MULTISCALE IDENTIFICATION OF PARAMETERS OF INHOMOGENEOUS MATERIALS BY MEANS OF GLOBAL OPTIMIZATION METHODS

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1. Introduction

Microscopically inhomogeneous materials like composites or porous materials state an important group of structural materials. Their macroscopic material properties depend on such parameters as the properties of constituent materials, the volume fraction of constituents and shape and the location of reinforcement or voids. Determination of the properties of constituents of composite materials is an essential problem in many engineering applications.

It is assumed that considered material is macroscopically homogeneous and microscopically heterogeneous. To determine the effect of micro-structure of heterogeneous materials on their behavior at the macro level, different homogenization methods may be applied [1]. Numerical homogenization method with the representative volume element (RVE) concept is employed in the paper to obtain the connection between two considered scales [2].

The aim of this paper is to perform the identification of the material properties of the constituents of composite or porous media on the basis of measurements. The identification is performed by means of global optimization methods in the form of the evolutionary algorithm (EA) to avoid problems with multimodal objective functions and the calculation of the objective function gradient [3]. The finite element method software ANSYS Workbench is applied in both scales to solve the boundary-value problem. Modal analysis of the component made of porous material is carried out to obtain necessary measurement data.

2. Formulation of the problem

The aim of the identification is to estimate the properties of constituents of inhomogeneous material at the micro-scale level by means of the measurements performed at the macro level. The following properties are identified: i) the volume ratio and the elastic constants (Young modulus E and Poisson ratio v) for both isotropic constituents of composite materials; ii) the porosity p and the elastic constants of the material without pores in the case of the porous material.

The identification is performed as the minimization of an objective function J_0:

(1)
$$\min : J_0(\mathbf{x}) = \sum_{i=1}^{n} (\hat{q}_i - q_i)^2$$

where: $\mathbf{x} = (x_i)$ – a vector of identified parameters; $\hat{q}_i$ – measured values of state fields; q_i – values of the same state fields from the numerical model, N – the number of measurement data.

3. Numerical example

A porous steel cantilever beam of dimensions $b{\cdot}h{\cdot}l$=20·30·100 mm is considered (Fig. 1a). It is assumed that the porosity (and the same the density) is determined by one of the methods of the porosity estimation [4]; as a result two elastic constants E and ν are design variables. Homogenized material properties were obtained by the numerical homogenization of RVE containing 27 uniformly distributed spherical voids (Fig. 1b). A first five eigenfrequencies of the beam were taken into account as macroscopic measurement data. The design variables ranges were: 70 ÷ 400 GPa for

E and 0.25 ÷ 0.35 for ν, with the actual values E = 200 GPa and ν = 0.3. The porosity p = 0.15 and the density ρ = 7850 kg/m^3 are assumed to be known.

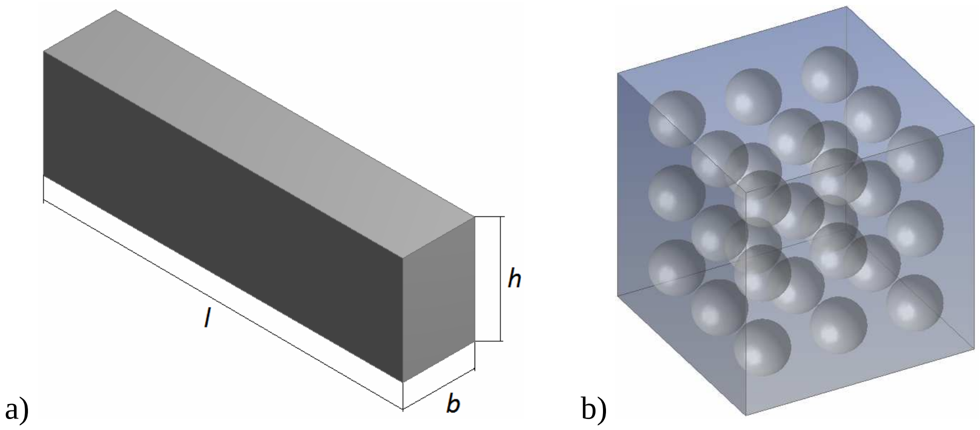

Figure 1. a) The cantilever beam and b) the RVE geometry

The parameters of EA were: the arithmetical crossover probability: p_{ac} = 0.98; the uniform mutation probability: p_{um} = 0.01; the maximum number of iterations n_{it} = 12. The values of the design variables and identification errors for different population sizes are collected in Table 1.

No.	Pop. size	E [GPa]	Error [%]	ν [-]	Error [%]
1	50	199.18	0.412	0.27683	7.724
2	100	200.17	0.083	0.30762	2.541
3	200	200.14	0.069	0.30036	0.120

Table 1. Results of the identification.

4. Conclusions

Multiscale identification of the properties of microscopically inhomogeneous material has been performed. To solve the identification problem the numerical homogenization methods, evolutionary algorithms and finite element method have been simultaneously employed. Positive evolutionary identification results have been obtained, especially for relatively large population sizes.

5. References

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