ON THE MODELLING OF REPRESENTATIVE UNIT-CELL GEOMETRIES WITH GID®

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Abstract: *The mechanical behaviour of heterogeneous composite material structures can be simulated by homogenisation methodologies considering representative unit-cells with adequate periodic boundary conditions. These procedures often lead to lower computational costs when compared to global structural analysis. This justifies an increase in the use of those methods. Accurate unit-cell modelling requires the control of some relevant geometrical parameters such as volume fractions, particle sizes and their distributions, and periodicity features. For this purpose, the authors developed an automatic unit-cell generation code within GiD®. Files containing the geometric definition of cubic unit-cells (geo files in GiD® ASCII format), with either spherical particles or unidirectional fibres, can be automatically generated, allowing the use of diverse particle arrangements. Structured or unstructured meshes of periodic unit-cells can be generated.*

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1 INTRODUCTION

The mechanical behaviour of heterogeneous composite material structures can be simulated by homogenisation methodologies considering representative unit-cells with adequate periodic boundary conditions[i]. In fact, if a spatially periodic microstructure is assumed for the composite material, its microstructural characteristics can be represented with a unit-cell. Lower computational costs, when compared to a global analysis, can be achieved whenever adequate boundary conditions (those enforcing well-posedness of the mathematical problem) are used. These can be periodic, symmetry or anti-symmetry boundary conditions[ii,iii].

2 AUTOMATIC UNIT-CELL GENERATION

The geometrical modelling of simple unit-cells is a relatively straightforward task. However, when complex unit-cells are necessary, modelling problems may arise. The need for a wider variety of models and geometrical specifications led to the development of an algorithm dedicated to the automatic generation of unit-cells.

Accurate unit-cell modelling requires the control of some relevant geometrical parameters such as: (i) volume fractions; (ii) particle sizes and their distributions and (iii) periodicity features. Consequently, the algorithm developed performs a wide range of tasks. The resulting code can generate several types of 3D cubic or 2D square unit-cells. In both cases, the user can choose between standard unit-cells and random generation. On standard generation, different combinations of particle sizes may be generated, in BCC (body-centered cubic) or FCC (face-centered cubic), leading to a selected volume fraction of reinforcement. In the case of random generation, the user can choose to (i) have particle interference or not; (ii) define the upper and lower limits in sphere sizes and (iii) chose the reinforcement volume fraction in the unit-cell.

One of the most relevant aspects of the code is related to the generation of boundary (periodicity) conditions. Each particle position is determined and complementary particles are generated in order to guarantee cell-to-cell continuity and periodicity.

3 GEOMETRY FILE OUTPUT AND GID®

Automatic generation of the placement and sizes of particles in a composite material unit-cell, no mater how efficient, tends to be useless without a way to automatically generate a representative geometry model. In order to perform this task, some geometry file generation subroutines were added to the original code. Consequently, the choice for GiD®'s ASCII format seems to be the logical step because it is the ideal option in terms of debugging. Additionally, GiD®'s Geo format offers a format flexibility that justifies its use instead of other ASCII formats (e.g. IGES or STEP). The possibility of using several types of curve and surface generating algorithms, from simple two point lines to complex NURBS surfaces, allowed the authors to optimise the generation of the geometry in order to achieve better results in latter Boolean operations.

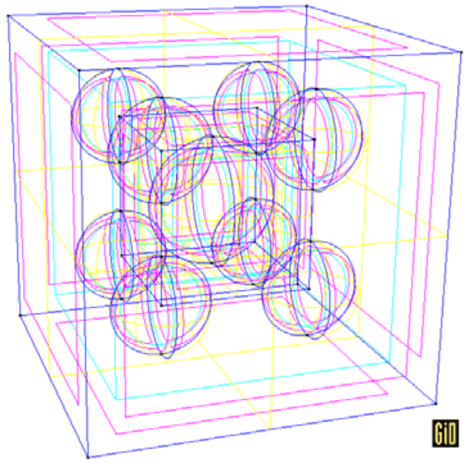
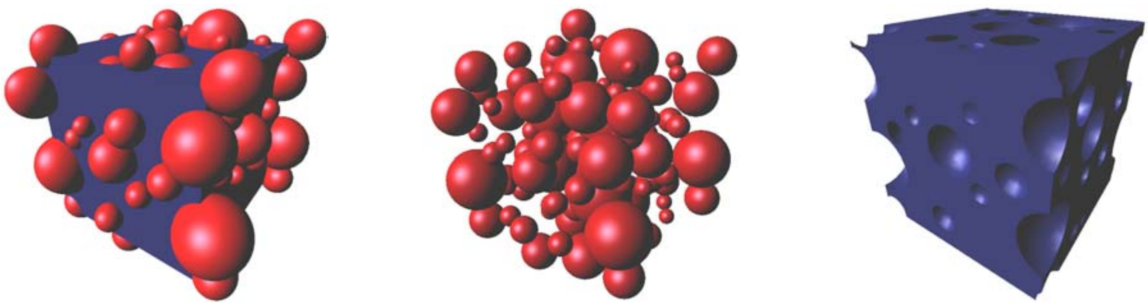


