PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Nicola Isernia

XXXIV Cycle

Training and Research Activities Report – Second Year

Tutor: Prof. Fabio Villone

1. **Information**
   a. Nicola Isernia, M.Sc. in Electrical Engineering, Università degli Studi di Napoli Federico II
   b. XXXIV Cycle - ITEE Doctoral School, Università degli Studi di Napoli Federico II
   c. Athenaeum fellowship
   d. Tutor: Prof. Fabio Villone

2. **Study and Training activities** (Credits in brackets)
   a) Modules and Courses (15.4)
      I. Analisi Funzionale – Prof. Luciano Carbone - Master Degree in Mathematics (6)
      II. Scientific Programming and Visualization with Python – Dottorato del Dipartimento di Strutture per l'Ingegneria e l'Architettura (3)
      III. Machine Learning – ITEE ad hoc Course (2.4)
      IV. Mathematics of the Finite Element Method – Prof. Francesco Calabrò – Dottorato del Dipartimento di Matematica e Applicazioni (4)
   b) Seminars (4.2)
      I. Seminar Cycle "*Intelligenza Artificiale ed Etica*" – Organized by Prof. Guglielmo Tamburrini (1.4)
      II. "*Formulation of the magneto-mechanical problem by using the principle of energy – C. Serpico*" (Internal Seminar Electrical Engineering Group)
      III. "Derivation of Balance Equations of Electrodynamics Materials based on Averaging of Microscopic Fields" – Prof. Claudio Serpico (Internal Seminar Electrical Engineering Group)
      IV. "How to get published with IEEE?" – Eszter Lukacs (0.4 CFU)
      V. "Elettromagnetismo e salute" - Prof.ssa Rita Massa (0.4 CFU)
      VI. "Premixed model for interactions of a plasma with the injection of atoms (large Z)" - Boniface N'Konga [for JET T17-13 Group] (0.1)
      VII. "Asymmetric wall force and thermal quench in JET disruptions" – Hank Strauss [for JET T17-13 Group] (0.1)
      VIII. "Noninvasive Mapping of Electrical Properties using MRI" – Prof. Riccardo Lattanzi (0.3)
      IX. "Maximum Likelihood Tomography on JET: an overview with focus on bolometry"- Andrea Murari [MST1 Task Force for JET]
      X. "How to publish Open access with IEEE to increase the exposure and the impact of your research"
      XI. "We are at a cross-roads" – Prof. Hannes Wethner [TU Wien] in the framework of the online event "Digital Humanism" organized by Prof.ssa Viola Schiaffonati [Politecnico di Milano] (0.2)
      XII. "IBM Quantum: i primi computer quantistici per la ricerca e la didattica", PhD Federico Mattei (IBM Quantum Ambassador) organized by Segreteria CRUI (0.2)
      XIII. "On Dead-Time Compensation in Repetitive Control", Prof. Leonid Mirkin [Technion-IIT, Haifa, Israel], organized by Prof. Paolo Bolzern for Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano (0.2)
      XIV. "Valutazione dei livelli di esposizione e del rispetto dei limiti Antenne e 5G", Prof. MD Migliore [Università di Cassino e del Lazio Meridionale], organized by the advanced course "Campi elettromagnetici: valutazione del rischio e protezione" directed by Prof. Rita Massa, (0.3)
      XV. "Cybersecurity nella fabbrica intelligente", Prof. Stefano Zanero, [organized by Politecnico di Milano, Polo territoriale di Cremona] (0.4)
      XVI. "Nonintrusive reduced order models using physics informed neural networks" – Prof. Jan Hesthaven [EPFL, Seminar organized by Prof. Alfio Quarteroni for MOX, Politecnico di Milano] (0.2)

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3. Research activity

a) Title

<div align="center">Plasma – Structures Electromagnetic Interaction</div>

b) Study

<div align="center">Magneto-Hydro-Dynamic plasma models and MQS models.</div>

c) Research description

The PhD research topic deals with the coupling between plasma fluid models and electromagnetic models of surrounding structures and devices. Some experimental and design activity is keep going from the previous year, see details in Section *"Collaborations"*. Three main sub-topics were considered this year, as reported in the dedicated paragraphs.

As main research result for this year, a mathematical model of the energy balance in tokamak experiments was developed. This is showing how to tackle the problem of energy balance with evolutionary equilibrium models. The main energy exchange mechanisms during fast transient events were analysed, revealing that the magnetic energy available for conversion to dissipated heat depends on the ratio between the event duration and the electromagnetic time constant of the conducting vessel surrounding the plasma. Analytical formulas for simple high-aspect-ratio scenarios were also provided and compared to numerical simulations, also in the context of a more general review of analytical models aimed at future works on the subject.

Studies of the extended MHD models and related numerical codes VMEC, JOREK and M3D-C1 were performed, also interacting with Oak Ridge Laboratories, Princeton Plasma Physics Laboratories, ITER organization and Max-Planck Institute for Plasma Physics. These studies are preliminary to the design and implementation of coupling strategies with the eddy current code CARIDDI in next years. The planned 6-months visit to Princeton Plasma Physics Laboratories was cancelled due to Sars-Cov-2 pandemic, where this topic was supposed to be further developed.

