Cluster B: Blades and Rotors (3 page version)

Blades and rotors

In 1997, the average nominal power of the wind turbines erected in Germany and Denmark was about 600 kW. In 2003 this average nominal power has grown to more than 1600 kW. The corresponding rotor diameter has increased from about 44 m to 70 m. Nowadays the first prototypes of 5 MW turbines are being erected with rotor diameters of more than 120 m.

These large wind turbines are generally more economical, especially for offshore applications. However, although the generated power increases with the square of the rotor diameter, the mass of the blades increases to the third power of the rotor diameter if the dimensions are simply scaled up. In a continuous effort to fight this square-cube law, rotor blade design is becoming ever more critical as the size of the turbines increase. Furthermore, almost all the loads on the whole wind turbine are introduced through or from the rotor.

A reduction in the uncertainty in the design calculations and material properties will give a more balanced design, resulting in a weight reduction and a more reliable wind turbine and therefore reduced costs of wind power. In order to accomplish a more balanced and reliable design, the designers must have a thorough understanding of all the aspects related to the material behaviour of the blades, the aerodynamics and the aero-elastic stability. Further, on top of all this, they must have available verified and qualified computer codes to perform detailed analyses of all load cases. The material properties should be consistent and well documented for all possible load situations and environmental conditions. To limit aerodynamic noise emission the designer must also be aware of the coupling between the aerodynamic and acoustic properties of profiles and blade tips.

In order to fill in some of the knowledge gaps faced by a designer, a number of projects are being carried out within FP5. Key areas where a lot of research is needed are aerodynamics, aero-elasticity and stability. The design tools currently available to the industry, still contain a lot of uncertainties and, especially in the field of aero-elastic stability, the available models have limited capabilities.

The KNOW-BLADE project aims to reduce the uncertainties in the aerodynamic and aero-elastic analyses by applying Navier-Stokes solvers instead of today's more common BEM (Blade Element Momentum theory) solvers. The areas looked into in detail include 2D and 3D modelling, blade tip problems and aerodynamic accessories such as vortex generators and stall strips.

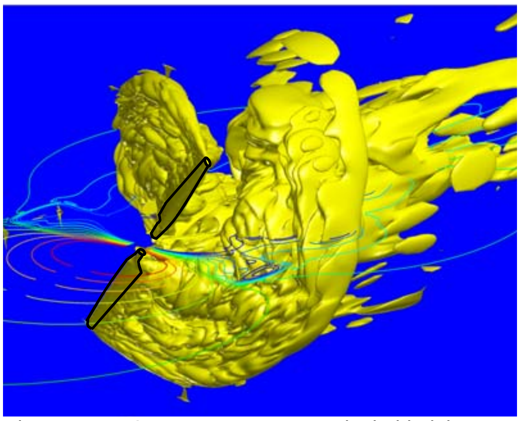

Figure X KNOW-BLADE: Vortex wake behind the NREL-Phase-VI rotor computed with the Detached Eddy Simulation technique

Another important issue in this field is the verification and qualification of the aerodynamic design tools. In order to enable the wind community to improve, qualify and verify their aerodynamic design tools an experimental database obtained under controlled and well-established conditions is needed. The MEXICO project aims at the provision of such a well-documented database through a set of detailed wind-tunnel measurements in the German Dutch wind tunnel DNW. An area closely related to this, is the production of aerodynamic noise from wind turbines, which is still one of the major hindrances for the onshore implementation of wind energy.

Figure X MEXICO: CAD drawing of model of wind turbine in the windtunnel

In the SIROCCO project an aerodynamic/acoustic design method is developed by which silent airfoils can be designed. The airfoils will be applied to existing turbines which will subjected to extensive measurements campaigns. As shown in the figure, the main cause of noise turns out to be the outboard part (but not the tip) of the downward moving rotor blade.

