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Dipartimento Energia "Galileo Ferraris"

Energetics PhD

Energetics PhD ANNUAL REPORT 2018

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This document contains a series of one-page reports from the students enrolled in the Energetics PhD program at Politecnico di Torino, Italy, including the highlights of their research activity in 2018. The previous editions of the Annual Report can be downloaded from ***http://dottorato.polito.it/ene/en/documents***

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Acknowledgments

The following Companies are gratefully acknowledged for supporting the research activities of Energetics PhD students by granting academic licenses of their softwares:

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CONTENT

First name: Pranav **LAST NAME**: ARYA

Topic: Calibration methodologies for last generation automotive powertrains

Course year: 3rd **Tutor(s)**: Prof. F. Millo

Academic context

[1] Millo, F., Arya, P., Mallamo, F., *"Optimization of automotive diesel engine calibration using genetic algorithm techniques"*, Energy, 2018, Vol. 158 pp 807-19. https://doi.org/10.1016/j.energy.2018.06.044
[2] Mallamo, F., Millo, F., Rolando, L., *"Model-based development and calibration of last generation diesel powertrains for passenger cars"*, International Journal of Powertrains, 2014, Vol. 3, Issue 1. https://doi.org/10.1504/IJPT.2014.059415
[3] Mallamo, F., Badami, M., Millo, F., *"Application of the Design of Experiments and Objective Functions for the Optimization of Multiple Injection Strategies for Low Emissions in CR Diesel Engines"*, SAE Technical Paper 2004-01-0123, 2004. https://doi.org/10.4271/2004-01-0123

External collaborations

- FEV Italia
- General Motors Global Propulsion Systems
- RWTH Aachen, Germany

Highlights of the research activity

The advancements in the diesel engines have led to lower emissions and lower fuel consumptions. At the same time, these advancements have resulted in increased complexity of diesel engines. Modern day diesel engine can easily have more than 15 control parameters. Higher number of control parameters have increased the difficulty of diesel engine calibration. Engine calibration is the process of finding the optimal combination of these control parameters in the complete operating range to maximize the efficiency and minimize the emissions. The focus of the PhD has been to develop a methodology for faster and more robust calibration for the latest generation of the diesel engines.
With this aim in mind, an optimizer was developed in the first year of PhD to find the optimial combinations of control parameters in different operating conditions using the diesel engine models and advance optimization algorithms like genetic algorithm. In second year this optimizer was modified to a multi objective optimizer capable of reducing the emissions and fuel consumtion simultaneously.
In the third year the efforts were focused towards integrating optimized calibration for different engine operating conditions into smooth calibration maps. These smooth calibrations maps are finally stored into engine control unit. The engine calibration maps need to be sufficiently smooth so as to avoid problems during transient phase of the engine operation. Using an automated methodology large number of calibration maps were generated and some of these maps were selected if they satisfied the smoothness and the performance crieteria. In the figure, performance of some of these selected calibrations have been shown as an example.
The methodology developed has the capability of reducing the time and effort required for calibrating a modern day diesel engine by more than a factor of half. At the same time, the tool can provide better and more robust calibration maps in comparison with the traditional calibration techniques.

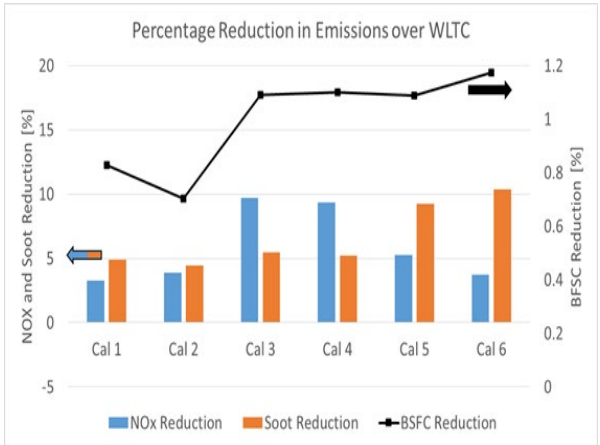


Fig 1. Simulated percentage reduction in emissions over WLTC using some calibration maps generated by the tool.

First name: Azharuddin **LAST NAME**: AZHARUDDIN

Topic: Application of chemical looping CO_2/H_2O dissociation for syngas production for power and fuel production plants-feasibility and technological assessment

Course year: 3rd **Tutor(s)**: Prof. M Santarelli, Prof. J. Llorca (UPC)

Academic context

[1] Azharuddin Farooqui, Archishman Bose, Domenico Ferrero, Jordi Llorca, Massimo Santarelli, Techno-economic and exergetic assessment of an oxy-fuel power plant fueled by syngas produced by chemical looping CO_2 and H_2O dissociation, Journal of CO_2 utilization 27 (2018) 500-517.
[2] Azharuddin Farooqui, AM Pica, P Marocco, D Ferrero, A Lanzini, S Fiorilli, J Llorca, Massimo Santarelli, Assessment of kinetic model for ceria oxidation for chemical-looping CO_2 dissociation, Chemical Engineering Journal (2018) 346, 171–181.
[3] N.P. Siegel, J.E. Miller, I. Ermanoski, R.B. Diver, E.B. Stechel, Factors affecting the efficiency of solar driven metal oxide thermochemical cycles, Ind. Eng. Chem. Res. 52 (2013) 3276–3286.

External collaborations

- Institute of Energy Technologies, Nanoengineering of Materials Applied to Energy (NEMEN) group, Department of Chemical Engineering and Barcelona Research Center in Multiscale Science and Engineering, Universitat Politècnica de Catalunya (UPC), Spain.
- Catalysis group, University of Udine, Italy.
- SPI Group, Department of Chemical Engineering and Chemistry, Technical University of Eindhoven (TU/e), the Netherlands.

Highlights of the research activity

Chemical looping syngas production is a two-step syngas fuel production process that produces CO and H_2. The process is composed of two redox reactions with metal oxide looping between the steps. The metal oxide during reduction loses oxygen and become lower valence metal oxide by creating vacancies in the lattice at higher temperature and during oxidation step the reactant gas CO_2 and or H_2O reacts with the reduced metal oxide forming CO and or H_2. After a detailed analysis of the metal oxide investigated in the literature, Ceria has been selected for the application. The present work focuses on both solar chemical looping (CL) syngas production based on the splitting of CO_2 and H_2O. For the solar-driven cycle, a kinetic moving bed reactor model in the commercial software ASPEN Plus was developed using kinetics available in the literature, for both reduction and oxidation. Results, including sensitivity studies, were performed, with good agreement to literature data. Thereafter, a CL unit integrated combined cycle power generation layout was developed, to be retrofitted to a 100 MW Oxyfuel NGCC with CCS (SCLP-OXYCC). A maximum power output of 12.9 MW at a solar to electricity efficiency of 25.4% was obtained while working with CO_2 recycling. This would reduce the efficiency penalty suffered by NGCC with CCS from 11.3 to 6 percentage points. Nevertheless, the reduction reactor would be needed to operate at 1600°C and 10^{-7} bar vacuum pressure to obtain the maximum output, which would limit the applicability of the cycle to only a few hours during the day without storage integration.

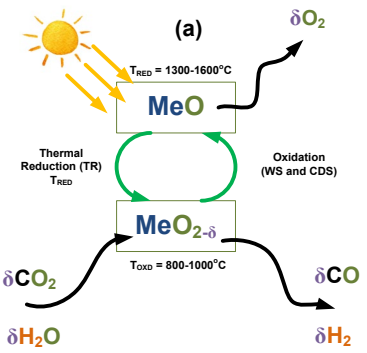


Fig 1. Schematic concept description of solar two-step thermochemical redox cycle

First name: Verena Marie **LAST NAME**: BARTHELMES

Topic: Impact of Occupant Behaviour (OB) on building energy use and thermal comfort: From stochastic modelling and occupant profiling to interdisciplinary user engagement

Course year: 3rd year **Tutor(s)**: Prof. S.P. Corgnati, Dr. Y. Heo, Dr. R.K. Andersen

Academic context

[1] Yan, D. and Hong, T. (2018). IEA-EBC Annex 66 - Definition and Simulation of Occupant Behavior in Buildings: Final Report. Available online: https://annex66.org
[2] Heckerman, D., Geiger, D., and Chickering, D. (1995). Learning Bayesian networks: The combination of knowledge and statistical data. *Machine Learning* 20, pp. 197-243.
[3] Wilke, U., Haldi, F., Scartezzini, J.L., and Robinson, D. (2013). A Bottom-up Stochastic Model to Predict Building Occupants' Time-Dependent Activities. *Building and Environment* 60, pp. 254–64.

External collaborations

- University of Cambridge, Cambridge, UK
- Technical University of Denmark, Copenhagen, DK
- Lawrence Berkeley National Laboratory, Berkeley, USA

Highlights of the research activity

The overall goal of this doctoral research is to (i) understand, analyse and numerically model the behaviour of occupants and its influence on building energy use and comfort conditions, and to (ii) deploy energy engagement strategies for raising awareness among users. The aim is to address some research gaps and shortcomings in the current research body, which have stirred the focus of this dissertation, such as:

(i) Lack of understanding to which extent OB can impact building energy use and thermal comfort in high performing buildings;
(ii) Gap between real and predicted building energy use due to an oversimplification (e.g. fixed schedules) of the human factor in simulation programs;
(iii) Absence of qualitative data and individual characteristics and preferences of building occupants in existing models;
(iv) Lack of reliable and affordable ways to collect large-scale occupant behaviour data;
(v) Lack of innovative solutions for motivating and assessing behavioural change towards energy efficiency goals.

In this context, the final methodological framework of this dissertation is aimed at contributing to new knowledge in occupant behavioural research through the development and implementation of methods for the following five lines of research:

(i) **Impact estimation of OB** lifestyles on building energy use and thermal comfort in low energy buildings, also in relation to (i) high/low performing building features and (ii) building automation;
(ii) Exploration of the Bayesian Network framework for developing advanced stochastic **OB models** (e.g. window control behaviour) towards bridging the gap between real and predicted energy consumptions;
(iii) Investigation and introduction of qualitative data and **individual traits of OB** characteristics (e.g. thermal comfort attitudes) of the occupants in these models through tailored OB surveys;
(iv) Profiling **OB on a large scale** (daily activities and occupancy) using national Time Use Survey data that allows for providing valuable input for building simulation programs;
(v) Development and evaluation of **OB energy engagement** campaigns (e.g. Horizon 2020-Mobistyle) in different sectors (residential, offices, hotel, and university) aimed at raising the energy awareness of the occupants in a long-term perspective in order to hit energy efficiency targets and optimize comfort/health conditions at the same time.

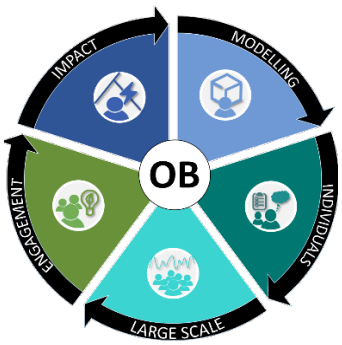


Fig 1. Overall methodological framework of the Ph.D. thesis.

First name: Andrea **LAST NAME**: BERSANO

Topic: Innovative heat removal and transport systems for advanced nuclear reactors

Course year: 2nd **Tutor(s)**: Prof. M. De Salve, Dr. C. Bertani

Academic context

[1] A. Bersano, N. Falcone, C. Bertani, M. De Salve, B. Panella, Conceptual design of a bayonet tube steam generator with heat transfer enhancement using a helical coiled downcomer, Progress in Nuclear Energy, 108, pp. 243-252, 2018
[2] M. Caramello, M. Gregorini, C. Bertani, M. De Salve, A. Alemberti, B. Panella, Thermal hydraulic analysis of a passively controlled DHR system, Progress in Nuclear Energy, 99, pp. 127-139, 2017
[3] C. Bertani, N. Falcone, A. Bersano, M. Caramello, T. Matsushita, M. De Salve, B. Panella, Verification of RELAP5-3D code in natural circulation loop as function of the initial water inventory, Journal of Physics: Conference Series, 923, 2017

External collaborations

- ENEA
- SIET

Highlights of the research activity

During this year of PhD activity it has been continued the study of innovative heat removal and transport systems for advanced nuclear reactors, in particular passive systems operating in natural circulation, both with new experimental campaigns and numerical simulations. Using the facility PROPHET built at the Energy Department of Politecnico di Torino, two experimental campaigns have been carried out, the first one to enlarge the available experimental data set and the second one to test the system at a higher power level with some modification to the facility. The experimental transients have been simulated with the thermal-hydraulic code RELAP5-3D to evaluate possible limitations in the code, in particular related to the presence of non-condensable gases and the stagnant pools of liquid. A possible way to improve the performance of bayonet tube heat exchangers has been proposed and its feasibility has been evaluated performing numerical simulations, showing a significant heat transfer enhancement.

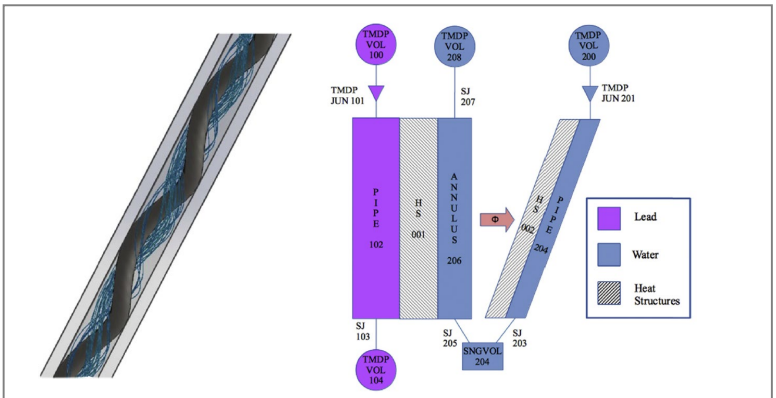


Fig 1. Improvement of bayonet tube heat exchanger with a helical coiled downcomer and RELAP5-3D nodalization

In the framework of the OECD/NEA/CSNI activities, in cooperation with several international organizations, it has been started the production of a state of the art report on thermal-hydraulic passive systems design and safety assessment. In the activity, an open international benchmark hosted by ENEA has been started on PERSEO facility available at SIET laboratory in Piacenza (Italy). PERSEO was designed to study the possibility to move the system activation valve from the high pressure primary side to the low pressure pool side.
In this year of PhD I have supported ENEA Bologna for the preparation of the technical documents for the benchmark and performed the numerical simulation as one of the benchmark participants. In addition, an external research activity has been conducted at ENEA Bologna for a training on TRACE thermal-hydraulic code and for the application of uncertainty methodologies to thermal-hydraulic transients.

First name: Andrea **LAST NAME**: BERTINETTI

Topic: Multi-physics modeling and design of the resonance cavity for gyrotrons for fusion applications

Course year: 3rd **Tutor(s)**: Prof. L. Savoldi

Academic context

[1] Bertinetti, A., Albajar, F., Cau, F., Leggieri, A., Legrand, F., Perial, E., Ritz, G., Savoldi, L., Zanino, R., and Zappatore, A. (2018). Design, Test and Analysis of a Gyrotron Cavity Mock-Up Cooled Using Mini Channels. IEEE Transactions on Plasma Science 46, 2207–2215.
[2] Bertinetti, A., Froio, A., Ghidersa, B.E., Hernández González, F.A., Savoldi, L., and Zanino, R. (2018). Hydraulic modeling of a segment of the EU DEMO HCPB breeding blanket back supporting structure. Fusion Engineering and Design.
[3] Avramidis, K.A., Bertinetti, A., Albajar, F., Cau, F., Cismondi, F., Gantenbein, G., Illy, S., Ioannidis, Z.C., Jelonnek, J., Legrand, F., et al. (2018). Numerical Studies on the Influence of Cavity Thermal Expansion on the Performance of a High-Power Gyrotron. IEEE Transactions on Electron Devices 65, 2308–2315.

