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Modelling of guided wave propagation for detecting delamination in large composite structures

Siavash Shoja, Viktor Berbyuk and Anders Boström
Chalmers University of Technology, Sweden, siavash.shoja@chalmers.se

Abstract

The aim of this study is to identify the challenges in computational modelling of guided wave (GW) propagation in large composite structures and propose approaches to overcome them. Firstly, effects of using shell elements and a stiffness reduction approach to model delamination in composite laminates and sandwich structures are investigated. Secondly, the obtained methods and conclusions are used to model GW propagation in a wind turbine blade with the aim of delamination detection. Results show that low frequency GW can be used as a potentially efficient tool for structural health monitoring of composite wind turbine blades.

1. Introduction

Finite element (FE) modelling of GW propagation in composite structures is an efficient way of studying their application for structural health monitoring (SHM) and defect detection. One common way of FE modelling of GW in such materials is to use explicit dynamic solvers and 3D solid elements. Here, convergence criteria need to be taken into account which make the element size a function of frequency (1). To model GW in large composite structures a large number of elements has to be created which makes the problem very difficult or in some cases impossible to solve. Previously, it was shown that in certain cases it is possible to use shell elements and methods of homogenization to reduce the size of the FE models (2). However, accuracy of these methods are depended on the frequency range and type of the wave modes. Additionally, due to high damping of composite materials, low frequency GW seem to be the best choice in such large structures. The low frequency GW propagate with large wavelength and they are less attenuated.

This extended summary is a brief description on the studies and approaches that have been developed to reduce the size of FE models for propagation of low frequency GW. The structures in question could be made of both laminated composites and sandwich ones. The effect of using homogenization methods are studied in these two types of materials. To model delamination regions in laminated composites the stiffness reduction approach (SRA) is developed. An application of GW propagation in a wind turbine blade is performed with focus on delamination detection.

2. FE modelling of GW

Previously, it was shown that reflections and mode conversion happen when the GW are passing through the delaminated region. Furthermore, GW travel with different velocities in delaminated regions compared to healthy parts in a laminated composite (3). This change is due to the stiffness change in the delaminated region. Therefore, it is possible to create the delaminated regions in the FE model of GW propagation in a composite laminate by locally reducing the stiffness (SRA). Effects of using such approach together with shell elements is investigated by comparing the results with two other methods, one shell elements together with sub-laminates for the delamination regions, and the other one solid elements with duplicated nodes to create delamination. Results show that good agreement can be reached using the SRA and shell elements compared to solid elements.

In sandwich structures, due to large differences between the stiffness and density of the core material and the laminated skins, the Lamb waves start to show leaky behaviour above a certain frequency (4). Here, a study is done on a sandwich material in a wide range of frequencies using FE simulations. Results show that existence of leaky Lamb waves causes constant transferring of wave energy between the top and bottom skins. However, in the low range of frequency where Lamb waves show no leaky behaviour, the multi-layered sandwich material performs as a single layer. Here homogenization methods can be used for FE modelling of GW propagation.

3. SHM of wind turbine blade

Based on the proposed approaches a FE model of a wind turbine blade is created. The blade consists of regions of laminated composites and sandwich materials. Explicit dynamic procedure is applied on shell elements and Abaqus is used as the FE solver. A delamination region is then created using the SRA. Comparisons of the wave pattern of 15 kHz GW propagated in the blade is shown in Fig. 1. Results clearly show reflections and mode conversion due to the delamination region on the propagated GW.

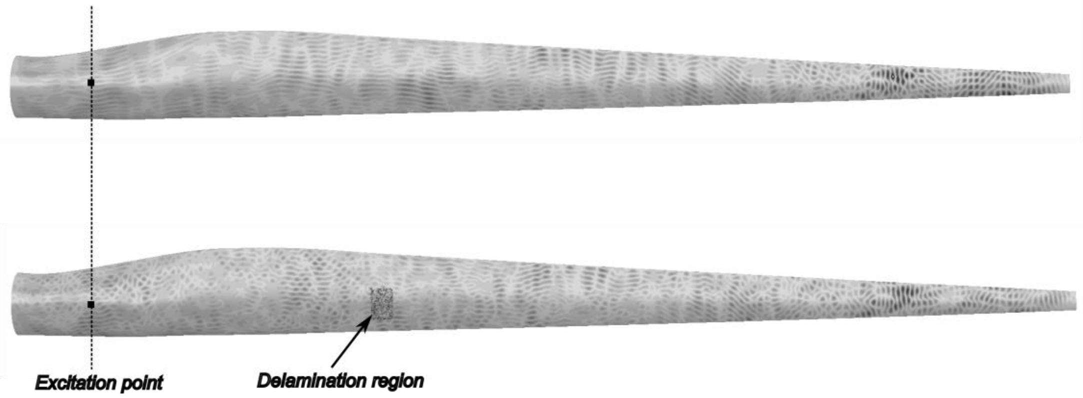

Figure 1. Wave pattern of GW propagating in a wind turbine blade when there is no delamination (top) and a delamination region is introduced using the SRA (bottom)

3. Conclusions

In the low range of frequencies, the laminated composites and sandwich materials can be homogenized through the thickness for FE simulations. Moreover, the delamination regions can be modelled by locally reducing the stiffness. This causes a significant reduction on model size and makes it possible to model GW propagation in large composite structures. Using the proposed approaches, a FE model of GW propagation in a wind turbine blade is created with the aim of delamination detection. Results show that GW in the low range of frequencies can be used as a potentially efficient tool for SHM of wind turbine blades.

References

1. S Shoja, V Berbyuk, A Boström, "Guided wave-based approach for ice detection on wind turbine blades", J. Wind Engineering. Doi:10.1177/0309524x18754767, 2018.
2. L Maio, V Memmolo, F Ricci, N D Boffa, E Monaco, R Pecora, "Ultrasonic wave propagation in composite laminates by numerical simulation", Composite Structures 121, pp 64-74, 2015.
3. B Feng, A L Ribeiro, H G Ramos, "Interaction of Lamb waves with the edges of a delamination in CFRP composites", IEEE MetroAeroSpace, pp 217-222, 2017.
4. S Mustapha, L Ye, "Propagation behaviour of guided waves in tapered sandwich structures and debonding identification using time reversal", Wave Motion 57, pp 154-170, 2015.