External referee's report on the doctoral thesis
Diffusion of particles from tokamak by stochastisation of magnetic field lines
by Mgr. Pavel Cahyna

This theoretical dissertation work treats the effects of resonant magnetic perturbations (RMP) on the field structure and particle motions in tokamaks. This topic is of high interest because it is believed that intentionally created non-axisymmetric magnetic field perturbations can help to mitigate the impact of a detrimental plasma edge-pressure driven instability, so-called Edge Localised Modes (ELMs). This hypothesis is important for the upcoming International Thermonuclear Experimental Reactor (ITER) construction of which has started in Cadarache (France). ITER is predicted to have ELMs with large energy losses that very likely lead to wall material erosion. In the present ITER design, the divertor is covered with graphite. The erosion of carbon from divertor tiles and re-deposition with tritium in obstructed areas in the ITER vessel is a mission-critical problem, if ELM losses exceed a certain level. ELM mitigation or ELM suppression has been demonstrated experimentally in existing tokamaks, but neither the physics nor the prospect of extrapolating these results to ITER are understood as yet. Present models invoke an increase of radial transport in the plasma edge region (the „pedestal") due to transport parallel to the magnetic field. This additional transport may cause a reduction of the pressure gradient in the pedestal region, resulting in a stable (ELM-free) plasma. This is picture is not unanimously confirmed by experiments, and more experimental and theoretical work remains to be done. The COMPASS-D tokamak, now in Prague, is the smallest experiment that can reach relevent plasma parameters for ELMs and has additional perturbation coils that can be used to create RMPs. It is therefore reasonable to prepare for such experiments in COMPASS-D.

The present thesis addresses the effect of RMP from a first principles view-point, by calculating the field line and particle trajectories in a perturbed tokamak field. Main results are addressing particle motions in a perturbed field, the preparation of COMPASS-D RMP experiments, and the link of divertor power load pattern with magnetic perturbations of the main plasma. The investigation of particles motion is done numerically and uses the established Hamiltonian approach. The simulations show that chaos (stochasticity) in the particle motion is obtained with a single island chain. This is quite contrary to field line ergodicity, which requires the presence of two overlapping island chains. The underlying reason is the inherent m=1 drift motion of particles which constitutes a helicity that interacts with that of the single island chain. A second focus of the work is the preparation of RMP experiments for COMPASS-D. Using a computer code, ERGOS, that has already been found useful for other experiments as well as the prediction if RMP effects in ITER, the island width and Chirikov ergodisation parameter are calculated and optimised. As a third main topic, the divertor power load structure is analysed from the viewpoint of field line connections with the plasma core. The numeric analysis establishes the relation ship between the power load pattern and the shielding of the RMP inside the core plasma which establishes a way of experimentally observing the field penetration with available divertor measurements.

The work is sound and based on established and proven theoretical techniques. The results are convincing and in many cases confirmed by other theoretical work in this field which has currently attracted wide interest in the community. Thus, the unique value of the present thesis is not so much in the novelty of most of the results, but rather in the clean and didactical treatment of the problem and in the usefulness of the calculations for quantitative predictions that can be helpful, e.g., in the design and interpretation of the upcoming experiments in COMPASS-D on this topic. The candidate has proven his excellent theoretical and numerical skills and creativity with this work. The results are presented in a clear and meaningful way in the thesis manuscript and in the underlying publications that show high scientific standard. Therefore I recommend that this thesis be accepted for the doctoral degree of its author.

Wolfgang Suttrop