We finally decided to review the macroscopic plasma modelling through the tools offered by Classical Irreversible Thermodynamics. This view-point was initially adopted to place in a consistent mathematical framework the constitutive relations provided for closure of MHD models. This framework allowed to understand the general physical constraints due to spatial symmetry and microscopic reversibility the constitutive relations should satisfy in presence of a strong magnetic field. Moreover, a generalisation of the energy balance already presented, which accounts for the *kinetic energy of diffusion* seems possible. This might help the understanding of the energy implications related to *runaway electrons* population in thermal plasmas of tokamak devices*.* We are preparing a manuscript on this subject.

d) Collaborations
   - Prof. Claudio Serpico and ITEE PhD student Valentino Scalera – Energy Balances in multi-physics problems, with application to fusion plasmas
   - PhD Vadim Yanovskiy – Design of COMPASS-U and modelling of COMPASS experiments.
   - Joint European Torus (JET) Work Package T17-13 *"Disruption and runaways"* – Coupled plasma-structure models for JET experiments.
   - Prof. Guglielmo Rubinacci, PhD David Terranova (Ricercatore CNR) and PhD Mark Cianciosa (Oak Ridge National Laboratories) – VMEC-CARIDDI coupling activities
   - Joint European Torus (JET) Work Package M18-33 *"Mitigation of Disruption electro-magnetic load with SPI"* – analysis of experimental data.
   - Prof. Steve Jardin, Head of the Computational Plasma Physics Group at Princeton Plasma Physics Laboratories, - Studies of extend-MHD code M3D-C1 for integration with CARIDDI

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- o PhD Javier Artola Such (ITER organization), PhD Mathias Hoelzl (Researcher at the Max Planck Institute for Plasma Physics) – Studies of the extended-MHD code JOREK for integration with CARIDDI

4. Products
a) Publications (Journal Papers)
- o N. Isernia, V. Scalera, C. Serpico, N. Isernia, Energy balance during disruptions, Plasma Physics and Controlled Fusion, Volume 62, Number 9, 2020.

b) Publications (Conference Proceedings)
- o – (Conference suspended)

c) Under review or in preparation
- o N. Isernia, F. Villone, "*Magneto-Hydro-Dynamics in the framework of Classical Irreversible Thermodynamics*"

5. Conferences and Seminars
- a. The European Physical Society Conference on Plasma Physics was postponed to 2021

6. Activity Abroad
- o 11/11/19-15/11/19 Culham Science Centre for Fusion Energy (UKAEA-JET) in the frame of the T17-13 modelling campaign
- o Abroad Research Period at *Princeton Plasma Physics Laboratories* (*Theory Department, Computational Plasma Physics Group*)*,* planned for the period 01/04/2020-31/09/2020 was cancelled due to SARS-CoV-2 pandemic.

30/10/20

Student: Nicola Isernia   **Tutor: Fabio Villone**   **Cycle XXXIV**

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	Credits year 1								Credits year 2								Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Total	Check
Modules	23	9	9.4		9			27.4	15		3			8.4	4	15.4	20							0	43	30-70
Seminars	7	0	0.6	0.7	1	0	3	5.3	3	1.4		0.8	0.5		1.5	4.2	5							0	9.5	10-30
Research	34	2	1	6.3	5	8	6	28.3	42	8.6	7	9.2	9.5	1.6	4.5	40.4	34							0	69	80-140
	64	11	11	7	15	8	9	61	60	10	10	10	10	10	10	60	59	0	0	0	0	0	0	0	121	180

Year	Lecture/Activity	Type	Credits	Certification	Notes
1	Elettromagnetismo e Relatività	Ad hoc module	5	x	
1	Mathematical Physics Model	MS module	9	x	
1	A leap into functional data analysis	Ad hoc module	2	x	
1	MHD Equilibrium and Stability	Ad hoc module	2.4	x	
1	Meccanica Statistica	MS module	9	x	
1	Computational And Machine Learning for Complex Ecosystems	Seminar	0.2	x	
1	Chaos in Magnetizationd Dynamics	Seminar	0.4	x	
1	Spin-orbit optical phenomena	Seminar	0.2	x	
1	IEEEXplore Training and Authorship Workshop	Seminar	0.5	x	
1	Medical Thermal Therapy and Monitoring using Microwave Inverse Scattering	Seminar	0.2	x	
1	Scuola F. Gasparini - Viterbo	PhD School	0.8	x	
1	Scuola F. Gasparini - Napoli	PhD School	3	x	
2	Scientific Programming and Visualization with Python	Ad hoc module	3	x	
2	Analisi Funzionale	MS module	6	x	
2	Machine Learning	Ad hoc module	2.4	x	
2	Mathematics of the Finite Element Method	Ad hoc module	4	x	
2	Seminar Cycle "Intelligenza Artificiale ed Etica"	Seminar	1.4	x	
2	Formulation of the magneto-mechanical problem by using the principle of ene	Seminar	/	/	
2	Derivation of Balance Equations of Electrodynamics Materials based on Avera	Seminar	/	/	
2	How to get published with IEEE?	Seminar	0.4	x	
2	Elettromagnetismo e Salute	Seminar	0.4	/	

2	Premixed model for interactions of a plasma with the injection of atoms	Seminar	0.1	/
2	Asymmetric wall force and thermal quench in JET disruptions	Seminar	0.1	/
2	Noninvasive mapping of electrical properties using MRI	Seminar	0.3	x
2	Maximum Likelihood Tomography on JET: an overview with focus on bolomet	Seminar	/	/
2	How to publish Open access with IEEE to increase the exposure and the impa	Seminar	/	/
2	We are at a cross-roads (digital humanism)	Seminar	0.2	x
2	IBM Quantum: i primi computer quantistici per la ricerca e la didattica	Seminar	0.2	/
2	On Dead-Time Compensation in Repetitive Control	Seminar	0.2	x
2	Valutazione dei livelli di esposizione e del rispetto dei limiti Antenne e 5G	Seminar	0.3	/
2	Cybersecurity nella fabbrica intelligente	Seminar	0.4	x
2	Nonintrusive reduced order models using physics informed neural networks	Seminar	0.2	x