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A numerical methodology for detection of impact damage using natural frequency

Zhihong Liang
Karthik Ram Ramakrishnan
Zhifang Zhang
Antonio Pellegrino

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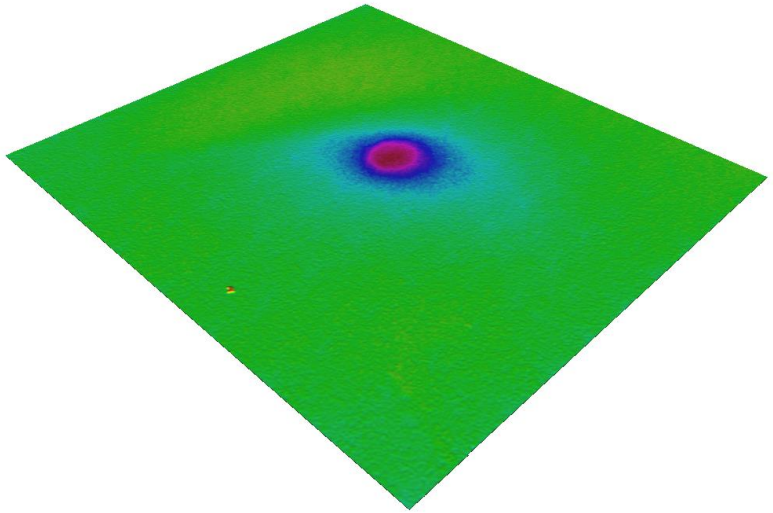
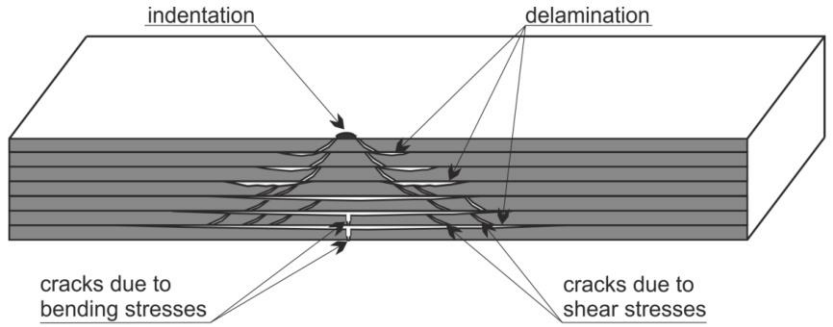
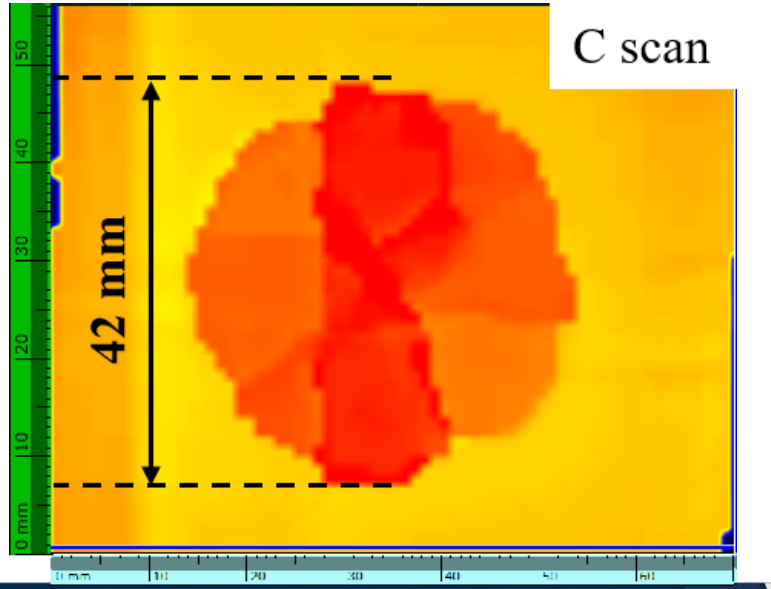
Motivation

