TWO-SCALE MODELLING OF METAL MATRIX COMPOSITES' THERMOMECHANICAL BEHAVIOUR USING GID

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Abstract. *The thermomechanical modelling of the behaviour of Metal Matrix Composites (MMCs) requires a deep understanding of the physical phenomena that span two or more spatial length scales. The Asymptotic Expansion Homogenisation (AEH) method appears to be a highly suitable technique to address this multiscale dependence. In this context, this methodology is applied to the two-scale modelling of the thermomecanical behaviour of metal matrix composites, focusing mainly on engineering issues related to its finite element implementation and applications. Geometrical models are built using GiD's pre-processor. All the process data are introduced in a dedicated problem type with a graphical user-friendly interface (GUI) developed within GiD. The problem type was implemented with the use of Tcl/Tk. Post-processing is also carried out with GiD. This fact enables the straightforward simulation of linear/non-linear and stationary/transient thermomechanical behaviour of metal matrix composites. An illustrative example of the simulation of linear thermoelastic homogenised behaviour of an aluminium matrix composite reinforced with spherical SiC particles (AlSiCp MMC) is presented.*

1 INTRODUCTION

Several physical processes exhibit coupling between mechanical and thermal phenomena. In general terms, due to the thermal expansion of the material, an increase in temperature induces deformations on the body. This, in turn, may contribute to an increase in the temperature. Therefore, the mechanical response of the solid medium generally depends on its thermal behaviour and *vice versa*. On the other hand, the thermomechanical modelling of the

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behaviour of Metal Matrix Composites (MMCs) requires a deep understanding of the physical phenomena that span two or more spatial length scales. In fact, constituent thermoelastic properties of metal matrix composites are generally temperature dependent, which affects the effective overall behaviour of the composite material. In this context, the Asymptotic Expansion Homogenisation (AEH) method[i,ii] appears to be a highly suitable technique to address this multiscale dependence. With this approach it is possible to estimate the effective thermoelastic properties of complex microstructures. Several AEH frameworks have been applied to the solution of linear and non-linear structural problems[iii,iv]. Moreover, in contrast to other homogenisation approaches, this methodology is useful due to its inherent capability to seamlessly perform both homogenisation and localisation within a single method by considering the microstructural details on a macrolevel analysis. Following previously developed work by the authors, the AEH methodology is applied to the two-scale modelling of the thermomecanical behaviour of an $AlSiC_p$ MMC, focusing mainly on engineering issues related to its finite element implementation and applications[v,vi]. To adequately simulate this kind of processes it is essential to have an intuitive graphical user interface in order to solve the problem and to analyse results properly. The simulation of an AEH thermomechanical problem requires the definition of the (i) thermomechanical properties of the material and (ii) boundary conditions (both mechanical and thermal). Although trivial, this procedure can be time consuming. In this context, GiD was used as pre- and post-processor together with the developed AEH thermoelastic finite element code.

The expansion of an $AlSiC_p$ MMC bar due to a prescribed temperature in one of its edges is used to exemplify an application of the two-scale AEH methodology. All geometrical models are built and discretised with GiD's pre-processor. The results are subsequently analysed with GiD's built-in post-processor. A dedicated problem type was developed in order to collect all the process input data – geometry and discretisation included – and to write it into an AEH thermoelastic finite element code input data file.

2 GiD IMPLEMENTATION AND APPLICATION ASPECTS

All the process data are introduced in GiD's dedicated problem type with a graphical user-friendly interface (GUI) developed within GiD. The problem type was implemented using Tcl/Tk. Both the thermal and mechanical boundary conditions are assigned to entities in the problem type. 8-node hexahedral and 4-node tetrahedral elements were used in the macro- and microscale meshes, respectively. While the macroscale finite element coarse mesh was automatically generated with GiD, the microscale mesh was generated within GiD using SphereCell. This automatic unit-cell generation code[v] allows the generation of reinforcement particles in order to guarantee cell-to-cell continuity and periodicity, *i.e.* ensuring the existence of periodic boundary conditions. In this analysis, a 40% reinforcement unit-cell was automatically generated. The considered macro- and microscale finite element meshes can be seen in figures 1 and 2a, respectively. In the analysis, a prescribed temperature of 393 K was imposed on one edge of a metallic bar, initially at room temperature (293 K). Constant thermoelastic material properties where considered, leading to a transient linear numerical analysis. Reinforcement particles distribution is illustrated in figure 2b, in which cell-to-cell continuity and periodicity can be observed. The original/deformed geometry and an intermedi-

