Chaotic Advection and targeted mixing in flows

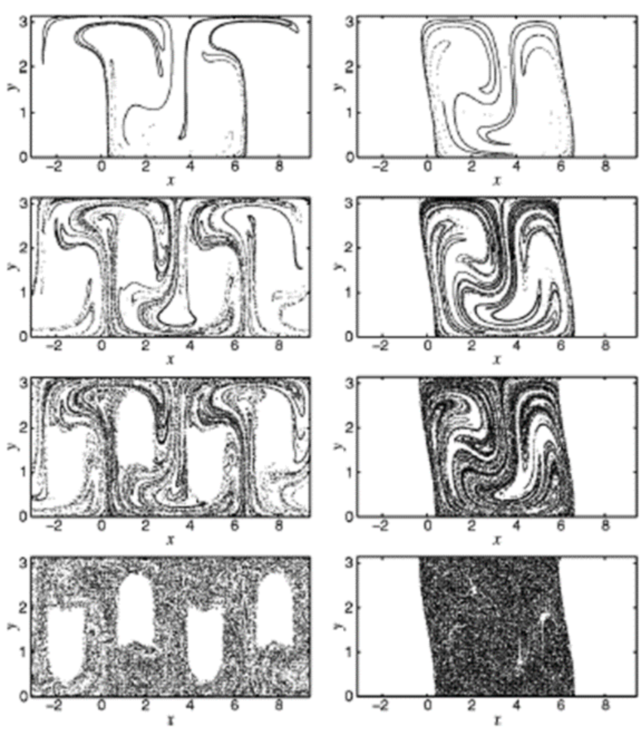
Energy and particle losses due to abnormal transport in magnetic confinement devices (tokamak) are still a serious obstacle to controlled thermonuclear fusion. Even modest changes in containment properties can drastically change the energy amplification factor. The French laboratory CPT worked on a new model (computer code) to improve targeted mixing by adding a suitable perturbation to the ideal flow. The induced chaotic advection exhibits two remarkable properties which do not hold in the case of a generic perturbation: Particles remain trapped within a specific domain bounded by two oscillating barriers (suppression of chaotic transport along the channel), and the stochastic sea seems to cover this whole bounded domain (enhancement of mixing within the rolls).

Description of the technology

It is often desirable to reduce chaotic transport while one also often wants more chaos in order to enhance mixing. To enhance mixing in flows, chaotic advection is used. This phenomenon translates the fact that despite the laminar character of a given flow, trajectories of fluid particles or advected passive tracers are chaotic (Lagrangian chaos). As a consequence, mixing is considerably enhanced in regions where chaos is at play, as it does not need to rely on molecular diffusion.

Considering two-dimensional incompressible flows, chaotic advection occurs when the flow is unsteady. One particularity of these flows is that the dynamics of passive particles can be tackled from the Hamiltonian dynamics point of view. In order to achieve such properties, the dynamics of passive tracers in an array of alternating vortices is considered.

A given perturbation is introduced with tracers in order to trigger et visualize chaotic advection. In order to enhance mixing inside the cells, it is not sufficient to increase the value of the parameter of the stream function, since by breaking invariant tori, one increases chaotic transport along the channel. Adding a suitable perturbation (forcing), implies a combination of two effects: creation of barriers which are explicitly known and which suppress the chaotic advection, and enhancement of mixing of passive tracers while maintaining the oscillations of the rolls.



Numerical simulation of the dynamics of a dye at $t = 30$, $t = 50$, $t = 70$, and $t = 140$ (from top to bottom): left column for the stream function and right column for the stream function. The parameters are $\alpha = 0{:}6$ and $\epsilon = 0{:}63$.

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Innovation and advantages of the offer

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Non-fusion Applications

In order to enhance mixing in flows, the model based on chaotic advection could be used in promising non-fusion applications such as space propulsion, chemical engineering, multifluidics or geophysical flows.

EUROfusion Heritage

Energy and particle losses due to abnormal transport in magnetic confinement devices (tokamak) are still a serious obstacle to controlled thermonuclear fusion. Even modest changes in containment properties can drastically change the energy amplification factor. The empirically found states of best containment and the possibility of reducing and/or eliminating chaos with parametric perturbations (mainly developed for dissipative systems), suggest to study the possibility of an abnormal chaotic transport control strategy by appropriate perturbations acting at the microscopic level of the movements of charged particles. The main scenarios for fusion are based on transport barriers (mode H, ITB, etc.). These transport barriers are often associated with a high energy input. The idea is both related to the creation of transport barrier to enhance confinement, or to target mixing of fast particles using this approach for the ergodic divertor. This control strategy opens up a possible avenue of investigation to create barriers (or reduce turbulent transport) and improve low energy cost magnetic containment in controlled fusion devices such as tokamaks.

The laboratory is a founding member of the National Research Federation for Fusion by Magnetic Confinement created in 2005 and has carried out several research activities in the framework of EUROFUSION Consortium (for example WP14/ER/CEA09 Joint experimental - theoretical effort to investigate large scale self-organisation of turbulence and flows in the framework of the L-H transition).

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