bird strike



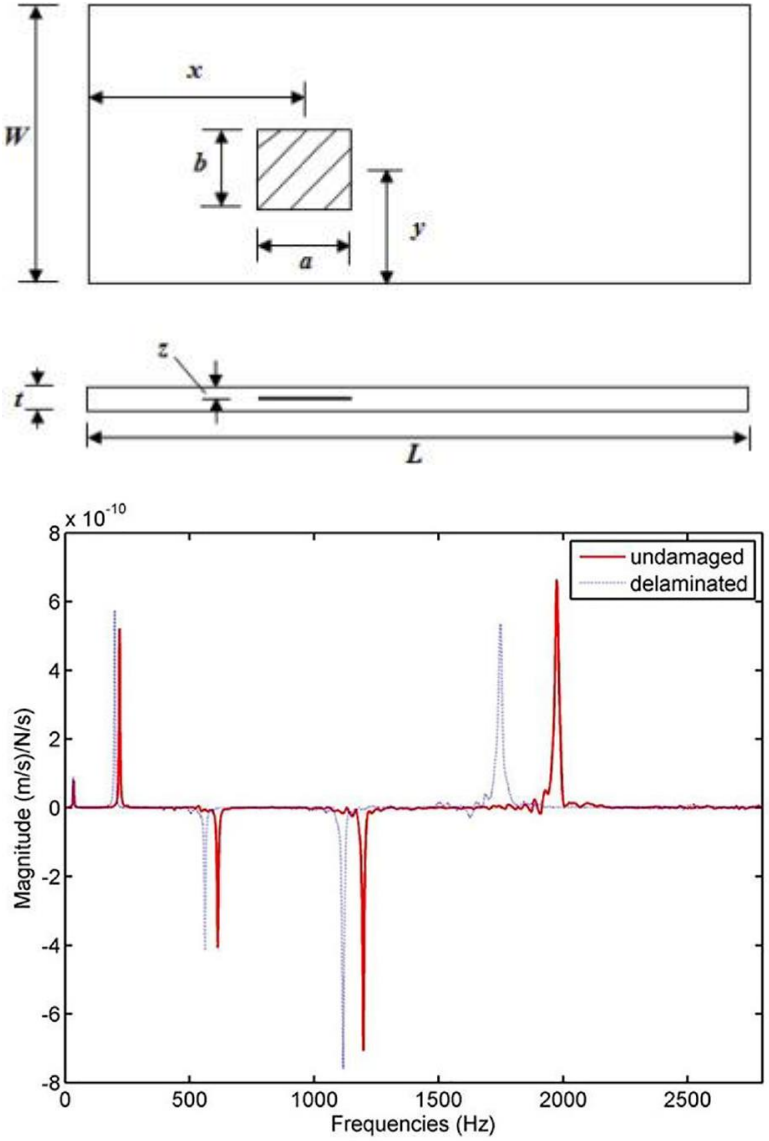




- Impact loading during service life causes damage
- Delamination, matrix cracking and fibre failure

Forward problem

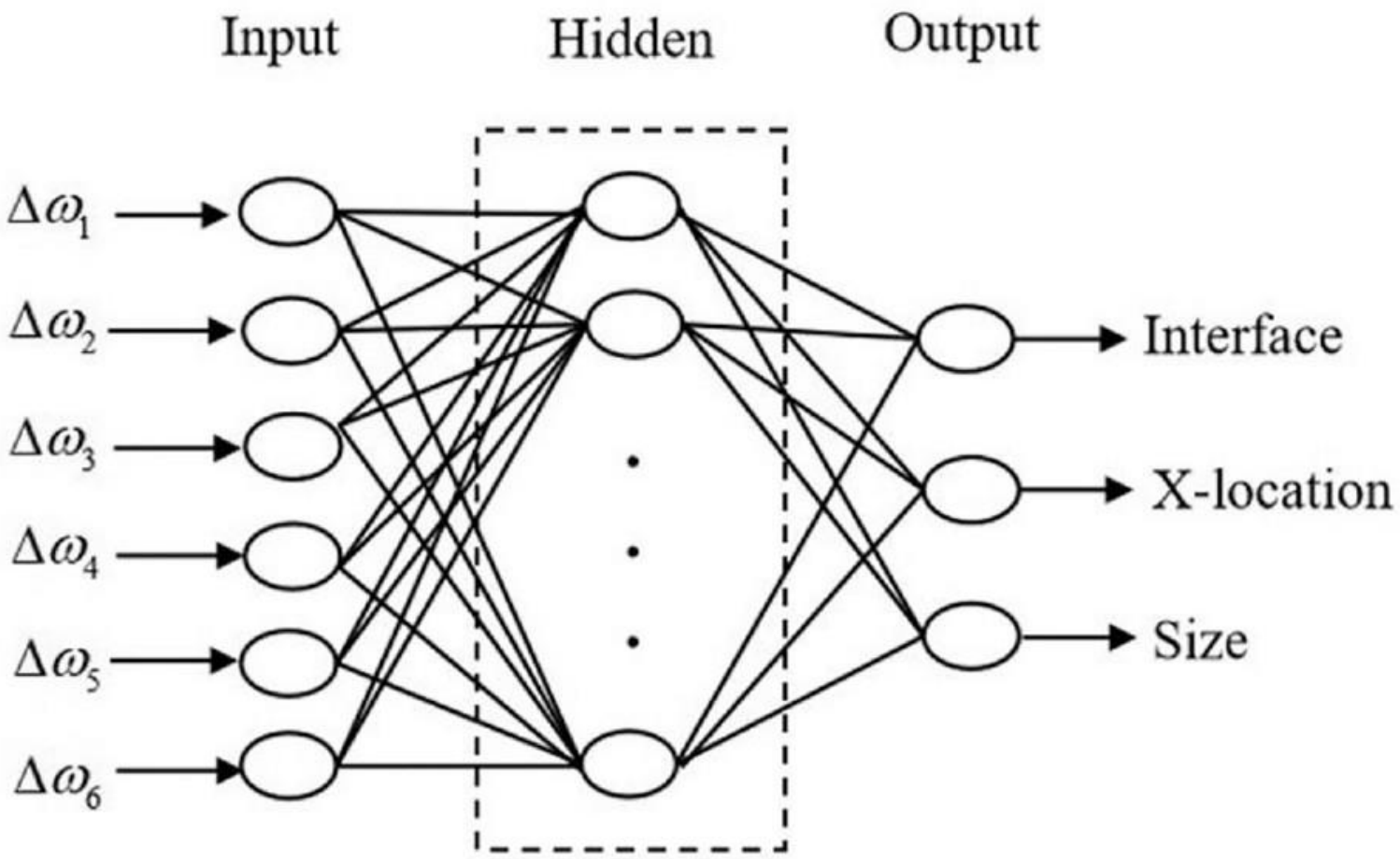
- Known location, size and interface of damage
- Evaluate change in natural frequencies



Zhang Z et al.. Vibration-based assessment of delaminations in FRP composite plates. Composites Part B: Engineering. 2018 Jul 1;144:254-66.

