Control of transport in magnetized fusion plasmas

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Habilitation à Diriger des Recherches

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Ecole Centrale Marseille

Composition du jury

M Per Helander	Max-Planck-Insitut fur Plasmaphysik	Rapporteur
M Stefano Ruffo	Università delgi Studi di Firenze	Rapporteur
M Angelo Vulpiani	Università degli Studi di Roma La Sapienza	Rapporteur
Mme Pascale Hennequin	CNRS, Ecole Polytechnique	Examinateur
M Paolo Ricci	Ecole Polytechnique Fédérale de Lausanne	Examinateur
M Pierre Sagaut	Université Pierre Marie Curie Paris 6	Examinateur
M Peter Beyer	Aix-Marseille Université	Examinateur
M Patrick Bontoux	CNRS, Aix-Marseille Université	Examinateur
M Cristel Chandre	CNRS, Aix-Marseille Université	Examinateur
M Philippe Ghendrih	CEA, IRFM	Examinateur
M Eric Serre	CNRS, Aix-Marseille Université	Examinateur

Abstract

Control of transport in magnetized plasmas plays a central role for several critical aspects involved in the road map towards a magnetic fusion reactor. On the one hand, we consider here control of turbulent transport that is crucial in the core region for improving the energy confinement time and performance of the device. Barriers are key structures in achieving such a control. On the other hand, we address the control of plasma wall interaction that encompasses such issues as safety, wall components engineering, as well as reactor performance limitation.

Three main parts will be presented. A first one on a control method based on Hamiltonian formalism for reconstructing confining structures in the phase space, the so called KAM tori, able to reduce the chaoticity of the system and to reestablish a more regular behavior. An example on the reduction of stochasticity of magnetic field line dynamics will be detailed. Then I will consider the problem of controlling plasma turbulence in the edge of tokamak devices via a biasing potential. Referring to fluid simulations for interchange turbulence, the dominant role of coherent structures, called bursts, in transport properties is highlighted and their interplay with transport barriers investigated. In this case the transport barrier is obtained with a more “brute force” approach, imposing a strong external biasing or switching off the turbulence drive in the equations. The numerical simulations are analyzed in terms of a stochastic model that gives predictions on the long term behavior of the barrier in stopping the incoming turbulent bursts. Finally, I will present the transport code SOLEDGE2D for modeling edge plasma transport in complex and realistic tokamak geometries. I will make a focus on the implementation of the penalization technique for taking into account plasma wall interaction in complex geometries with a relatively simple method. Then simulations in realistic tokamak geometries will be presented especially for the “WEST” geometry, the new configuration of Tore Supra tokamak in Cadarache. A special focus will be given to the investigation of supersonic flows in edge and SOL plasmas, comparing numerical results and theoretical predictions.