and is part of a wider study of approaches to predicting the buckling behaviour and ultimate strength of composite plates. In the first stages of this study the influence of various simplifications such as the following are being examined for plates with various thicknesses and lay-ups:

• Use of small-deflection theory as opposed to fuller non-linear theory that models postbuckling behaviour.
• Neglect of out-of-plane shear deformation, and simplified modelling by first order shear deformation theory.
• Simplifications in the way degradation is modelled in successive plies.

In the present paper, an analytical approach to buckling analysis assuming small deflections combined with first order shear deformation theory (FSDT) is presented for simply supported plates. Plates having a range of thicknesses and initial geometric imperfections have been investigated for first ply failure. Then simplified degradation models have been applied to reduce the material properties and the ultimate load has been estimated by investigating a last ply failure condition. To validate the method, FE analyses are performed using ANSYS, and the results are also compared with the parametric studies conducted by Misirlis [1].

An evaluation is made of the influence of neglecting post-buckling effects in the linearised (small-deflection) buckling analysis. Different failure criteria are applied to investigate the occurrence of first and last ply failure. A linear degradation model is adopted in association with the Hashin failure criterion, and an instantaneous degradation model with the Tsai-Wu failure criterion. In both cases a simplification is first made in that the same degradation is applied to an entire ply. In a slightly more detailed model, degradation is limited to specific regions. The effects of initial geometric imperfections of differing amplitudes on the ultimate
compressive strength are investigated.

The simplified model presented here is based on solving the differential equations describing the buckling problem. The following double Fourier series, as used in the Navier solution for a thin plate, is assumed to represent the plate deformation [2]:

$$w(x, y) = \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} w_{mn} \sin \left( \frac{n\pi x}{a} \right) \sin \left( \frac{m\pi y}{b} \right)$$

For increasing applied load, each ply is checked for failure. In the ply, or the region of a ply, which has exceeded a given stress criterion, the corresponding properties are degraded. The applied load is again increased until either a further criterion is exceeded in the same region or failure occurs in a different ply or region. The associated properties are also degraded, and the process is continued until the occurrence of last ply failure.

The full paper will show the results based on the simplified method compared to Misirlis’ analysis using ABAQUS [1].

The linearised model provides a useful approach up to first ply failure. However, a more advanced model that traces the post-buckling behaviour is needed to give a better match to the ultimate loads predicted in the parametric studies conducted in ABAQUS.

REFERENCES