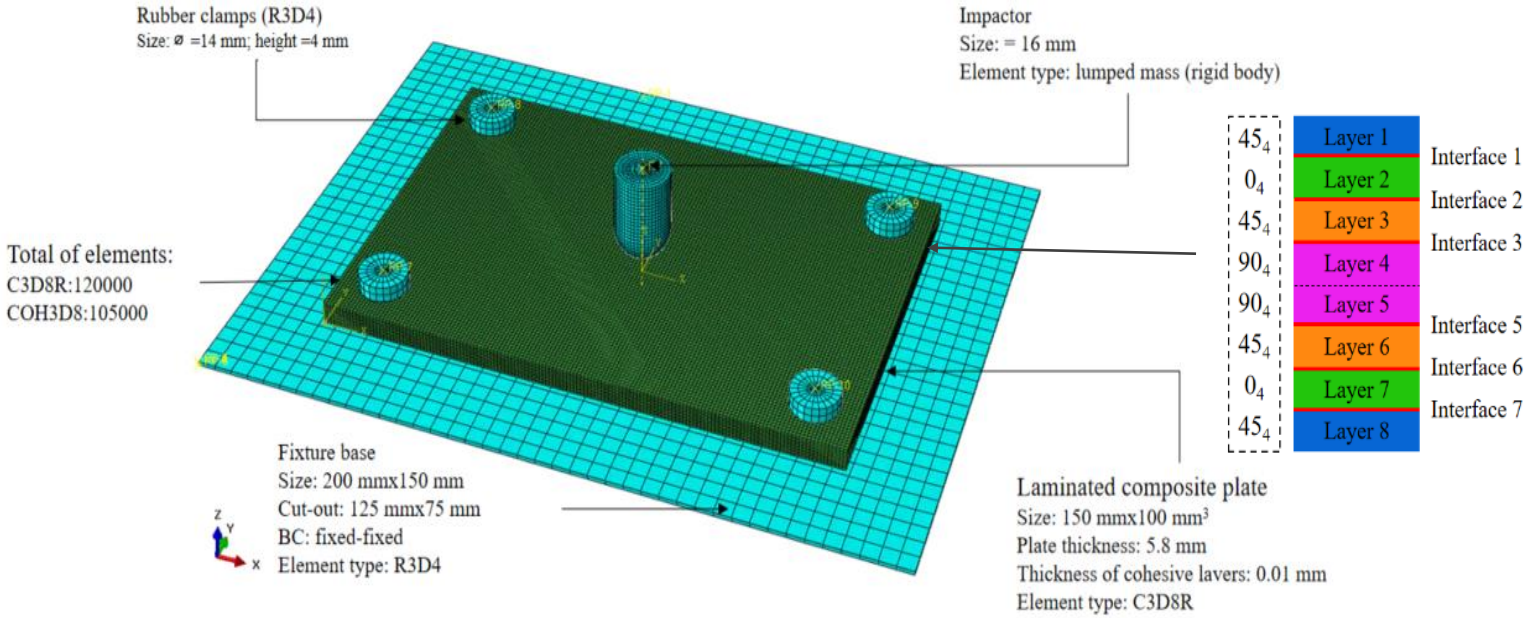
Inverse problem

- Predict location, size and interface of damage from frequency shifts

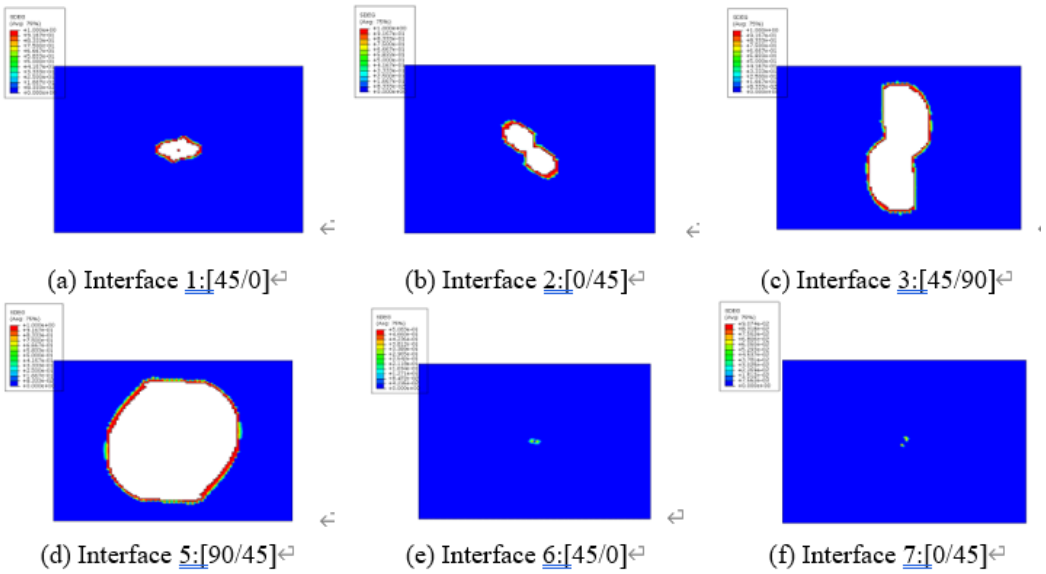


He M et al. A comparison of machine learning algorithms for assessment of delamination in fiber-reinforced polymer composite beams. Structural Health Monitoring. 2021