External collaborations

- Fusion for Energy – Barcelona (Spain)
- EUROfusion – Garching (Germany)
- Karlsruhe Institute of Technology – Karlsruhe (Germany)

Highlights of the research activity

During the third year of PhD, the MUlti-physiCs tool for the integrated simulation of the CAvity (MUCCA) of the 1 MW and 2 MW gyrotrons was further developed. The MUCCA tool was applied on two layouts of the gyrotron cavity, and namely that involving the use of the Raschig Rings (RRs) as cooling promoter in the 1 MW gyrotron designed for ITER, as well as that with the annular cooling circuit configuration in the 2 MW gyrotron with coaxial insert under development for DEMO.
The simulations of the cavity of the 1 MW gyrotron were performed to obtain a finer calibration of the thermal conductivity of the RRs, starting from the successful result of the validation process carried out in the second year of the PhD (see Figure 1a), based on the results of the test campaign performed at Karlsruhe Institute of Technology (KIT) in 2015. The participation to the test of the gyrotron subject to long pulses at the EPFL premises in 2018 was of help to get experimental data that are currently under investigation, as they constitute an independent set of data for the further validation of MUCCA.
The simulations of the 2 MW cavity were performed to determine the evolution of the working condition of the system (see Figure 1b), made by the resonator and the coaxial insert (not shown) in order to highlight the criticality of that cooling configuration.
The works on the RRs and on the annular cooling strategy of the cavity were performed in collaboration with KIT and Fusion for Energy.

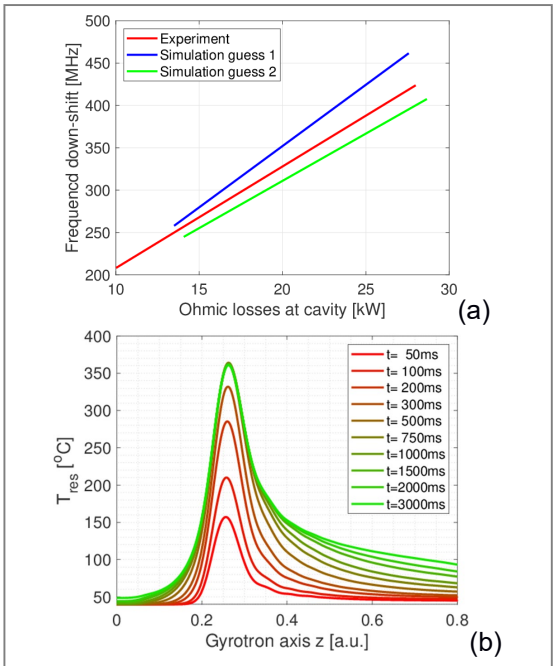


Fig 1. (a) calibration of the simulation for the cavity with RRs, and (b) evolution of the temperature profile on the heated surface of the resonator for the prototype of the gyrotron with annular cooling.

First name: Andrea **LAST NAME**: BOTTEGA

Topic: Mechanical and Optical Analysis of Sprays for Low and Medium Speed Marine Engine's Injectors

Course year: 3rd **Tutor(s)**: Prof. C. Dongiovanni

Academic context

[1] C. Dongiovanni, C. Negri, Sulla misura della forza di impatto, Atti della Giornata Nazionale di Studio – MIS-MAC IX – Metodi di Sperimentazione nelle Turbomacchine SGEditoriali MIS-MAC IX, Trieste, ISBN: 9788889884027, 2006, pp. 232–242.
[2] Postrioti, L., Battistoni, M., Ungaro, C., & Mariani, A. (2011). Analysis of diesel spray momentum flux spatial distribution. SAE International Journal of Engines, 4(1), 720-736.
[3] C. Dongiovanni, C. Negri, D. Pisoni, Macroscopic spray parameters inautomotive diesel injector nozzles with different hole shape, ASME. InternalCombustion Engine Division Spring Technical Conference

External collaborations

- OMT - Officine Meccaniche Torino S.p.a.

Highlights of the research activity

After the assessment and validation of the SMSA sensor proposed during the first two years (Bottega, A., & Dongiovanni, C. (2018). A new sensor for the analysis of jet momentum spatial distribution. Sensors and Actuators A: Physical, 269, 283-293.) an experimental facility for the optical analysis of diesel sprays has been designed and realized.
The test rig chamber has a diameter (500 mm) comparable with the bore of the actual cylinder engine that mount the investigated injector. This chamber can be pressurized up to 1,5 MPa by using Sulphur Hexafluoride that shows a density of about 5 times the air one.In this way, the actual in cylinder density condition can be reproduced. SF6 is an inert gas in order to avoid combustion; temperature is kept at room condition avoiding evaporation of the oil. A recirculating system provide the cleanness of the test volume separating the injected oil from the gas and the SF6 recovery that is a greenhouse gas. Ad hoc illuminating system has been designed. The system consist of 8 High Power LEDs placed inside the test chamber. The light intensity emitted from each led can be independently controlled via a tailor-made micro-controller electronic system. In this way, it is possible to create different light patterns in the injection chamber in order to test different strategies for spray analysis algorithms. An air-driven booster pressurizes the rail injector up to 220 MPa and an open ECU manage the injection timing and opening. The High-Speed camera is able to acquire images up to 70kFPS with a resolution of 256x256 pixels allowing the study of small pilot injection (showing a duration of 500 micros) with sufficient spatial and temporal resolution. Finally, a method for spray images macroscopic parameter estimation has been proposed. This alghoritm is based on the Karunen-Lòeve decomposition. A tailored beta version of the analysis software has finally been complied. This software is MATLAB based and allows a fully automatic analysis of the acquired image set. It starts locating the centre of the injector, than performs a correction of the background illumination, count the spray plumes and their mean direction of evolution, and finally evaluate by using the said algorithm the penetration and diffusion angle of each plumes, giving the temporal evolution of the spray formation.

Fig 1. Optical Test Rig

First name: Alberto **LAST NAME**: BRIGHENTI

Topic: Validation and improvements of the thermal-hydraulic modeling of superconducting magnets for fusion applications

Course year: 3rd **Tutor(s)**: Prof. L. Savoldi

Academic context

[1] L. Savoldi Richard, F. Casella, B. Fiori, R. Zanino, "The 4C Code for the Cryogenic Circuit Conductor and Coil modeling in ITER," *Cryogenics*, vol. 50, pp. 167-176, 2010.
[2] L. Savoldi Richard, R. Bonifetto, S. Carli, F. Froio, A. Foussat, R. Zanino, "Artificial Neural Network (ANN) modeling of the pulsed heat load during ITER CS magnet operation," *Cryogenics*, vol. 63, pp. 231-240, Sep.-Oct. 2014.
[3] L. Savoldi Richard, R. Bonifetto, U. Bottero, A. Foussat, N. Mitchell, K. Seo, R. Zanino, "Analysis of the Effects of the Nuclear Heat Load on the ITER TF Magnets Temperature Margin," *IEEE Trans. Appl. Supercond.*, vol. 24, n. 3, Jun 2014.

External collaborations

- Università di Bologna (UniBo), Bologna, Italy

Highlights of the research activity

During the third year of the PhD course, the tool has been used to perform predictive simulations of the expected normal and off-normal operation of the ITER CS and TF coils. From the analysis of experimental data collected during the ITER inserts campaigns of the last three years, i.e. the CSI (2015) and the TFI (2017), it has been possible to obtain the operating parameter (e.g. friction factor, strain, …) of the full size magnets.

Concerning the ITER CS simulations, results showed better performances with respect to previous expectations [2], mainly for the updated estimation of the strain, which turned out to be smaller than expected. As outcome of the assessment of AC losses coupling time constant for virgin and cycled conductor and the simulation of the standard plasma pulse, the minimum temperature margin (ΔT_{marg}^{min}) requirement of 0.7 K is satisfied in both cases, see Figure 1a, even if the uncertainties on the coupling time constant are accounted for. In case of an off-normal mass flow rate, reduced by 25 % in the most critical pancake, in the worst case (virgin conductors) the ΔT_{marg}^{min} is additionally eroded of ~0.15 K, while other conductors are unaffected.

Concerning the ITER TF simulations, results showed that all the pancakes satisfy the ΔT_{marg}^{min} requirement during the normal operation, see Figure 1b, but also if the most critical pancake faces a 25% reduction of the mass flow rate (for any reason), showing only an additional ΔT_{marg}^{min} erosion of <0.1 K. Coming to the off-normal operation, during the quench propagation and the fast discharge, the coil satisfies the ITER design criteria on the hot-spot temperature and the maximum pressure in the coil.

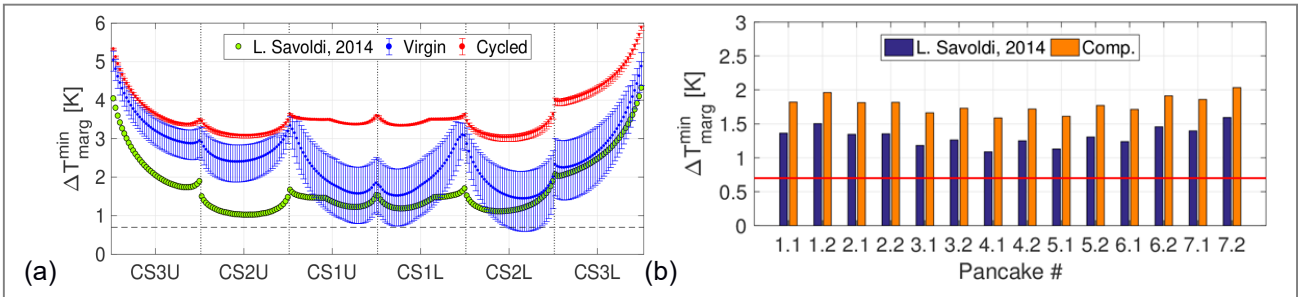


Fig 1. (a) ΔT_{marg}^{min} in all conductors of the CS coil from [2] (green circles) and from present simulations considering the coupling time constant for virgin (blue dots) and cycled (red dots) conductors. (b). ΔT_{marg}^{min} in all pancakes during the periodic pulse comparing present results (orange bar) with those in [3] (blue bars).

First name: Mattia **LAST NAME**: CAGNOLI

Topic: Analysis of thermal losses for CSP applications

Course year: 3rd **Tutor(s)**: Prof. R. Zanino, Prof. L. Savoldi

Academic context

[1] J. Coventry, C. Andrak, J. Pye, M. Blanco and J. Fisher. "A review of sodium receiver technologies for central receiver solar power plants" Solar Energy 122 (2015) 749–762
[2] N. Boerema, G. Morrison, R. Taylor, G. Rosengarten. "High temperature solar thermal central-receiver billboard design" Solar Energy 97 (2013) 356–368
[3] D.L. Siebers and J.S. Kraabel. "Estimating convective energy losses from solar central receivers" SANDIA report SAND84-8717 (1984)

External collaborations

- Australian National University (ANU), Canberra, Australia
- Centro National de Energias Renovables (CENER), Sarriguren, Spain
- IK4-TEKNIKER Research Alliance, Eibar, Spain

Highlights of the research activity

Numerical analysis of a sodium cooled central receiver: this work deals with the numerical modeling of a pilot solar tower power plant located in Australia. Particularly, the analysis focused on the thermal-hydraulic modeling of the sodium cooled billboard receiver, which consists of a bundle of parallel straight tubes surrounded by an external structure of complex shape (see Figure 1). This receiver has been studied both at the component and system level. At the component level, a 3D CFD model has been developed considering only the external flow to predict accurately the convective heat losses at different wind speeds and directions. The results from this part of the study indicate that the external structure of the receiver plays a key role in reducing the convective heat losses because of the protection offered against the wind. The system level analysis has been conducted by means of a dynamic lumped parameter model of the receiver developed in the Modelica language, which simulates the internal flow of sodium, while uses correlation to estimate the convective losses. The system model can be included in a whole plant Modelica model, including the solar field, the storage units, the control system and the power block, to simulate the overall performance. A preliminary validation of the system level model was carried out against available experimental data, which shows a good agreement. The first application of the model is the study of a fast transient consisting in a passing cloud. Combining the CFD and the Modelica model, an accurate description of both the external and internal flow has been obtained for a test case.

Fig 1. Billboard receiver at the JSS pilot plant [Coventry et al. Solar Energy 122 (2015) 749-762]

Performance prediction of the innovative MOSAIC receiver: The MOSAIC project is part of the H2020 initiative and it aims developing an innovative solar power system based on the solar bowl concept, which should be able to reduce the LCOE cost with respect to the others available solar technologies. This system consists of a fixed spherical mirror, while the receiver, consisting of a bundle of parallel helical pipes, moves tracking the sun. The optimization of the receiver design in order to reach satisfactory thermal performance is one of the main goals to be reached; at this purpose, a 1D finite volumes model has been developed in the Modelica language in order to simulate the receiver thermal performance in steady state and transient operations. A first parametric study was performed on the receiver proposed for the prototype stage, in order to assess the effect on the thermal performance of the main design parameters, which helped in selecting the prototype configuration that maximize the thermal efficiency and pointed out the main criticalities of the proposed design.

First name: Sabino **LAST NAME**: CAPUTO

Topic: Development and analysis of a low heat rejection diesel engine

Course year: 3rd **Tutor(s)**: Prof. F. MILLO

Academic context

[1] Caputo, S., Millo, F., Cifali, G., and Pesce, F., "Numerical Investigation on the Effects of Different Thermal Insulation Strategies for a Passenger Car Diesel Engine," SAE Int. J. Engines 10(4):2154-2165, 2017.
[2] Kogo, T., Hamamura, Y., Nakatani, K., Toda, T. et al., "High Efficiency Diesel Engine with Low Heat Loss Combustion Concept - Toyota's Inline 4-Cylinder 2.8-Liter ESTEC 1GD-FTV Engine -," SAE Technical Paper 2016-01-0658, 2016.
[3] Uchida, N. and Osada, H., "A New Piston Insulation Concept for Heavy-Duty Diesel Engines to Reduce Heat Loss from the Wall," SAE Int. J. Engines 10(5):2565-2574, 2017.

External collaborations

- General Motors Global Propulsion Systems
- AVL Italia S.r.l.

