Nonlinear finite element analysis of buckling driven delamination growth in wind turbine blades

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ABSTRACT

Wind turbine blades are made of light and strong composite materials. Low weight core materials are used as well as strong fiber materials. The different material components are typically laminated or bonded together by polymer adhesives. Inside the composite structure various types of damages and cracks such as buckling driven delamination can occur. Delaminations are defects and can be defined as areas without bonding between adjacent layers. Structures with delaminations subjected to compressive loading, like for example the load carrying box girder of a wind turbine blade, may buckle and this can reduce the strength of wind turbine rotor blades significantly. Hence delaminations are considered as one of the most critical failure types that can occur in composite structures.

For better, lighter and more reliable constructions it is necessary to understand the evolution of damage. Numerical analyses are excellent suitable to intensify this understanding. Usually a fine discretization has to be used to simulate the delamination growth accurately. Therefore, delamination modeling in large scale is challenging and computation time costly.

A less computational expensive procedure for the numerical analysis of buckling driven delaminations in wind turbine blades is presented and leads to new findings in the field of delamination growth. Cohesive zone elements based on a continuum damage mechanic approach are used to model large scale delamination growth and to analyze the effects of defects on the structure. For this purpose nonlinear finite element analyses (NLFEA) of buckling driven delaminations in the load carrying part of a novel 10 MW wind turbine blade are investigated and compared with experimental and numerical data of small scale panels.

Summarizing the analysis of buckling driven delamination growth shows two different kind of buckling modes, local and global buckling modes. It can be concluded that initial delaminations close to the surface and with larger initial delaminated area tend to cause a local buckling, whereas deeper and smaller delaminations are likely to cause global buckling. Additionally, two different kinds of delamination behavior can be assigned to local and global buckling modes. In local buckling modes the sublaminate buckles and delaminates from the basic laminate, which causes a significant decrease of the critical buckling load. In contradistinction to the local buckling behavior, the numerical simulation shows that global buckling behavior does not have a significant effect on the strength.

Furthermore the analysis shows that delaminations with local buckling mode behavior seem to be triggered by a combination of normal (mode I loading) and shear stresses (mode II loading), whereas delaminations related to global buckling modes are mainly caused by shear stresses. Moreover local delaminations growth during the local buckling occurs gradually as contrasted with global buckling that occurs at higher energy levels instantly.

Keywords:

- Buckling
- Cohesive element
- Crack growth
- Delamination propagation
- Nonlinear finite element analysis
- Wind turbine blade