# A study on the progressive damage development in a wind turbine blade aeroshell during virtual full-scale structural test

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## Abstract

Within the scope of this paper the previous work of the authors of this study concerning the strength analysis of an existing 5-m GFRP wind turbine blade using linear and nonlinear Puck's physically based phenomenological model is revisited. As an important outcome of this study, for a more realistic simulation of failure mechanisms nonlinear Puck material model is found out to be necessary. In the first stage of the current work, highly stressed critical regions of the blade subjected to extreme flapwise loading are identified using the global FE Model. In the second stage, a physically based phenomenological fatigue damage analysis methodology is introduced, which will be used to investigate the failure mechanisms in the blade aeroshell under flapwise cyclic loading. As an ultimate goal of the study damage development during static and fatigue loading will be compared.

*Keywords*: progressive damage modelling, reliability, wind turbine blade, Puck failure criteria, Finite Element Model

## 1. Introduction

Composite blades are among the main components of a wind turbine, which are subjected to complex loading conditions. Their long-term structural integrity can be achieved with an in-depth understanding of the failure mechanisms and/or modes that may lead to their ultimate breakdown. In this regard, full-scale structural tests enable us to monitor mechanical response of blades under various loading conditions. Yet these tests must be accompanied with numerical simulations, so that the physical basis of the progressive damage development can be captured and understood correctly [1]. Moreover, failure initiation and ultimate failure can be determined using progressive damage models prior to testing. In the previous work of the authors of this paper it was found out that Puck's nonlinear material model is necessary for more realistic results concerning damage progression compared to linear Puck model [2]. Therefore, in the current study Puck's nonlinear material model is implemented.

## 2. Method

In first stage of this work, for the progressive failure analysis of the blade subjected to monotonic flapwise loading Puck's physically based phenomenological model is implemented in the FE Model of the 5 m GFRP METUWind blade using ANSYS Parametric Design Language (APDL). The blade is modelled with plane stress elements. The degradation rules are applied to the elements according to specific Puck's failure criteria as presented in [3]. In the second stage of this work blade aeroshell subjected to flapwise cyclic loading will be investigated. For this purpose current progressive failure analysis based on Puck's action plane approach will be extended to the fatigue damage analysis, which incorporates strength and stiffness degradation curves of the GFRP laminate under cyclic loading conditions.

## 3. Results and Discussions

After 80% of the extreme flapwise load case blade is found to show nonlinear load-displacement behaviour and starts to deflect excessively. In Figure 1, contour plots of IFF (C) modes for the suction side of the blade using progressive Puck criteria at 90%, 100% and 110% of extreme load case is depicted. From the results, the main failure mechanism is predicted as debonding at the leading and trailing edges. It is noted that plane strength elements are not capable of capturing the main failure mechanism, which is triggered by the through-the-thickness stresses and hence solid elements need to be used.

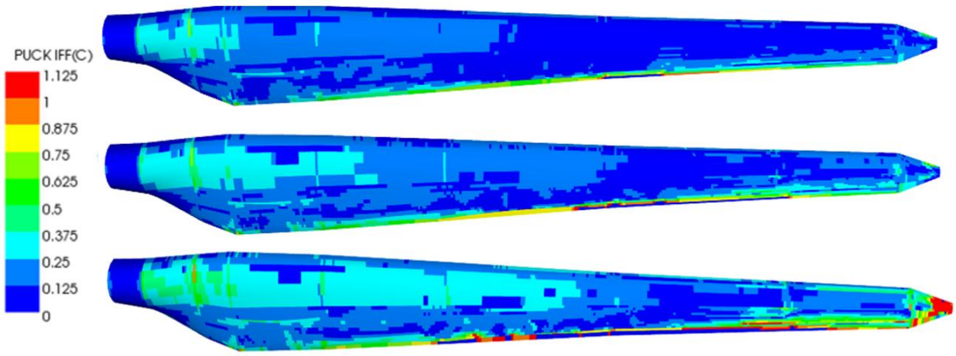


**Figure 1** Contour plots of IFF (C) modes for the suction side of the blade using progressive Puck criteria at 90%, 100% and 110% of extreme flapwise loading.

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## Bibliography

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