Referee report on the doctoral thesis "Study of instabilities in tokamak plasma using radiation diagnostics" by Ing. Martin Imríšek

The submitted doctoral thesis is devoted to the study of the magneto-hydrodynamic instabilities (MHD) in COMPASS and JET tokamaks and studies dedicated to the construction of new tokamak COMPASS-U.

Investigation of the MHD instabilities in this work was mainly done using Soft X-ray cameras and tomographic reconstruction of the plasma radiation, which is very sensitive to core MHD. The main instability studied in the thesis is the sawtooth crash. At present, this instability is one of the most important for ITER and DEMO tokamaks. It is not dangerous for the plasma confinement itself, but it could trigger Neoclassical Tearing Modes (NTMs) which could even lead to disruption. The author of the thesis made a wide range of different investigations regarding the behavior of sawteeth in COMPASS and JET. He also looked at the accompanied phenomena like disruption, ELMs, L-H transitions. He confirmed in COMPASS the following findings by other tokamaks:

- the sawtooth crash is often incomplete and post-cursors are observed,
- coupling of the edge physics (ELMS, L-H transition) to sawteeth is present in some plasma scenarios,
- NBI heating influence on sawtooth instability,
- dependencies of the sawtooth period are in agreement with Porcelli model predictions.

Based on the investigation of global parameters (plasma density, pressure, energy confinement time, temperature, and plasma resistivity), the author concludes that the diffusion of the plasma current into the plasma core is not a dominant process governing the sawtooth period at COMPASS.

The next part of the work is dedicated to improving tomographic algorithms for fusion. The author's contribution in this part is especially interesting. He published two papers as the main author where he discussed optimization and application of the tomographical methods. The first paper describes the particular optimization of Tikhonov regularisation and its application for tomographic inversion for Soft X-ray tomography in COMPASS tokamak. The second paper discusses a fast tomographic algorithm, with the potential for real-time, for the determination of the center of SXR radiation and its application for studies of MHD activity in COMPASS. Both papers provide new pieces of knowledge, which could be potentially used in tomographic algorithms on present-day tokamaks and ITER.

Chapter four of the thesis describes a search for the optimal position of the poloidal field (PF) coils concerning the toroidal field (TF) coils position for the new COMPASS-U tokamak. Simulations of a set of plasma equilibria, carried out in the collaboration with other members of the COMPASS team, shown that PF coils should be placed inside TF coils to ensure vertical stability and avoid unacceptably high current demands for PF coils.

From the formal point of view, the thesis is well structured into chapters. It contains all usual items like the lists of tables, references, figures, and abbreviations used in the text. The author describes clear and concise the state of the art of the field. The general overview of MHD instabilities, the Soft X-ray diagnostic used in the work, and main theoretical findings for

sawtooth instability are well described and contain generally accepted basic theories as well as the latest results. The identified similarities with other sources are minimal and do not affect the originality of the work. The bibliography of the work contains 171 references in a standard format. SI units are systematically used throughout the thesis. The quality of the work, from the formal viewpoint, is very good.

The results of the thesis have been already published by the author in 2 papers as the first author and 12 papers as co-author, in reputable journals. To conclude, Martin Imríšek has proven his ability to solve complicated scientific problems. His main new contributions are related to the improvement of tomography, but he also worked in a team for the design of the new tokamak COMPASS-U and investigation of the sawtooth instability. This shows his potential both to perform independent creative scientific work and to cooperate effectively in scientific teams. Based on all this, I recommend this thesis be accepted by the Ph.D. committee. I do believe that after successful defense Martin Imríše will be awarded the Ph.D. scientific degree.

Comments and remarks on the thesis:

1) A small comment on figure 2.5. The stable region starts from zero in the figure. In reality, it starts from particular currents and density, also this part of the operational space is not interesting.
2) As was mentioned above, the author finds that the diffusion of the plasma current into the plasma core is not a dominant process governing the sawtooth period at COMPASS. Is this valid also for purely Ohmic heated discharges (without NBI/ECRH)? Do you think about verification of this finding by comparison of profile evolution measured between the crashes and transport code simulations?
3) The fast algorithm of the SXR radiation center, published in Rev.Sci Instrum, traces the center of SXR radiation. As mentioned by the author, centrifugal effects on high Z impurities would shift the maximum position. How do you see the correction for this effect?

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