Simulating tokamak edge instabilities: advances and challenges

M. Hoelzl[1], G.T.A. Huijsmans[2,3], F. Orain[1], F.J. Artola[4], S. Pamela[5], F. Liu[2,6], D. van Vugt[3], S. Futatani[7], M. Becoulet[2], A. Cathey[1], K. Lackner[1], S. Günter[1], MST1 Team[*], ASDEX Upgrade Team[1]

[1]Max Planck Institute for Plasma Physics, Garching, Germany [2]CEA, IRFM, 13108 Saint-Paul-Lez-Durance, France [3]Eindhoven University of Technology, Eindhoven, The Netherlands [4]Aix-Marseille University, 13397 Marseille Cedex 20, France [5]CCFE, Culham Science Centre, UK [6]Université Côte d'Azur, 06108 Nice Cedex 02, France [7]Barcelona Supercomputing Center, Barcelona, Spain [*]H. Meyer et al, Nucl. Fusion 57,102014 (2017)

Large scale magneto-hydrodynamic (MHD) instabilities are of common interest in astrophysical, space and fusion plasmas. In all these research fields, the progress in non-linear MHD simulations has significantly increased the understanding of the observed phenomena. This talk is devoted to the recent progress in non-linear MHD simulation for tokamak plasmas. After giving an overview of the most important instabilities in tokamak plasmas and introducing the JOREK non-linear MHD code used for our studies, we focus on so-called edge localized modes (ELMs). Such instabilities lead to a periodic expulsion of energy and particles from the plasma. Uncontrolled ELMs are expected to considerably deteriorate the life-time of divertor components in ITER.

It is shown how simulations contribute in the effort of pushing forward the fundamental understanding of ELM physics. Based on recent experimental and simulation advances, the most important aspects of ELM physics are reviewed. This includes precursor modes, filament formation, field stochastization, impurity transport, and heat loads onto machine structures. An overview is also given of ELM control including natural ELM free regimes, and techniques for ELM pacing, mitigation and suppression.

It will be shown that quantitative agreement of simulations is achieved with many key experimental observations for ELMs and ELM control. Simulations allow to perform complementary investigations to the experimental approaches, and are successively developing the predictive capabilities to establish robust operational scenarios for future fusion devices. Open challenges will also be addressed.