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Wrinkle measurement in glass-carbon hybrid laminates comparing ultrasonic techniques: A case Study.

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Abstract

Wrinkles, (also known as out-of-plane waviness) are, unfortunately, a common phenomenon that has caused some wind-turbine blades to unexpectedly fail in service. Being able to detect the wrinkles while in the factory will reduce the risk of catastrophic failure and characterising the wrinkles would minimise the repaired area, thus increasing the efficiency of the repair and the design. This work compares the effectiveness of three different ultrasound techniques for detecting and characterising out-of-plane wrinkles in the typical glass-carbon hybrid laminates that are used for wind-turbine blades. The tests samples were manufactured so that the laminates and the defects are representative of those used in the wind-turbine industry. Basic mechanical tests were performed to check the drop in mechanical properties due to wrinkling. The ideal probe frequency was determined as the resonance frequency of the plies using an analytical ultrasonic-propagation model. The three different ultrasound techniques used are: full-matrix capture (FMC) with the total focusing method (TFM), a commercial phased-array instrument and an immersion test with a raster-scanned single-element focused probe. When possible, severity parameters of the wrinkle were measured on the ultrasonic images and compared with the measurements of the actual sample in order to determine which method best characterises such wrinkles and which would be more appropriate to implement in an industrial environment. Not all of the techniques allowed full characterisation of out-of-plane waviness on the specimens. The FMC/TFM method gave better results whilst phased-array technology and single-element immersion testing presented more challenges. An additional enhancement to the TFM imaging was achieved using an Adapted-TFM method with an angle-dependent velocity correction.

Keywords: A. Carbon Fibre; A. Glass Fibre; D. Non-destructive testing

1. Introduction

The development and utilization of wind power for energy generation has increased worldwide since the energy crisis in 1970 mainly because it is now a mature green technology. Nowadays, giant wind turbines are being developed(1) with enormous turbine blades that are designed using thick carbon- and glass-fibre laminates in order to withstand the large bending moments that appear at the root of those parts. Unfortunately, during the manufacturing process of such laminates, misalignment in fibre orientation is a common defect that seriously degrades the mechanical properties (2). When such defects are not detected during the manufacturing process, the blades may unexpectedly fail in service, which forces wind-farm operators to repair the blades in-situ if the failure has not destroyed the whole turbine. These kinds of repairs are expensive and inconvenient (3). In order to reduce the risk of catastrophic failure, the