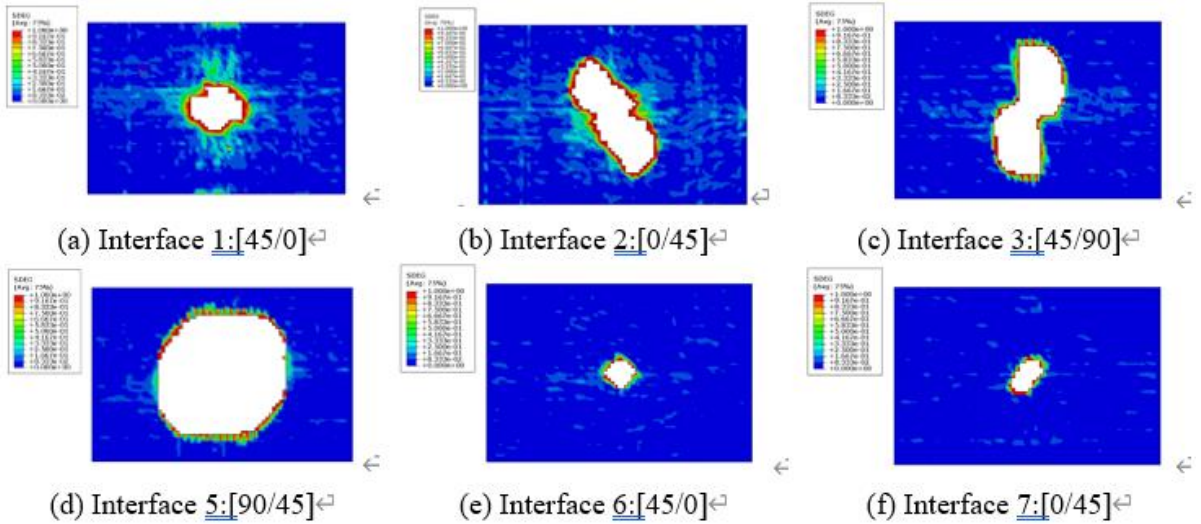
Impact modelling in Abaqus



Results of impact model

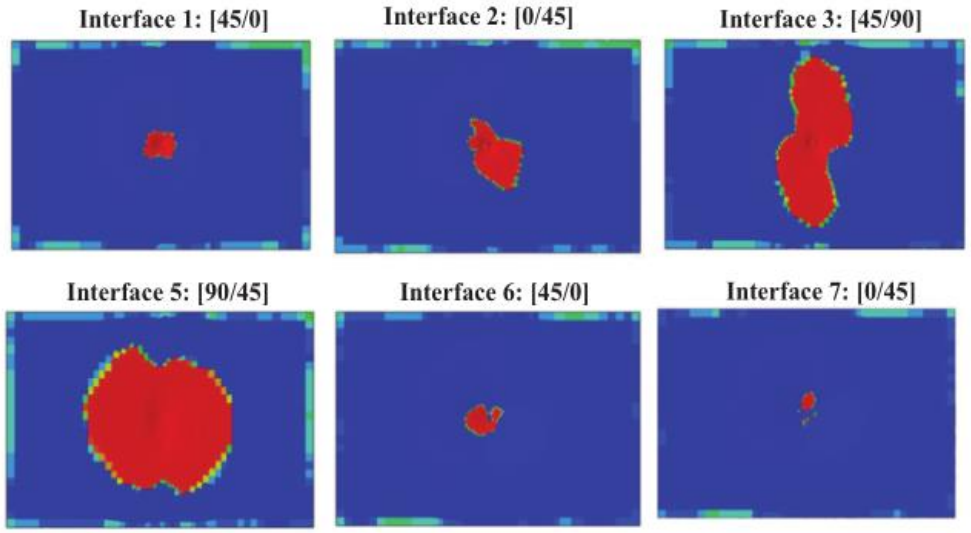


In-built 2D-Hashin model

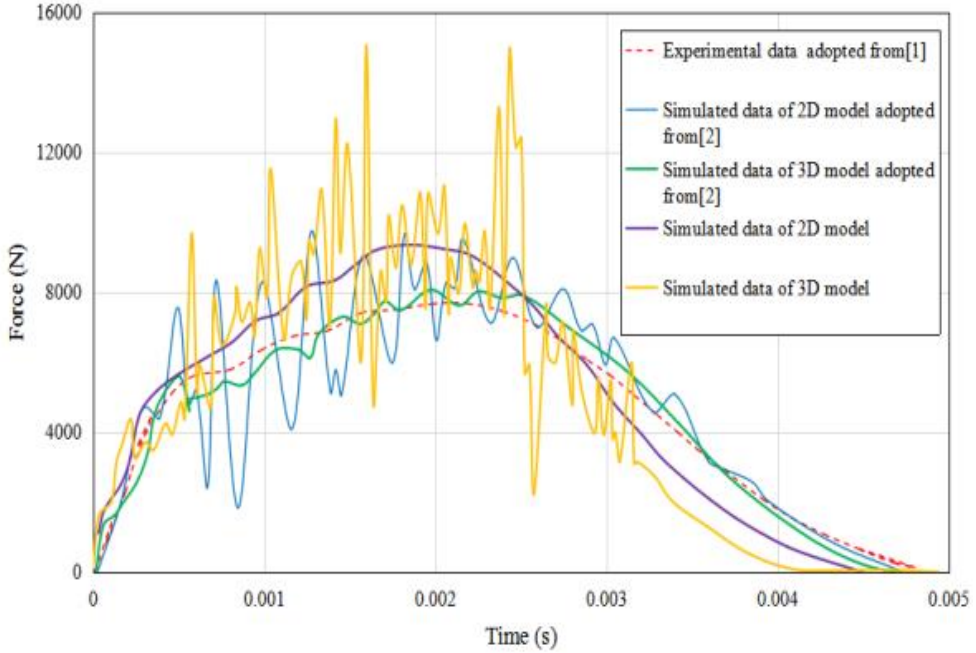


3D-Hashin model as VUMAT

Validation of impact model

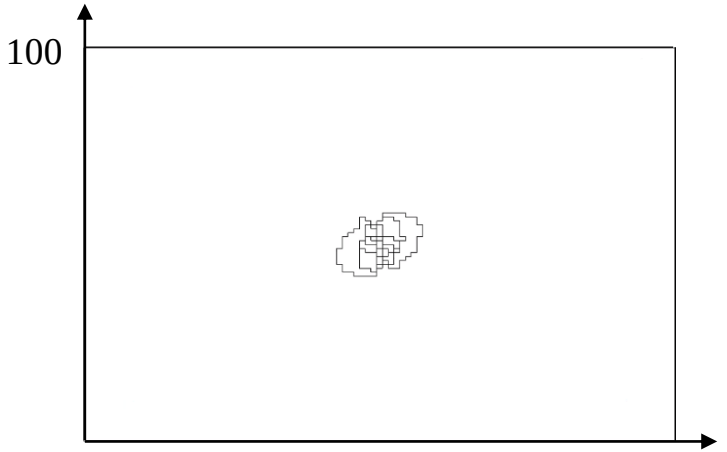


Pham D C, Lua J, Sun H, et al. Journal of Composite Materials, 2020, 54(4): 449-462.

