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Subcomponent development for sandwich composite wind turbine blade bonded joints analysis

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ABSTRACT

In the sector of wind energy, the trend to increasing turbine size is ongoing and it will continue to do so. This research focuses explicitly on a particular aspect of structural design which is reported to be very critical in many designs of wind turbine blade wing box structures, namely the connection between the spar web and the spar cap, which are usually built up with sandwich materials. A pyramid structured approach is developed which links local phenomena of stress transfer and failure in the adhesive connection to overall loads on the entire machine. This paper focuses on the subcomponent level of the pyramid scheme and it shows the relevance of investigations and experiments on this level. A specific test structure is designed and manufactured as a C-beam to reproduce load transfer phenomena as they occur in real blades. An experimental test campaign is conducted using different data acquisition principles and sensors to monitor structural behaviour. Results from a finite element model are compared to experimental results and satisfactory results are obtained.

Keywords: wind turbine blade; subcomponent; bonded joint; experimental.

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1. Introduction

Fossil fuel dependency reduction has become an important issue all over the world. Renewable energy production, in particular wind energy generation, has seen a dramatic growth. However, wind energy systems face a difficult competition when compared with traditional carbon-based energy sources regarding cost competitiveness. Wind turbine systems have increased in size and power. Fig. 1 shows that the average wind turbine rated power has increased from 0.1 MW in 1985, to current large-scale systems averaging 5 MW. In the future systems are expected to have power levels of 10-20 MW with rotor diameters on the order of 170-240 m.

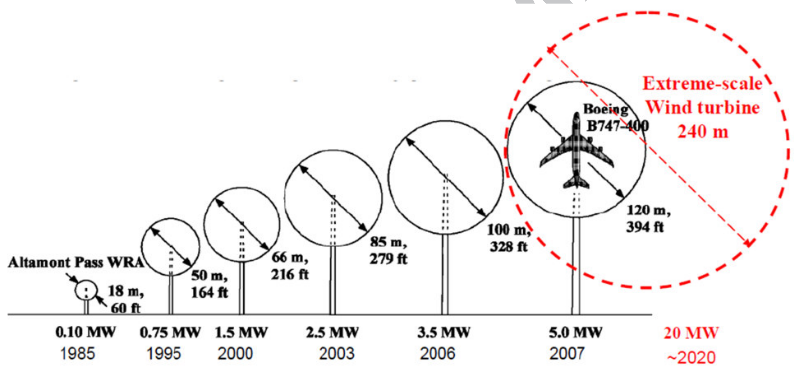

Fig. 1. Increase in wind turbine scale and power [1].

Wind turbine blades, which are mainly assembled with fibre-reinforced composites components which are glued together, experience a multitude of events that can affect reliability, including variable amplitude cyclic loading, daily and seasonal temperature and humidity changes and, for colder climates, ice impact. For very warm climates, long-term exposure can cause degradation of composite structures and adhesives. For the safe and cost-effective operation of wind turbines, it is necessary to understand how these variables, whether or not in combined effect, can affect reliability. Numerical models should be capable of predicting in a sufficiently accurate way structural deformation of a blade when it is subjected to different loads, in different aerodynamic conditions, and also strength of the blade and its components, including adhesive joints, ply drops, even in the presence of material defects [2, 3].

One of the most critical points in wind turbine blades is the joint between the spar cap and the shear web. This joint is the main focus of this paper. A pyramid structured approach is developed which links local phenomena of stress transfer and failure in the connection to overall loads on the entire machine. For that purpose, a subcomponent structure is designed and tested. Section 2 introduces the pyramid approach and the scope of this paper; the subcomponent structure designed as a C-beam. Section 3 deals with the sizing of this C-beam. Section 4 describes the experimental campaign performed in the coupon level to be able to feed the upper levels correctly. Section 5 presents the finite element model of the subcomponent, and Section 6 gives a detailed description of the experimental test which is conducted on this structure. Section 7 analyses the results obtained in the experimental test and finally, Section 8 compares the experimental and numerical results with a quite fine degree of correlation.

2. Pyramid approach and subcomponent introduction

The load carrying capacity of wind turbine blades contains significant uncertainty due to the usage of composite materials and the overall structural behaviour of the blade. In order to reduce these uncertainties, the wind turbine standards IEC 61400-1 [4]