Highlights of the research activity

During the third year of PhD, we conducted a wide campaign of experimental tests at dyno-test bench of Politecnico di Torino in order to assess the potential of thermal insulation strategies applied on a 1.6 l, passenger car, turbo-charged, diesel engine, provided by General Motors Global Propulsion System.
The engine test bench was equipped with the following devices: fuel mass flow meter, smokemeter to estimate the Particulate Matter concentration, gas analyzers to measure CO_2, CO, NOx, HC and O_2 concentrations at engine out and intake manifold. Furthermore, we used thermocouples and pressure sensors in several points of the engine like intake system, exhaust manifold, EGR line, coolant and oil circuits in order to monitor the engine performance; and piezoelectric transducers for acquiring the in-cylinder pressures.
The tested engine configurations were:
- baseline: it was the standard engine configuration taken as a reference (with aluminum pistons).
- Piston Full Coated (PFC): it was the insulated piston configuration in which the entire piston surfaces were covered with 90 µm of anodized aluminum.
For each engine configuration we performed the following tests: injection sweeps, EGR sweeps, automatic DoEs (each DoE realizes 71 engine calibrations with different boost pressure level, EGR quantity, rail pressure, injection pattern and swirl).
Each test was repeated for different engine operating points (1500x5, 2000x8, 2000x16, 2750x12) both in warm and cold conditions.
The results of injection and EGR sweeps (with a single injection event) have shown a reduction of the engine efficiency passing from the standard pistons to the PFC especially at lower loads and speeds (about 2% in ISFC increments at 1500x5); while, at higher load (2000x16) the gap is reduced (below 1%).

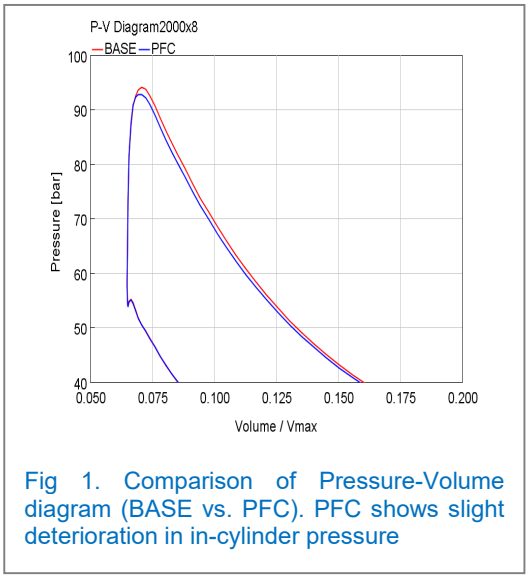


Fig 1. Comparison of Pressure-Volume diagram (BASE vs. PFC). PFC shows slight deterioration in in-cylinder pressure

Moreover, the analysis of the in-cylinder pressure signals has shown a slowdown of the diffusion phase of the combustion passing from baseline to PFC (Fig.1) probably due to: 1. the delay of the peak of piston wall temperature when combustion is already finished, and 2. the porosity and surface roughness of the coating (Ra 8 µm of PFC vs Ra 3.2 µm of baseline). These results are in contradiction respect to those obtained with the 1D simulations. The differences between the numerical predictions and the experimental results may be due to the three dimensional effects inside the combustion chamber (as coating roughness and porosity) which cannot be captured with a 1D engine model.

First name: Angela **LAST NAME**: CARBONI

Topic: Rail-road combined transport: Integrated Smart Sensing (ISS) to support intermodal terminals, throughput and logistics energy efficiency (within the project Cluster ITS Italy 2020)

Course year: 3rd **Tutor(s)**: Prof. B. della Chiara

Academic context

[1] Carboni A., Deflorio F. (2018) *Performance indicators and automatic identification systems in inland freight terminals for intermodal transport*, in IET Intelligent Transport Systems, Volume 12, Issue 4, May 2018, p. 309–318, doi 10.1049/iet-ts.2017.0349.
[2] Carboni A., Dalla Chiara B. (2018), *Range of technical-economic competitiveness of the rail-road combined transport,* in European Transport Research Review, Volume 10, Issue 2, September 2018, doi: 10.1186/s12544-018-0319-3.
[3] Carboni A., Deflorio F. (2017), *Quality and energy evaluation of rail-road terminals by microsimulation*, Transport Infrastructure and Systems: Proceedings of the AIIT International Congress on Transport Infrastructure and Systems (Rome, Italy, 10-12 April 2017), Editors G. Dell'Acqua and F. Wegman, CRC Press, ISBN 9781138030091

External collaborations

- Hupac s.p.a. di Busto Arsizio-Gallarate (project *Cluster ITS Italy 2020)*

Highlights of the research activity

The research covered two main aspects: *rail-road combined transport chain* and *rail-road terminal*. Nodes and chain are strictly correlated due to the important role of the intermodal terminal in the competitiveness of rail-road combined transport. On the other hand, the study of the entire transport process is fundamental to define the terminal requirements and performance. Having analyzed the process and the actors involved, the range of technical-economic competitiveness of combined transport in terms of covered distance through total costs and energy analysis has been examined. Rail-road transport may be competitive if the external costs are internalized and if the total distances are sufficient to exploit the advantages of rail transport. These considerations may not be suitable in some cases, such as shuttle train service.

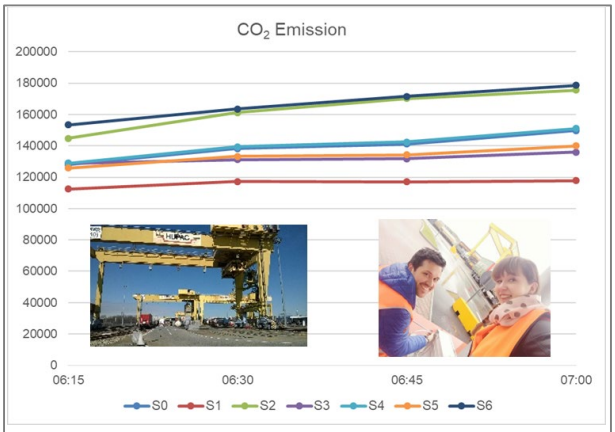


Fig 1. Total CO_2 emission in different scenarios

About rail-road terminal the focus is on the influence of *automatic identification sensors* on *terminal process* which can be measured through selected *performance indicators*. These impacts were addressed in different ways:

- *System architecture using a standard language* allows a clear explanation with stakeholders on the role of technologies within business process. Both the relation between indicators and technologies, as well as the comparison of different sensors solution are modelled.
- *Terminal simulation*, the method evaluates the quality and energy performance of inland freight terminals, using a quantitative approach based on traffic microsimulation models. The model allows a comparison of chosen performance indicators in several scenarios using realistic data. Seven scenarios are modelled to consider the implementation of technologies during check-in and out operations, also by varying the input flow. The use of technologies during gate operations (in and out) could improve the performance (turnaround time and fuel consumption) of intermodal terminal also in the case of worst scenario (Figure 1).
- *On-field application*, some technological solutions (Bluetooth and Wi-Fi sensors) are tested in the field to monitor the inland terminal and evaluate the scenarios.

First name: Marco **LAST NAME**: CAVANA

Topic: Integrated energy networks

Course year: 2nd **Tutor(s)**: Prof. P. Leone

Academic context

[1] Sust.Gas Institute, “A Greener Gas Grid: What are the Options?”, white paper, July 2017;
[2] K. A. Pambur et al. , “An integrated transient model for simulating the operation of natural gas transport systems”. In: Journal of Natural Gas Science and Engineering, vol. 28 (2016), pp.672-690;
[3] Pellegrino S., Lanzini A., Leone P. , ”Greening the gas network - The need for modelling the distributed injection of alternative fuels”. In: Ren. & Sust. En. Rev, vol. 70 (2017), pp. 266-286.

External collaborations

- Anigas
- Snam
- TU-Delft – Green Village

Highlights of the research activity

The feasibility and affordability of an increasing electrification of the energy uses is becoming a trend lately, with several studies stating that the energy transition costs may be limited if renewable gases (such as bio-methane and hydrogen) would be included in the energy mix. To similar findings, our research group came this year: with Chiara Delmastro, [PhD Thesis: Advanced Urban Energy Planning: an interdisciplinary approach to improve heat decarbonization assessments, 2018] we experimented a new modeling methodology willing to couple energy scenario analysis with technical modelling of energy networks infrastructures (electricity and gas networks) to simulate and test pathways towards decarbonization. A case study on a sample urban context was used. From the scenario analysis, two different options to reach 80% decarbonization has been considered: excluding or including renewable-gases. When excluding renewable gases, reaching the targets requires the carbon emission factor for the imported electricity to be 64% less than the 2015 value. In the second case, it has to be just 36% less, thus relaxing the investments on the whole electrical sector and promoting the diversification of energy vectors.

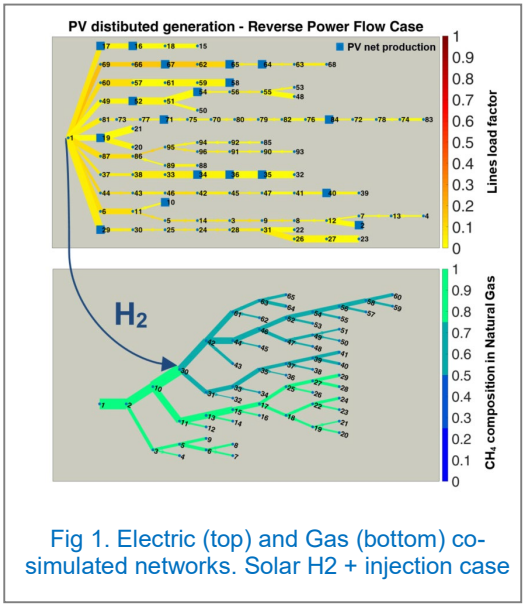


Fig 1. Electric (top) and Gas (bottom) co-simulated networks. Solar H2 + injection case

These results justify the need of an integrated modeling of energy infrastructures to test their suitability with respect to the expected pathways coming from the scenario analysis and/or to highlight criticalities that need to be addressed. In this sense, a few “stress tests” have been carried on the electricity and gas networks of the sample urban area.

1) Electrification of the heating sector: the progressive substitution of gas fired boiler for residential and office users was modeled, with a random spatial scattering of the substitution. The results showed that the current medium voltage (MV) electricity grid is able to stand the electrification of up around 38% of users – 42% of thermal needs. Passing this threshold, the contingencies (line overloading hours) happening throughout the electrical system increase very rapidly.

2) Renewable gas injection into the gas distribution system: a case study based on modeling “solar hydrogen” production and local injection was investigated. A progressive penetration of PV distributed generation was considered and its consequences on the electrical power flow in the MV network simulated. Assuming to avoid reverse power flow towards the higher voltage network thus using the solar overproduction for producing H_2 and injecting it into the medium pressure (MP) gas distribution network. The results highlight a negative superposition between solar overproduction and low rate of utilization of natural gas in the distribution grid leading to a higher impact of H_2 injection on the gas distribution system in terms of higher variability of natural gas quality.

First name: Andrea **LAST NAME**: COSTANTINO

Topic: Towards a smart farm: energy efficiency and climate control in livestock houses and greenhouses

Course year: 1st **Tutor(s)**: Prof. E. Fabrizio, Prof. S. Calvet Sanz (UPV)

Academic context

[1] FAO, Energy-Smart Food at FAO: an Overview, FAO, Rome, Italy, 2012.
[2] M.A. Hellickson, J.N. Walker, Ventilation of Agricultural Structures, ASAE Monograph Number 6, American Society of Agricultural Engineers, St. Joseph, Michigan, 1983.
[3] ASHRAE, Environmental Control for Animals and Plants, in: ASHRAE Handbook-HVAC Applications, SI Edition, Atlanta, Georgia, 2007.

External collaborations

- Department of Agricultural, Forest and Food Sciences, Università degli Studi di Torino, Grugliasco (TO), Italy
- Munters Italy S.p.a., Chiusavecchia d'Imperia (IM), Italy
- School of Agricultural Engineering and Environment, Universitat Politècnica de València (UPV), Valéncia, Spain

Highlights of the research activity

Energy consumption in agricultural sector is expected to increase in the coming future. To feed the entire population and to decrease the level of energy intensity, improvements in the food supply are needed. Aim of this thesis is to develop a new smart-energy farm concept characterized by high productivity and reduced energy consumption due to climate control in greenhouses and livestock houses.
The first year of the PhD was characterized by both numerical and experimental approaches. The numerical approach was focused on the definition of robust and reliable energy simulation models for these building types. In particular, the development and validation of an energy simulation tool for the production of broilers, that was started in the framework of the EPAnHaus project, was concluded. A new energy simulation model for growing-finishing pig houses has been developed in collaboration with animal scientists of the University of Turin. In the same period, the numerical approach concerned also intensive crop production through the development of an energy simulation model for greenhouses. This activity has been carried out in collaboration with Munters Italy S.p.a.

Fig. 1: The mechanically ventilated greenhouse used as second test site.

As for the experimental approach of the first year, monitoring campaigns aimed at acquiring data from two selected test sites were conducted. The first one concerned two pig houses, where a long-term monitoring campaign was completed: both indoor environmental parameters and the total electrical loads were acquired. To obtain the partial electrical loads, a new methodology for loads identification and unbundle was developed. The second test site (Fig. 1) concerns the set-up of a long-term monitoring campaign inside a large greenhouse that is currently ongoing. The monitoring system is acquiring indoor air temperatures and relative humidity values in various spots inside the greenhouse. The sensors placed in the electrical panel are monitoring the energy uses inside the greenhouse and other aspects of operation, such as the window openings and the activation of evaporative cooling. The dataset that were obtained from the two test sites have been used to validate the energy models and to carry out further analysis, such as the trend of various electrical loads as a function of climate parameters or the influence of the indoor climate conditions on animal and crop production.

First name: Alessio **LAST NAME**: DESANDO

Topic: Aircraft engine efficiency improvement through an innovative Active Clearance Control System

Course year: 3rd **Tutor**: Dr. E. Campagnoli

Academic context

[1] Lattime, S. B., Steinetz, B. M., Turbine Engine Clearance Control Systems: Current Practices and Future Directions, NASA Tech. Mem. TM-2002-211794 (2002).
[2] Zuckerman, N., Lior, N., Jet Impingement Heat Transfer: Physics, Correlations, and Numerical Modeling, Advances in Heat Transfer, 39, 565-631 (2006).
[3] Yu, R., Peng, C., Chaoyi, W., Experimental and Numerical Investigations of Impingement Heat Transfer on the Surface with Micro W-shaped Ribs, Int. J. Heat Mass Transfer, 93, 683-694 (2016).

External collaborations

- GE Avio Aero

Highlights of the research activity

An adequate control of the engine clearances, which are the small gaps between rotor blades and their external case, is an important task to be accomplished towards the design of the engines for the next-generation civil aircrafts. The main features of these engines are a very high efficiency and very low fuel consumption and pollutant emissions. In this context, the present research is focused on the Active Clearance Control (ACC) system for Low Pressure Turbines (LPT) in large aircraft engines. The ACC performs its control action by means of the cold air jet impingent, cooling down the LPT case during cruise and consequently reducing the clearances. This way, the energy loss related to hot gases leaking through these gaps can be significantly reduced.
The activities, which have been previously accomplished, aimed to improve the current configuration by utilizing an innovative design approach. The result was a 1D numerical tool that couples the effects on the available air mass flow rate due to the system pressure losses to the pipeline heat pick-up.
The research activity performed during this year was focused on the jet impingement region and it was carried out by using the Computational Fluid Dynamics (CFD) approach. First of all, a numerical model, representative of the ACC impinging jets, has been developed and compared to the literature studies. The interaction between a jet and a cross flow, representing other engine leakages, has been analyzed. Then, the focus was moved on geometrical solutions, where the target surface exhibited roughening elements. The objective was to obtain a heat transfer enhancement by using the interaction between the impinging jet boundary layer and these elements. The obtained effects have been studied also under cross flow conditions and several interesting solutions have been found.
There are two ways to consider the efficiency improvement obtained. First of all, the heat transfer enhancement could be used to reduce the spent cooling air. Secondly, the improved heat transfer also allows to reduce the system response time: the amount of spent air is the same, but the desired clearance value can be reached faster during rapid maneuvers.

