PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Vincenzo Paolo Loschiavo

XXIX Cycle

Training and Research Activities Report – Second Year

Tutor: Prof. Ing. Raffaele Albanese

1. Information

Vincenzo Paolo Loschiavo

M.Sc. Degree in Mechanical Engineering – University of Naples Federico II

ITEE Ph.D. XXIX Cycle

Grant

Tutor: Prof. Eng. Raffaele Albanese

2. Study and Training activities

During the second ITEE Ph.D. year, I had the opportunity to attend different interesting courses with the aim to improve my previous knowledge and my skills. In particular:

- FORMULAZIONI NUMERICHE PER L'ELETTROMAGNETISMO (NUMERICAL FORMULATIONS FOR THE ELECTROMAGNETISM);
- ENGLISH COURSE AT C.L.A.

Furthermore, I had the opportunity to attend many seminars as:

- "MPC for plasma magnetic control", S. Gerksic, 24 March 2015, 15:30-17:30 (DIETI)
- "Modelli matematici per il calcolo scientifico nell'ingegneria e nell'innovazione tecnologica", Prof. Alfio Quarteroni, 15 April 2015, 11:00-13:00 Sala dei libri antichi (Facoltà di Ingegneria)
- "Instrumentation and control integration of EU diagnosticsin the ITER tokamak", Dr. Andrè Cabrita Neto, 6 May 2015, 9:00-10:00 Edifice 5, C5B
- "La ricerca nel settore scientifico disciplinare della elettrotecnica negli ultimi decenni", Prof. M. Salerno, 28 October 2015, 17:00-19:00 SOFTEL
- "Gielis Transformations in the Natural Sciences and Technology", Prof. Yohan Gielis, 17 February, 11:00-13:00 (DIETI)

Finally, I took part in different events organized by the Scuola Nazionale Dottorandi di Elettrotecnica "Ferdinando Gasparini" (26-30 October 2015) in which I had the opportunity to attend different lectures on the topics:

- OPTIMIZATION METHODS FOR THE ELECTRICAL ENGINEERING;
- SPIKING NEURAL NETWORKS CHARACTERIZATION AND APPLICATIONS;
- INVERSE PROBLEMS AND ELECTROMAGNETIC IMAGING.

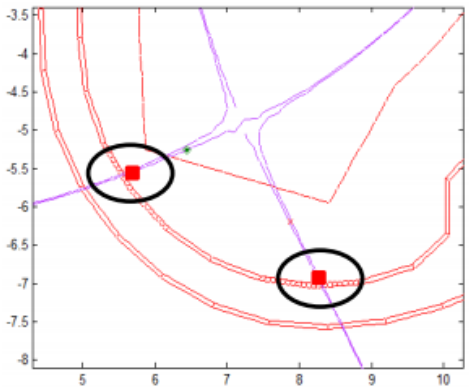
In the table, there is a short credits recap.

	Credits year 1								Credits year 2								Credits year 3									
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Total	Check
Modules	21			3		3	5	**11**	15		6		1		12	**19**								**0**	30	30-70
Seminars	5	0,4	0,8		1	0,2	2	**4,4**	5	0,8	0,2		0,4		0,4	**1,8**								**0**	6,2	10-30
Research	34	10	8	8	8	6	0	**40**	40	10	6	10	10	10	0	**46**		10	10	10	8	10	10	**58**	144	80-140
	60	10	8,8	11	9	9,2	7	**55**	60	11	12	10	11	10	12	**67**	60	10	10	10	8	10	10	**58**	180	180

