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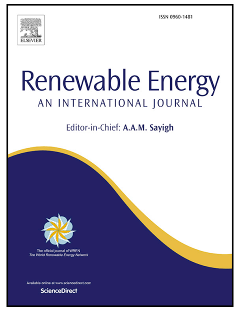

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Impact fatigue damage of coated glass fibre reinforced polymer laminate

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Abstract. Impact fatigue caused by rain droplets, also called rain erosion, is a severe problem for wind turbine blades and aircraft. In this work, an assessment of impact fatigue on a glass fibre reinforced polymer laminate with a gelcoat is presented and the damage mechanisms are investigated. A single point impact fatigue tester is developed to generate impact fatigue damage and SN data. Rubber balls are repeatedly impacted on a single location of the coated laminate. Each impact induces transient stresses in the coated laminate. After repeated impacts, these stresses generate cracks, leading to the removal of the coating and damage to the laminate. High-resolution digital imaging is used to determine the incubation time until the onset of coating damage, and generate an SN curve. An acoustic emission sensor placed at the back of the laminate monitors changes in acoustic response as damage develops in the coated laminate. The subsurface cracks are studied and mapped by 3D X-ray computed tomography. A finite element method model of the impact shows the impact stresses in the coating and the laminate. The stresses seen in the model are compared to cracks found by 3D tomography. The damage is also evaluated by ultrasonic scanning.

Keywords: Impact fatigue; glass fibre reinforced polymer; leading edge erosion; acoustic emission; X-ray computed tomography; ultrasound scanning

1. Introduction

Wind energy is recognized as a key renewable energy source, reducing dependency on fossil fuels [1, 2, 3, 4]. There are a variety of designs for energy generation by wind, but in all cases, the kinetic energy of wind is converted to electrical energy. The three bladed horizontal axis wind turbine is a common design, comprising rotor blades, a tower and a power converting part including a generator and a gear box. Since the power generation capacity of a wind turbine highly depends on the swept area of the blades, lighter and larger blades are demanded [5, 6]. Fibre reinforced polymer composite materials can meet the demand for lighter and larger wind turbine blades due to their high strength-to-mass ratio, a high stiffness-to-mass ratio, good fatigue resistance, corrosion resistance, flexible formability and low thermal expansion.

Surfaces of wind turbine blades in both onshore- and offshore-installations are exposed environmental and tribological effects over their operational lifetimes [7], including extreme wind/gusts, rain showers, hailstone showers, airborne particles of sand, snow, icing, extreme temperatures and ultraviolet light exposure. Among them rain erosion is often thought to be a major damage source [8]. In particular, the leading edge of the blade tips, whose speed is commonly greater than 80 m s^{-1} [9], can experience significant damage, and thus a protective coating is usually applied. Such damages are collectively called "leading edge erosion". However, erosion is only one of the damage phenomena, and in fact, very little is known about the different damage