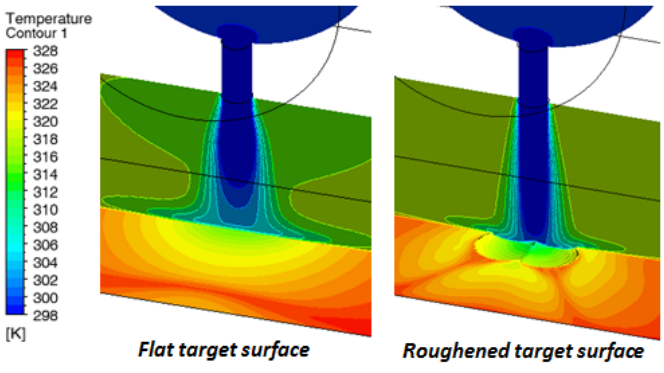


Fig 1. Heat transfer enhancement by target surface roughening.

First name: Giuseppe **LAST NAME**: DI PIERRO

Topic: Analysis, Development and Optimization of Automotive Electric Hybrid Powertrain Systems

Course year: 2nd **Tutor(s):** Prof. F. Millo

Academic context

[1] Cubito, C.; Rolando, L.; Millo, F.; Ciuffo, B.; Serra, S.; Trentadue, G.; Marcos Garcia, O.; Fontaras, G., "Energy Management Analysis under Different Operating Modes for a Euro-6 Plug-in Hybrid Passenger Car," SAE Tech. Pap. 2017.
[2] Millo, F.; Badami, M.; Ferraro, C.V.; Rolando, L., "Different Hybrid Powertrain Solutions for European Diesel passenger cars," SAE Int. J. Engines 2010, 2, 493–504.
[3] F. Millo, L. Rolando, and M. Andreata, "Numerical Simulation for Vehicle Powertrain Development," in Numerical Analysis - Theory and Application, 2011, pp. 519–540.

External collaborations

- FEV Italia s.r.l.
- FEV Europe GmbH
- Joint Research Centre (JRC)

Highlights of the research activity

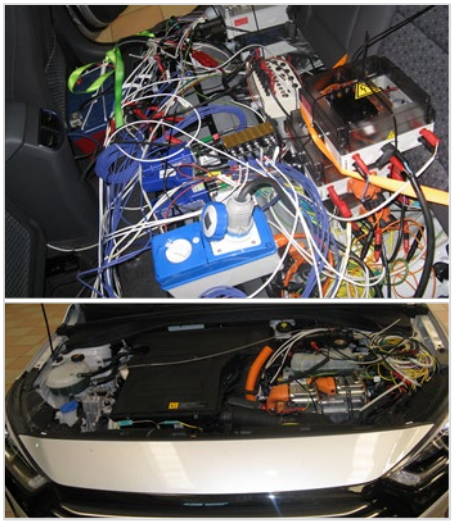


Fig. 1: Powertrain instrumentation and sensors collection

In the decarbonization-of-transport framework, Hybrid Electric Vehicles (HEVs) represent an extremely promising solution for the automotive industry to bridge the gap between the desirable features of electric powertrains, the range capability and the more affordable costs of conventional vehicles. They ensure higher fuel efficiency and lower pollutant emissions due to the flexibility provided by the integration of the ICE with the electric powertrain, while still maintaining comparable range capabilities and costs. Thus, the aim of my research activity is to analyze different solution available on the market and optimize a generic electric hybrid powertrain system, using both experimental and numerical methodologies. During the first two years, I have focused on benchmarking of the most innovative electric hybrid solutions already on the market. This includes literature analysis, selection and procurement of the vehicles; electrical and thermal full instrumentation; testing both on roller-dyno and on track; analysis and post processing of the output data. Thanks to FEV test facilities, I had the opportunity to test different types of vehicle, such as: Renault Scenic Hybrid Assist (Mild HEV – 48V), Toyota Yaris Hybrid (Full HEV), BMW i3, Hyundai Ioniq and Volvo XC11 prototype (Plug-in HEV), VW e-Golf and Renault Zoe (Battery Electric Vehicle). This has given me the chance of building up an internal database for further model-based investigation approach. Moreover, dealing with newly developed alternative vehicle is not very common in the automotive field, thus the entire activity has been useful to implement a comprehensive and integrated methodology to test this type of vehicle with the specific aim of understanding the powertrain control logic and developing it in a virtual environment. In this contest, the aim of my research activity is the analysis, design and optimization of an electric hybrid powertrain system, using both experimental and numerical methodologies. Especially throughout the second year, I have been working on creating a universal hybrid electric vehicle model, in a 0D Matlab/Simulink environment, the purpose of which is to be able to simulate all the types of hybrid vehicles, independently of the architecture implemented. More needs to be done on this side, especially for what complex hybrid layouts are concerned and their energy management strategies. Some new up-to-date vehicles will be tested in the 3rd year in order to gain more expertise and further improve the model.

First name: Nicolò **LAST NAME**: FALCONE

Topic: Power and passive decay heat removal in SMR power plant

Course year: 1st **Tutor(s)**: Dr. C. Bertani, Prof. M. De Salve

Academic context

[1] A. Bersano, N. Falcone, C. Bertani, M. De Salve, B. Panella, Conceptual design of a bayonet tube steam generator with heat transfer enhancement using a helical coiled downcomer, Progress in Nuclear Energy, 108, pp. 243-252, 2018
[2] G. Chiesa, C. Bertani, N. Falcone, A. Bersano, M. De Salve, B. Panella, Horizontal Air-Water Two-Phase Flow Measurement Using an Electrical Impedance Probe and a Venturi Flow Meter, Proceedings of 36th UIT Heat Transfer Conference, June 25-27, 2018, Catania (Italy)
[3] C. Bertani, N. Falcone, A. Bersano, M. Caramello, T. Matsushita, M. De Salve, B. Panella, Verification of RELAP5-3D code in natural circulation loop as function of the initial water inventory, Journal of Physics: Conference Series, 923, 2017

External collaborations

- ENEA
- SIET

Highlights of the research activity

During the first year of PhD, my research activities were related to the analysis of heat removal system for Small Modular Nuclear Reactors (SMR), in particular passive systems operating in natural circulation. The experimental facility PROPHET built in the Energy Department laboratory has been used to study heat removal systems operating in natural circulation. I have design the new bayonet heat exchanger in order to permit the increase of the thermal power that can be provided to the system. A new experimental campaign has been carried out and this new configuration of the PROPHET facility has been simulated with the RELAP5-3D code.

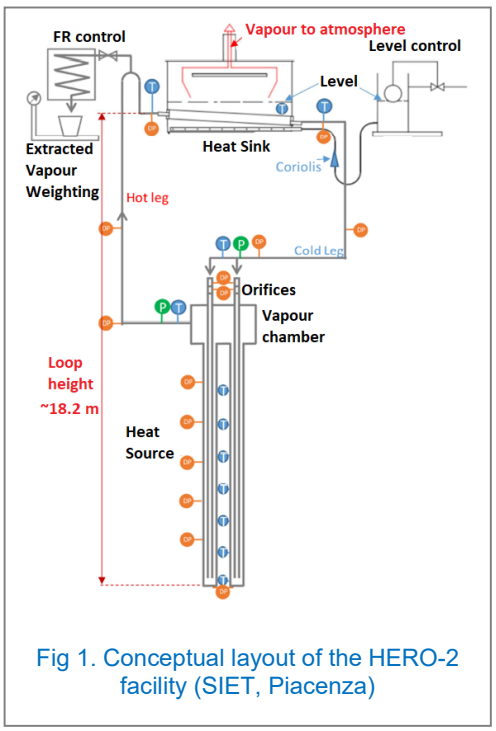


Fig 1. Conceptual layout of the HERO-2 facility (SIET, Piacenza)

The facility HERO-2 installed at SIET laboratory in Piacenza (Italy), representative of a decay heat removal system with bayonet heat exchangers to be used in pressurized water SMRs, has been simulated with the system code RELAP5-3D in order to assess the code capability of simulating natural circulation in presence of parallel pipe instabilities. An analysis of the different scaling techniques applied in the nuclear field has been done and the methodology "Power to Volume" has been applied to the facility HERO-2 in order to analyze the behavior and the performance of a scaled-up system that may operate in an SMR, always with the system code RELAP5-3D.
In the field of the study of two-phase mass flow rate measurement, that is a fundamental aspect in the study of natural circulation heat removal systems, a new experimental campaign has been carried out on the spool piece facility built in the Energy Department laboratory. With respect to the old configuration of the apparatus, I have installed a new capacitance probe together with different home-made electrodes for the measurement of the void fraction inside the test tube. The new results have been compared with the ones obtained with the experimental campaigns carried out in the past. This work was presented by me at the 36th UIT Heat Transfer Conference held in Catania in June.

First name: Vincenzo **LAST NAME**: GENTILE

Topic: Solar atmospheric water generation (SAWG)

Course year: 2nd **Tutor(s)**: Dr. M. Simonetti, Prof. G.V. Fracastoro

Academic context

[1] V. Gentile, M. Simonetti, P. Finocchiaro, G.V. Fracastoro. (2017). *Water production from the atmosphere in arid climates using low grade solar heat. ISES Solar World Congress 2017. doi:10.18086/swc.2017.17.02.*
[2] P.Finocchiaro, M.Beccali, V.Gentile, 2016. *Experimental results on adsorption beds for air dehumidification. International Journal of Refrigeration* 103, 781-789.
[3] M.Simonetti, V.Gentile, G.V.Fracastoro, A.Freni, L.Calabrese, G.Chiesa, 2016. *Experimental testing of the buoyant functioning of a coil with SAPO34 zeolite, designed for solar DEC (Desiccant Evaporative Cooling) systems of building with natural ventilation. Applied Thermal Engineering* 103, 781-789.

External collaborations

- Princeton University, Andliger Center for Energy + Environment (F.Meggers)
- CNR – ICOOM (A. Freni)
- Politecnico di Milano, DIpartimento Energia (M.Motta)

Highlights of the research activity

By 2050, the world population is projected to exceed 9 billion. This significant increase in population will require over 60% improvement in crop yields to feed future generations, and agriculture will consume more than the actual 70% of freshwater available globally. I am investigating new techniques for atmospheric water harvesting using a solar driven adsorption technology to achieve a water autonomy system for civil application and cultivation. A day-night thermodynamic cycle is presented to produce water from air using low regeneration temperature, 50-80 °C, enabling the integration of solar energy. In the laboratory of the Energy Department (DENERG) of Politecnico di Torino a prototype (SAWG version 1) consisting of an adsorption heat exchanger has been assembled. The adsorption system contains about 20,5 kg of silica gel grains with an average diameter of 3 mm. Preliminary results demonstrate that more than 10 liters/day can be produced with air condition similar to that of an arid climate (dry and hot). The average value of the specific heat consumption (kWh lt^{-1}) is under 2 kWh lt^{-1}. This promising number is comparable with performance of other competitor systems, such as desalination technology, which relies on salted water availability, opening a chance for a deeper development of the technology to real application. The first one is the use of SAWG for water production for potable use. The SAWG version 2 is an integrated system with solar thermal collectors and automation components. This prototype version will give the possibility to test the technology in a real environment, upgrading the technology readiness level to 5 and producing water with potable requirements.

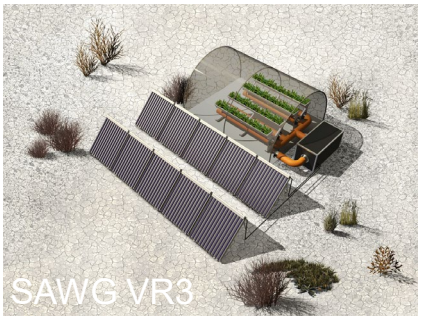
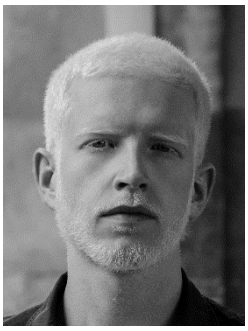


Fig 1. Project of the SAWG system for agriculture applications in arid climates with a controlled environments (greenhouse). This system is supported by Proof Of Concept – Politecnico di Torino

The second application is producing water for agriculture: by coupling SAWG system with a greenhouse is possible either to produce water from air to feed the plant, either to recover all the water transpired trough vegetation for the photosynthesis. The recycle of this water consistently reduces water consumption of the cultivation system, reaching the quasi neutrality in terms of external source of freshwater.



First name: Luigi **LAST NAME**: GIOVANNINI

Topic: Transparent adaptive façades: a novel approach to optimize global energy performance and comfort for the occupants

Course year: 3rd **Tutor(s)**: Prof. V. Serra, Prof. A. Pellegrino, Dr. V. R. M. Lo Verso

Academic context

[1] Favoino F, Fiorito F, Cannavale A, Ranzi G, Overend M. Optimal control and performance of photovoltachromic switchable glazing for building integration in temperate climates. Applied Energy 2016, 178:943-961.
[2] Warwick MEA, Ridley I, Binions R. The Effect of Transition Hysteresis Width in Thermochromic Glazing Systems. Solar Energy Materials and Solar Cells 2015, 140:253-265.
[3] Giovannini L, Goia F, Lo Verso VRM, Serra V. A Comparative Analysis of the Visual Comfort Performance between a PCM Glazing and a Conventional Selective Double Glazed Unit. Sustainability 2018, 10(10):3579.

External collaborations

- University of Cambridge, Cambridge, United Kingdom
- Eckersley O'Callaghan - Engineers, London, United Kingdom
- Norwegian University of Science and Technology, Trondheim, Norway

Highlights of the research activity

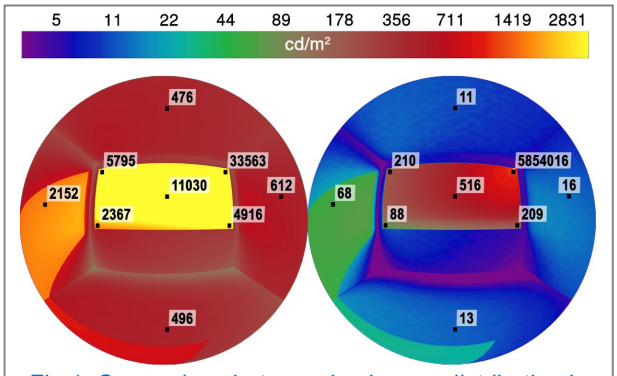


Fig 1. Comparison between luminance distribution in the visual field: a) Specular glazing with T_v=66%; b) Specular glazing with T_v=3%. Jan 24th, h 14:30.