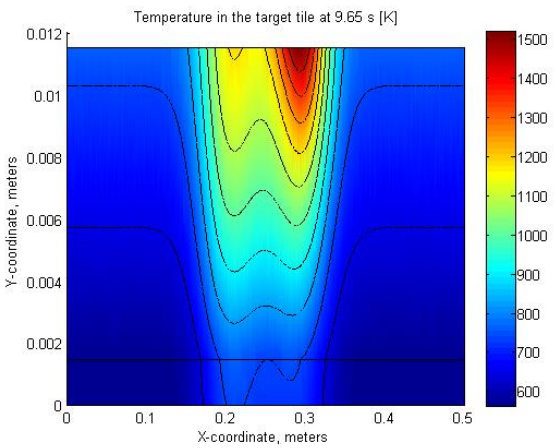
3. Research activity

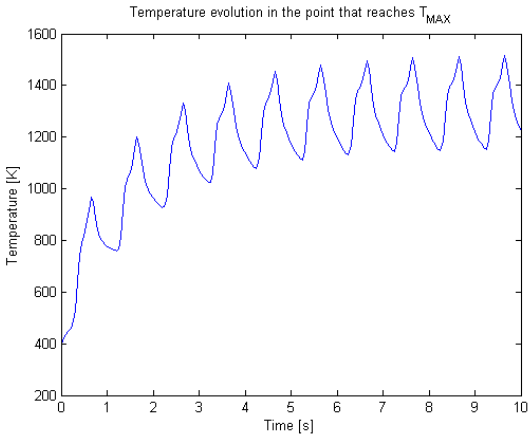
The research activity proposed by my tutor - that I accepted enthusiastically - is *addressing the power exhaust and particles in the next generation fusion reactors*. This topic is regarded as one of the ultimate challenges for the design of DEMO reactor. During my first ITEE PhD year, we identified the *Strike-Point Sweeping* as one of the most promising techniques for spreading the huge heat load impinging on the material surfaces (PFCs – Plasma Facing Components)

The strike points sweeping is a periodical movement of the strike points produced by dedicated coils, which are connected in antiseries. These coils should be located in a position suitable to allow shielding and maintenance.

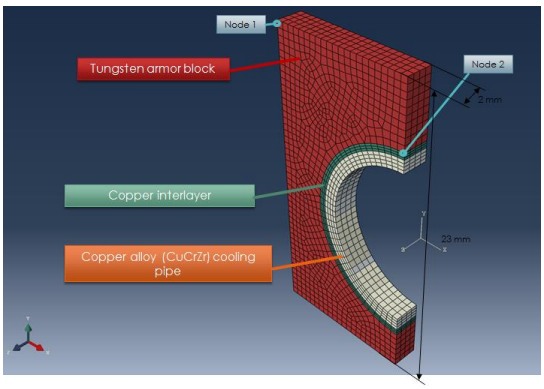


A *2-D FE model* has been developed (in MATLAB environment) in order to quantify the benefits achievable with the Strike Point Sweeping technique (varying amplitude and frequency), in terms of maximum temperature and heat flux on the material surfaces of the DEMO divertor reactor.

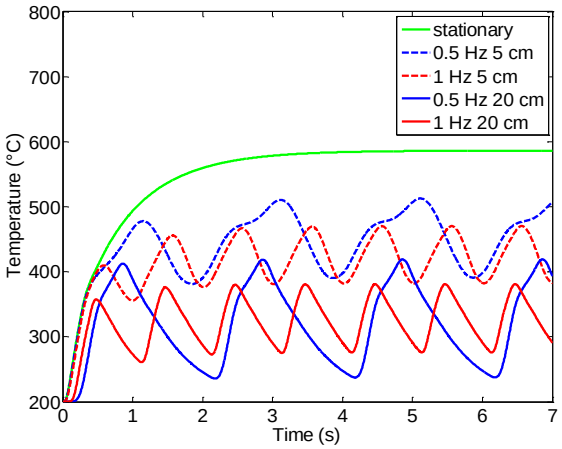




Due to its cyclic nature, the periodical movement of the plasma strike points produce a cyclic heating and cooling of the divertor PFCs, inducing the thermal fatigue phenomenon. In order to determine the thermal fatigue damage of the DEMO divertor target components, during my second PhD year a 3-D FE model has been realized in ABAQUS environment.



Numerical simulations have been carried out for peak heat flux densities of 15 MW/m^2 and 30 MW/m^2, sweeping amplitudes of 5 cm and 20 cm and sweeping frequency values of 0.5 Hz and 1 Hz.



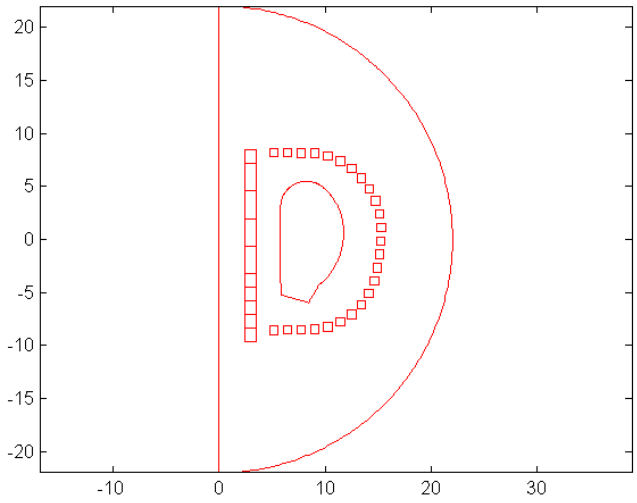
Equivalent strain range (%) / fatigue lifetime (N) in the copper interlayer

