HIGH PERFORMANCE SIMULATION OF SHORT FIBER SUSPENSIONS FOR MANUFACTURING PROCESSES

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Introduction

The microstructure of a short fiber thermoplastic composite greatly affects its mechanical properties. We wish to simulate the flow behavior of concentrated fiber suspensions containing a significant number of fibers in order to understand the evolution of fiber orientation during the forming process. We aim to ensure a scale transition in numerical rheometry by simulating a whole injected part or a thickness of a part with a complex geometry. This paper focuses first on a numerical method to generate an initial isotropic state of concentrated fiber suspensions. Then, kinematic of fiber suspensions under Newtonian shear flow is studied through a direct numerical simulation (DNS), taking into account the different existing interaction forces [1].

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In this paragraph, we present the numerical method used to generate a sample representing an initial isotropic state of concentrated fiber suspensions in a cubic cell, with fully periodic boundary conditions. Here, a random sequential adsorption algorithm RSA [2] which is a widely used process for rigid particles generation has been choosen. Fibers are subsequently positionned in predefined locations uniformly distributed in the domain. If the fiber to be placed intersects one other, this fiber is repositioned by randomly selecting a new orientation and keeping the same position. To better represent the real configuration of fiber suspensions, fibers are generated with a distribution of length. We start by generating an isotropic initial state containing thousands of fibers. Figure 1a presents an example of the generated microstructure containing 1000 fibers. First, a sequential C + + algorithm has been implemented. Then, in order to improve the efficiency of the previous presented code, we integrate an Octree algorithm into it. Indeed, the Octree, in our case, allows to organize fibers according to their locations in boxes AABB (Axis Aligned Bounding Box) and to accelerate collision detection between them. To quantify the considerable gain brought by the Octree, we present the evolution of the calculation CPU time, t, according to the number of generated fibers, N (figure. 2).

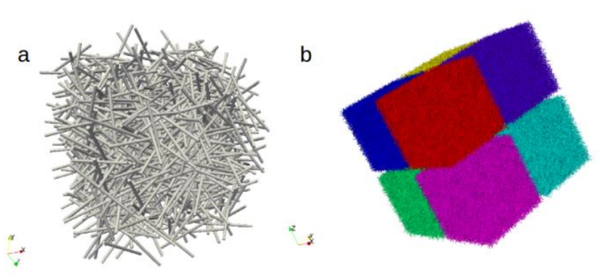

Figure 1: *Generated microstructure example: Sequential generation, b Parallel generation*

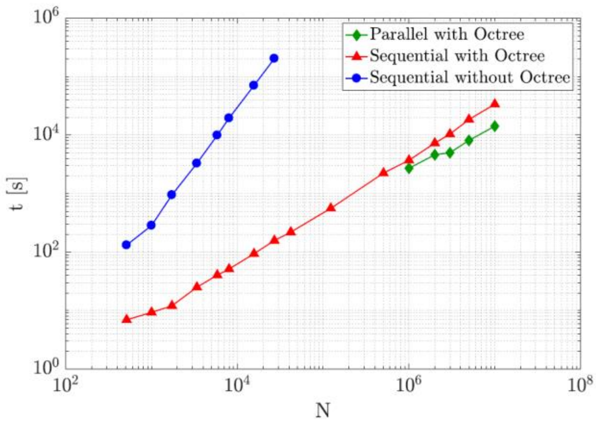

Figure 2: *Time comparison*

Afterward, the code has been parallelized and millions of fibers have been quickly generated. Figure 1b illustrates the parallel fibers generation method and figure 2 shows the gain of time compared to the sequential Octree method.

Kinematics of fiber suspensions

A simple shear flow is applied to the generated microstructures. In concentrated regime, interactions between fibers occur and modify the orientation state. Induced forces are calculated and two states of flow are distinguished: a transient one in which fibers are rotating and a steady one in which the majority of fibers are aligned according to the flow direction. Figure 3 illustrates this result (Simulation is made using the initial state presented in figure 1a).

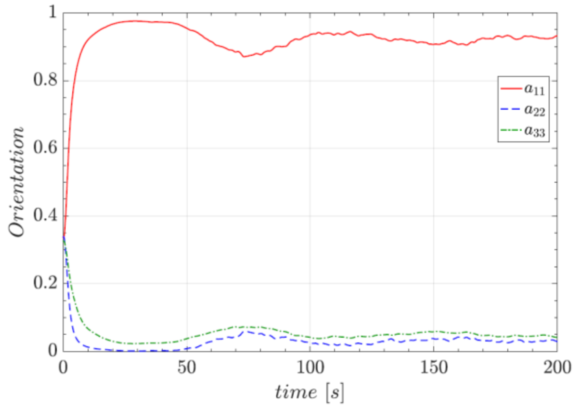

Figure 3: *Second order tensor orientation components evolution under a shear flow*

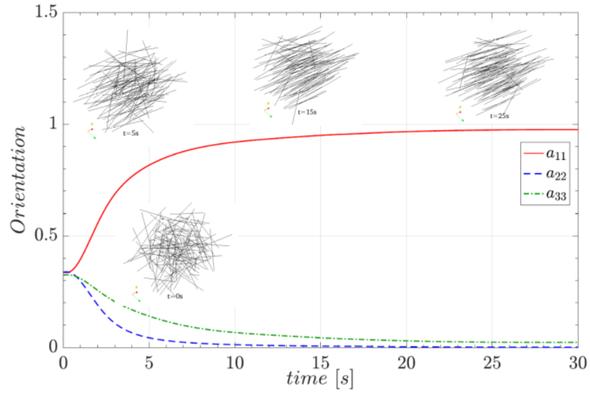

Figure 4: *Zoom in on the transient regime*

In future work, the application of combination of simple flows will be used to create non isotropic states and the coupling with a fluid code to take into account the fibers effect on the fluid flow will be performed**.**

References

[1] G. Ausias, X.J. Fan, and R.I. Tanner. Direct simulation for concentrated fibre suspensions in transient and steady state shear flows. Journal of Non-Newtonian Fluid Mechanics, 135(1):46– 57, 2006.

[2] Rabih Mezher. Modeling and Simulation of concentrated suspensions of short, rigid and flexible fibers. Theses, Ecole Centrale de Nantes (ECN), December 2015.