11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

POSTBUCKLING OPTIMISATION OF VARIABLE ANGLE TOW, VARIABLE THICKNESS, COMPOSITE PLATES USING LAMINATION PARAMETERS

Zhangming Wu[1], **Gangadharan Raju**[1] **and Paul M Weaver**[1]

[1] Advanced Composite Centre for Innovation and Science, Department of Aerospace Engineering, Queen's Building, UniversityWalk, z.wu@bristol.ac.uk

Key words: *Optimisation, Postbuckling, Variable Angle Tow, Variable Stiffness, Lamination Parameters*

This paper presents a two-level optimisation strategy for the design of postbuckling performance of orthotropic Variable Angle Tow (VAT) composite using lamination parameters as design variables. For the postbuckling analysis [2], a semi-analytical formulation based on a mixed variational approach is developed using the Rayleigh-Ritz method [1]. The non-linear algebraic equations are solved by use of a perturbation technique. The objective function for the optimisation of postbuckling behaviour of composite plates is to minimise either the maximum normal displacement or the end-shortening strain in the loading direction. In the first level, the variation of lamination parameters over the planform of VAT plates is represented in the form of B-splines. A gradient-based algorithm (GCMMA) is used to determine the optimal distribution of lamination parameters. In the second level, the target distributions of lamination parameters are converted into realistic VAT layups using a genetic algorithm. The thickness variation is also taken into account in the optimisation process as an additional design factor to further improve the postbuckling performance of VAT plates. Finally, numerical examples are studied and compared with the optimal solutions obtained by a direct genetic algorithm approach. The robustness and computational efficiency of the proposed methodology for the optimal design of postbuckled VAT laminates are demonstrated.

The optimal layups which give minimum end-shortening strain or the maximum transverse displacement may be different when the level of axial compressive load N_{x0} is changed. The value of axial load N_{x0} is fixed to be twice of the critical buckling load ($2N_{iso}$) of an equivalent quasi-isotropic laminate. The optimal variations (7×7 control points) of the four lamination parameters of VAT plate that gives minimum end-shortening strain ϵ_x are plotted in Fig. 1.

The postbuckling equilibrium paths for the optimised constant stiffness and VAT laminates are compared and illustrated in Fig. 2. The layup $[\pm 45/0_6]_s$ gives the minimum

end-shortening strain among the constant stiffness laminates. VAT #1 is the optimal design using a direct GA approach [2], and VAT #2 is the optimal design using lamination parameters. The numerical results demonstrate the robustness and computational efficiency of the proposed optimisation methodology for the postbuckling design of VAT plates.

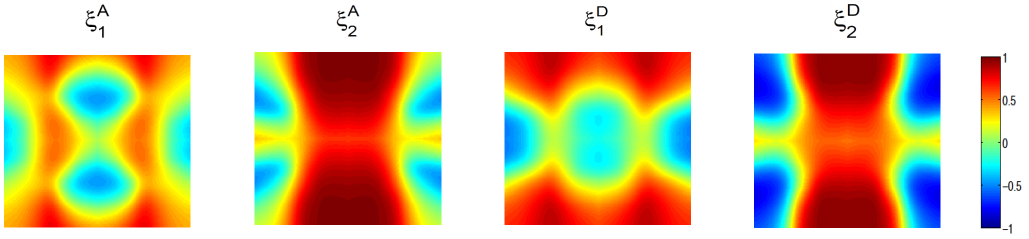

Figure 1: Optimal lamination parameter distribution of a square VAT plate that gives minimum end-shortening strain under a given uniaxial compressive loading ($N_{x0} = 2N_x^{iso}$), 7×7 control points of B-splines

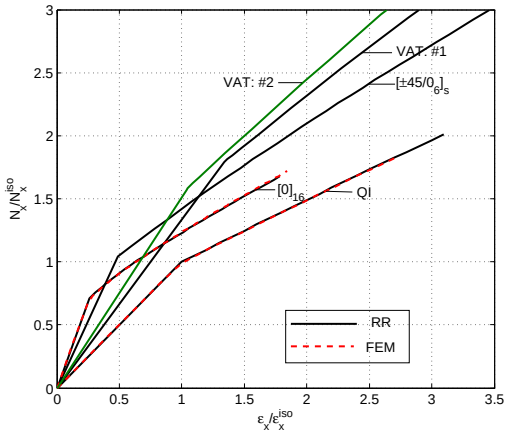

Figure 2: Normalised axial loads $N_x = N_x^{iso}$ versus normalised axial strain.

REFERENCES

[1] Wu, Z., Weaver, P. M., Raju, G., and Kim, B. C., Buckling analysis and optimisation of variable angle tow composite plates. *Thin-Walled Structures*, Vol. 60, No. 0, 2012, pp. 163 – 172.

[2] Wu, Z., Weaver, P. M., and Raju, G., Postbuckling optimisation of variable angle tow composite plates. *Composite Structures*, Vol. 103, No. 0, 2013, pp. 34 – 42.

[3] Z. Wu, G. Raju, P. M. Weaver, Postbuckling analysis of variable angle tow composite plates. *International Journal of Solids and Structures*, Vol. 50, No. 10, 2013, pp. 1770 – 80. .