Ultimate strength of wind turbine blade structures under multi axial loading

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Introduction

Wind turbine blades must endure a variety of weather conditions including uncontrollable, extreme winds without developing damage and fracture during a lifetime of minimum 20 years. The variety of loading leads to multi axial loading resulting in complex states of stress.

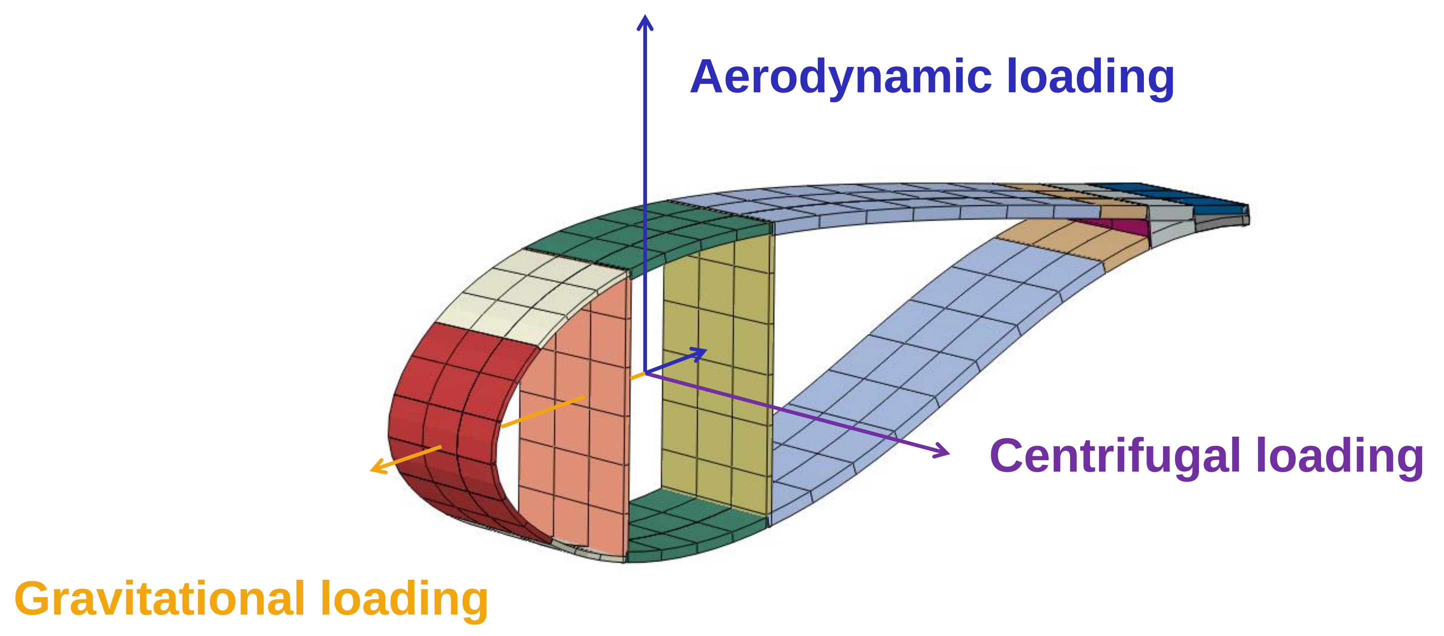

Figure 1: Blade loads

The prediction of the effects of the complex states of stress with existing failure criteria can be uncertain and damages and failures often occur earlier than expected. Where doubts regarding the reliability of failure criteria exist, it is normal practice to err on the safe side by favouring conservative methods including high safety factors, leading to heavier and thicker laminates. In order to decrease weight and to increase reliably and robustly operating wind turbine systems it is of great importance to predict damage initiation and growth accurately.

