Simulation of mixing in intermeshing co-rotating twin-screw extruders

Citation for published version (APA):
Simulation of Mixing in Intermeshing Co-Rotating Twin-Screw Extruders

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Introduction
The simulation of fluid flow in industrial processes often involves geometries that may contain moving internal parts. A typical example is that of the twin-screw extruder. It is evident to classical finite element practitioners 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 Intermeshing co-rotating twin screw: standard conveying element and kneading element with a stagger angle of 45° in a forward configuration.

Objective
The objective of this work is mixing analysis in the 3D intermeshing co-rotating twin screw extruders via particle tracking.

Methods
We selected two kinds of screw elements: standard conveying element and kneading element with a stagger angle of 45 in a forward configuration (figure 1).

Fig. 2 A cross section view of elements that refined near screw surface: (a) before refinement, (b) after refinement.

For 3D simulation of fluid flow in the twin screw extruders (TSE), we used a combination of the fictitious domain and finite element methods. To improve accuracy we applied non-conformal mesh refinement[1,2]. Periodic boundary conditions were applied for inlet and outlet boundaries. Non-conformal mesh refinement is needed to obtain adequate accuracy in the gaps that may be very small and the position of which varies over time. The reference mesh may be adapted locally according to the position of the screws in the computational domain. Ensuring continuity at the interface between non-conformal elements is implemented by using a Lagrangian multiplier(figures 2-3).

Fig. 3 Three-dimensional view of refined mesh.

Results
From the Eulerian velocity field \( \mathbf{v}(\mathbf{x}, t) \) the particle path of \( \mathbf{X} \) is given by the numerical solution of:

\[
\frac{d\mathbf{x}}{dt} = \mathbf{v}(\mathbf{x}, t), \quad \mathbf{x} = \mathbf{X}_0 \text{ at } t = t_0
\]

Residence time distributions were obtained based on the calculation of particle tracers. The residence time density function \( f(t) \) is defined as the probability that the residence time is in the interval \((t, t + \Delta t)\). We calculated cumulative distributive function: \( F(t) = \int_0^t f(t) dt \). Figure 4 shows the cumulative residence time distribution.

Fig. 4 Cumulative residence time distribution vs. normalized residence time.

Conclusion
Introducing a novel technique based on the fictitious domain method and 3D mesh refinement procedures. Ensuring continuity for non-conformal elements is enforced by using a Lagrangian multiplier, shown to be accurate and well adapted to the simulation of fluid flow in twin-screw extruders. Residence time distributions were determined as a way to study aspects of distributive mixing.

References: