Two-scale analysis of composite plates with in-plane periodic heterogeneities

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ABSTRACT

A method of two-scale analysis of composite plates with in-plane periodic and local heterogeneities is presented. The overall structure is replaced by an equivalent laminate at macro-scale, each of whose lamina has its own homogenized material properties, and its in-plane, bending and coupling stiffness characteristics can be evaluated by the numerical plate testing (NPT) based on the in-plane homogenization method.

The NPT, which is similar to the numerical material testing (NMT) [1], is realized by finite element analyses with solid elements that are conducted on the three-dimensional unit cell models only with in-plane periodicity constraints. Also, the data obtained from the NPT can be used to identify the material properties for all the laminae. Note here that the macro-scale plate is regarded as a laminated composite plate, even if a laminated structure is not assumed for the microstructure. This setting enables us to assume nonlinear material behavior for constituent materials at micro-scale.

Our first trial on this development focuses on the linearly elastic materials so that the in-plane, bending and coupling stiffness matrices in the conventional laminate model can be evaluated as macro-scale properties. The second stage of our presentation is extension to NPT with nonlinear materials, in which material properties for each macroscopic lamina are identified with the method of particle swarm optimization or differential evolution with the help of the novel method of NPT conducted on a unit cell discretized with laminated plate elements.

Several numerical examples are presented to demonstrate the processes of NPT and identification of material parameters as well as the homogenization and localization capabilities of the proposed two-scale analysis method.

REFERENCES

[1] K. Terada, J. Kato, N. Hirayama, T. Inugai and K. Yamamoto, Comput. Mech. **52**, 1199 (2013).