Quantifying Deterministic Chaos of Flows Transport in Fully-baffled Stirred Vessels by Finite-time Lyapunov Exponents

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Introduction

Lagrangian coherent structures (LCSs) have been proved with its efficiency to evaluate the flow structures and reveal the complex flow transport behaviors in a wide range of applications, which is defined by the ridges of the finite-time Lyapunov exponent (FTLE) field [1,2]. Understanding this complexity and being able to model it, will undoubtedly represent a big step towards improving current engineering practice.

In this study, a data exploration platform on flow structures of chaotic mixing in fully-baffled stirred vessel is performed, where the 2D velocity fields at different azimuthally planes are obtained from CFD modelling and then the LCSs can be numerically detected by FTLE field computation and ridge extraction.

Methodology

CFD numerical simulation [3] is firstly used to obtain continuous velocity field, then input it into our data exploration platform (Fig. 1) based on chaos theory, which will identify specific coherent structure, to understand and predict the behavior of flow transport in stirred vessel.

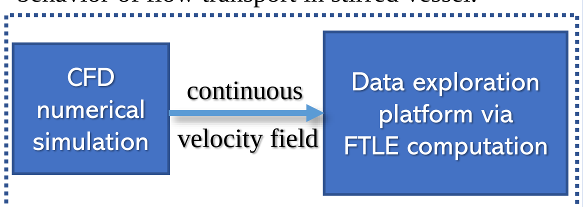

Fig. 1 *Workflow of Lagrangian flow transport features exploration*

A simple case of single-liquid turbulence flow in fully-baffled stirred vessel has been investigated to demonstrate the feasibility of built data exploration platform, see Fig. 2.

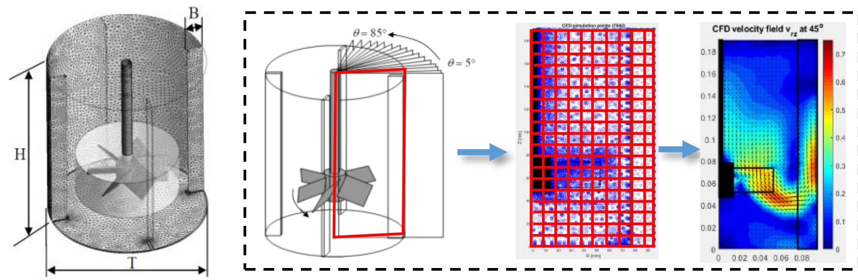

Fig. 2 *CFD simulation and 2D velocity field calculation*

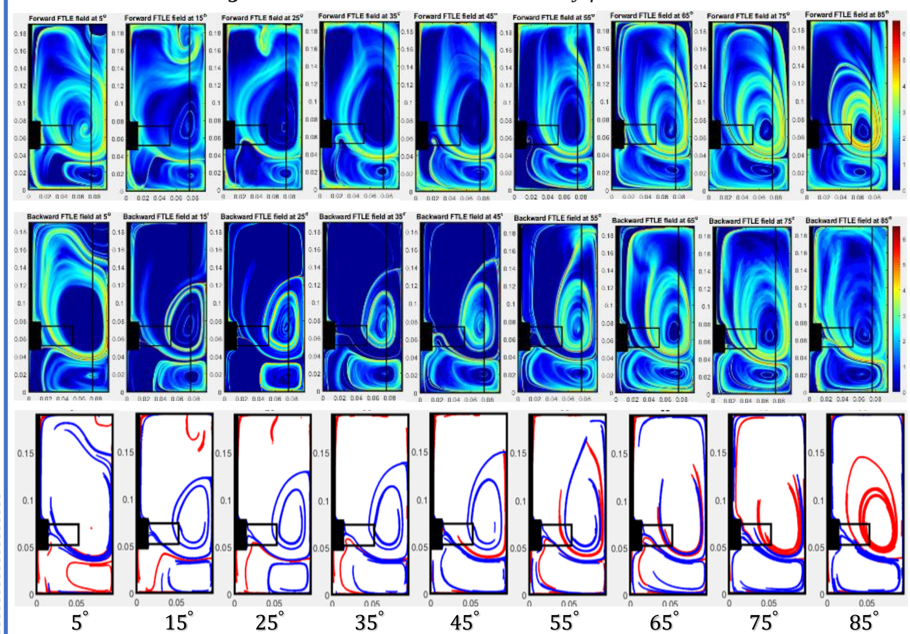

Fig. 3 *Forward FTLE field (top row), Backward FTLE field (middle row) with integration time T=1s, and extracted LCSs (bottom row. red: repelling LCS; blue: attracting LCS) at different azimuthally planes (5°~ 85°) of fully-baffled stirred vessel*

Forward FTLE ridge (repelling LCS) and backward FTLE ridge (attracting LCS) reveal the flow nature of repelling and attracting neighboring fluid elements [4,5]. Both repelling and attracting LCSs behave as the flow region boundaries which governs chaotic Lagrangian transport.

Conclusions

The simple case has demonstrated the feasibility of built data exploration platform and reveals flow transport features in fully-baffled stirred vessel, which are verified by numerical simulation data.

(1). The azimuthally-invariance concept of flow field cannot be assumed in a baffled configuration without a considerable loss of information.

(2). Based on the flow system configuration, 2 distinctive vortices with clear boundary are formed in fully-baffled stirred vessel, but flow transport behaviors vary at different azimuthally positions.

References

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