Review of the doctoral thesis "*Study of probe diagnostics of tokamak edge plasma via computer simulation*" by Mr. Aleš Podolník

Univerzita Karlova, Matematicko-fyzíkální fakulta

Dr. Jordan Cavalier
Ústav fyziky plazmatu AV ČR, v. v. i.
Za Slovankou 1782/3
182 00 Praha 8

The thesis of Aleš Podolník represents an important contribution for the fusion community on the insight of how electrostatic probes, a widely use plasma diagnostic, operate in tokamak devices. It is very well written in a clear english, introducing all necessary general concepts down to the very details of probe physics. The work performed by Mr. Podolník is also distinctly highlighted all along the manuscript, showing, in addition to the probe physics analysis performed in the thesis, his joined team efforts in the SPICE code development and contribution to ITER relevant researches.

In the first chapter, Mr. Podolník introduces the basic concepts of fusion energy and tokamak physics in a pleasingly succint, but yet, quite complete manner, only missing a short section describing the energy challenge face by the mankind and the related importance of nuclear fusion. The second chapter presents the plasma meachnisms involve in plasma facing physics, for instance as electrostatic and magnetic sheaths, with clear and useful illustrative examples obtained from the SPICE code. The rest of the chapter is devoted to the description of electrostastic probes and in particular Langmuir probes. The problem about interprating the experimental probe current-voltage (I-V) characteristics, due to the sheath expension that occurs especially under the influence of oblique magnetic field, is raised. The different main models used for the analysis of these characteristics in the plasma physics community are presented with an exhaustive list of references, and will serve all along the thesis. The next chapter serves to put the thesis work into context and proof to be a very useful transition. In the two following chapters, different models used to simulate plasma behavior are introduced, giving a clear overview of what exists, useful information for non-specialists. A special care is devoted to the description of the particle-in-cell simulation type and, more specifically, to the SPICE code, as the thesis' results were obtained thanks to it. Efforts of Mr. Podolník to improve the efficienty of the SPICE code, especially regarding parallelisation, are also mentioned. These five past chapters, preluding to Mr. Podolník main results, were really appreciated, as they serve adequately to the understanding of the doctoral's work and put it into the general context of fusion researches.

The two last chapters represent the core of Mr. Podolník's work. In the chapter six, simulations with SPICE of flush-mounted probes, a tool worlwide-spread to diagnose the plasma of tokamaks, are used to compare the different theoretical model of I-V characteristics introduced in the second chapter. The results show valuable insights on which model to use under different plasma conditions and how the plasma quantities that can be estimated from probe analysis are affected. This work not only serves for the analysis of existing experimental data from flush-mounted probes, but proves to be useful in the design of new systems of probes, for the COMPASS-U tokamak for instance. The seventh chapter tackles the case of protubing Langmuir probes measuring the ion saturation current and how, from this measurement, to retrieve the plasma density, i.e. accounting for the variation of the probe area due to the sheath expansion. The simulation were performed to mimick an experiment realized on the COMPASS tokamak with a reciprocating probe head but could serve for other fusion devices. It is shown in the thesis

how the probe area should be accounted for and the simulation results are further supported by comparison of the obtained plasma density with the one obtained by beam emission spectroscopy. This is clearly a useful results for the plasma community, as proved by Mr. Podolník's publication in Plasma Physics and Controlled Fusion. In the conclusion of the thesis, Mr. Podolník remind the reader that the results are simulation-based, and not directly experiments, showing his scientific honesty and carefulness. The last paragraph about the perspectives is rather short and it would be good to extend it, to understand what Mr. Podolník would work on in the near future.

In this manuscript, Mr. Podolník shows that he clearly acquired an excellent expertise in the probe simulation field and that his work has brought valuable contributions to a better understanding of plasma physics. He also demonstrates to have the ability to present his very complex work in an understandable and well-structured manner. Mr. Podolník has surely all the qualities required to become a scientist and I wholeheartedly recommend that he be granted the title of Doctor.

Recommendations:

The conclusions brought by this work does not only apply to COMPASS but also to other tokamaks (as said in the thesis, also applied to ToreSupra for instance), as they are rather general. I recommend to continue in that direction. Complementary to that, it is adviced to continue to make comparison (like the one Langmuir probe/Li beam) of corrected probe data, thanks to simulation output, and other diagnostics, to strenghten the results. I also advice Mr. Podolník to take more part to experiments to continue running simulations relevant to realistic cases.

Questions:

Q1) In chapter 4 p.43, non physical heating in simulation is evoked. Is it possible to illustrate this effect or any non physical effects that arise in simulation, so that non specialists could see what it is like? With SPICE or any illustrative example.

Q2) In chapter 7 p.90, it is stated that a scan of the potential of the pin in the simulation was made. Can Mr. Podolník comment why he did not do a similar study to what was done for flush-mounted probes and only focused on the sheath expansion when measuring Isat?

Signed Jordan Cavalier

Prague, Czech Republic
June 14, 2019