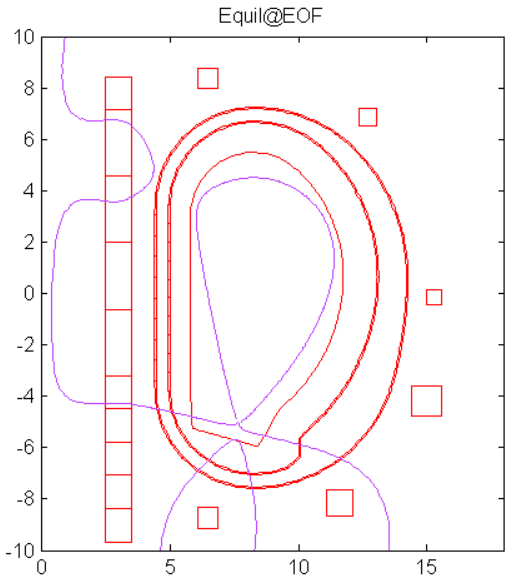
Sweeping amplitude (cm)		5		20	
Sweeping frequency (Hz)		0.5	1	0.5	1
Peak heat flux density (MW/m^2)	15	0.13/65344	0.09/356612	0.19/16518	0.10/189324
	30	0.32/1682	0.20/11908	0.45/564	0.22/8508

Investigating the strike point sweeping as the ultimate solution in the mitigation of the DEMO power exhaust, the results show that the fatigue lifetime of the divertor copper interlayer seems to be the limiting factor. It is evident that even in the best case scenario (15 MW/m^2, with 5 cm and 1 Hz sweeping parameters), the fatigue lifetime of the copper interlayer, in stationary sweeping conditions, is less than 100 working hours.

Part of this main activity has been carried out during 22 days spent in ENEA – Brasimone working with Davide Bernardi and 5 days in Max Planck Institut for Plasma Physics – EUROfusion (Garching - Munich) working with Francesco Maviglia. In those days, I had also the possibility to meet relevant engineers and physicists (Gianfranco Federici, Ronald Wenninger, Muyuan Li) working on the DEMO reactor design and those meetings resulted in helpful collaborations.

I also worked, all over the year, with Prof. Roberto Ambrosino and my tutor on the "Optimization of PF coils position in DEMO tokamak". We demonstrated that, starting from a redundant PF coils configuration, it is possible to produce a given plasma equilibrium reducing the number of coils to a set optimizing the currents and respecting the force constraints. The procedure has been already developed but not yet published.





Finally, I spent 11 additional days in the Max Planck Institut for Plasma Physics – EUROfusion (Garching - Munich) working with my tutor and many engineers of the CREATE research group (M. Mattei, R. Ambrosino, G. Calabrò) working on "Equilibrium optimization and calculations for 2nd X-pt scan".

4. Products

During this year, I was involved in one Paper: F.Maviglia et al, "Limitations of transient power loads on DEMO divertor and analysis of mitigation techniques", published on "Fusion Engineering and Design", doi:10.1016/j.fusengdes.2016.01.023.

I took part, as a contributor, in the "DTT (Divertor Tokamak Test) facility Project Proposal: an opportunity for facing one of the major challenges along the roadmap to the realisation of fusion energy", printed in July 2015 at ENEA Frascati Research Center (http://fsn-fusphy.frascati.enea.it/DTT/downloads/Report/DTT_ProjectProposal_July2015.pdf).

I am also involved in other papers on "Optimization of PF coils position in DEMO tokamak" and "3D plasma identification", which will be submitted in the next months.

5. Conferences and Seminars

A preliminary version of the work on the "Limitations of Transient Power Loads on DEMO and Analysis of Mitigation Techniques" has been presented by Francesco Maviglia at the 12th International Symposium on Fusion Nuclear Technology, September 14-18 2015, Jeju Island, Korea.

6. Activity abroad

I spent 17 days (29 July – 8 August and 6 – 11 September 2015) in the Max Planck Institut for Plasma Physics – EUROfusion (Garching - Munich) with my tutor and M. Mattei (CREATE research group). In those days, I worked also with F. Maviglia, G. Federici, R. Wenninger (EUROfusion) on the DEMO reactor design. Furthermore, I've been involved 7 days in the TCV tokamak experimental campaign (EPFL "Ecole Polytechnique Federale de Lausanne", 1 – 7 November 2015) working with E. Giovannozzi (ENEA - Frascati), P. Uccello (IFP – CNR, Milano), P. Innocente (Consorzio RFX - Padova) and H. Reimerdes (EPFL - TCV). Finally, I spent 22 days (11- 20 May and 5 - 16 October 2015) in ENEA - Brasimone working with Davide Bernardi.

7. Tutorship

I've been involved – 10 hours - in practice exercises proposed to the students of the "Elettrotecnica" and "Introduzione ai Circuiti" courses held by professors R. Albanese and M. de Magistris.