Multicriteria Optimization of a Composite Shell Using Network-Based Surrogate Model and Genetic Algorithms

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ABSTRACT

The paper presents a multicriteria optimization of the dynamic behavior of a composite shell. Machine learning and genetic algorithms are applied, and the frequency spectrum of the analyzed shell and the total cost of materials are optimized. The optimized dynamic parameters of the structure under the study are the shell’s fundamental natural frequency and the gap in the frequency spectrum around an arbitrarily selected excitation force frequency.

A novel optimization framework—allowing the reduction of numerical effort—is proposed, with a deep neural network-based surrogate model of the analyzed shell and multi-fidelity FE models applied for surrogate model training and verifying final results. This approach leads to the reduction of necessary FE calls and an even higher reduction of FE computational costs since some tasks are performed using simple FE models.

Different variants of neural network-based surrogate models (i.e., only a single network or five networks ensembles) were tried out; moreover, the advantages and disadvantages of surrogate model transfer learning are verified, and the possibility of building surrogate models based on a limited number of examples is investigated. During the construction of surrogate models, the identification of vibration mode shapes is also applied. The results obtained are compared with the classical approach, with the natural frequencies ranked in ascending order.

The numerical simulations presented in the paper are also carried out using a pseudo-experimental model, in which the values of the natural frequencies are obtained as FEM-generated values disrupted using linear or nonlinear functions.

The optimization algorithm proposed in the paper is very efficient, allowing multicriteria optimization to be carried out with significantly reduced computational costs. Moreover, the most numerically costly calculations are performed in the preliminary phase and used to build and test the surrogate model.

Keywords: deep neural networks, dynamic, genetic algorithms, multi-objective optimization, surrogate model.