Project title	Evaluation of manufacturing methods and material selection for cost optimal rotor blades
Project number	TG4-2
Organisation	Chalmers University of Technology, Applied Mechanics
Project leader	Thomas Abrahamsson
Other participants	Anders T. Johansson (Postdoc)
Report for	2011-11-01 - 2014-09-30
Participating companies	DIAB, Marström Composite AB

Project description

A study made at the Linnaeus University in Kalmar on a request by Marström Composite AB shows that a significant reduction in rotor blade weight can be achieved when the design is swapped from a glass fibre composite design into a carbon fibre design with an autoclave manufacturing technique. In a comparison made against the most light-weight glass fibre blade on market, a reduction of about 11 metric tonnes, from 17.7 tonnes to 7 tonnes, was achieved for a 61.5 m long blade. Although we believe that a carbon fibre blade will be pricier than glass fibre blades, except for the most extreme MW wind turbines, we assume that the life cycle cost of the entire turbine system with such blades will be lower, resulting in less cost per produced electric energy. The reason for this is the exceptionally good fatigue strength of the autoclave hardened carbon fibre composite and its low weight that alleviate the gravity load on wind turbine components such as bearings, nacelle, yaw control system and turbine tower. Further use of stiffening polymeric foam may bring down the blade weight even further. That is by reducing the need for stiffening internal spars, ribs and load carrying hollow beams. Polymeric foam may also be added to the composite skin to increase the load carrying capability of the blade by eliminating buckling.

The industrial partners of this project have several interesting concepts, such as DIAB Core InfusionTM, prepreg without autoclave and prepreg with autoclave, for wind turbine blade design. These concepts are developed to suit their best design practice experience and production infrastructure. Amongst the components in a complete wind turbine, their expertise is presently focused on blade design, which is assumed to give the greatest cost reduction potential. In the wind turbine system, the blades are important components that affect the remaining structural components by heavy loading. Most of that loading is from wind and weight. To do a relevant life cycle cost analysis of the wind turbine system, and use the full potential of the reduced blade weight, a coupled system analysis and system optimization is required. The academic partner will do system modelling, simulation and optimization to substantiate cost reduction claims.

Results

A finite element based study of composite wind turbine blade modelling has been made in collaboration with Composites Consulting Group (CCG). An investigation of methods for wind turbine system modelling has been made with the support of Teknikgruppen AB. A detailed model of the NREL 5MW virtual test bed wind turbine blade has been developed in collaboration with CCG Composites and the parallel project TG4-1. Model reduction techniques designed to allow more direct coupling between high-quality blade models and reduced-order models for aeroelastic simulations have been investigated in collaboration with the sister project TG4-1. Synergy has been obtained from a parallel project (involving the project partner Marström Composites and the consultancy company Scandinavian Wind) that aims at developing and install new blades for Chalmers experimental wind turbine at Hönö. The manufacturing of the new blades to the Hönö 50kW machine has recently started. A measurement series will commence shortly. Studies of the Brazier effect, a nonlinear effect which causes conservative material selection for the core material towards the root section of many commercial blades, have been performed together with CCG. This work consisted partly of simulation work using the NREL model previously developed in the project and partly of experiments on representative scale models tested at DIAB's laboratory in Laholm. The above activities are aimed to support the development of an optimisation tool for wind turbine system design.

Fulfilment of SWPTC's goals

This project has contributed to the research aimed at achieving optimal wind turbines. It has contributed by a step that hopefully eventually will lead to that new material will be used in the blade design which can give a weight reduction of 60 % of the blades. By supporting and supervising MSc students in wind turbine blade testing and validation, high-quality training of students to expertise in wind power engineering has been provided. The project has contributed to the scientific output of the Centre in form of conference papers.

Deviations from project plan

According to the project plan of the project proposal the project should start in Q3 2011. The project was instead started in Q2 2012. The revised time plan wss followed.

Publications

1. A. T. Johansson, C-J. Lindholm, M. Khorsand Vakilzadeh, and T. Abrahamsson, *Modeling and calibration of small-scale wind turbine blade*, Topics in Experimental Dynamic Substructuring, Volume 2, Proceedings of the 31st IMAC, A Conference on Structural Dynamics, 2013, 2 ISBN/ISSN: 978-1-4614-6539-3
2. M. Khorsand, A.T. Johansson, C.-J.Lindholm, J. Hedlund, T. Abrahamsson, *Comparison of Model Reduction Techniques of an NREL 5MW Offshore Wind Turbine Blade*, Proceedings of IMAC XXXII, Orlando, Florida, USA, 2014
3. A.T. Johansson, C.-J. Lindholm, J. Hedlund and T. Abrahamsson, *Development of simplified models for wind turbine blades with application to NREL 5MW offshore research wind turbine*, Proceedings of IMAC XXXII, Orlando, Florida, USA, 2014
4. I. Echaniz, C. Ekberg, M. Josefsson, M. Ljungberg, J. Wass, *FE-modelling and testing of sandwich composites*, Project Report, Applied Mechanics programme, Chalmers 2014
5. I. Fransen, K-J. Larsson, J-A. Lindhult, M. Gonera, A. Suryanarayana, E. Eliasson, *FE-modelling of wind turbine blade*, Project Report, Applied Mechanics programme, Chalmers 2014
6. T. Jungbark, *Power regulation of a vertical axis wind turbine*, MSc Thesis, 2014

Submitted

- C-J. Lindholm, A.T. Johansson, J. Hedlund, *Experimental analysis of stresses in sandwich structures due to the Brazier effect*, submitted to ICCM20 2015

As in-kind contribution from the university also:

1. A. T. Johansson, A. Linderholt, Y. Chen and T. Abrahamsson, *Model Calibration and Uncertainty Quantification of A600 Blades*, submitted to IMAC XXXII, Orlando, Florida, USA, 2014
2. M. Gibanica, A. T. Johansson, A. Liljerehn, P. Sjövall and T. Abrahamsson, *Experimental-analytical Dynamic Substructuring of Ampair Testbed: A State-Space Approach*, submitted to IMAC XXXII, Orlando, Florida, USA, 2014
3. Dynamics of an offshore-based vertical axis wind turbine, Project Report, Applied Mechanics programme, Chalmers 2013

External activities

Work on the small-scale wind turbine model has continued, both in terms of blade modelling and in assembling blade models to the hub using substructuring methods. Full system measurements and comparisons with similar systems set up at the Linneaus University in Växjö and the Technical University of Stuttgart have also been investigated. Dr Anders Johansson has also at two occasions been visiting the prominent research group working with model calibration under Prof. Scott Cogan at the University of Franche-Comté. Dr Johansson has furthermore supervised two project course projects studying the geometrically nonlinear effects of large-scale wind turbine blades in collaboration with the project partner DIAB. A master thesis on development of vertical axis wind turbines, resulting in a scale prototype tested in a wind tunnel at Volvo Trucks, was also supervised by Dr Johansson. The above-mentioned parallel project to develop the experimental turbine at Hönö has been furthered to the point of blade manufacturing.