11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

NUMERICAL SIMULATION ON MULTIPHASE MICROSTRUCTURES OBTAINED FROM 3D IMAGING

L. Silva*[1], J.X. Zhao[1], H. Digonnet[1] and T. Coupez[1]

[1] MINES ParisTech - CEMEF, 06904 Sophia-Antipolis,
luisa.silva@mines-paristech.fr, www.cemef.mines-paristech.fr

Key Words: *Finite elements, 3D Imaging, 3D X-Ray Tomography, Mesh Generation and Adaptation*

Nowadays, to accurately simulate evolution of the behavior of material microstructures at mesoscopic or microscopic scales, the finite element method appears as a powerful tool, with the increase on the computational power through the use of grids or cloud computing. In order to be quantitatively pertinent, the numerical descriptions of these microstructures must be well defined and in-situ 3D imaging techniques, like X-Ray tomography (micro or nano) are very interesting, since they access the heterogeneity of the different phases with a definition and quality that can be important. To pass from imaging to finite element domains, we need to have performing mesh generation algorithms, preferably directly from the real data (like the 3D images). In the literature, generation of finite element meshes from images is the most often treated using image analysis tools like ImageJ, coupled with mesh construction ones (for example, Amira). They are based on a three-step procedure: segmentation, for the identification of the different phases in the image; construction of a surface mesh for each phase, representing its boundary; construction of one or several volume meshes on which the specific properties of each phase can be defined.

In this paper, we propose an alternative way to build directly finite element representation of microstructures using an “image immersion” method, by skipping the Marching Cubes’ step. Firstly, a coarse mesh is considered and the image voxel values (color or grey scale) are mapped in this mesh by a direct interpolation, providing a topographic distance field distribution on the mesh. Hence, in regions where there is a strong difference on the topographic function, the mesh will become finer in the sense of this difference. Then, an appropriate error estimator built from this distance is used to compute a metrics field that our topological mesher will consider to adapt the mesh [1]. Finally, we define a topographic’s distance isovalue for each interface contour and we build, through a coupled reinitialization - automatic anisotropic mesh adaptation algorithm, the distribution of a phase function for each existing phase. Meshes obtained using these techniques are well adapted for monolithic based methods (one mesh containing all the phases, each represented by an implicit - phase – function, like in classical diffuse interface methods). Mesh adaptation provides nodal enrichment near these interfaces, which will allow results to converge to a “sharp-interface” solution.

Computations on such meshes will illustrate the relevance of our methodology, on flow applications on composites materials, both at the fibre (microscopic) and at the yarn (mesoscopic) scales. At the fibre scale, images containing thousands of fibres are analysed and flow around these fibres will be calculated using a mixed finite element method, obtained through discretization of the Stokes equations and by considering rigid body motion for the fibres. At the yarn scale, Stokes-Brinkman equations are also solved through a mixed finite element method, but by modifying its stabilization. Applications include, for example, permeability determination.

REFERENCES

[1] T. Coupez, « Metric construction by length distribution tensor and edge based error for anisotropic adaptive meshing », *Journal of Computational Physics*, vol. 230, p. 2391-2405, 2011.

[2] H. Digonnet, L. Silva and T. Coupez, « Cimlib: A fully parallel aplication for numerical simulations based on components assembly », *Air conference proceedings*, vol. 908, p. 269-274, 2007.

[3] J. Viguie , P. Latil, L. Orgeas, P.J.J. Dumont, S. Rolland du Roscoat, J.F. Bloch, C. Marulier and O. Guiraud, « Finding fibres and their contacts within 3D images of disordered fibrous media», *Composites Science and Technology*, on-line, 2014.