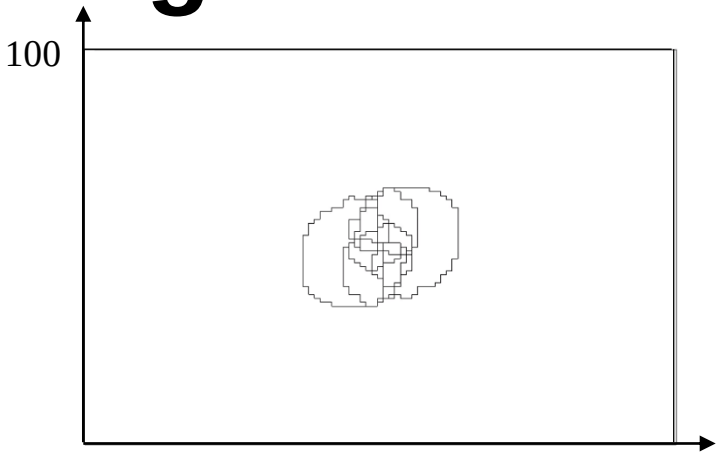


Time history force of different models.

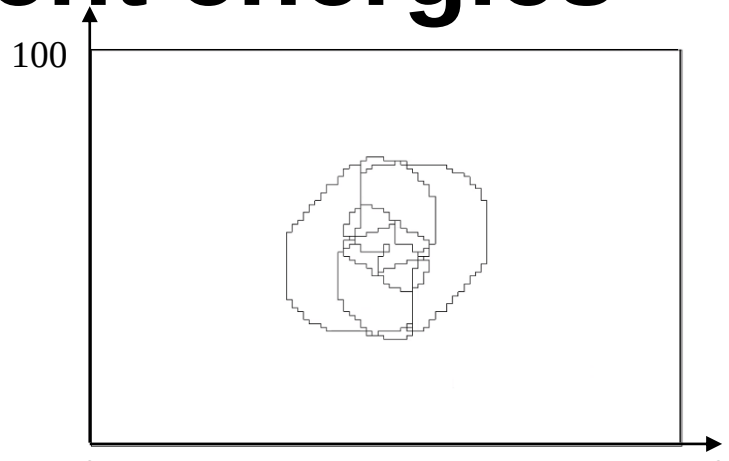
Delamination damage for different energies



