Structural optimisation has been performed on the external aerodynamic shell from a 39m low wind speed wind turbine blade. The material layer thicknesses of the aerodynamic shell were varied in order to minimise mass. Local deflection, strength and buckling constraints were imposed. The result was a lighter aerodynamic shell than the baseline blade with aerodynamic shell parameters taken from an equivalent high wind speed blade.

**Keywords:** composite materials, buckling, optimisation, wind turbine blade.

**INTRODUCTION**

Wind turbine blades are large composite structures with complex geometry. Finite element analysis enables a designer to represent the geometry and materials distribution of a wind turbine blade accurately, whilst reducing analysis time and the number of prototypes required. Numerical models also allow the possibility of applying mathematical optimisation algorithms to the design problem, a technique which forms the basis of many recent studies. Modern wind turbine blades are up 85m long, and consist of varying composite materials layups throughout the structure (see Figure 1).

The large physical size combined with complex aerodynamic loads results in large computational requirements for the numerical model. This is of particular concern in structural optimisation, as the model is analysed thousands of times. Because of this, simplified models are typically used in wind turbine optimization problems. In many cases, the geometry is simplified by considering only the internal spar of the wind turbine blade, and neglecting the structural effect of the external aerodynamic shell (Figure 2). This approach...
greatly reduces the complexity of the optimisation problem and the size of the numerical model. The spar-only simplification is conservative, in that it underestimates the stiffness of the structure. This means that blades designed using this approach will tend to exceed structural requirements, however this is at the cost of increased mass. Given that the aim of a structural design optimisation is typically to minimise mass, optimisations performed on a spar-only model could therefore be improved if the structural effect of the aerodynamic shell were considered.

The aerodynamic shell faces very different design requirements to the structural spar. Whereas the driving design constraint for the spar is typically global deflection, the aerodynamic shell is constrained primarily by local deflections and buckling constraints. The two components can therefore be considered separately for the purposes of preliminary design, in order to reduce the number of parameters considered.

This work considers the aerodynamic shell of a 39m low wind speed blade, expanding on a design previously developed by the present authors (Barnes et al., 2015). In the previous work, the structural spar was optimised to minimise mass subject to strength and deflection constraints. The blade is predominately made of glass fibre reinforced polymer (GFRP), with sandwich sections in the shear webs and the trailing edge, as indicated in Figure 1.

A finite element model of the blade has been created in ANSYS, using shell elements. The blade model is subjected to extreme loading, corresponding to the maximum gust wind speed with a 50 year return period. The optimisation problem is defined as minimisation of mass, subject to local deformation, strength and buckling criteria. The design variables are the thicknesses of the angle ply skins for both the leading and trailing edge sections and the sandwich core layer of the trailing edge.

RESULTS AND CONCLUSIONS

The results of the structural optimisation were compared to a baseline model with aerodynamic shell thickness parameters the same as an equivalent high wind speed blade design. The optimised structure had lower thicknesses and reduced mass compared to the baseline, as was expected due to the lower aerodynamic forces associated with the low wind speed conditions.

REFERENCES