Finite element simulation and delayed TR-NEWS analysis of contact gap in carbon fibre composite

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Abstract
Carbon Fibre Reinforced Polymer material with a contact gap defect is simulated by finite element method. The 2D simulation is based on a simple laminate model of the anisotropic material layers. It is conducted in a 2D quarter space of simulated material with Lysmer and Kuhlmeier absorbing boundary conditions. The contact gap is included in the epoxy layer near the receiving transducer. It is modelled using node-to-node contact algorithm. The Kuhn-Tucker normal contact conditions are satisfied by penalty plus Lagrangian multiplier method. Friction effects are included using penalty method. The finite element dynamic wave propagation problem is solved explicitly by central difference scheme using diagonalized mass and damping matrices. The simulation results are to be used to compare various non-destructive testing methods meant for nonlinear defect detection, such as delayed Time Reversal - Nonlinear Elastic Wave Spectroscopy (TR-NEWS) and Pulse Inversion. Using the simulation results, the interaction of the wave field with the defect inside the material can be closely examined to investigate the benefits of advanced non-destructive testing methods.

Introduction
Original TR-NEWS signal processing can be used to focus the wave energy under the receiving transducer or vibrometer of an ultrasonic Non-Destructive Testing (NDT) setup. It is a promising method for evaluation of complex, dispersive and nonlinear media because it relies on the internal reflections for the focusing process of the wave energy into a specific spot in a certain time, therefore taking advantage of the complex internal structure of the material. Such focused wave has an improved signal-to-noise ratio, making it suitable for investigating dispersive, chaotic or highly attenuating media. The investigation has been carried out initially experimentally on bi-layered aluminium block, then on a CFRP sample. The findings are studied further using Finite Element Method (FEM) simulation of wave motion in a stochastic layer thickness laminate model of CFRP sample. The 2D simulation is based on a simple laminate model of the anisotropic material layers. The investigation has been carried out initially experimentally on bi-layered aluminium block, then on a CFRP sample. The findings are studied further using Finite Element Method (FEM) simulation of wave motion in a stochastic layer thickness laminate model of CFRP sample. The simulation results are to be used to compare various non-destructive testing methods meant for nonlinear defect detection, such as delayed Time Reversal - Nonlinear Elastic Wave Spectroscopy (TR-NEWS) and Pulse Inversion. Using the simulation results, the interaction of the wave field with the defect inside the material can be closely examined to investigate the benefits of advanced non-destructive testing methods.

Delayed TR-NEWS

The delayed TR-NEWS allows to use the single focusing as a basis of amplitude modulation, to create arbitrary wave envelope shapes in the focusing region. This could be used to introduce a low-frequency component into the material by using high-frequency transmitter. It was found that the reduction of the sidelobes in CFRP is still possible and effective by using delayed TR-NEWS directly on the sidelobes: using a larger delay and smaller amplitude waves tailored to directly arrive at the focusing point at the same time and magnitude as sidelobes but in an opposite phase. The future work in this subject will include the analysis of a local nonlinearity in the focusing region using the proposed delayed TR-NEWS signal processing method. The FEM model can be used to predict the probable size of a defect that could be detected with this method.

Conclusion

The delayed TR-NEWS allows to use the single focusing as a basis of amplitude modulation, to create arbitrary wave envelope shapes in the focusing region. This could be used to introduce a low-frequency component into the material by using high-frequency transmitter. It was found that the reduction of the sidelobes in CFRP is still possible and effective by using delayed TR-NEWS directly on the sidelobes: using a larger delay and smaller amplitude waves tailored to directly arrive at the focusing point at the same time and magnitude as sidelobes but in an opposite phase. The future work in this subject will include the analysis of a local nonlinearity in the focusing region using the proposed delayed TR-NEWS signal processing method. The FEM model can be used to predict the probable size of a defect that could be detected with this method.

Aknowledgments

This work is supported by the Région Centre-Val de Loire (France) under the PLET project. This research has been conducted within the co-tutelle Ph.D. studies of Martin Lints, between the Institute of Cybernetics at Tallinn University of Technology in Estonia and the Institut National des Sciences Appliquées Centre Val de Loire at Blois, France. The laboratory visits have been funded by European Social Funds via Estonian Ministry of Education and Research and Archimedes Foundation (30.1-9.3/287, 30.1-9.3/1137 and 16-3-4/1390) through DoRa and Kristjan Jaak Scholarship programmes. This research is partly supported by Estonian Research Council (project IUT33-24). This work is supported by the Région Centre-Val de Loire (France) under the PLET project. This research has been conducted within the co-tutelle Ph.D. studies of Martin Lints, between the Institute of Cybernetics at Tallinn University of Technology in Estonia and the Institut National des Sciences Appliquées Centre Val de Loire at Blois, France. The laboratory visits have been funded by European Social Funds via Estonian Ministry of Education and Research and Archimedes Foundation (30.1-9.3/287, 30.1-9.3/1137 and 16-3-4/1390) through DoRa and Kristjan Jaak Scholarship programmes. This research is partly supported by Estonian Research Council (project IUT33-24). This work is supported by the Région Centre-Val de Loire (France) under the PLET project. This research has been conducted within the co-tutelle Ph.D. studies of Martin Lints, between the Institute of Cybernetics at Tallinn University of Technology in Estonia and the Institut National des Sciences Appliquées Centre Val de Loire at Blois, France. The laboratory visits have been funded by European Social Funds via Estonian Ministry of Education and Research and Archimedes Foundation (30.1-9.3/287, 30.1-9.3/1137 and 16-3-4/1390) through DoRa and Kristjan Jaak Scholarship programmes. This research is partly supported by Estonian Research Council (project IUT33-24).

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