Dynamics and hybrid optimization of cylindrical composite shells

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Abstract

Civil engineering, as many other engineering fields like e.g. aircraft engineering, is facing the necessity of application of new materials: strong, light and durable. New types of usual and well-known materials like steel or concrete are still being introduced, but the modern engineering and the requirements of bridges, high-rise buildings and other engineering structures need something new.

Composites are fabricated out of a number of layers, each of them created using at least two types of materials: one playing a role of a reinforcement (fibre) and the other being a matrix. The combination of a reinforcement and a matrix allows the creation of a new material with some parameters outclassing both a reinforcement and a matrix properties. Moreover, it is possible to control and tune the parameters of a composite material through careful selection of reinforcement fibres orientation, possibly different for each of composite layers. The properties tuned through the changes in the lamination fibre (reinforcement) angles are the dynamic properties such as free vibration frequencies and mode shapes.

In many engineering problems the dynamic parameters have to be tuned, e.g. to avoid a dynamic resonance or to mute a noise produced by a vibrating structure. The optimisation of a composite structure through the selection of optimal lamination fibre angles needs a number of fitness function evaluations, each of them being in case of non-linear problems very computationally expensive and time-consuming. Moreover, for multi-modal fitness functions the application of zero-order search algorithms is recommended, so the number of time-consuming fitness function evaluations increases rapidly and the whole process of optimisation may be lengthened into several hours or even more.

The paper presents a new approach to the optimisation of composite structures dynamic properties. As a procedure for minimisation of a fitness function, describing the desired parameters of investigate structure, Genetic Algorithms (GA) are applied. Since GA are working simultaneously on a big population of possible solutions the number of fitness function evaluation may be very huge. The application of a Finite Element Method (FEM) to obtain fitness function values is possible, but in case of thousands of evaluations this may lead to the optimisation process lasting for hours of even days.

Herein, instead of FEM fitness function evaluations, a well-trained neural network (NN) is applied. Since NN needs to be trained in advance on examples prepared through FEM the application of NN may only lead to the shift of the time-consuming FEM calculations into the stage of NN training, without any significant time savings. In the presented approach NN is being trained on a limited number of examples, moreover the whole set of examples prepared through FEM calculations is used together with a trained NN as an auxiliary "lookup table". The NN being a replacement of FEM model, reads input vector composed not only of parameters being tuned (e.g. lamination angles) but also of optimised structure parameters of a "neighbouring" cases read from a FEM generated lookup table of examples. The number of examples obtained using time-consuming FEM calculations may be thus significantly reduced.

Keywords: **Dynamics, composites, optimisation, neural networks, genetic algorithms**