The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

NUMERICAL SOLUTION OF INVERSE PROBLEMS FOR IDENTIFICATION OF A COMPOSITE MICROSTRUCTURE. APPLICATIONS IN DESIGN OF FUNCTIONALLY GRADED MATERIALS

Marek Wojciechowski[1*] Marek Lefik[1] and Daniela P. Boso[3]

[1] Faculty of Civil Engineering, Architecture and Environmental Engineering, Technical University of Lodz, Al. Politechniki 6, 90-924 Łódź, Poland, marek.wojciechowski.1@p.lodz.pl, marek.lefik@p.lodz.pl
[2] Department of Civil, Environmental and Architectural Engineering University of Padova, Via Marzolo 9, 35131 Padova, Italy, daniela.boso@unipd.it

Key Words: *Inverse problem, Artificial Neural Networks, Composites, Homogenization.*

In this paper machine learning techniques are used to identify the characteristics of the micro components of a composite, starting from the knowledge of the macro behaviour of the heterogeneous material or structure. Proper homogenisation theories are considered as a source of the direct relation between the micro-structural description (involving both geometry and the constitutive data of the components) and the mechanical macro characteristics of the composite. The inverse relation provides the information on the micro geometry and the single material properties of the periodic composite medium. In our numerical analysis, we focus on the use of artificial neural networks (ANN), which are trained with the macroscale properties at the input layer and with the microstructural parameters at the output layer. For the training process, the pairs macroscale properties - microstructural parameters are obtained by solving a set of boundary value problems on the unit cell, by means of a numerical homogenisation procedure implemented in a Finite Element software designed to this purpose. For a periodic medium, we show that the inverse relation can be approximated via ANNs as easily as the direct one [1]. The presented method proved computationally efficient and can be a valid alternative when the analytical formulation of the homogenization inverse problem results very difficult. In recall mode, the trained network attributes to the measured or wanted macro properties at the input the unknown or sought microstructural parameters at the output. This approach opens an easy way to design Functionally Graded Materials (FGMs). At each point of an FGM at the macro scale, for the desired stiffnesses (input data) the ANN gives the required elements of the description of the periodicity cell microstructure. In this way, the ANN can generate the microstructure of the FGM. We show the potentiality of the method presenting some examples, related to a material structured by X shaped cell of periodicity with suitably varying geometrical parameters and to the real case of superconducting magnets used for nuclear fusion or high energy physics.

REFERENCES

[1] M. Wojciechowski, M. Lefik and D.P. Boso, Inverse problems in the light of homogenisation methods: identification of a composite microstructure. *Int. J. Mult. Comp. Eng.*: 10.1615/IntJMultCompEng.2022040213.