Numerical Vibration Analysis of CFRP Specimens with Impact Damage

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Introduction: The vibration behavior of CFRP specimens with impact damage is presented in order to evaluate if an before/after modal analysis can be used as a non-destructive testing method to detect delaminations.

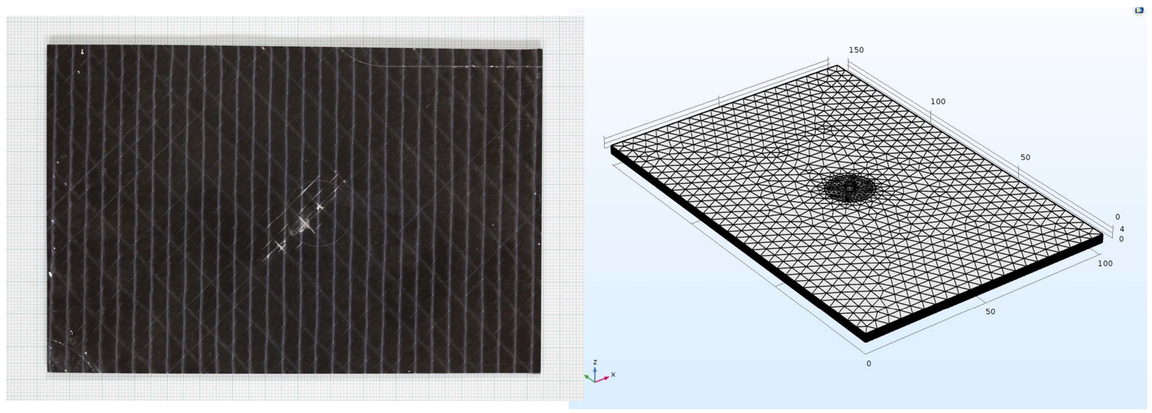

Figure 1. Left: CFRP specimen with delaminations due to an impact. Right: Modeled geometry in COMSOL after meshing

Computational methods: The structural mechanics interface of COMSOL Multiphysics® is used to conduct eigenfrequency studies. The models are three-dimensional with mixed tetrahedral and prism elements. Furthermore a linear elastic and orthotropic material model is used to for the CFRP specimens. The boundary condition is a free-free support to match the conditions of the experimental investigation where the specimens are loosely placed on soft foam [1].

Modeling of defects: As shown in Figure 2, the shape of the delaminations is estimated to be an ellipse with the long axis pointing in the fiber direction [2]. Since no ultrasound data has been recorded yet, the area of delamination is estimated by visual inspection of the top and bottom ply and interpolating linearly through the thickness of the laminate. The impact damage is modeled by decreasing the stiffness in the described area [3].

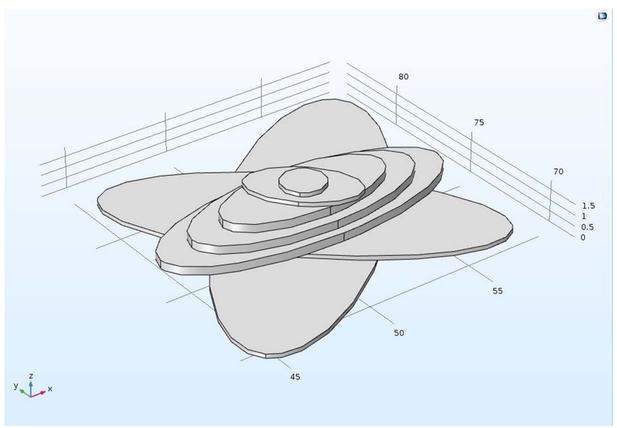

Figure 2. Domain where the material parameters are modified to model delaminations due to the impact damage

Results: The results for five specimens with different geometries, laminate thicknesses and defect sizes are depicted in Figure 3. The green data points show how the simulated eigenfrequencies with impact damage differ from the ones without damage. The red data points are obtained by experiment [1].

