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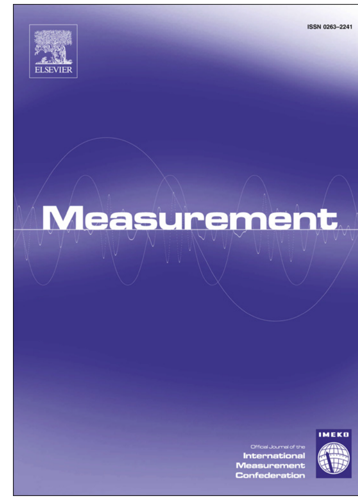

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Fatigue damage assessment of wind turbine composite blades using corrected blade element momentum theory

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ABSTRACT

This paper presents a method for estimating the fatigue life of composite blades of horizontal axis wind turbines, and a real blade example of the NREL 5 MW reference wind turbine is employed to verify this proposed method. First, the distributions of aerodynamic loads are analysed by new corrected blade element momentum theory, and then the aerodynamic performance of the blade under various wind speeds is assessed. The time-history of the wind speed is generated by using the Weibull distribution based on the offshore wind parameters available. The maximum stress caused by the aerodynamic loads due to wind is then calculated through the finite element analyses. The fatigue cycle during the certain time period is estimated by fast Fourier transform for the load spectrum, which converts the time-stress spectrum to stress cycles. The fatigue damage and remaining service life of wind turbine composite blades are estimated by the Goodman diagram and *S-N* curve for stress cycles during the service time. Finally, the remaining service life is predicted by utilising the Miner's law for linear fatigue damage accumulation. The results of the real wind turbine composite blade show that the proposed approach can provide an effective tool for evaluating the fatigue damage and assessing the structural performance of the wind turbine composite blades during the service life.

Keywords: Wind turbine blades; Blade element momentum theory; Finite element modelling; Aerodynamic loads; Wind turbine performance; Fatigue damage.

1 Introduction

Energy crisis and greenhouse effects have led to an increasing demand for clean energy to replace fossil fuel. Wind is the most cost-effective and feasible energy resources by using wind turbines, since wind produces significant amount of power in some regions [1]. In a wind turbine system, the most critical component is the wind turbine blades since the manufacturing cost of the blades is approximately 22.2% of the total cost for all components, and replacing them during operation is not only difficult but also expensive [2]. In order to improve the performance of blades in offshore wind turbines, layered fibre-reinforced polymer composite materials are usually used for the large blades, since these materials have better mechanical properties, such as higher fatigue resistance and lighter weight, compared with traditional homogeneous materials, e.g. metals [3]. During operation, the wind turbine blade is under complex load conditions, such as aerodynamic load, gravitational load, inertial loads and operational loads [4]. Among these loads, the aerodynamic load is significantly affected by wind speed in environmental conditions, since the spectrum of wind speed is in high frequency and amplitude. In the design and analysis of wind turbine blades, wind speed could be generated by deterministic distribution [5], and the