# Commercialization of homogenization-based two-scale analysis method for composites with ANSYS

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## ABSTRACT

This paper presents our recent efforts to commercialize a method of two-scale analysis based on the homogenization theory for composite materials and structures. Our approach of the two-scale analysis hinges on the method of *numerical material testing* [1], which enables us to identify the macroscopic material parameters by means of optimization methods, in conjunction with the *micro-macro decoupling scheme* [2]. The procedure for the relevant micro- and macro-scale analyses is integrated and implemented into ANSYS, one of the popular general-purpose FEM software.

The *first step* of the micro-macro decoupling scheme for two-scale analysis is to prepare a *numerical specimen* for numerical material tests (NMT's), which is actually a finite element model of the periodic microstructure (unit cell) of a composite material under consideration. All the material models and their parameters as well as the geometrical information for the unit cell have to be prepared, though some of the standard unit cells are prepared in the CAD database. The *second step* is to conduct a series of NMT's on the prepared unit cell to obtain the macro-scale stress-strain curves so that the corresponding macroscopic constitutive law can be selected and the calibration can be conducted. To impose the periodic boundary conditions on the unit cell boundaries, we implemented the equations for the multiple point constraints with control nodes into ANSYS so that users would not be bothered by special operations. The *third step* is to identify the material parameters for the employed macroscopic constitutive equations by performing relevant optimization methods with the macroscopic stress-strain curves obtained by the NMT's. In the present version of the software, we have employed and implemented the particle swarm optimization (PSO) along with the standard least-square method. After obtaining the material parameters, the standard FE analysis can be carried out for the macro-scale structure in the *forth step*. If the employed macroscopic constitutive equations are not available in commercial software, the corresponding user material subroutine must be written and implemented by ourselves. The *fifth step* is to come back to micro-scale analyses to see what have happened during the macroscopic response in the unit cell, which was used to characterize the macroscopic material behavior in the second step. To do this, we first pick up macroscopic points or elements being of interest and extract the macroscopic strain histories and then impose them to the unit cell boundaries. This final step, which might be optional, can be conducted in almost the same manner as the NMT's.

Choosing some specific composite materials, the functions and capability of the developed software commercialized in Japan is demonstrated by conducting a series of numerical analyses along with some validations with experimental data.

## REFERENCES

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