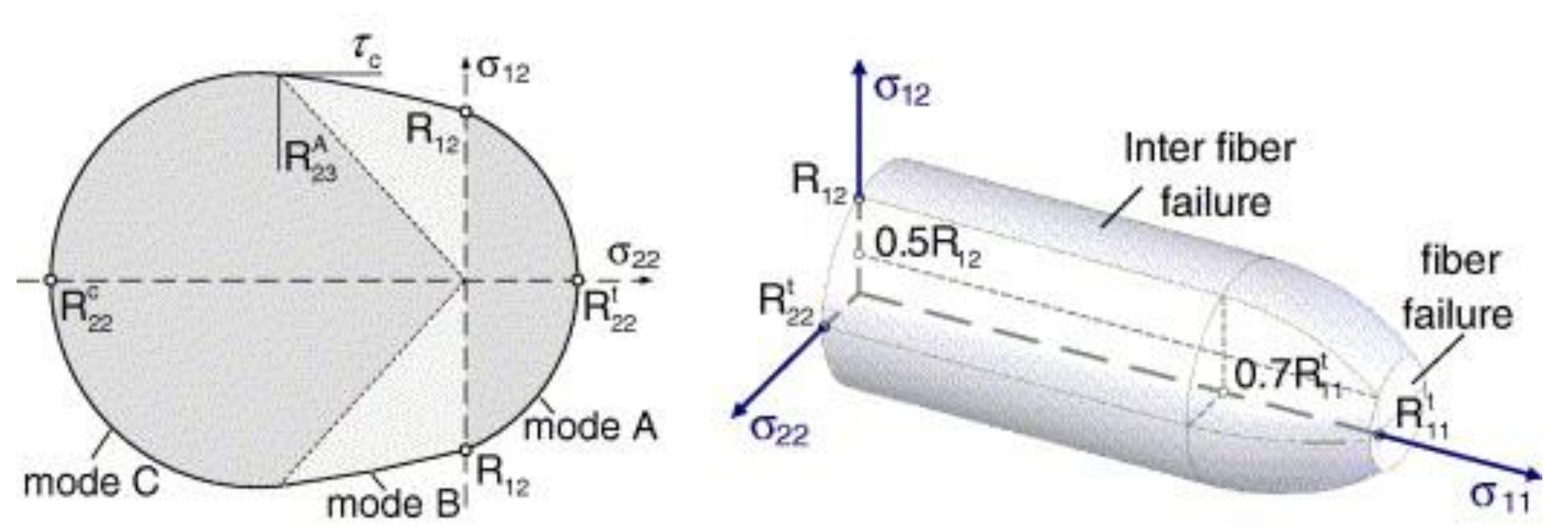

Figure 2: Puck failure criterion envelop

Problem in focus

- Multi axial loading leads to complex states of stress
- Prediction of complex loading effects with existing failure criteria can be uncertain
- Damages and failures in wind turbine blades often occur earlier than expected
- According to the World Wide Failure Exercise - most of the leading failure theories often greatly differ from the critial final failure strength of multi-directional laminates
- The accuracy of curve-fitting criteria is often restricted to load and material combinations corresponding to those from which the fitted curves originate

Purpose of the project

- Investigation how multi axial loading effects influence the ultimate strength of typical composite structures in wind turbine blades
- Studying the ability of different criteria to predict failure under mulit axial loading conditions
- Develping methods to perform reliable prediction of failure based on physics-based failure criteria

Methods

- Analysing wind turbine blade structures subjected to different load cases
- Characterising areas particularly exposed to multi axial loading
- Investigation of the ability of different state-of-the-art failure criteria to predict failure under multi axial loading
- Developing and performing sub-structure tests for multi axial loading
- Creating analytical and / or numerical models to predict failure