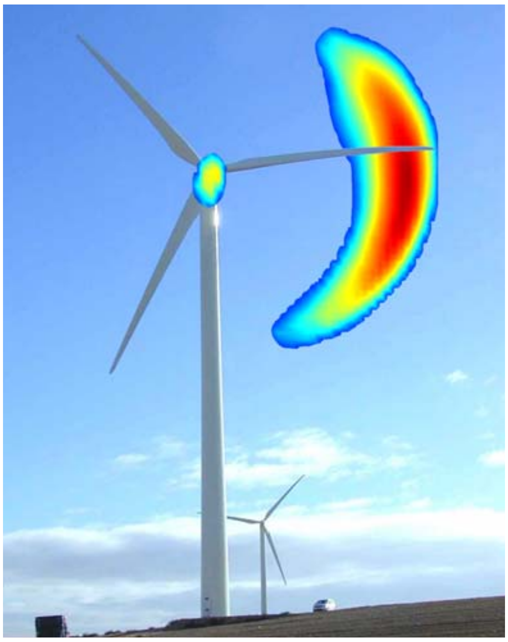

Figure X SIROCCO: Noise generated by wind turbine

To improve knowledge in the field of the aero-elastic stability and control of large wind turbines the project STABCON has been funded. Through the formation of a European Network on aero-elastic stability this project aims to develop reliable design tools for aero-elastic stability analyses and the optimisation of large wind turbines.

Figure X STABCON: Aeroelastic stability

Another key area where progress is being made is in the understanding of the material behaviour of blades. In particular the static and fatigue properties of fibre-reinforced blades is being investigated. As a part of this research, the OPTIMAT BLADES project is progressing with a detailed parametric study which will result in a comprehensive and consistent database for fibre reinforced materials, for use by the industry. Besides this database, design guidelines, ready to be implemented into the design standards, will be formulated.

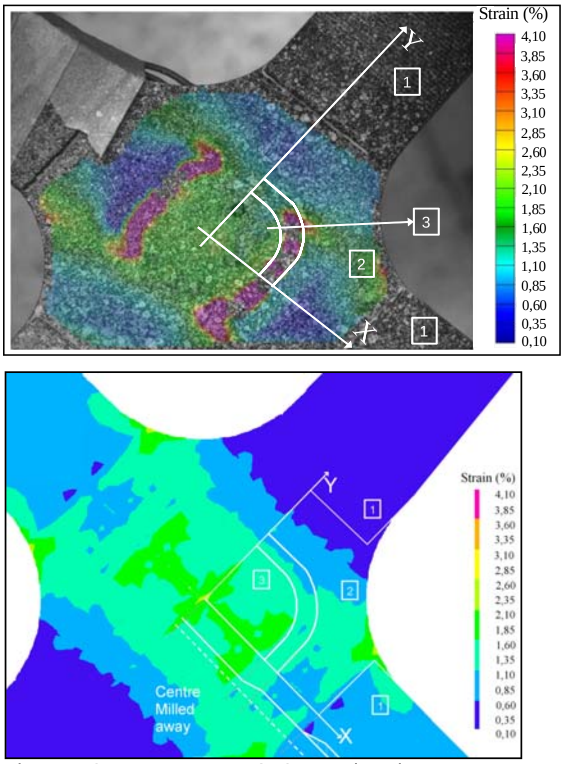

Figure X OPTIMAT BLADES: Comparison between isochromatic image and FE analysis of a bi-axially loaded cruciform specimen

At the intersection of material development and aero-elastic stability, research is being carried out on the development of damped composite blades. The DAMPBLADE project is focussing on using the benefits that can be gained from material damping in the design of large composite blades. As an additional result, the project will provide the wind industry with an analytical tool to incorporate the explicit modelling of composite structural damping in stability and fatigue analyses.

Figure X DAMPBLADE: Prototype damped blade tested at CRES'. Modal testing showed a nearly 80% increase in damping properties for the first flap and lag modes

Another innovative idea under investigation in the FP5 programme is the design and realisation of a fibre reinforced hub as an alternative to the conventional cast-iron hub used in the present generation of turbines. The COMHUB project has demonstrated that it is practical to produce a composite hub with a significant weight reduction over the conventional designs.

Figure X COMHUB: manufactured composite hub

The Future

After completing these projects, not all the problem areas and uncertainties will be solved. Further weight reductions can be achieved by the introduction of new materials, innovative and smart rotor designs, improved understanding of all the aerodynamic and aero-elastic phenomena, and supported by harmonised measurement and testing procedures. All this will be necessary to enable the industry to design the next generation of wind turbines aiming at enhanced reliability and efficiency and reduced environmental impact, to make wind energy competitive with other energy sources. This next generation might well include turbines larger than 8 MW introducing ever more challenging demands for the designers and the tools available to them.