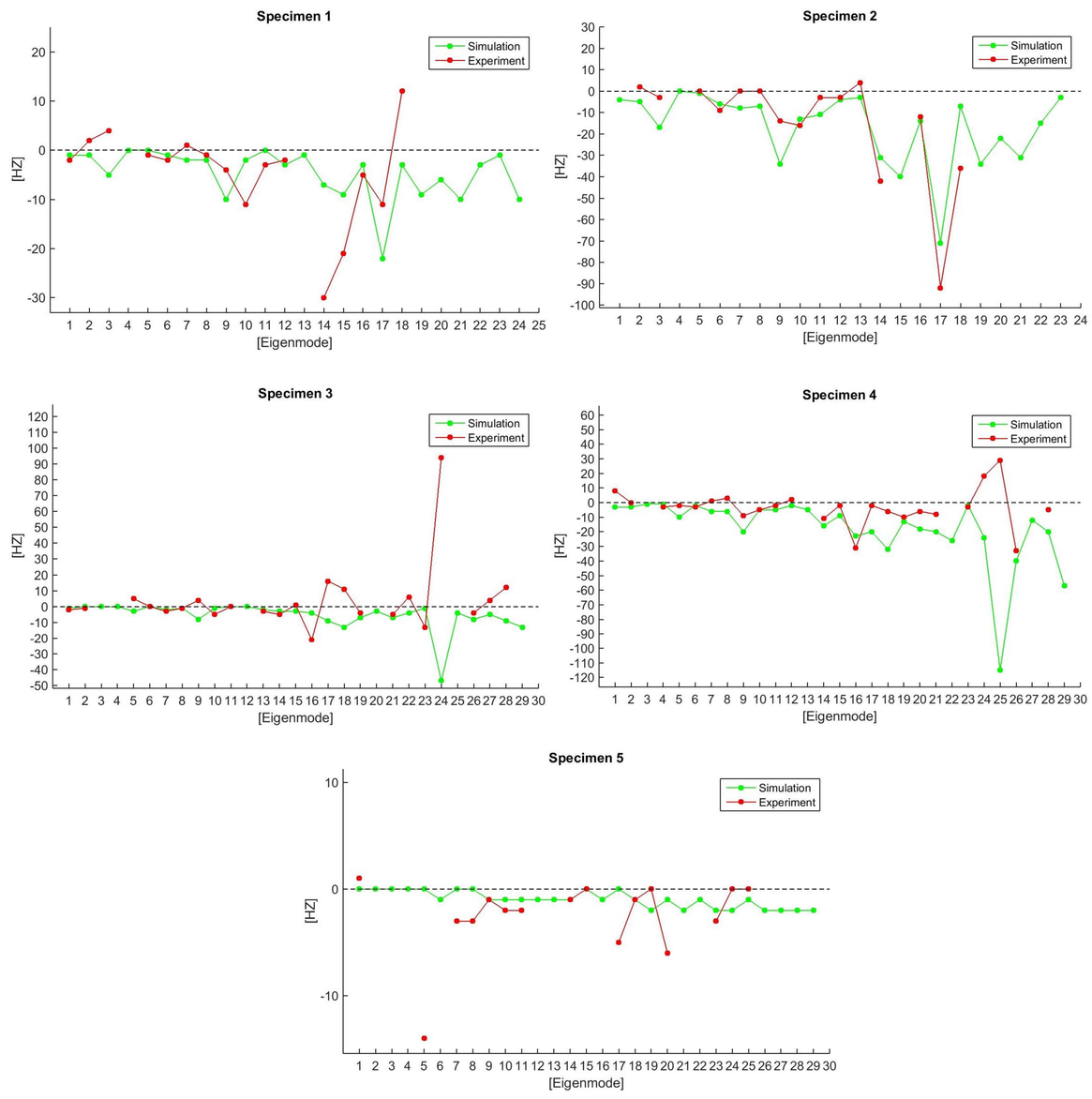

Figure 3. Difference between eigenfrequencies with impact damage and without impact damage for five different specimens. The green data points represent the simulated results and the red data points represent the experimental results.

Conclusions: As detailed experimental data exists for the modeled structure, the study shows the importance of the availability of exact material properties. The data suggests a slight affection of the low eigenfrequencies by the delaminated areas. Higher eigenfrequencies partly show significant deviations from the experimental data.

References:

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2. Cawley, P., & Adams, R. D.: The location of defects in structures from measurements of natural frequencies. *Journal of strain analysis , 14* (2), S. 49-57 (1979)
3. Soutis, C., & Curtis, P. T.: Prediction of the post-impact compressive strength of CFRP laminated composites. *Composites Structures and Technology* (56), S. 677-684 (1996).