Transparent adaptive façade components are building envelope technologies able to vary their thermo-optical properties according to environmental boundary conditions as well as to users' needs. They are difficult to design and to manage, as their behavior can simultaneously affect different aspects, relative to different physical domains, often interdependent and conflicting with each other. The research activity is aimed at developing a novel methodology to simultaneously evaluate the effects of the behavior of transparent adaptive façade technologies on the different aspects they affect, such as visual comfort for the occupant and overall energy performance of a space. This methodology bridges the existing gap between the component characterization and its application to spaces with occupants. By means of a *step-by-step* simulation strategy, this methodology allows overcoming some of the main limitations related to the use of currently available building simulation tools. In fact, its application allows taking into consideration complex physical phenomena such as i) the influence of the building thermal inertia (influenced in turn by the adaptiveness of these innovative components) on the final energy demand, and ii) the hysteretic behavior of some transparent adaptive façade technologies, such as thermochromic glazing. A new approach to address the annual glare condition across a space was devised. This is based on the estimation of daylight glare comfort classes, that are determined through a proxy based on the eye vertical illuminance. This approach allows significantly reducing the computation time, which is typically high for glare simulations. The methodology presented was tested for both a passive and an active transparent façade technology, namely a thermochromic glazing and an electrochromic glazing, respectively. To feed the numerical model with accurate experimental data both technologies were characterized by means of an integrating sphere at ENEA Casaccia Research Centre. The numerical models were validated against experimental data from an in-the-field campaign carried out by means of the TWINS facility at Politecnico di Torino. Different control strategies for active adaptive components were analyzed in their strengths and drawbacks, and a Rule-Based control strategy for the electrochromic glazing was proposed, aimed at optimizing visual comfort for the user.

First name: Prashant **LAST NAME**: GOEL

Topic: Development of advanced CFD models for diluted CNG combustion simulation in SI engines

Course year: 1st **Tutor(s)**: Prof. M. Baratta, Prof. D. Misul

Academic context

[1] Experimental and Numerical Analysis of Diluted Combustion in a Direct Injection CNG Engine Featuring Post- Euro-VI Fuel Consumption Targets: doi: 10.4271/2018-01-1142
[2] Development of a High Performance Natural Gas Engine with Direct Gas Injection and Variable Valve Actuation: doi: https://doi.org/10.4271/2017-24-0152
[3] Turbulent combustion modelling. doi: https://doi.org/10.1016/S0360-1285(01)00017-X

External collaborations

- Renault Technocenter, France
- IFP Energies nouvelles, France
- Continental Automotive, Germany

Highlights of the research activity

Currently working on a research project funded by European commission, which aimed on the development of a dedicated CNG engine featuring 25% CO2 reduction w.r.t. an equivalent diesel engine with same performance targets. To achieve the goal of technological development in NG engine, Politecnico Di Torino along with Renault and IFPEN, (WP4), are responsible for the study of Charge dilution (Lean burn and EGR limits) and exhaust temperature management. Within this group, Politecnico Di Torino is responsible for the study of EGR limits with the help of numerical modelling in CNG direct injection engine.
This activity has been started with the development of 3D CFD numerical model with homogeneous charge mixture on the commercial CFD code CONVERGE. First activity has been to validate this model with respect to the experimental test (performed by IFPEN) available from the single cylinder research engine. The model has been developed with the introduction of Laminar flame sub-model (LFS) which is helpful in the accurate prediction of flame propagation speed during combustion with less computational cost.
LFS model simulation have been performed with the help of chemical kinetic (GRI Mech 3.0, USC MECH 2 and NUI Galway Mech) and compared with the experimental results available in literature. Based on the comparison and literature studies, GRI Mech 3.0 has been accepted. LFS lookup tables have been built for different compositions of fuel ([i]. 100% Methane, [ii]. 94% Methane, 6% higher hydrocarbons). Effect of different fuel composition has been checked on the laminar flame speeds and found them to be invariable for small %age of higher hydrocarbons present in fuel.

After the validation of homogeneous charge model with experimental tests in terms of In-cylinder pressure, trapped mass and combustion speed, EGR dilution effects have been studied on the validated working points. Numerical model has been used as predictive model and different EGR dilution limits has been simulated. Combustion phasing and IMEP have been used as the defining parameters for the acceptance of EGR dilution. (For more details, Refer [1]). After finishing this activity, the direct injection simulation model has been prepared with the purpose of studying the effect of injection on charge motion and mixture formation inside the combustion chamber using different injection strategies such as early injection (during intake phase) and late injection (during compression phase). This activity is on-going and will conclude within the defined time.

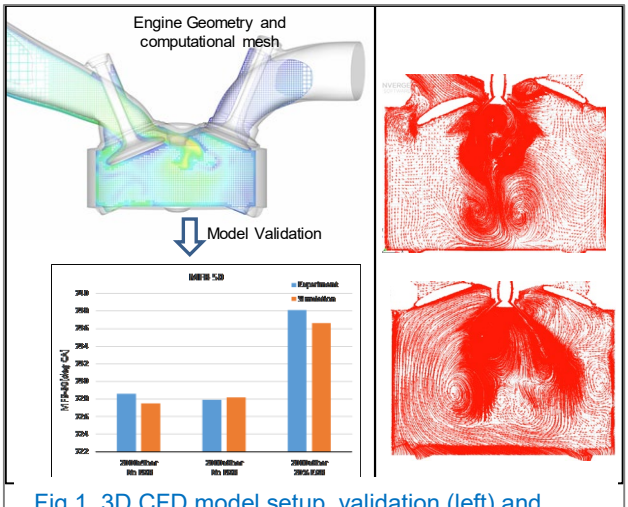


Fig 1. 3D CFD model setup, validation (left) and Results of Injection on charge motion (Right)

First name: Francesco **LAST NAME**: ISAIA

Topic: Exploiting the potential of adaptive building components by means of innovative control strategies

Course year: 2nd **Tutor(s)**: Prof. M. Perino, Prof. V. Serra

Academic context

[1] Aste N., Manfren M., Marenzi G., *Building automation and control systems and performance optimization: a framework for analysis*, Renewable and Sustainable Energy Reviews; Volume 75, 2017, pp.313–330; ISSN 1364-0321; http://dx.doi.org/10.1016/j.rser.2016.10.072
[2] Favoino F., Goia F., Perino M., Serra V., *Experimental analysis of the energy performance of an ACTive, RESponsive and Solar (ACTRESS) façade module*, Solar Energy, Volume 133, 2016, pp.226-248, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2016.03.044
[3] Shaikh P.H., Bin Mohd Nor N., Nallagownden P., Elamvazuthi I., Ibrahim T., *A review on optimized control systems for building energy and comfort management of smart sustainable buildings*, Renewable and Sustainable Energy Reviews; Volume 34; 2014; pp. 409-429; ISSN 1364-0321; DOI: 10.1016/j.rser.2014.03.027

External collaborations

- ENEA Casaccia
- University of Wollongong (UOW), Sidney

Highlights of the research activity

Building façade systems has seen significant improvements over the last years, with the result of enabling modern buildings to adapt and respond to changing boundary conditions, in order to meet the users' comfort needs while reducing the building energy demand; however, advanced control strategies need to be explored with the aim of exploiting adaptive capabilities during building operation. In this context, a thorough research activity was carried out to build a comprehensive picture on the current progress of responsive technologies for building façades and, above all, on control strategies, with a special focus on Model Predictive Control (MPC).

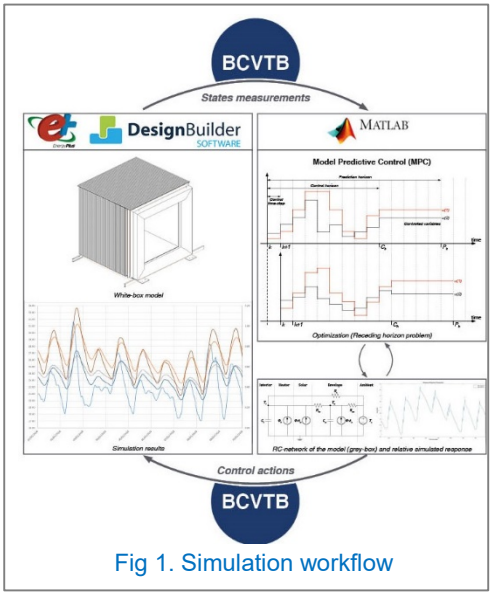


Fig 1. Simulation workflow

A first approach to the study of active façade control has been carried out in the framework of an experimental campaign on a solar air heating façade system, for which the relative calibrated white box model was built in EnergyPlus. The system consists of a double-skin building envelope composed by an opaque internal face and a glazed external face. An axial fan, placed on the inner-top part of the component, forces external air through the component cavity and into the internal environment. External air is thus indirectly heated by the solar radiation. Using the calibrated model, two control modes were implemented: an On/Off control and a PID control. In both cases, the EMS (Energy Management System) of EnergyPlus was used. These activities enabled the development of control strategies to optimise its performance during operation.

An ongoing collaboration with the SBRC (Sustainable Buildings Research Centre) of University of Wollongong aims at exploring the opportunities offered by active façades equipped with an electrochromic glazing, which can be electrically controlled in order to change its light and solar transmission properties.

The joint research with the SBRC consists of two parallel activities: on the one hand, numerical simulations are being set up in order to test and tune different control strategies based on MPC; on the other hand, two outdoor test cells are being designed in order to experimentally test the most promising control strategies and validate the numerical results. Moreover, these two parallel activities will allow the numerical models to be calibrated with monitoring data, enabling further and more tuned tests on different control strategy approaches.

First name: Alessandro **LAST NAME**: MANCARELLA

Topic: PCCI concept and combustion control techniques on a 3.0 l diesel engine.

Course year: 2nd **Tutor(s)**: Prof. S. d'Ambrosio

Academic context

[1] d'Ambrosio S., Iemmolo D., Mancarella A., Vitolo R., "Preliminary optimization of the PCCI combustion mode in a diesel engine through a design of experiments", 71st Conference of the Italian Thermal Machines Engineering Association, ATI2016, 14-16 September 2016, Turin, Italy.
[2] Spessa, E., d'Ambrosio, S., Iemmolo, D., Mancarella, A. et al., "Steady-State and Transient Operations of a Euro VI 3.0L HD Diesel Engine with Innovative Model-Based and Pressure-Based Combustion Control Techniques," SAE Int. J. Engines 10(3):1080-1092, 2017, doi:10.4271/2017-01-0695.
[3] d'Ambrosio, S., Gaia, F., Iemmolo, D., Mancarella, A. et al., "Performance and Emission Comparison between a Conventional Euro VI Diesel Engine and an Optimized PCCI Version and Effect of EGR Cooler Fouling on PCCI Combustion," SAE Technical Paper 2018-01-0221, 2018, doi:10.4271/2018-01-0221.

External collaborations

- FPT Motorenforschung AG, Arbon (SWI)

Highlights of the research activity

Premixed charge compression ignition (PCCI) is a non-conventional combustion concept able to reduce simultaneously both nitrogen oxides (NO_x) and particulate matter (PM) emissions. This is achieved by advancing the fuel injection timings (thus speaking about "early" PCCI concept) and applying high EGR rates. The former feature tends to realize a more homogeneous air-fuel mixture than in conventional diesel combustion, giving more time to the injected fuel to properly mix with the available oxygen, thus reducing soot formation, while the latter, adding inert chemical species to the inducted charge, is able to decrease in-cylinder flame temperatures, strongly related to NO_x formation. Several drawbacks related to PCCI concept are generally found, including higher unburned hydrocarbons (HC) and CO emissions, as well as increased combustion noise (CN), fuel consumption and combustion instability.

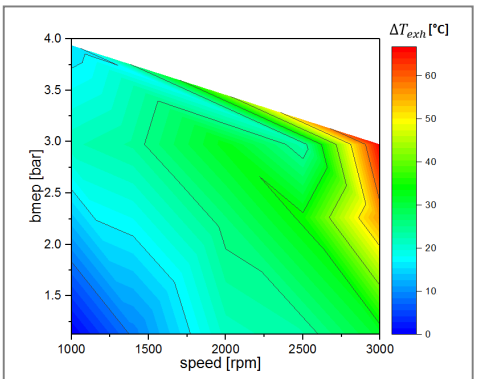


Fig 1. Exhaust gas temperature increase before DOC with uncooled EGR strategy and PCCI operation.

To highlight PCCI potentialities, proper designed hardware modifications have been implemented on the production version of a 3.0 l diesel engine. This includes reduced compression ratio, modified piston bowls, different fuel injectors (with reduced cone angles) and higher volume EGR cooler. Compared to its standard version, the prototype engine allowed a suitable calibration in PCCI mode on a relatively wide area of the engine map. Several solutions have been tested to address some of the typical drawbacks of PCCI implementation. Uncooled EGR (i.e. exhaust gas recirculated by-passing the EGR cooler), proved to be effective to increase exhaust gas temperatures at the lowest load engine operating conditions (up to +60 °C, see side figure), thus promoting HC and CO oxidation rate by the diesel oxidation catalyst (DOC), reducing their tailpipe emissions. Combustion control techniques, able to control in real-time the MFB50 by properly managing the start of injection (SOI), have been tested on the standard engine, under both conventional and PCCI combustion modes, to prove their robustness. Benefits in terms of better combustion stability (i.e., reduced cylinder-to-cylinder and cycle-to-cycle variations) have been highlighted, thus possibly being a feasible way to enhance PCCI operations.
Additional tests will be carried out in the near future, including a small DOC installation upstream the EGR cooler (to face its detected fouling process) and split fuel injection strategies (to address excessive CN increase).

First name: Marco **LAST NAME**: MARCHESE

Topic: Conversion of industrial CO_2 to value-added fuels and chemicals via Fischer-Tropsch upgrade

Course year: 1st **Tutor(s)**: Dr. A. Lanzini, Prof. M. Santarelli

Academic context

[1] R. Yang et al., "*Effects of experimental operations on the Fischer-Tropsch product distribution*", Catal. Today, vol. 298, pp. 77–88, 2017.
[2] N. Moazami et al., "*A comprehensive study of kinetics mechanism of Fischer-Tropsch synthesis over cobalt-based catalyst*", Chem. Eng. Sci., vol. 171, pp. 32–60, 2017.
[3] G. Cinti et al., "*Integration of Solid Oxide Electrolyzer and Fischer-Tropsch : A sustainable pathway for synthetic fuel*", Appl. Energy, vol. 162, pp. 308–320, 2016.

External collaborations

- VTT Technical Research Centre of Finland (FI)
- Ineratec GmbH (DE)
- Altana AG (DE)

Highlights of the research activity

The PhD research activities are carried out within the framework of the EU H2020 project ICO2CHEM. The project aims at demonstrating the technical and economic feasibility of the installation of a Mobile Synthesis Unit (MOBSU), recycling industrial CO_2 to value-added Fischer-Tropsch products (synthetic oils and high molecular weight waxes), with a Reverse Water Gas Shift in series with a microchannel Fischer-Tropsch reactor. The first converts CO_2 to CO, the latter synthetizes hydrocarbons via the reaction $CO+H_2 \rightarrow -CH_2-+H_2O$. Within the PhD, the response of the Fisher-Tropsch is studied, in order to maximize the production of long-chain hydrocarbons. In partnership with project partner VTT, a Co/Pt-Al_3O_2 catalyst has been tested for kinetic studies. Kinetic data have been collected on a laboratory-scale tubular reactor, obtaining 17 unique experimental points that unveil the response of the catalyst at values of 205-230°C and 15-30bar, variating H_2/CO feed ratio. These data are used for the generation of an ad-hoc kinetic model, describing the phenomena developing over the catalyst surface. The kinetic data fitting procedure is carried out with an optimization technique based on a genetic algorithm for global optima, followed by an interior-point algorithm for local optima search by means of application of a carbide mechanistic model, giving information about activation energies and kinetic constants. Such information can be used to both predict the production and distribution of synthetic hydrocarbons and for further process modelling. In parallel to the experimental activities, Power-to-Liquid routes for industrial CO_2 recycling are being studied to evaluate the most economically viable when applying a Fisher-Tropsch system. They comprise of CO_2 capture via MEA-based biogas upgrade, a syngas generation unit (RWGS if H_2 is available, SOEC if H_2 is not available) and FT microchannel reactor. All the models have been developed on the commercial tool ASPENPlus®, with an external subroutine used to implement the kinetic information. A first thermodynamic comparison between state-of-the-art of the RWGS and a Solid Oxide Electrolyser in co-electrolysis has been done. Even if RWGS is a proven technology, it allows a maximum CO_2-to-CO conversion of about 65%. The SOEC technology allows producing a better syngas quality for the FT reaction, enhancing the production of high molecular weight waxes at the FT side. Moreover, an SOEC system allows a better thermal integration with the main full-plant sections (CO_2 capture and FT reactor). Further research will focus on the generation of syngas for FT via co-electrolysis.

