Analysis of large CFRP plate with delamination due to drop-weight impact

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INTRODUCTION: The influence of delamination in a small area of a large composite structure, a wind turbine blade, due to drop-weight impact is studied in this work. Since the structure is very large and the composite material is with too many layers, it is not computationally efficient to model the whole structure with layerwise theory, which is capable of modelling delamination. Therefore, in this study, layerwise theory was only applied to the delamination area to save computational memory. The vibration analysis coupling composite shell and acoustic simulation with consideration of delamination was also investigated.

COMPUTATIONAL METHODS: The 60 meters long, with a total 19 layers NREL 5MW wind turbine blade structure from the COMSOL application libraries is used [1, 2]. It is assumed that a 5 cm radius round shaped delamination area is located near the root of the blade.

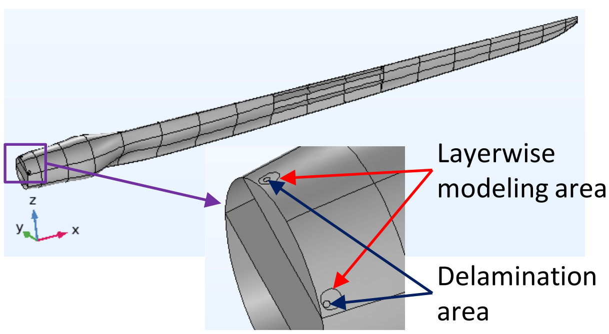

Figure 1. Geometry of the blade and location of the laywise modeling area with delamination

The model is set up with Composite Material module of COMSOL Multiphysics V5.5. The area near delamination is modeled with Layered shell interface, which is based on layerwise theory and capable of modeling delamination, with the cost of large memory consumption. All the other areas are modeled with ESL theory based Layered Linear Elastic Material feature in Shell interface. The coupling between the two interfaces along the shared boundaries is realized with the preset multiphysics coupling node.

First, a stationary study to investigate the performance of the structure with the delamination area that subject to gravity and Centrifugal Force for 1 rpm rotation is considered. Then a transient study on the local area including delamination is performed to explore the possibility of ultrasonic nondestructive testing modeling of the coupled shell structure.

The simulation area and the input vibration signal used in the transient study are shown in Fig.2.

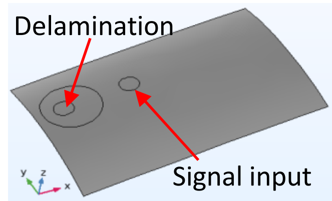

Figure 2. Transient modeling area

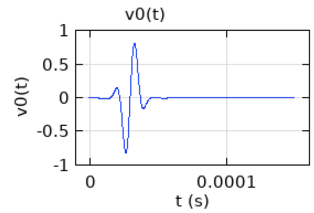

Figure 3. Input signal

RESULTS: The mises stress and displacement distribution of the structure near the root of the blade are presented in Figure 4 and 5. The effect of delamination area on the stress distribution can be observed. The mises stress and displacement plot for the transient study are shown in Figure 6 and 7. Complex reflection wave can be observed from the delamination area. The memory used in computation for both stationary and transient study is about 9 GB.

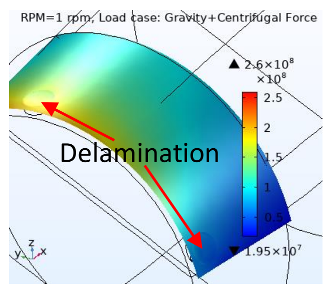

Figure 4. Mises stress near the root under gravity and centrifugal force

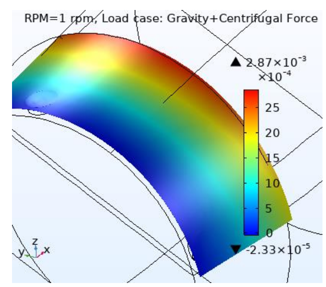

Figure 5. Displacement near the root under gravity and centrifugal force

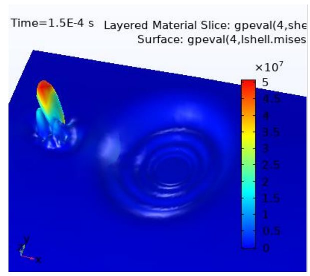

Figure 6. Mises stress plot at Time=1.5E-4 s

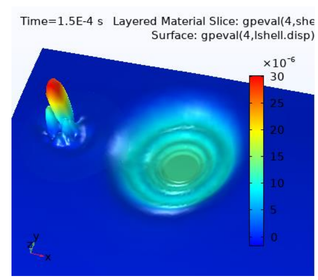

Figure 7. Displacement plot at Time=1.5E-4 s

CONCLUSIONS: The structural analysis of a large layered composite structure with delamination is performed by combining small area of layerwise interface with ESL interface. Results show that presented method is memory efficient to compute large composite laminate with delamination. The results also shown the possibility of ultrasonic nondestructive testing modeling of the large shell.

REFERENCES:

1. J. Jonkman, S. Butterfield, W. Musial, and G. Scott, Definition of a 5-MW Reference Wind Turbine for Offshore System Development, Technical Report, NREL/TP-500-38060, (2009)
2. M.K. Yeh, and C. H. Wang, Stress Analysis of Composite Wind Turbine Blade with Different Stacking Angle and Different Skin Thickness, ICMSEA and MCEBM, (2017)