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Optimisation and state identification of composite shell using Deep Neural Networks

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Abstract: Multi-layer composite structures have many advantages from the point of view of potential use in e.g. civil engineering. Their shaping and optimisation can exploit possibilities unavailable in other types of materials. A genetic algorithm-based optimisation of selected dynamic and buckling parameters of a cylindrical composite shell is presented herein. The natural frequencies of vibrations of the shell and the mode shapes were chosen as the source of data for optimisation. In order to eliminate problems related to the natural frequencies crossing, two approaches for the identification of mode shapes were proposed: analytical and based on deep learning with the use of convolutional neural networks. Automatic identification of mode shapes allowed was applied to perform some selected tasks usually associated with structural health monitoring, namely the detection of the state of local degradation of the composite material and localization of such a change.

Keywords: multi-layer composite, deep networks, optimisation, damage detection

1. Introduction

Multi-layer composite structures have many advantages from the point of view of potential use in e.g. civil engineering, among these are lightness, durability and strength. Moreover, their shaping and optimisation can exploit possibilities unavailable in other types of materials; by changing parameters such as lamination angles in individual layers, it is possible to change and optimise the entire structure, while leaving its shape and the materials used to build the composite shell (matrix and reinforcement) unchanged.

This abstract presents a genetic algorithm-based optimisation of selected dynamic and buckling parameters of a cylindrical composite shell. The natural frequencies of vibrations of the shell and the mode shapes were chosen as the source of data for optimisation. In order to eliminate problems related to the natural frequencies crossing (see [1]), two approaches for the identification of mode shapes were proposed: analytical (see [2]) and based on deep learning with the use of convolutional neural networks (see [3]).

Automatic identification of mode shapes allowed, apart from accelerating and increasing the accuracy of the optimization process, was applied to perform some selected tasks usually associated with structural health monitoring, namely the detection of the state of local degradation of the composite material and localization of such a change.

The FE model and the applied optimisation procedure were verified by comparing the results with test examples available in the literature.

2. Results

Example results of identification errors of the appearance of local material degradation in the considered shell are shown in Fig. 1. The horizontal axis in Fig. 1 shows the width and height (equal to each other) of the area with local material degradation expressed in the number of finite elements, the vertical axis shows the number of so called “False Negatives”, i.e. misidentification of an damaged state as undamaged. The value of 2 on the horizontal axis means that the area of local degradation was as high as 2x2 finite elements, which is about 0.04% of the total coating area (the whole shell consisted of 9600 finite elements). The total number of test cases was 6000, the number of errors even for the smallest area of material degradation, at the level of a few dozen cases should be considered negligible. Subsequent series in Fig. 1 show identification cases with different number of mode shapes taken into account.

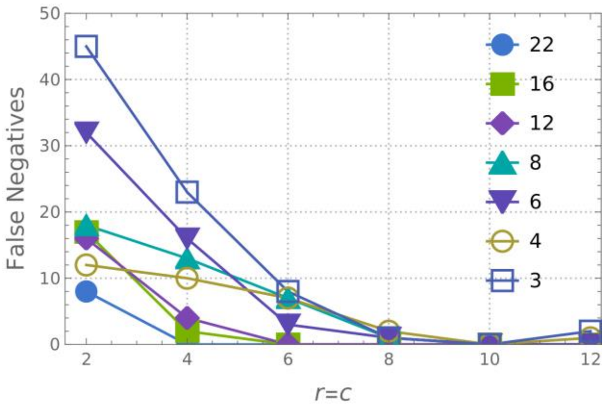

Fig. 1. False negatives for different sizes of area with material constants degradation.)

3. Concluding Remarks

The proposed optimisation method of dynamic and buckling properties of a composite shell and the identification of local degradation state on the basis of identified mode shapes are very robust. The change of the material or even occurrence of local material degradation do not affect the accuracy of the method.

References

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