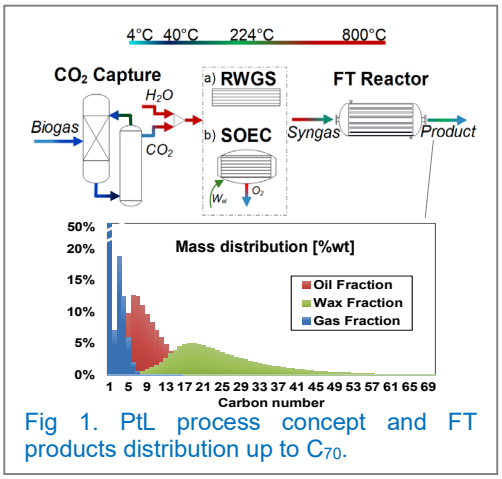


Fig 1. PtL process concept and FT products distribution up to C_{70}.

First name: Omar **LAST NAME**: MARELLO

Topic: Development and assessment of model-based algorithms for torque and emission control in diesel engines

Course year: 1st **Tutor(s)**: Prof. R. Finesso, Prof. E. Spessa

Academic context

[1] *Finesso, R., Hardy, G., Marello, O., Spessa, E., Yang, Y.,* "Model-Based Control of BMEP and NOx Emissions in a Euro VI 3.0L Diesel Engine" *SAE International Journal of Engines 10(5), 2017:2288-2304,* [2] *Finesso, R., Hardy, G., Maino, C., Marello, O., Spessa, E.* "A New Control-Oriented Semi-Empirical Approach to Predict Engine-Out NOx Emissions in a Euro VI 3.0 L Diesel Engine"*Energies 10(12):1978, 2017*

[3] Finesso, R., Marello, O., Misul, D., Spessa, E. et al., "Development and Assessment of Pressure-Based and Model-Based Techniques for the MFB50 Control of a Euro VI 3.0L Diesel Engine,"*SAE Int. J. Engines* 10(4):1538-1555

External collaborations

- FPT Motorenforschung AG
- GM- Global propulsion systems (GM-GPS)

Highlights of the research activity

Model-based combustion control techniques for internal combustion engines are becoming more and more interesting in the last years, due to the increasing computational performance of modern ECUs and to the increased complexity of engines (especially diesel engines). The adoption of this kind of control can give benefits in reducing the experimental effort required for engine calibration (compared with map-based approach) and could be useful to exploit the potential of real-time optimization techniques. However, model-based controllers need accurate predictions of the metrics to be controlled and must be characterized by a low computational effort, in order to be implementable in the engine control unit.

My research activity in the first year of my PhD has been devoted to these aspects: the development and improvement of combustion models for control-oriented applications, the development of methodologies to reduce the required computational time and finally the application of these models to control purposes through rapid prototyping. These activities have been carried out in the frame of several projects in collaboration with FPT Industrial (Imperium H2020 European project) and GM-GPS (HERCULES project). In particular, two types of model-based controllers were developed. The first one has been developed within the Imperium project, and has the aim of controlling torque and NOx emissions (figure 1) in real time, on the basis of the targets which are decided by an energy management supervisor. The controller has been tested on an 11.0L diesel engine through rapid prototyping. The second controller, developed within the HERCULES project, has the aim of controlling the torque by acting on the main injection quantity, in presence of multi-after injection patterns.

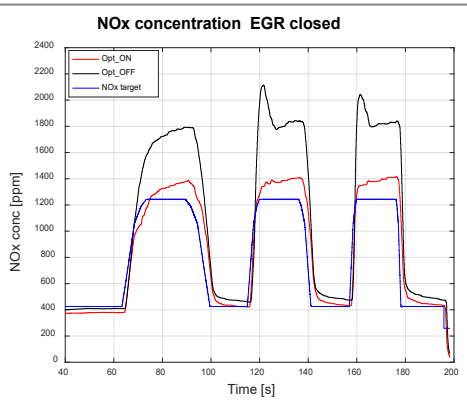


Fig 1. Time histories of NOx emissions for a pedal ramp test without EGR, in which the controller is activated (red line) or deactivated (black line). The blue line represents the NOx emission target

First name: Paolo **LAST NAME**: MAROCCO

Topic: Analysis of different power-to-power (P2P) configurations for electrical energy storage

Course year: 1st **Tutor(s)**: Prof.M. Santarelli, Dr. A. Lanzini

Academic context

[1] L. Gracia, P. Casero, C. Bourasseau, and A. Chabert, "Use of Hydrogen in Off-Grid Locations, a Techno-Economic Assessment," *Energies*, vol. 11, no. 11, p. 3141, 2018.
[2] F. J. Vivas, A. De las Heras, F. Segura, and J. M. Andújar, "A review of energy management strategies for renewable hybrid energy systems with hydrogen backup," *Renew. Sustain. Energy Rev.*, vol. 82, no. Part 1, pp. 126–155, 2018.
[3] A. Brka, "Optimisation of stand-alone hydrogen-based renewable energy systems using intelligent techniques," 2015.

External collaborations

- SINTEF, Trondheim, Norvegia
- Electro Power Systems (EPS), Rivoli, Italia
- Enel Green Power, Roma, Italia

Highlights of the research activity

The PhD research activity is mainly performed within the framework of the EU H2020 project REMOTE (https://www.remote-euproject.eu/), which aims at demonstrating the technical and economic feasibility of hydrogen-based energy storage solutions in four different DEMOs, based on renewables, in isolated micro-grid or off grid remote areas.
First, a preliminary system analysis was conducted in order to underline how the local situation could be improved with the operation of the H_2-based solution. Outcomes of the simulations revealed that the need for an external source, e.g. traditional fossil fuel generator, can be drastically reduced thanks to the exploitation of local RES sources coupled with hydrogen-battery energy storage systems.
The research was then addressed to study and model in greater detail the various electrochemical components which can be involved in an energy storage system based on H_2. The Solid Oxide Cell (SOC) technology (both in fuel cell and electrolysis mode) was first considered. Unlike PEM and alkaline systems, high temperature and thermal gradients can cause significant problems for the practical application of SOC devices, especially in the fuel cell mode because of its highly exothermicity. A model of the SOFC stack with heat pipe integration (for a better thermal management) was developed showing a remarkable improvement of the system performance since higher current density values can be reached.
The research is now focusing on low temperature electrochemical devices, which are the components that have been adopted within the REMOTE project. First, the concept of degradation will be deeply analysed through experimental approaches to provide a more realistic description of the system and a better assessment of optimal operational strategies. Then, the enhanced models will be used for the optimal economical sizing and hour-by-hour management of isolated P2P systems will be developed.

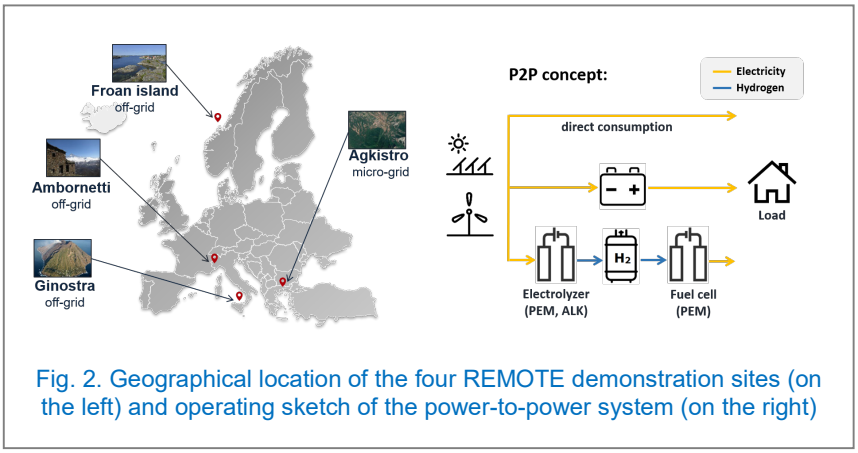


Fig. 2. Geographical location of the four REMOTE demonstration sites (on the left) and operating sketch of the power-to-power system (on the right)

First name: Jesus Alberto **LAST NAME**: MEJIAS TUNI

Topic: Fires in tunnels and enclosures and its extinction, using mist sprinklers

Course year: 1st **Tutor(s)**: Prof. V. Verda, Dr. E. Guelpa

Academic context

[1] F. Colella, G. Rein, V. Verda, R. Borchiellini, Multiscale modelling of transient flows from fire and ventilation in long tunnels, Computer & Fluids, 51:16-29, 2011.
[2] Cosentino S. et al. Integrating 1D and 3D modeling for the analysis of ventilation control in tunnels, ICHMT 2017, pages 2041-2060, 2017
[3] F. Colella, G. Rein, J. Torero, R. Borchiellini, A novel multiscale methodology for simulating tunnel ventilation flows during fires. Fire Technology, 2010.

External collaborations

- NIST (National Institute of Standards and Technology)

Highlights of the research activity

In the last decades some incidents involving fires in tunnels have taken place. Some of them in Europe, like the Montblanc tunnel fire (1999) and the Fréjus Tunnel fire (2005). As a result, the interest in fire extinction has grew noticeably. But making test fires in tunnels or similar places requires investing money and logistics in it, being highly unpractical at times. Economizing resources drives most academic studies towards the use of CFD simulations. But one issue that remains troubling of CFD simulations is the amount of time they can require, as it gets higher with the increasing size of the simulated domain.

An algorithm was developed at Politecnico to optimize the time spent and reduce the impact of this issue. The algorithm is based in using 2 programs to simulate the tunnel. The first, a CFD program (FDS, Fire Dynamics Simulator) capable of simulating the more important areas of the domain, in 3D, and fully describing the properties of the field. The second, a 1D program (Whitesmoke) capable of quickly simulating large parts of the domain where the properties of the flow are highly homogeneous, and the occurring phenomena are less complex.

This algorithm was validated for its use on ventilation in tunnels, but its capabilities to simulate fire were still to be tested. Up to this point some adjustments have been done to the algorithm during the first year of my Ph.D.:

- Adaptation to Linux, reducing the execution time to a 10% of the time previously needed.
- Improvements to the communications between the 2 programs, solving issues with stability in the 1D simulation and in exchanging the boundary conditions.
- Change in the 3D simulation mode, updating the algorithm to the last FDS version it was possible to use a new wall roughness solver, involving huge gains in the precision of results.

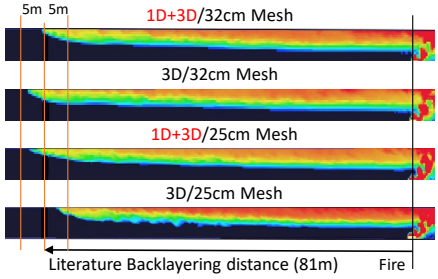


Fig.1 Comparison of backlayering in the Tunnel using FDS and Weng formula for backlayering. Measures taken in the middle of the tunnel

The results obtained from the 1D+3D algorithm approach closely to the physic reality. The most remarkable result is an error of around 5% on the backlayering distance of the smoke (Fig.1), comparing the results obtained from the 1D+3D algorithm and different expressions found in the literature.

Aside of the tunnel fires, the research in Mist sprinklers continues, preparing the apparatus in the laboratory to start the tests, some logistics issues are still to be solved. These will be used to validate the mist model in FDS. At last some collaborations with other departments within Politecnico are guiding our efforts towards the construction of a Virtual Reality (VR) application to help in the training of Firefighters. Our involvement is referred to provide a reduced model from the CFD to reproduce interactive scenarios through the VR application. This would allow firefighters to train with situations as real as possible, inside a safe VR interface.

First name: Matteo **LAST NAME**: MORCIANO

Topic: Nanotechnology-enabled solar energy for water desalination and purification.

Course year: 3rd **Tutor(s)**: Prof. P. Asinari, Prof. E. Chiavazzo

Academic context

[1] Elimelech, M., & Phillip, W. A. (2011). *The future of seawater desalination: energy, technology, and the environment*. *Science*, *333*(6043), 712-717.
[2] Morciano, M., Fasano, M., Salomov, U., Ventola, L., Chiavazzo, E., & Asinari, P. (2017). *Efficient steam generation by inexpensive narrow gap evaporation device for solar applications*. *Scientific reports*, *7*(1), 11970.
[3] Ni, G., Zandavi, S. H., Javid, S. M., Boriskina, S. V., Cooper, T. A., & Chen, G. (2018). *A salt-rejecting floating solar still for low-cost desalination. Energy & Environmental Science*, *11*(6), 1510-1519.

External collaborations

- Gang Chen and Evelyn Wang, Massachusetts Institute of Technology (MIT) - Department of Mechanical Engineering.

Highlights of the research activity

Passive solar distillation. During the third year, I mainly focused my attention on improving the performances and reducing the cost of the passive, modular and low-cost lab-scale prototype developed and fully characterized during the second year. This prototype represents an innovative water desalination/purification device driven by non-concentrated solar energy ($< 1\ kWm^{-2}$). This optimized version of the distiller has been developed at MIT, where I carried out research for 6 months in collaboration with Prof. Gang Chen, Prof. Evelyn Wang. Three main issue have been addressed: i) optimizing the distillate mass flow rate, ii) reducing the cost of the device and iii) achieving an efficient salt rejection. Experimental campaign (validated by numerical simulations) demonstrated the effectiveness of the solution. Summarizing, the described activity combined both salt rejection strategy (developed in the Chen lab), as well as the heat recovery in the membrane distillation structure developed in the Small group, to form a high performance solar thermal distiller for contaminated waters and seawater treatment. This optimal configuration produced up to 40% more distilled water (in case of 1-stage configuration device) with respect to the sub-optimal version developed during the second year (corresponding to 2-4 times respect to state-of-the-art passive solar stills).

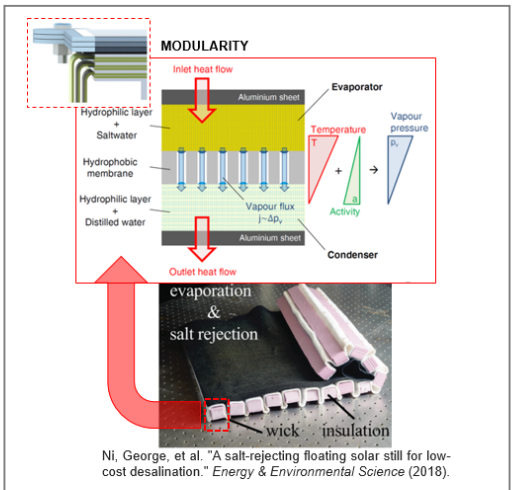


Fig 1. Layout of the salt rejecting solar passive distiller.

