On the necessity of accounting for second order terms in multiscale analyses

ICME 2016

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ABSTRACT

As composite materials become more complex, multi-scale methods based on homogenization principles are gaining strength, these allow obtaining the material performance taking into account its micro-structural configuration. The use of multiscale procedures is also encouraged by the continuous increase of computational capacity. A major concern in multiscale analyses is the information shared by the different scales because the micro-structural problem solved, and the results obtained from it, will vary depending on the amount and quality of the information received from the macro-structure.

Probably, the most common approach in multiscale analysis is the first-order approach [1]. It uses the macro-scale deformation gradient tensor (or the strain tensor) to solve the micro-scale problem and then, by means of the microscopic results, obtains the macro-scale stress tensor. The microscopic problem is solved through a Boundary Value Problem (BVP) on the Representative Volume Element (RVE) with particular boundary conditions, which are obtained using the macroscopic input.

When conducting numerical analyses using a first-order homogenization approach, there is no problem in discretizing the macro-structure using first order elements. However, there is no doubt that the analysis will be more accurate if second-order elements are used. These elements contain further information, such as the gradient of the deformation gradient (G), which can be added to the homogenization procedure to improve the quality and accuracy of the micro-analysis.

It will be shown that defining a full second-order homogenization approach, as it proposed in [2], demands solving a high-order equilibrium macro-problem that makes unfeasible using the method for large problems, unless considering structural elements for the simulation. Therefore, in order to use the extra information provided by the second-order terms of the macro-simulation, a new enhanced first-order approach is proposed.

From the results obtained analysing different composite structures, it will be shown that the addition of these second-order terms improves the solution of the numerical analysis of the RVE, as it is capable to account for bending effects. This is of special relevance for the characterization of structural damage in the micro-scale. On the other hand, it will be also shown that the addition of second order terms does not improve the results obtained in the macro-structure. Therefore, it can be concluded that the necessity of accounting for second order terms in multiscale analyses depends on the results required from the numerical analysis.

REFERENCES

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