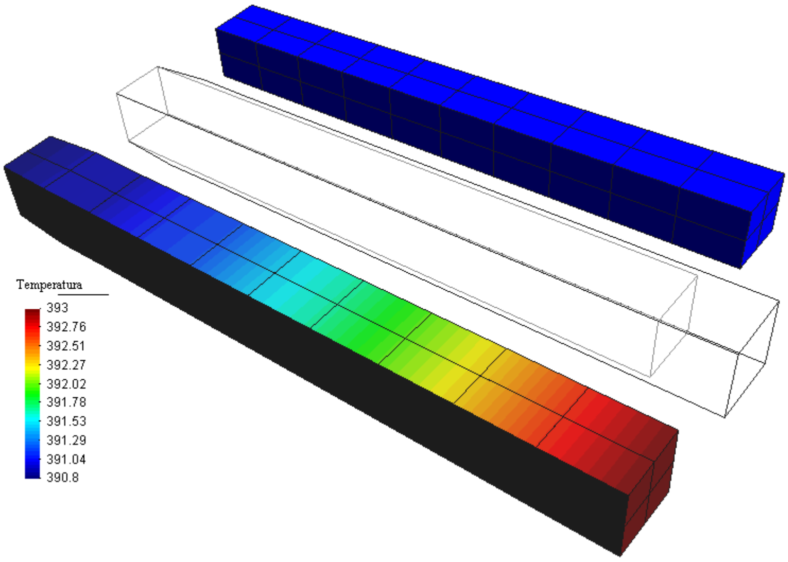
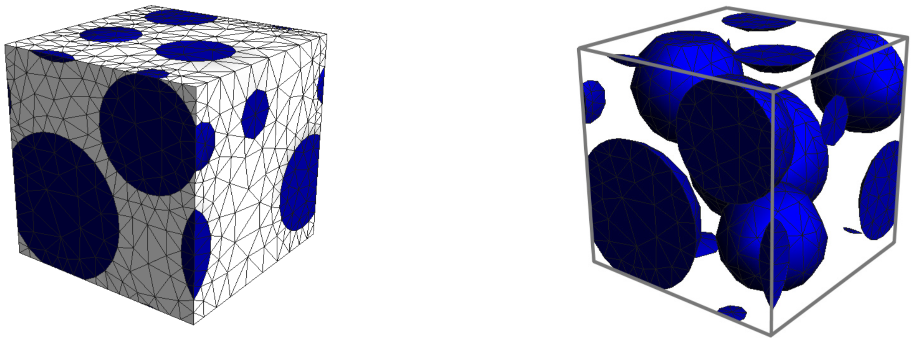


Figure 1: Macroscale mesh, original/deformed geometry and intermediate temperature field



(a) (b)

Figure 2: (a) Microscale mesh and (b) reinforcement particles distribution

ate temperature field are shown in figure 1. As it can be seen, the macroscale behaves like a homogenous material. This macroscale behaviour is defined on microscale eigendeformation information, which is generated by the AEH methodology. As an example, two of the six microscale unit-cell eigendeformation elasticity fields are shown in figure 3. The gradients of these fields are used to define the homogenised elastic coefficient values.

4 CONCLUDING REMARKS

An example of the application of GiD in the numerical simulation of two-scale homogenised linear thermoelastic behaviour of an $AlSiC_p$ MMC was presented. It can be stated that GiD's pre- and post-processor are highly useful tools for science and engineering applications, providing an efficient interface for the modelling of two-scale AEH thermomechanical problems.

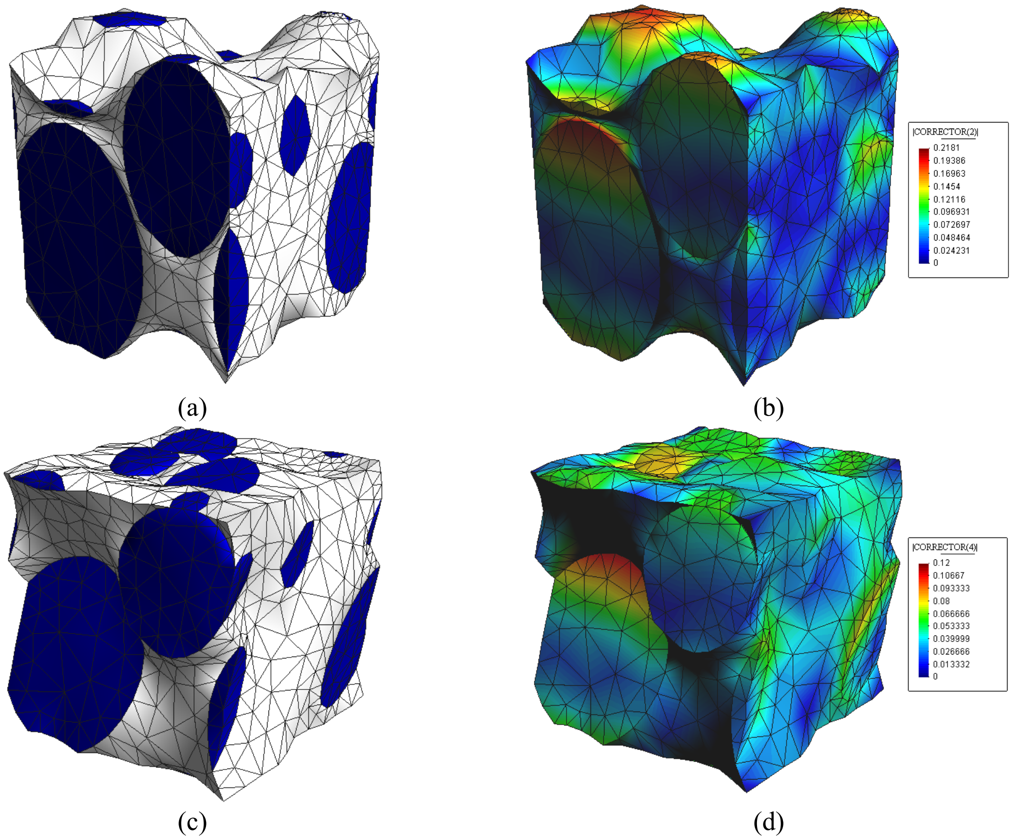


Figure 3: Microscale (a) 22 and (c) 23 deformed unit-cell and (b) 22 and (d) 23 eigendeformation fields

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