Passive cooling device. The second activity I dealt with concerns the study and the development of a passive heat pump, which comprises environmental friendly operating fluids (namely sodium chloride water solutions, which do not show a detrimental impact on the environment). The device operation is possible without any moving mechanical parts. Here, only capillarity and gravity operate. It is worth to pointing out that the operations occur under fixed total ambient pressure. Hence, I prototyped a modular, static, low-cost and environmentally benign cooling device able to convert a solution salinity difference into a temperature difference. Preliminary experimental tests (validated by numerical simulations) have been carried out achieving a maximum cooling power $\approx 100\ Wm^{-2}$ (at vanishing temperature drop). As a future perspective, a fully passive solar cooling could be achieved by coupling the present device with the passive solar distiller introduced above, which is expected to provide both a steady distillate flow at the evaporator and to restore the salinity.

First name: Giovanni **LAST NAME**: MURANO

Topic: Energy retrofit of existing buildings and cost optimality

Course year: 3rd **Tutor(s)**: Prof. V. Corrado

Academic context

[1] V. Corrado, I. Ballarini, S. Paduos, *The Application of the EU Comparative Methodology to Italian Reference Buildings for the Cost-Optimal Analysis*. In: CLIMA 2013 - 11th REHVA World Congress and 8th International Conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings, Praga, 16-19 June 2013.
[2] G. Maria Mauro, M. Hamdy, G. Peter Vanoli, N. Bianco, J. L.M. Hensen, *A new methodology for investigating the cost-optimality of energy retrofitting a building category*, Energy and Buildings 107 (2015) 456–478.
[3] L. Aelenei, S. Paduos, H. Petran, J. Tarrés, A. Ferreira, V. Corrado, S. Camelo, E. Polychroni, K. Sfakianaki, H. Gonçalves, J. Salom, G. Riva, G. Murano, *Implementing cost-optimal methodology in existing public buildings*, Proc. 6th International Building Physics Conference, IBPC 2015, Energy Procedia, ISSN: 1876-6102.

External collaborations

- Italian Thermotechnical Committee Energy & Environment (CTI);
- University of Pavia.
- University of Udine.

Highlights of the research activity

In 2016, the European Commission published the Recommendation 2016/1318 on guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings.
In relation to the European Commission document, the activity of third year examines the applicability of the design of nearly zero-energy buildings in various climatic conditions, evaluating possible global scenarios for the renovation of the existing residential buildings.
The analysis is applied to varios building types, ie single-family house and an apartment block, as case studies, located in different climatic zones, through the reference notional building. The requirement for the building under design is represented by the energy performance of the reference notional building.
This one is outlined at national level, by local legislation, aiming at the nZEB target. Therefore, in the research, the reference notional building is used to calculate the energy performance indexes, depending on different climatic conditions, chosen to be representative of various HDD (Heating Degree Days) ranges.
The results of activity are intended to demonstrate that there is not a unique nZEB level, but the reference strongly depends on the local conditions and the building features.
As the framework definition of nZEB in the EPBD and in the national legislation does not differentiate between new and existing buildings, the results of the study can be used as baseline energy performance for the quantification of energy and environmental savings, and to guide buildings refurbishment policies.

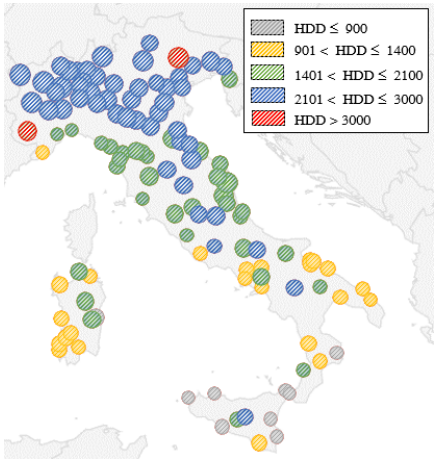


Fig 1. Reference single family-house. Energy need for heating for some locations.

First name: Giuseppe Francesco **LAST NAME**: NALLO

Topic: Modeling liquid metals for nuclear applications

Course year: 1st **Tutor(s)**: Prof. P. Ravetto, Prof. R. Zanino

Academic context

[1] G. F. Nallo, S. Carli, G. Caruso, F. Crisanti, G. Mazzitelli, L. Savoldi, F. Subba, R. Zanino, "Modeling the lithium loop in a liquid metal pool-type divertor", Fusion Engineering and Design 125, 206-215 (2017), DOI: 10.1016/j.fusengdes.2017.07.004
[2] F. Subba, L. Aho-Mantila, D. Coster, G. Maddaluno, G. F. Nallo, B. Sieglin, R. Wenninger, R. Zanino, "Modelling of mitigation of the power divertor loading for the EU demo through Ar injection", Plasma Physics and Controlled Fusion 60, 035013 (2018), DOI: 10.1088/1361-6587/aaa508
[3] D. Caron, R. Bonifetto, S. Dulla, V. Mascolino, P. Ravetto, L. Savoldi, D. Valerio, R. Zanino, "Full-core coupled neutronic/thermal-hydraulic modelling of the EBR-II SHRT-45R transient", International Journal of Energy Research 42, 134-150 (2018), DOI: 10.1002/er.3571

External collaborations

- ENEA (CR Bologna, CR Frascati)

Highlights of the research activity

This Ph.D. project involves the modelling of innovative systems based on liquid metals (LMs) in both fusion and fission nuclear reactors.
Fusion-related activities aim at modeling new LM-based divertor concepts for reliably addressing the heat and particles exhaust problem in fusion reactors. The motivation for this effort is the possibility to employ a LM film to coat the divertor plasma facing surface. This approach could dramatically increase the component lifetime and resilience to transient events. Both "open" and "closed" LM divertor configurations have been studied during this first year. A possible "open" LM divertor for DEMO has been studied by means of the currently employed tool for Scrape-Off Layer (SOL) plasma simulation, the SOLPS-ITER code. This tool provides a detailed, multi-fluid description of the charged plasma species (e.g. H^+, Li^+, Li^{2+}, Li^{3+}) and a fluid or kinetic description of neutral species (e.g. H^0, Li^0) within the SOL plasma. SOLPS-ITER could not be applied as is for simulating the behavior of the SOL plasma in presence of a LM divertor due to the lack of a surface model which includes evaporation. Therefore, within the framework of EUROfusion WPDTT1-LMD 2018, a model for the thermal response of a LM divertor target including evaporation has been developed and coupled to the code. A possible "closed" LM divertor of box type has instead been proposed for the Divertor Tokamak Test (DTT) facility and a simulation approach has been set up, involving a simplified treatment of the SOL plasma, a FEM thermal model of the structures (FreeFem++) and a Direct Simulation Monte Carlo model for the rarefied Li vapor implemented in the OpenFOAM framework.

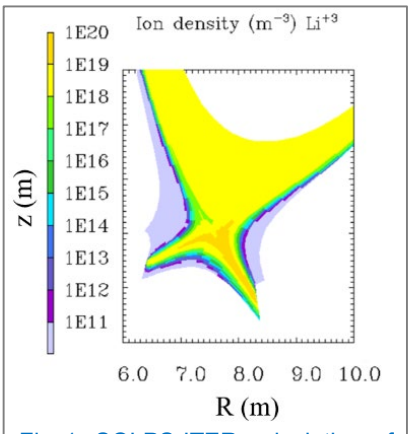


Fig 1. SOLPS-ITER calculation of Li+ density in the DEMO SOL in presence of a LM divertor.

Fission-related activities concern the further development, verification and validation of the FRENETIC code for the multi-physics (neutronic + thermal-hydraulic) modeling of Generation IV Lead-cooled Fast Reactors (LFRs). During this year, the FRENETIC code has been benchmarked against a detailed computational model obtained by coupling the neutronic Monte Carlo code Serpent to the a CFD OpenFOAM model. An upgraded ALFRED model in FRENETIC has also been set up.
In conclusion, this first year has been mostly dedicated to the development of new tools and to gaining confidence with the existing code packages for the multi-physics simulation of nuclear reactor systems employing LMs. In the next two years the models developed will undergo further development, verification and validation and will eventually be employed in support of the preliminary design of the various LM-based systems listed above.

First name: Benedetta **LAST NAME**: PEIRETTI PARADISI

Topic: Proton acceleration by laser-matter interaction for oncology radiotherapy

Course year: 3rd **Tutor(s)**: Prof. G. Coppa

Academic context

[1] B. Peiretti Paradisi, E. Boella, A. D'Angola and G. Coppa, Gridless simulation of collisionless systems with high degree of symmetry, Computer Physics Communications, 2017.
[2] G. Coppa, A. D'Angola and B. Peiretti Paradisi, Coulomb explosion in cylindric geometry, to be submitted to Computer Physics Communications, 2018.
[3] E. Richetta, B. Peiretti Paradisi, M. Stasi et al, PET-CT post therapy dosimetry in radioembolization with resin 90Y microspheres: comparison with pre treatment SPECT-CT 99mTc-MAA results, European congress of medical physics, Copenaghen, Denmark, 2018.

External collaborations

- Medical Physics Dept, A.O. Ordine Mauriziano, Torino (D.ssa Elisa Richetta)
- Università della Basilicata (Prof. Antonio D'Angola)

Highlights of the research activity

Hadron-therapy is one of the most promising techniques for treating different types of cancer, in particular those with a higher level of radio-resistance and next to vital organs, where any radiations needs to be avoided by the radiations. At present, protons and carbon ions are used for treatments and very expensive accelerators, such as cyclotron sand synchrotrons, have to be close to the radiotherapy center. In this context, the work of our group has the aim to find an alternative to hadron acceleration, by exploiting the high energy beams generated by the interaction of ultra-intense laser with solid targets. Coulomb explosions of hetero-nuclear slab was simulated, choosing a ratio section/thickness <<1 to enhance the peak of the energy spectrum. Numerical simulations are needed to study the phenomenon in this geometry, because a theoretical model is not possibile, therefore three new numerical tools were developed and deeply studied by our research group [1]. In the first stage the methods were validated in simple geometries (spherical systems) by comparison with the analytic solution, giving an excellent agreement. Once these three methods had been validated, they were used to simulate other geometries, where it is not possible to find a theoretical model, as in the case of a thin slab. Different configurations were tested, changing the ion species inside the slabs, the initial aspect ratio, initial charge distribution inside and so on. Very interesting results were found, in particular in terms of energy reached by the fast ions [2], Fig.1. Another important activity of the group is a collaboration with the Medical Physics Department at A.O. Ordine Mauriziano, Torino. The aim was to develop an in-house software for calculating the dose deposition inside tumour lesions, which had been treated by metabolic radiotherapy [3]. In particular, a radio-pharmaceutical with 131I is administered in case of metastatic lesions by thyroid cancer and the link between the success of the therapy and the activity delivered to the patient is needed. Generally 4 SPECT-CT acquisitions are performed after the pharmaceutical administration, obtaining the matrix representation of the counts distribution from the SPECT and the Hounsfield unit map from the CT. The developed software is divided in two parts. Firstly, it co-registers the SPECT with the corresponding CT, adapting the matrix dimension of the anatomic image. In the second part of the analysis, each section is taken into consideration and there are three possible methods to localize the volume of interest. At the end, the software is able to calculate the activity of each acquisition and fit the data to obtain the cumulated activity curve of the different lesions. To validate the software a 131 I phantom was used and many comparisons were done with datas from real patients.

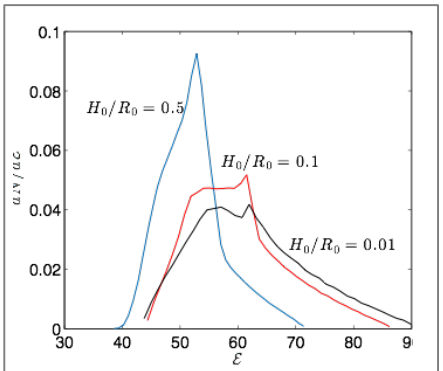


Fig.1: energy spectra of the fast ions, varying the initial aspect ratio of the slab.

First name: Marco Savino **LAST NAME**: PISCITELLI

Topic: Energy management in buildings through data analytics technologies

Course year: 2nd **Tutor(s)**: Prof. A. Capozzoli, Prof. M. Perino

Academic context

[1] Capozzoli A, Piscitelli M S, Brandi S., Grassi D., Chicco G. Automated load pattern learning and anomaly detection for enhancing energy management in smart buildings. Energy 2018; 157: 336-352
[2] Molina-Solana M, Ros M, Ruiz MD, Gómez-Romero J, Martín-Bautista MJ. Data Science for Building Energy Management: a Review. Renew Sustain Energy Rev 2017; 70: 598–609.
[3] Fan C, Xiao F, Madsen H, Wang D. Temporal knowledge discovery in big BAS data for building energy management. Energy Build 2015; 109: 75–89.

External collaborations

- The Hong Kong Polytechnic University – Department of Building Service Engineering
- IREN s.p.a.
- ENEA - Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Highlights of the research activity

In the context of smart buildings in smart cities, the growing spread of ICT and IoT is enabling the collection of a huge amount of building related-data.
In particular, several research activities were conducted in field of anomalous energy trend detection in buildings. In most of real cases, just few and aggregate variables related to the total energy consumption of the building are monitored and collected. Improving the building energy performance by analysing aggregate data is challenging, especially if several factors generate the existence of different energy consumption patterns not always easily inferable.
In this context, recognize which is the expected normal energy behavior, based on predictive analytics frameworks (**Figure 1**), plays a fundamental role in building commissioning during the post-occupancy phase. To this aim, the work conducted in [1] introduces a novel framework based on an effective transformation process of whole building energy consumption time series. Data reduction, transformation and machine learning methods (i.e. decision trees, symbolic aggregate approximation) have been coupled and applied for two different case studies (i.e Polytechnic of Turin, Sant Cougat Town Hall) to discover unexpected patterns in electrical energy consumption data. The identification of infrequent/anomalous patterns has been conducted by comparing the expected and the actual daily energy consumption profile. The prediction task is accomplished for sub-daily time windows considering as input parameters the indoor/outdoor climatic conditions, occupants' presence and the temporal variables. The process is able to distinguish infrequent from anomalous sub-daily patterns based on specific boundary conditions. Such advisory tool can be easily translated in a set of decision rules and embedded in a Decision Support System helping stakeholders in early detecting anomalous energy patterns avoiding further energy waste over time.

