DIPARTIMENTO DI INGEGNERIA DELL'ENERGIA ELETTRICA
E DELL'INFORMAZIONE "GUGLIELMO MARCONI"

Ph.D. Thesis Title: Feasibility Study of Artificial Intelligence Approach for Delamination Identification in Composite Laminates
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Reviewer name: Luca De Marchi
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Evaluation Report

1. Originality of the scientific contribution

The thesis introduces new concepts and ideas which can be used for Guided waves based inspections performed with scanning laser Doppler vibrometers (full wavefield imaging). These measuring devices sense the guided waves propagating in the structure multiple times at each point of a fine grid. Next, the acquired database of guided waves signals is processed to detect, locate and size damages. In many practical applications, this adds a level of complexity that other authors have not been able to tackle. Even when successful in revealing damage features, such measuring strategies have some drawbacks, including time and energy consumption for acquiring and handling a large amount of data. The scan time is a specific concern for scanning laser vibrometers (SLDV), because of their relatively low signal to noise ratio (SNR) which requires the implementation of averaging procedures.
This thesis makes major contributions in the damage detection and localization task and in proposing a novel strategy to speed up the acquisition process.

More specifically, Chapter 4 introduces new methodologies based on data driven approaches for (single and multiple) delamination identification and for the recovery of high resolution full wavefield frames from low-resolution frames acquired with SLDV. The ideas put forward are then extensively validated in Chapter 5.
It is worth noting that:

1) the implemented procedure is based on the development of a numerical model, which was used to generate a synthetic dataset of Lamb waves signals propagating in CFRP plates;
2) the final validation of the proposed algorithms was conducted also on experimental data.

Many different data-driven approaches have been investigated in this Thesis, these methods can be subdivided in:

1) One-to one approaches used to process RMS images of the full wavefield.
2) Many-to-one approaches used to process multiple frames and to output damage maps.
3) Deep learning -super resolution methods.

These approaches are not original per se but it is novel the application of these method in the context of Full wavefield inspections, the customization of the feature extraction process and the procedure put in place for the construction of the training dataset.

The long Chapter 5 demonstrates the possible advantages brought by the adoption of the considered approaches in practical application domains with respect to conventional alternatives proposed in literature such as adaptive wavenumber filtering for defect detection or Compressive sensing for the acquisition process.

Taken together, this thesis represents an excellent body of work, which provide a solid contribution to knowledge and innovation.

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2. Presentation of the state of the art and quality of the references

The thesis contains a very good review of the state of the art, and this is backed up by a full set of appropriate references. Chapters 2 and 3 provide very good background material for guided-wave based Structural Health monitoring, including important instrumentation such as Scanning Laser Doppler Vibrometers. Chapter 2 also gives an explanation of the Compressive Sensing Approach. In the subsequent Chapter, the data-driven based SHM/NDT techniques are presented. At each stage, the thesis gives references to the current state-of-the-art in terms of techniques and signal processing approaches that have been reported, and an explanation is given on why a new approach is needed. It is thus evident that the previous literature has been reviewed and cited properly, and the current work put into context.

3. Technical soundness

I could not find any areas where technical errors had been made. The provided information was complete throughout the thesis.

4. Quality/value/impact of obtained results and of publications produced in the PhD period

The candidate has prepared 4 journal papers (2 of them are under review), 2 conference papers and 3 scientific monographs. The journal papers are all in very respected journals. This is a very good record for a PhD student.

5. Presentation quality, readability, and manuscript organization

The thesis is very well-written. There are very few typographic errors. It is very readable, and the organization is logical. The diagrams are drawn properly, with axis labels on graphs which are all properly labelled. This is a good thesis from this viewpoint.

Overall recommendation: The thesis is of very good quality and the PhD should be awarded, to this reviewer opinion.

Suggested Improvements:

- Major recommendations (none)
- Minor recommendations:
  - In the Table of Contents, the title of Chapter 2 has to be corrected
  - In Section 3.2.3, I suggest to check this sentence "the future events are also used to predict the output". I suppose that the correct sentence should be "the past events are also used to predict the output".
  - Please clarify if the specimens used in the multiple delamination experiments (page 94) are different with respect to the ones used in the other experiments and in the simulations (16 vs 8 layers?).
  - In Section 6.2, I suspect that there are missing words ([xxx]) in this sentence: "Another issue that can be investigated is [xxx] when recovering an HR frame [...]

Yours sincerely.

Prof. Luca De Marchi, Luca De Marchi

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