UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
DIPARTIMENTO DI INGEGNERIA ELETTRICA E DELLE TECNOLOGIE DELL'INFORMAZIONE

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Subject: Assessment of the Master Thesis "Fast swept divertor suppressing transient heat pulses in tokamaks" by Samuel Lukeš

Dear Secretary,

Here is my assessment of the Master thesis of Samuel Lukeš.

The thesis deals with an innovative technique for the reduction of the effects of the transient heat loads of the ELMs on the divertor targets of a tokamak.
It is evident that the candidate is already integrated in a productive research group, as documented by the various publications indicated in the thesis.
In the preface, he clarifies that his work follows Richard Duban's master's thesis and that the main output of the project is a paper submitted to Nature Physics, where he is the second author.
I was impressed by the very good knowledge of the phenomena and by various innovative ideas and innovative concepts illustrated in the thesis, namely the fast sweeping method based on the Alternating Magnetic Conductor (AMC) and the resonant circuitry.
I made my own calculations and I verified that at a given distance the field of a circular wire can indeed be amplified by a large factor using the hollow cylinder with a longitudinal cut. This might be exploited for different applications too.
The first two chapters present an overview of the problems analyzed in this thesis and clearly state the objectives of the work, which is also summarized in Chapter 6.
I assume that the most significant part of the personal contribution of the candidate is illustrated in Chapters 3, 4 and 5.
The third chapter focuses on the electromagnetic simulations in COMSOL, showing the resulting magnetic configurations using the AMC in different conditions. The approach is well illustrated and a possible geometry suitable for DEMO is presented.

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The fourth chapter deals with an interesting analysis of the sweeping circuit. Its components are optimized on the basis of a parametric study, taking into account the components and the devices currently available on the market.
The fifth chapter includes an interesting discussion, highlighting the limits of validity of the analyses reported in the thesis.
The thesis is well written and presents a connected account of the activity, also testified by a number of publications.

I would personally rate this Master thesis comparable to the top 10% PhD dissertations I have read in the field of fusion science and engineering. For this reason, my assessment leads to the following grading: **A (excellent).**

I do not know whether there is margin to revise the text. In this case, I would suggest a few changes to the final text, summarized in the attached pages.

Best regards,

Raffaele Albanese

Comments on Master Thesis "Fast swept divertor suppressing transient heat pulses in tokamaks" by Samuel Lukeš

GENERAL COMMENTS

1) In my view, some references should be added, in particular [A-B], where the use of strike point sweeping was firstly proposed and applied to tokamaks, [C], reporting the experimental evidence of the damages of the ELMs testifying a temperature rise of several thousand degrees centigrade, and [D], introducing the two-point basic SOL model discussed in Section 2.2.1.
[A] J.C. Wesley, Thermal effects of divertor sweeping in ITER, (1991) Proceedings - Symposium on Fusion Engineering, pp. 933 - 936, DOI: 10.1109/FUSION.1991.218695
[B] E. Bertolini, JET with a pumped divertor technical issues and main results, (1995) Proceedings - Symposium on Fusion Engineering, 1, pp. 455 – 463
[C] K. Krieger et al., Experiments on transient melting of tungsten by ELMs in ASDEX Upgrade, 2018 Nucl. Fusion 58 026024, DOI:10.1088/1741-4326/aa9a05
[D] P.C. Stangeby, A tutorial on some basic aspects of divertor physics, 2000 Plasma Phys. Control. Fusion 42 B271, DOI: 10.1088/0741-3335/42/12B/321

2) Also in view of the discussion in Chapter 5, some assertions seem a bit overstated, e.g., "In this work, a system that solves one of eight main problems of DEMO (…) will be presented" at page 14.

3) The thesis is focused on the fast sweeping. It would be useful to stress the motivation to have frequency of the order of 1 kHz. It is mentioned, but it could be better clarified by citing [C], stating that the nature of the ELMs is typically three-dimensional with consequent concentration of heat flow in a small region with expected peaks of P~50 MW for Δt~5 ms, and reporting how the temperature increase ΔT due to the thermal shock scales with the parameters of the ELM and the plasma facing component material: $\Delta T \sim P \cdot (\Delta t / \langle \rho c_p \lambda \rangle)^{1/2}$, where $\langle \rho c_p \lambda \rangle$ is the average value of the product between material density, specific heat capacity and thermal conductivity (average value, since c_p and λ vary with the temperature). It is evident that for tungsten the above parameters yield a temperature increase above the melting temperature of 3423 °C.

SPECIFIC COMMENTS

1) Page 14:
"In this work, a system that solves one of eight main problems of DEMO (…) will be presented"
should by
"In this work, a system that deals with one of eight main problems of DEMO (…) will be presented"

2) Page 18:
"Tokamak, or toroidal vessel with magnetic coils, serves to sustain a discharge at thermonuclear temperatures and to understand both plasma and thermonuclear fusion. The plasma discharge is confined"
should be
"Tokamak, or toroidal vessel with magnetic coils, serves to sustain a discharge at thermonuclear

temperatures. The plasma is confined”

3) Page 19:
“But only a combination with the toroidal magnetic field coils creates a”
should be
“The superposition of the poloidal field due to the plasma with the toroidal magnetic field creates a”

4) Page 21:
“perpendicular (radial) direction to the toroidal magnetic field”
should be
“perpendicular direction to the magnetic surface”

5) Page 23:
“the larger $D_{\perp}$ gets the lower the heat flux will be in the divertor region”
should be
“a larger $D_{\perp}$ coefficient yields a lower heat flux in the divertor region”

6) Page 29:
“described in [28, 29, 30, 31]. Where no eddy currents “
should be
“described in [28, 29, 30, 31], where no eddy currents “

7) Page 47:
“The real conductor has a resistance, resistance creates a voltage drop and the voltage difference at the two ends of the conductor is actually a capacitor.”
should be
“The real conductor has a resistance, resistance creates a voltage drop, hence the two ends of the conductor behave as a capacitor.”