3D adaptive finite element simulation of fluid flow in twin-screw extruders

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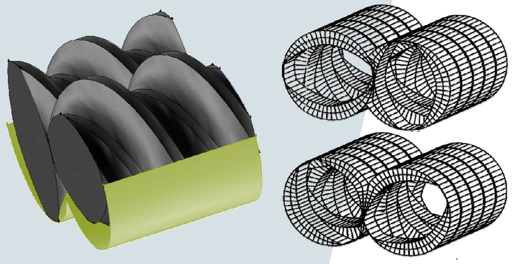
Introduction

The simulation of fluid flow in industrial processes often involves geometries with moving internal parts [1]. A typical example is that of the twin-screw extruder, a continuous mixer frequently used in polymer processing. It is evidence to CFD practitioners that the use of classical finite element methods to tackle such problems is far from being trivial since a new mesh is needed at each time iteration owing to the motion of the internal parts (Fig. 1).



(a) (b)

Figure 1 *(a) Intermeshing co-rotating twin screw (TSE) extruder, (b) Domain meshes at two different rotation angles.*

Objective

3D simulation of fluid flow for a Newtonian isothermal polymeric melt in the twin screw extruders (TSE).

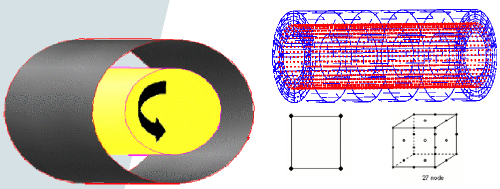
Methods

We use a combination of the fictitious domain and finite element methods [1,2]. Periodic boundary conditions were applied for inlet and outlet boundaries. Non-conformal mesh refinement using a Lagrangian multiplier has been implemented for adequate accuracy.

Results

Collocation points optimization

We select a 3D concentric co-cylindrical system with inner rotating cylinder as a test case study (Fig. 2).



(b)

(c)

(a)

Figure 2 *(a) Co-cylindrical geometry, (b) main mesh with collocation points (red points), (c) cubic element with characteristic length l and collocation points element with characteristic length l_1.*

Comparison with the analytical solution learns that accurate results for velocity and shear rate inside the fictitious domain are found for $l/l_1 = 1$ (Fig. 3).

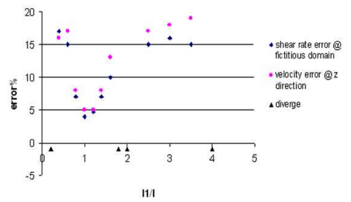
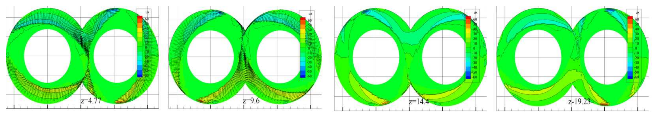


Figure 3 *Comparing numerical and analytical results*

TSE

Next, we implement methods for standard conveying screw elements in a twin screw extruder (Fig. 4).

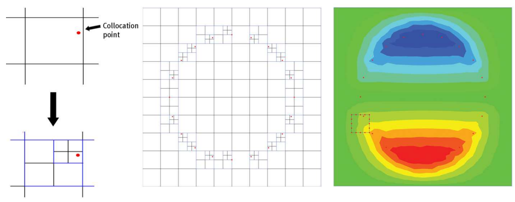


(a) (b)

Figure 4 *Velocity profile at x direction at different cross section of TSE, (a) vector, (b)streamline*

Mesh refinement

Non-conformal mesh refinement is needed to obtain adequate accuracy. The reference mesh may be adapted locally according to the position of the collocation points in the computational domain (Fig. 5). Ensuring continuity at the interface between non-conformal elements, is implemented by using a Lagrangian multiplier.



(a) (b) (c)

Figure 5 *(a) Element refinement technique, (b) a 2D cavity with rotating object in the center as a test case, (c) velocity contour at x direction*

Conclusions

- The characteristic length of the mesh for collocation points and the main finite element mesh in 3D should be equal.
- A method to compute the flow field in TSE has been successfully implemented.
- Ensuring continuity for non-conformal elements is enforced by using a Lagrangian multiplier.

References:

[1] Sarhangi Fard, A., Famili, N. and Anderson, P. D.: J. Computers and Chemical Engineering, in press, 2007.

[2] Bertrand, F., Thibault, F., Delamare, L., and Tanguy, P. A.: J. Computers and Chemical Engineering, 2003, 27, 491-500.

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