Composite wind turbine rotor blades - materials, structural design and testing

Ole Thybo Thomsen

Aalborg University, Department of Mechanical and Manufacturing Engineering,

Fibigerstræde 16, DK-9220 Aalborg East, Denmark.

E-mail: ott@m-tech.aau.dk

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Abstract

The days of cheap and abundantly available energy are over. The industrialized world is running out of fossil fuels at a time when a paradigm shift in energy prices is occurring. It is clear that this century will be characterised by intensified competition for energy and this will inevitably push up prices, lead to periodic scarcity and precipitate a scramble for reserves among the world's main economic blocks. Moreover, the dependency on imported fossil fuel has become a threat to economic stability because of the impact of increased fuel prices on the long term cost base. Perhaps most importantly, there is a growing awareness of the irreversible and potentially disastrous effects of climate change, to which the burning of fossil fuels contributes. Therefore it is essential that the internal energy resources are developed to the maximum extent possible, and in addition that energy efficiency is promoted as well.

At the moment, the most promising and mature renewable energy technology appears to be wind power. Wind energy will not only be able to contribute to securing energy independence and climate goals in the future, it could also turn a serious energy supply problem into an opportunity in the form of commercial benefits, technology research, exports and employment. To meet these challenges, the number and size of wind turbines has increased strongly in recent years. This development is expected to expand significantly, especially with the installation and operation of large numbers of wind turbines in offshore wind parks.

The presentation will give an overview of the current status of wind turbine blade technology. Today wind turbine blades are typically being manufactured using polymer matrix composite materials, in a combination of monolithic (single skin) and sandwich structures. Over the last

25 years wind turbines have become significantly larger, from a rated power of 50 kW in the late 1970s to the multi-megawatt power plants of today. This trend is expected to continue for at least another decade. The largest modern wind turbines have rated power outputs of 6 MW or more and rotor diameters of more than 125 m. The driving motivation is that larger wind turbines have larger energy output per unit rotor area due to increased mean wind velocity with height. Moreover, even though larger wind turbines are more expensive to install and operate than smaller ones, the total production cost per kilowatt hour of electricity produced has generally decreased with increasing wind turbine size. An overview is given of the use of composite materials in wind turbine blades, including loads, common failure modes, strength-controlling material properties, test methods and finally future directions of wind turbine blade technology including condition monitoring.

Strain Based NDE for Wind Turbine Blade Composite Materials and Structures

Janice Dulieu-Barton

School of Engineering Sciences , University of Southampton, Highfield, Southampton SO17 1BJ.

E-mail: *janice@soton.ac.uk*

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Abstract

The presentation will start with an overview of the different types of strain based NDE covering white light, infra-red and coherent light applications. The work focuses on full-field techniques where a field of data is collected as opposed to the single point reading extracted from a strain gauge. The physics behind each technique is described and put into context of application to wind turbine blades.

The main topic of the presentation is application of infra-red techniques to the evaluation of composite materials and structures, such as those that make up wind turbine blades. Infra-red imaging is usually associated with fairly the crude temperature measurements made to assess the condition of structures and for thermal based non-destructive evaluations. Highly sensitive infra-red detectors are now available that allow high spatial resolutions along with temperature resolutions of about 20 mK. If lock-in processing is used the temperature resolution can be improved to 2 mK. A technique that takes advantage of the high spatial and temperature resolution of modern IR detectors is TSA (thermoelastic stress analysis). Here the infra-red (IR) detector is used to 'measure' the small reversible temperature change associated with the thermoelastic effect from a component subjected to cyclic load. The detector output signal is related to the changes in the sum of the principal stresses on the surface of the material. Therefore the 'thermal image' provides full-field data that is a function of the surfaces stresses. For orthotropic materials, such as laminated composite structures, the small temperature change is related to the changes in the stresses in the principal material directions on the surface of the material. The data is recorded and processed in a matter of seconds enabling practically real-time studies and hence providing clear benefit in damage evaluations. Some practical applications are presented including those from a blade test.