Figure 1: Representation of geometrical entities for a generic spherical reinforcement unit-cell model.

The user's task is made easier because the geometry file is generated with entities separated in different layers. Turning selected layers on and off makes the task of performing operations between solid objects (union, intersection or subtraction) easier. The features are separated in reinforcement, matrix and auxiliary layers. Considering the example shown in figure 2, from which a periodic unit-cell with randomly distributed holes results, the use of the mentioned operations leads to the final geometry.



(a) (b) (c)

Figure 2: Unit-cell components: (a) full geometry, (b) particles' layer and (c) final composite matrix model.

4 MESHING CONSIDERATIONS AND CONCLUDING REMARKS

While, for the moment, representative cells with spherical particles can only be meshed with automatic mesh generation algorithms (see figure 3), structured meshes can be generated for two- and three-dimensional unit-cells with unidirectional cylindrical fibres. When generated, the entities within the geometry files are divided in four sided face sets, in order to allow hexahedral and/or quadrilateral finite element meshing. These files are generated as two-dimensional and can be extruded, resulting in solid unit-cells, as shown in figure 4.

As a concluding remark, it can be stated that GiD® is a highly useful tool for science and engineering applications, providing an efficient interface for the modelling of representative unit-cell geometries.

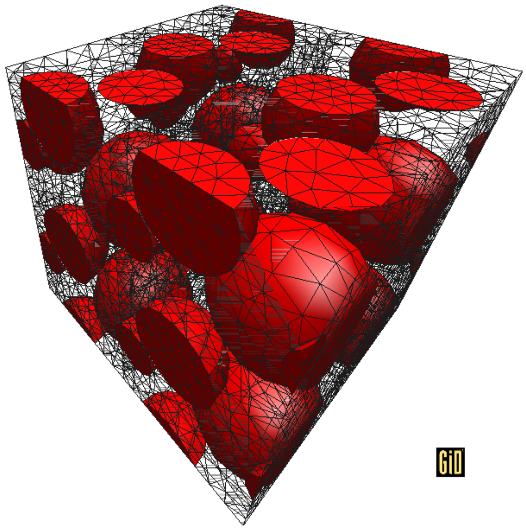
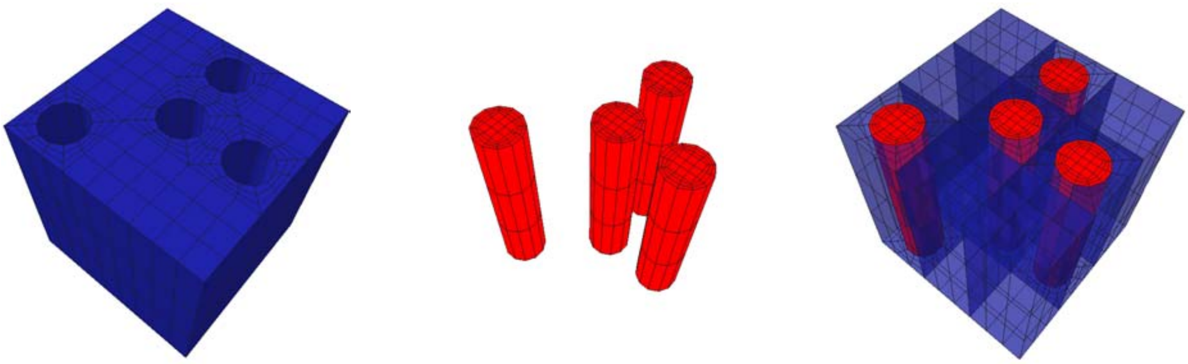


Figure 3: Automatically generated tetrahedral mesh of composite material.



(a) (b) (c)

Figure 4: Structured hexahedral mesh generation: (a) matrix, (b) unidirectional fibres and (c) full mesh.

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