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Progress and trends in nondestructive testing and evaluation for wind turbine composite blade

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ABSTRACT

Wind energy is one of the fastest growing renewable energy resources. It is distinctly important to increase reliability and availability of wind turbines and further to reduce the wind energy cost. Blades are considered to be one of the most critical components in wind turbine system because they convert Kinetic energy of wind into useable power. Blades are fabricated by carbon fiber reinforced polymer (CFRP) or glass fiber reinforced polymer (GFRP). Flaws and damages are inevitable during either fabrication or lifetime of a composite blade. Thus, non-destructive testing (NDT) and structural health monitoring (SHM) for wind turbine blade (WTB) are required to prevent failures and increase reliability in both manufacturing quality control and in-service inspection. In this work, a fully, in-depth and comprehensive review of NDT techniques for WTB inspection was reported based on an orderly and concise literature survey. Firstly, typical flaw and damage occurring in manufacturing progress and in service of WTB were introduced. Next, the developments of visual, sonic and ultrasonic, optical, electromagnetic, thermal and radiographic NDT for composite WTB inspection were reviewed. Thereafter, strengths and limitations of NDT techniques were concluded through comparison studies. In the end, some research trends in WTB NDT have been predicted, for example in combination with SHM. This work will provide a guide for NDT and SHM of WTB, which plays an important role in wind turbine safety control and wind energy cost savings. In addition, this work can benefit the NDT development in the field of renewable energy, such as solar energy, and energy conservation field, such as building diagnosis.

Contents

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1. Introduction

Wind energy is one of the fastest growing renewable energy resources, and it is going to have a remarkable share in the energy market. According to the collected statistical data, it is estimated that wind power could supply about 12% of global electricity supply by 2020, and rising above 20% by 2030 [1–3]. As the wind energy sector grows, business economics will demand increasingly careful management of costs [4–6]. The operations and maintenance (O&M) costs of wind turbines are about 25–30% of the overall energy generation cost [7,8]. In order to reduce wind energy costing, reduction of the O&M cost is a urgently needed [9]. Apart from applying optimization design of machine to improve the availability, another feasible way is employing reliable and cost-effective condition monitoring (CM), non-destructive testing (NDT) and structural health monitoring (SHM).

Wind turbine (WT) is a typical mechatronics system. It consists of numerous mechanical and electrical components including the blades, rotor, gearbox, shaft, generator, bearings, pitch and yaw system, and tower [2,10]. Among these components, blades are regarded as one of the most critical components [11,12]. Because the efficiency of WT capture energy is depending on the propeller-like blades. Furthermore, the blade manufacturing cost is accounting for 15–20% of each WT. In addition, more and more composite materials have been widely used to fabricate WT blades [13], due to their excellent advantages such as low cost, light weight, high strength/weight and high stiffness/weight ratios [14,15]. Nowadays most of blades are made of glass fiber reinforced polymer (GFRP). On the other hand, in order to further improve the efficiency of WT energy capture, longer and wider power blades are being fabricated [16]. Therefore, for very large blades, carbon fiber reinforced polymer (CFRP) is being increasingly used. However, the increasing size of WTB is accompanied increase in the load levels, which significantly affects the service safety of WTBs [11].

On one hand, some flaws can occur during blade manufacturing process. On the other hand, blades are effecting by the harsh and complex service environment including moisture absorption, sleet, ultraviolet irradiation, atmospheric corrosion, fatigue, wind gusts or lightning strikes, etc. Thus, a lot of flaws and damages are incurred by WTB. Furthermore, wind turbine blade failure is very costly, due to other blades damage, the wind turbine itself damage, and additional wind turbines damage located in neighbor [17]. Thus, once a wind turbine blade has been manufactured or installed, it is necessary to perform NDT techniques in order to avoid failure [18]. Nowadays, plenty of NDT techniques based on visual, sonics and ultrasonics, optic, electromagnetics, thermo and radiographics have been investigated for composite WTB inspection. Some NDT techniques have shown their potentials while some others are facing with problems due to their inherent