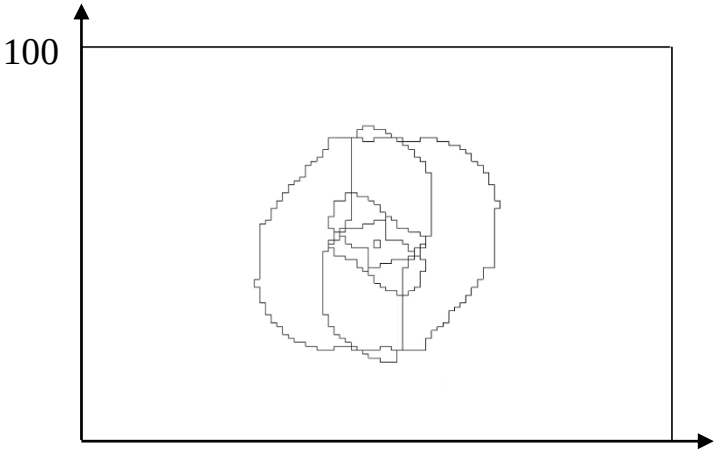
(a) Delamination area under 3J



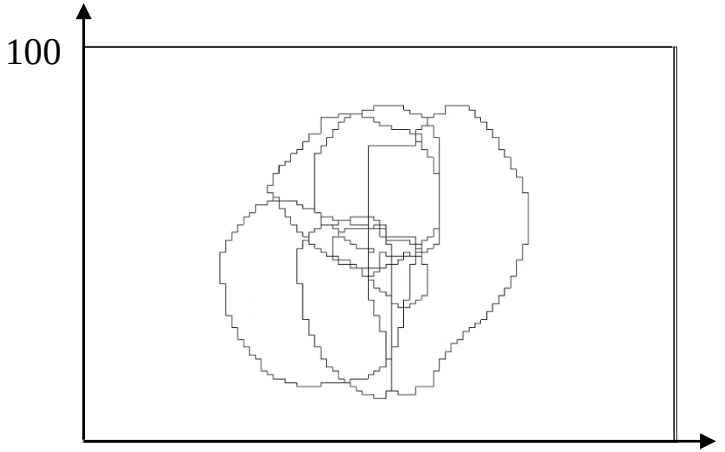
(b) Delamination area under 6J



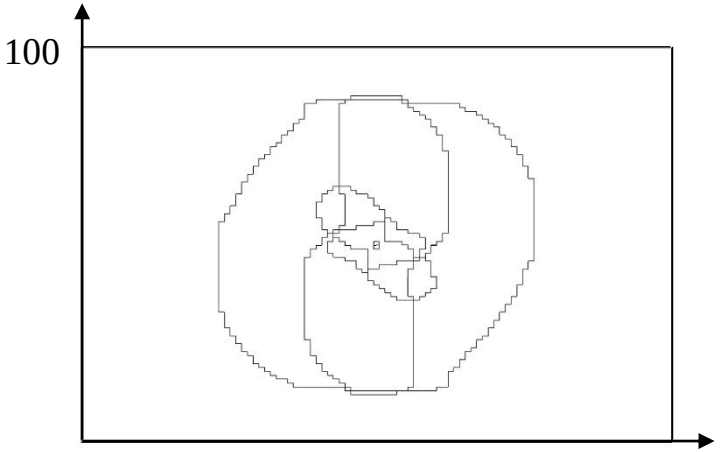
(c) Delamination area under 9J



(d) Delamination area under 12J

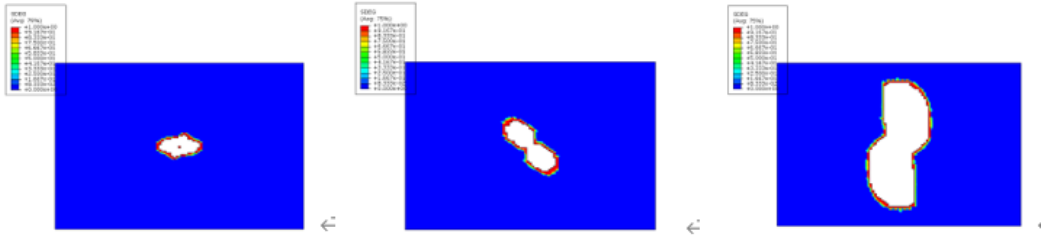


(e) Delamination area under 16J



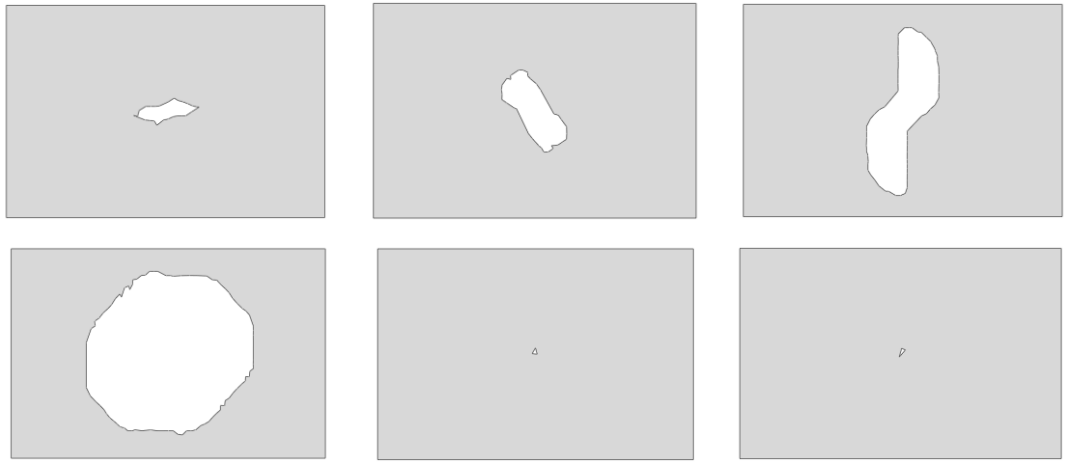
(f) Delamination area under 19.3J

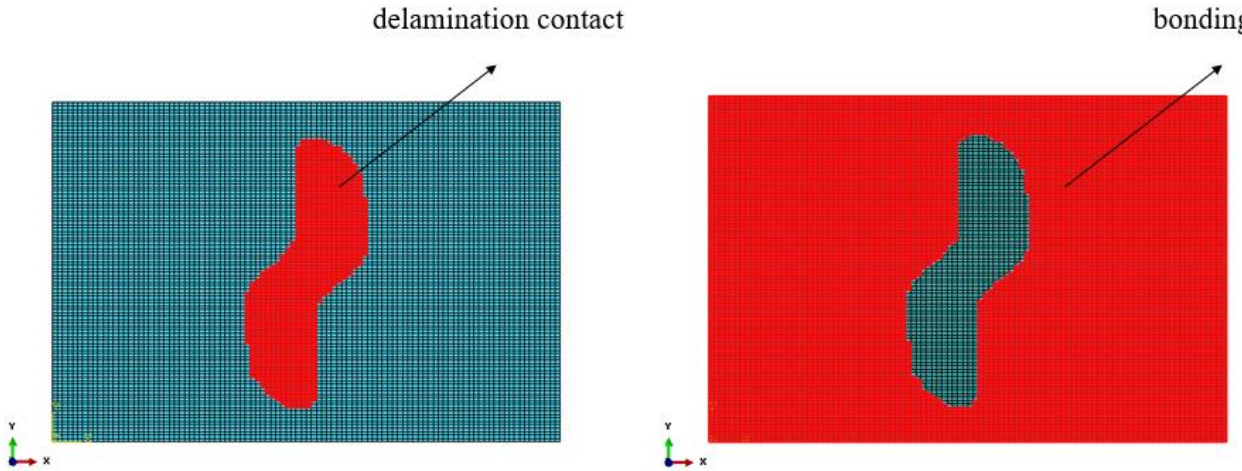
Delamination mapping



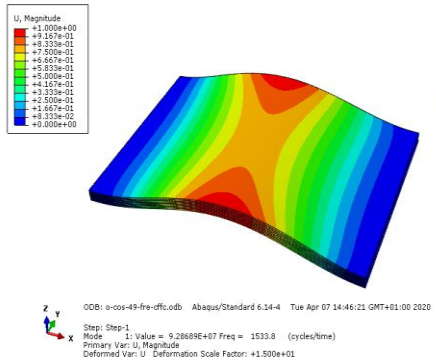
(a) Interface 1:[45/0]↵ (b) Interface 2:[0/45]↵ (c) Interface 3:[45/90]↵