Buckling driven delamination in blades

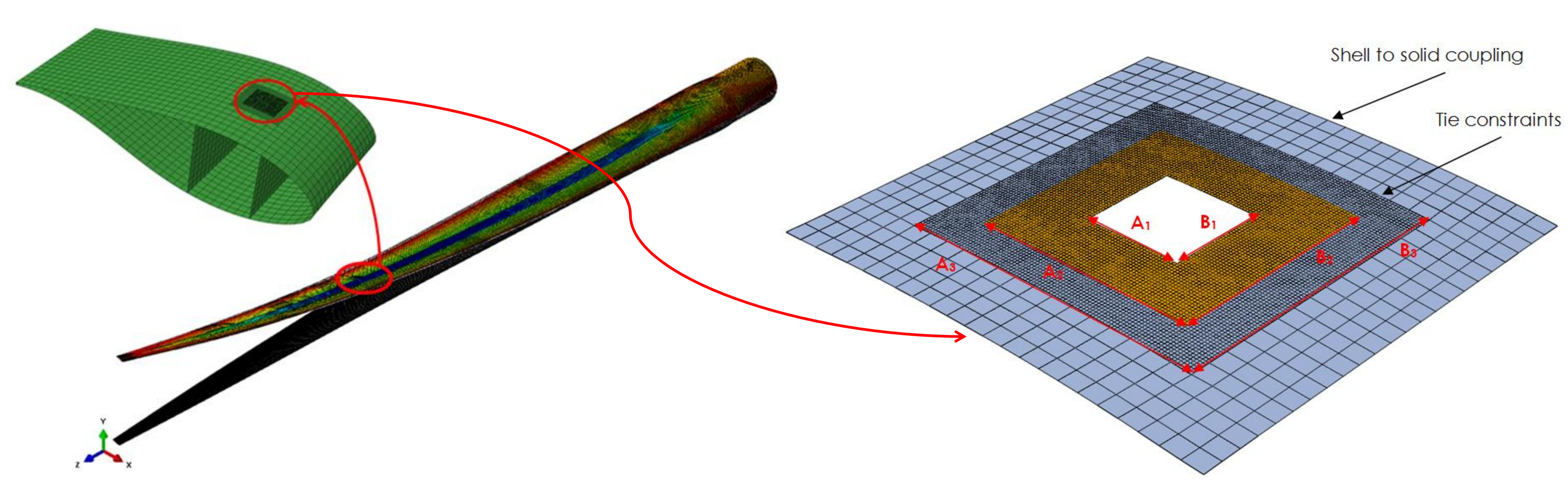

Figure 3: Large scale delamination simulation with cohesive elements

Small scale panel simulation

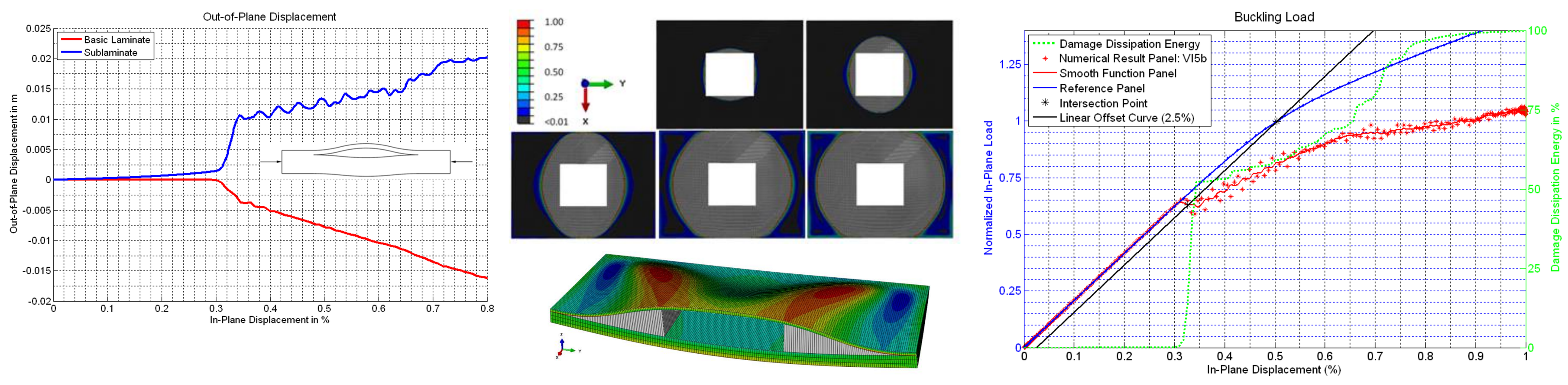

Figure 4: Local buckling in small scale panel simulation

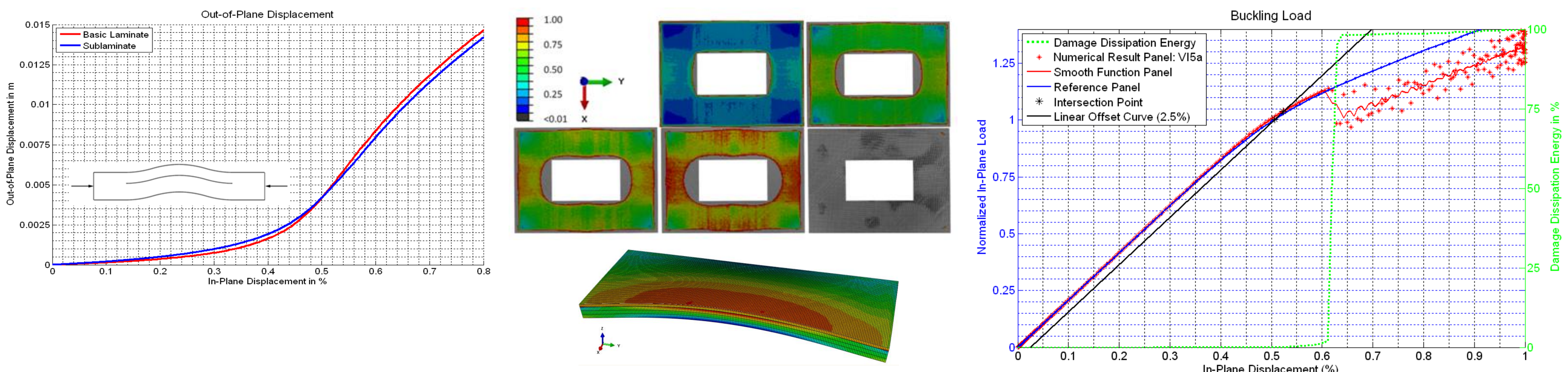

Figure 5: Global buckling in small scale panel simulation

Results from the panel simulation

Two different kind of buckling modes occur:

- For initial defects close to the surface and / or bigger initial delamination areas → local buckling occurs (Figure 4).
- Local buckling driven delamination growth is stable and mode I dominates.
- Local buckling driven delamination decreases the buckling load significantly.
- Initial delaminations with bigger distance to the surface and / or smaller initial area → global buckling occurs (Figure 5).
- Global buckling driven delamination growth is instable and mode II dominates.

Acknowledgement

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