(d) Interface 5:[90/45]↵ (e) Interface 6:[45/0]↵ (f) Interface 7:[0/45]↵

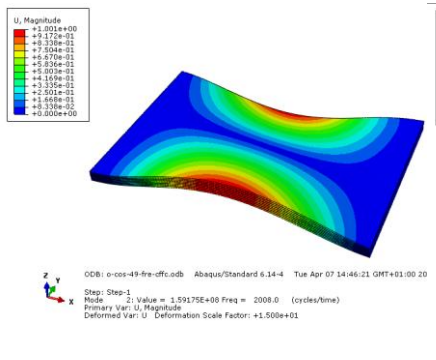




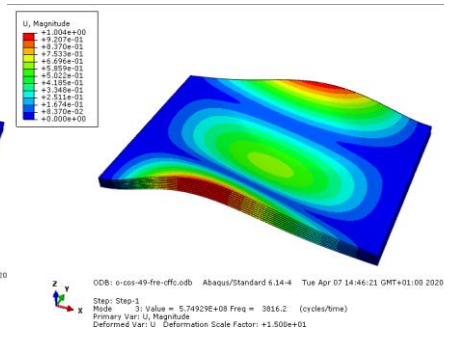
Mode shapes of undamaged plate



Mode 1



Mode 2



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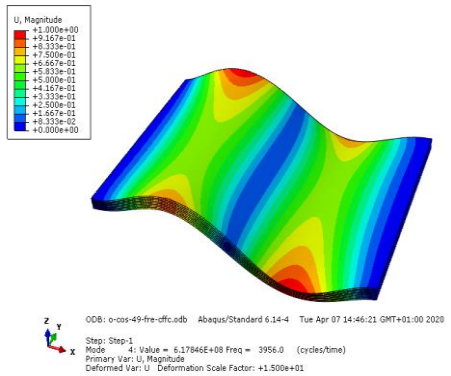
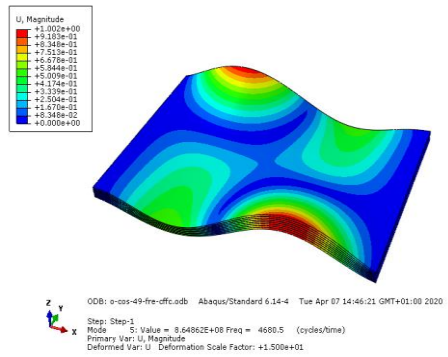


Mode 4

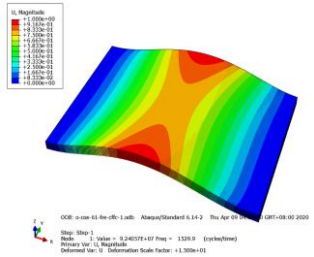


Mode 5

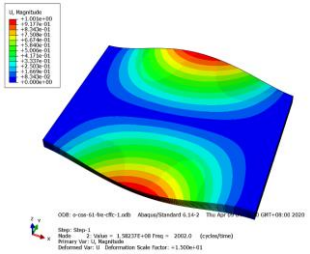
Mode shapes of damaged plate

3J Impact

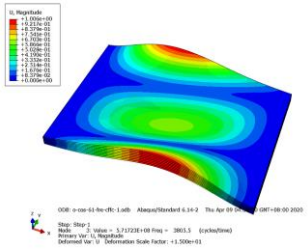
Mode 1



Mode 2



Mode 3



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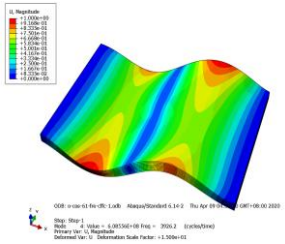
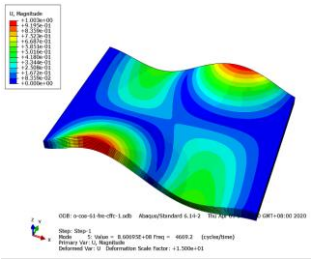
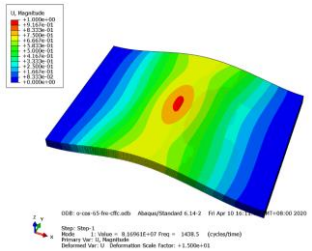
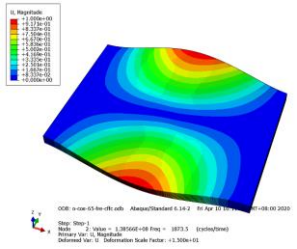


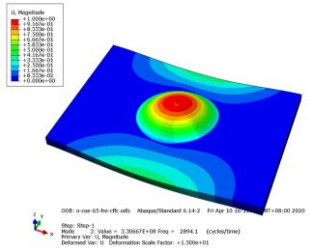
Mode 5

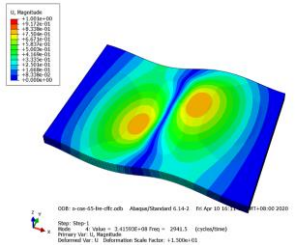


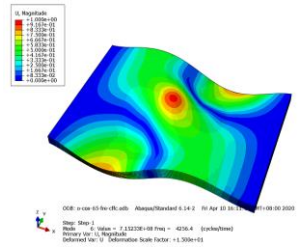
16J Impact



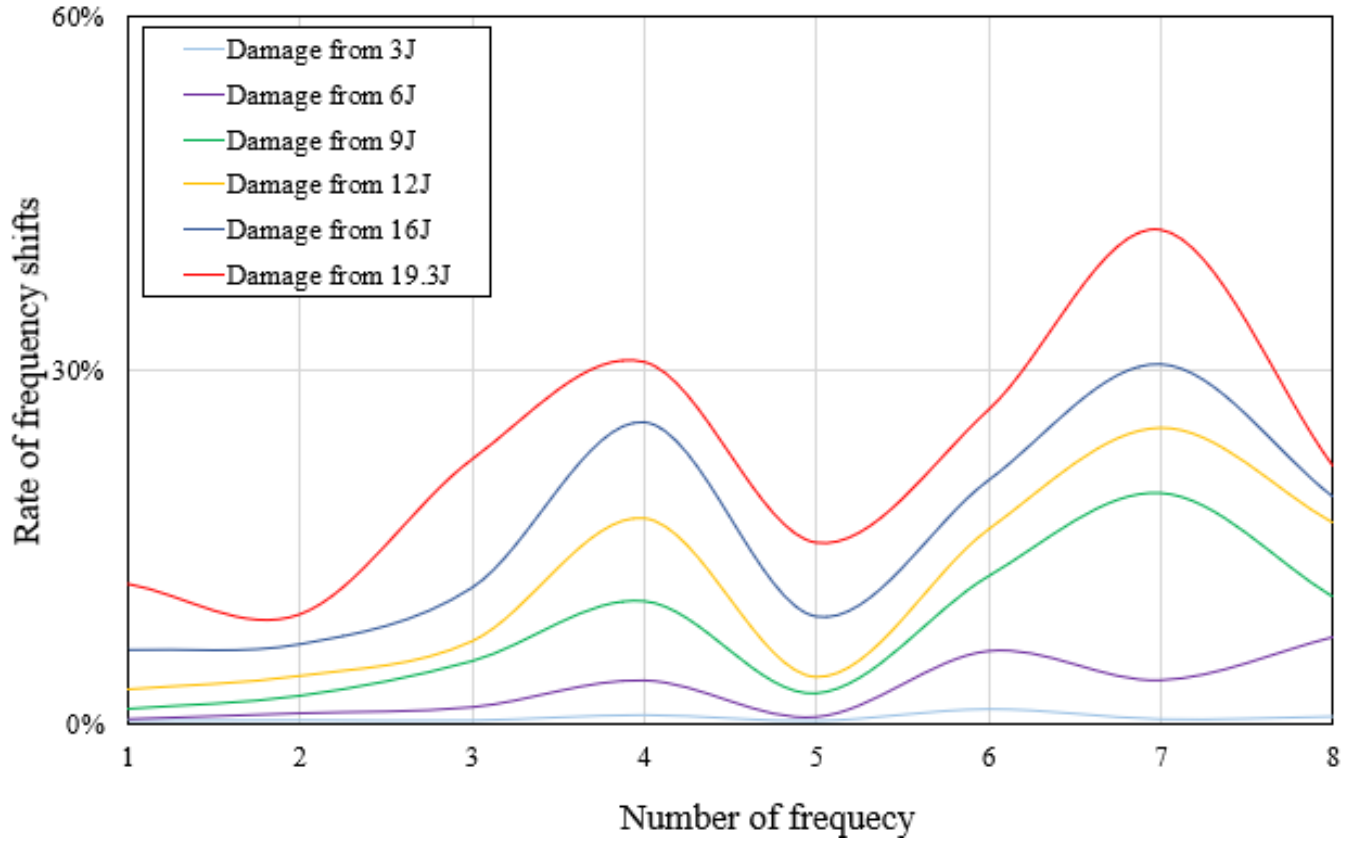








Effect of damage on natural frequency



- Frequency shift in different modes are not the same
- Non-linear response

Summary

- Impact loading causes complex damage modes
- Vibration based SHM uses frequency shifts
- Forward vs Inverse problem
- Numerical model with delamination mapping
- Training of Machine Learning algorithms
- Future work on experimental validation of frequency shifts

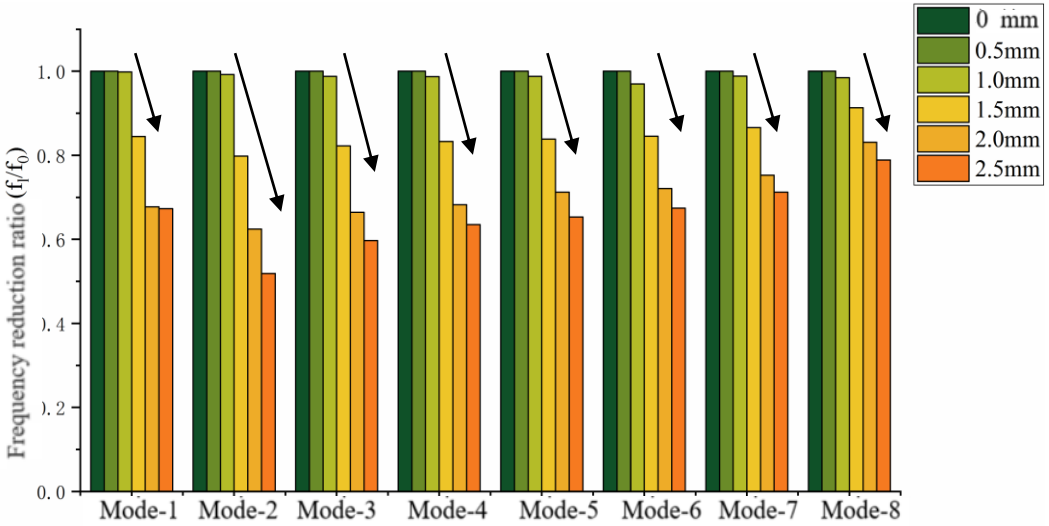


Fig.6. Frequency shift diagram of finite element model

Acknowledgements

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