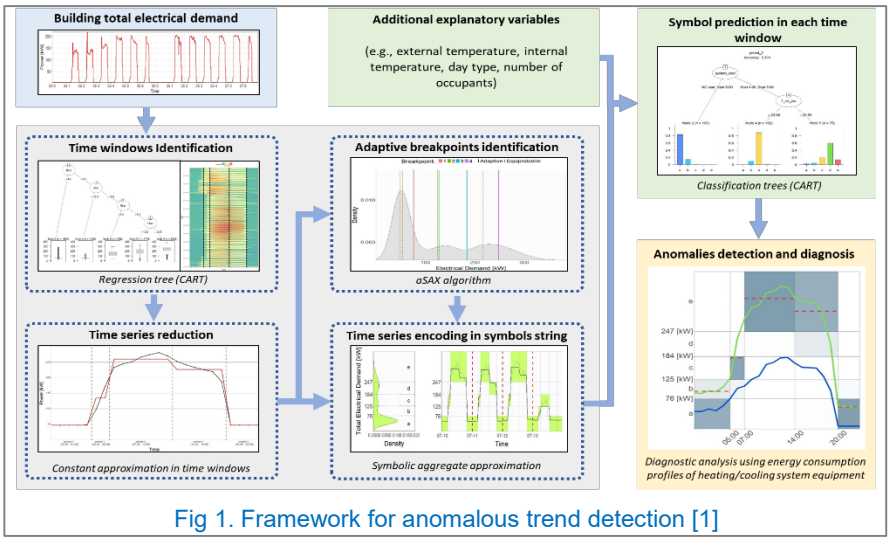


Fig 1. Framework for anomalous trend detection [1]

First name: Elisa **LAST NAME**: PRIMO

Topic: Actual energy performance and IEQ of buildings – the effect of occupancy

Course year: 2nd **Tutor(s)**: Prof. V. Corrado, Dr. I. Ballarini

Academic context

[1] Galvin R. Making the 'rebound effect' more useful for performance evaluation of thermal retrofits of existing homes: Defining the 'energy savings deficit' and the 'energy performance gap'. *Energy and Buildings* 69 (2014), 515-524.
[2] Guerra Santin O., Occupant behaviour in energy efficient dwellings: evidence of a rebound effect. *Journal of Housing and the Built Environment* 28 (2013), 311-327.
[3] Ben H., Steemers K. Household archetypes and behavioural patterns in UK domestic energy use. *Energy Efficiency* 11 (2018), 761-771.

External collaborations

- Technische Universität Wien (TU Wien, Austria)
- Italian National agency for new technologies, Energy and sustainable economic development (ENEA, Italy)
- Social housing agency of Central Piedmont (ATC Piemonte Centrale, Italy)

Highlights of the research activity

Though the energy consumption of buildings is supposed to decrease after retrofit, several studies showed that the energy performance does not increase as much as it would be expected and that a significant gap between the estimated and the real energy savings occurs. My research activity investigates the influence of real occupant behaviour on the effective energy refurbishment of the existing building stock. To this aim, an occupancy behaviour survey based on a detailed questionnaire is carrying out in some apartment blocks located in Torino (Italy) and recently refurbished, taken as a pilot case. The survey questions mainly concern the relation between the households and the dwelling (e.g. technical building systems operation, ventilation preferences), but also regard aspects influencing occupant behaviour indirectly, such as income, education level, employment.
On the basis of the survey results, a methodology to build occupancy patterns and reference users of the sample is going to be improved. Alongside the sample is going to be enlarged by submitting the questionnaire at a higher amount of dwellings.
The typical residential occupancy patterns resulting from the questionnaire survey are implemented in the dynamic simulation models. On this basis the actual energy performance of case studies will be assessed by calibrating the energy models by means of the monitored energy consumption before and after energy refurbishment.

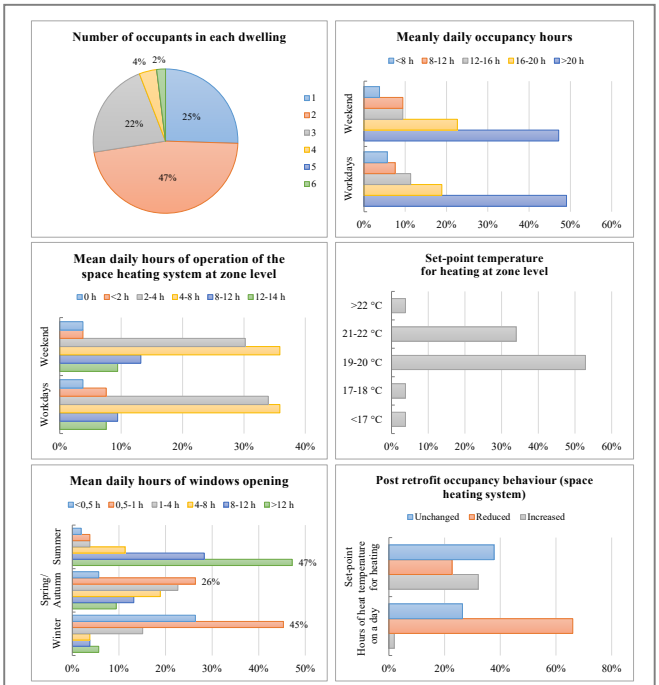


Fig 1. Questionnaire replies for a pilot case study: share of dwellings for main driving occupancy parameters

First name: Sofia **LAST NAME**: RUSSO

Topic: Thermoeconomic analysis and optimization under uncertainty of Municipal Solid Waste treatment plants

Course year: 1st **Tutor:** Prof. V. Verda

Academic context

[1] Andreasi Bassi, S., Christensen, T. H., Damgaard, A. (2017). Environmental performance of household waste management in Europe – An example of 7 countries. *Waste Management, 69,* 545-557
[2] Maqsood, I., Huang, H. G., (2012). A Two-Stage Interval Stochastic Programming Model for Waste Management under Uncertainty. *Air & Waste Management 53*, 540-552
[3] Stanek, W., Valero, A., Valero, A., Uche, J., Calvo, G. (2017).Thermodynamic Methods to Evaluate Resources. *Thermodynamics for Sustainable Management of Natural Resources*, *Chapter 6,* Springer

External collaborations

- Research Centre for Energy Resources and Consumption (CIRCE), University of Zaragoza ,Spain

Highlights of the research activity

Municipal Solid Waste management is still a crucial issue for European countries. The general objective of the research project is to assess a methodology for analysing the MSW treatment system, from the waste generation to the fabrication of end products from recovered waste streams. The operation of these kind of systems is strongly influenced by social, political and economic elements, which entail a high degree of uncertainty in external and internal parameters. The aim is to use the Thermoeconomic criteria to propose optimal management strategies for the allocation of the material streams into the MSW treatment system, according to the variety of operating conditions that can be faced. Stochastic and probabilistic tools are adopted for generating simulation scenarios and the optimization is conducted under uncertainty conditions. So far, a modelling and simulation of a Mechanical Biological Treatment (MBT) plant of unsorted MSW, for RDF production and metal recovery, has been performed. The parameters chosen for the evaluation were: yield of RDF, Lower Heating Value (LHV) of RDF, global energy and exergy efficiency with and without metal recovery, distribution of irreversibility in equipment, unit exergy cost of RDF and recovered metal. The linear variation of external and internal variables showed that the main differences in the performance parameters depend on the structure of the treatment chain; the waste composition has not a great influence on the unit exergy cost of products, while it affects more the LHV of the RDF. In order to account for the uncertainty, a crude Monte Carlo method was used to sample from a uniform distribution of degree of selective collection for single material stream, in order to reproduce the randomness in unsorted waste composition. The energy consumption of the equipment was considered as the internal uncertain variable, for which a normal probability distribution is supposed. In this case, the sampling was conducted on the Cumulative Distribution Function (CDF), using the inversion method. The results showed the primary influence of the external uncertain variables over the internal ones, at least in the considered range of variation. The next steps will be the modelling of the recycle chains of the separated material streams and the developing of an optimization model for the entire treatment system. In this regard, a two-stage stochastic mixed integer linear programming (MILP) model, based on capacity planning, appears to be the best choice.

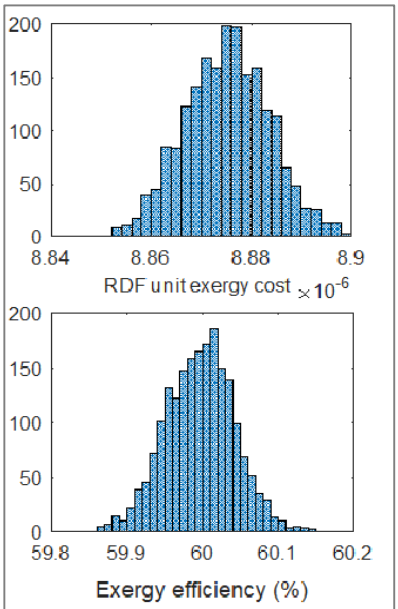


Fig 1. Distribution of values of RDF cost and exergy efficiency after Monte Carlo sampling on energy consumption

First name: Francesco **LAST NAME**: SAPIO

Topic: Diesel after-treatment modelling optimization techniques

Course year: 2nd **Tutor(s)**: Prof. F. Millo

Academic context

[1] Gundlapally, S.R., Papadimitriou, I., Wahiduzzaman, S., and Gu, T., "Development of ECU Capable Grey-Box Models from Detailed Models-Application to a SCR Reactor," Emiss. Control Sci. Technol. 2(3):124–136, 2016, doi:10.1007/s40825-016-0039-x.
[2] Millo, F., Rafigh, M., Sapio, F., Barrientos, E.J., and Ferreri, P., "Application of Genetic Algorithm for the Calibration of the Kinetic Scheme of a Diesel Oxidation Catalyst Model," 2018, doi:10.4271/2018-01-1762
[3] Millo, F., Rafigh, M., Sapio, F., Wahiduzzaman, S., Dudgeon, R., Ferreri, P., and Barrientos, E., "Modeling NOx Storage and Reduction for a Diesel Automotive Catalyst Based on Synthetic Gas Bench Experiments," Ind. Eng. Chem. Res. 57(37):12335–12351, 2018, doi:10.1021/acs.iecr.8b01813

External collaborations

- General Motors Global Propulsion Systems
- Gamma Technologies
- Cornaglia Group

Highlights of the research activity

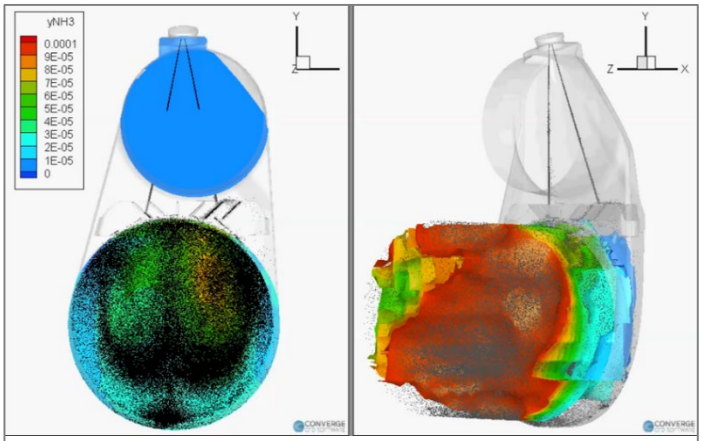


Fig 3. 3D-CFD UWS spray and ammonia distribution at the SCRoF inlet

Worldwide, a growing concern about pollution effects on the environment and human health is pushing through more severe emissions regulations and type-approval procedures for vehicles and engines technologies. In this framework, diesel AfterTreatment Systems (ATS) include a great variety of architectures combining several devices, therefore flexible aftertreatment modelling tools are required by the automotive modeling community to further develop such technologies, reducing the need of expensive and time-consuming experimental campaigns. The aim of this research project is to develop reliable models of the individual aftertreatment components which can be further used as a virtual test rig to evaluate the effectiveness of each technology in reducing pollutant emissions. To this aim, different modeling approaches have been investigated. First, a 1D-CFD LNT model has been developed and calibrated over reactor-scale Synthetic Gas Bench (SGB) experiments, whose data were provided by GM. The calibration of the kinetic scheme has been carried out with the aim to characterize LNT operations, using the Genetic Algorithm. The LNT model has been finally validated using the experimental engine-out emissions, mass flowrate and temperature data over WLTC and RDE driving cycles, assessing the components performance in terms of NOx reduction, CO and HC oxidation and ammonia production. To reduce the computational effort required by such models, during an internship in Gamma Technologies, a reduced order model for an SCR catalyst has been developed and validated over experimental data, achieving a computational time 100 faster than real time, which makes such model suitable for direct ECU integration. Finally, 3D CFD models of 2 state-of-the-art ATS have been investigated in a research project, sponsored by Cornaglia Group. The analyzed systems consisted of a DOC, for the oxidation of CO and unburned hydrocarbons, followed by a closed-coupled SCRoF (SCR on diesel particulate Filter), which integrates the SCR functions on a particulate filter. The scope of the 3D-CFD analysis has been to simulate the Urea Water Solution injection, breakup on the mixer walls, evaporation, hydrolysis and thermolysis, to predict the ammonia distribution at the SCRoF catalyst inlet, as shown in Figure 1. This information could be further used, for instance, to initialize a 1D-CFD model of the SCRoF component, with a calibrated kinetic mechanism, to simulate the ATS performance over driving cycles.

First name: Alicia **LAST NAME**: SOTO

Topic: Carbon capture utilization and storage (CCUS) and how to accelerate the development and commercialization of carbon-based products in the concrete industry in the U.S. and European markets

Course year: 2nd **Tutor(s)**: Prof. M. Santarelli, Porf. I. Casanova (UPC)

Academic context

[1] Ebrahimi, A., Saffari, M., Milani, D., Montoya, A., Valix, M., & Abbas, A. (2017). Sustainable transformation of fly ash industrial waste into a construction cement blend via CO2 carbonation. *Journal of Cleaner Production*, *156*, 660–669. https://doi.org/10.1016/j.jclepro.2017.04.037
[2] Wei, Z., Wang, B., Falzone, G., La Plante, E. C., Okoronkwo & Sant, G. (2018). Clinkering-free cementation by fly ash carbonation. Journal of CO2 Utilization, (December 2017), 117–127. https://doi.org/10.1016/j.jcou.2017.11.005
[3] Hoogendoorn, B., van der Zwan, P., & Thurik, R. (2017). Sustainable Entrepreneurship: The Role of Perceived Barriers and Risk. Journal of Business Ethics, 1–22. https://doi.org/10.1007/s10551-017-3646-8

External collaborations

- Universitat Politecnica de Catalunya (UPC), Barcelona Tech., Spain
- Eindhoven University of Technology (TU/e), The Netherlands
- University of California, Los Angeles (UCLA)

Highlights of the research activity

The PhD research has a two-prong approach. One approach is to develop a complete understanding of the technical processes concerning with the CO2 capture from the flue gas of a coal fired power plant, the recovery of fly ashes produced by the combustion of coal, and the mineral carbonation process for the production and utilization of carbonated fly ashes used in the concrete industry. The capacity of the process understanding is in progress and it is built from the development of mathematical models dealing with the technological mechanisms and techno-economic analysis for CCUS systems currently flourishing in Europe and the U.S. The process modeling is founded on experimental data recently developed at UPC in Barcelona, Spain. The second approach addresses the identification of business opportunities for carbon capture technologies and carbon-based products that yield an attractive return on investment. Various opportunities that indicate a promising short to medium term commercialization have been identified. After further analysis it has been determined that a qualitative study will be utilized by adopting an exploratory comparative case study to develop a better perception of the enablers and barriers to technology commercialization of CCUS in the concrete industry. Initial steps for the business analysis have been taken by initiating the data collection process which includes: identifying, visiting, and interviewing key personnel at utility companies; universities and research centers; and construction companies. These entities dedicate resources to the R&D and the early commercialization of CCUS technologies.

Moving forward, the work will focus on the completion of the mathematical models, and finalizing data collection for purposes of processing and analyzing the information to develop a business analysis and ultimately a business model. The project will generate the following outcomes: (1)complete development of the modeling approach; (2) complete analysis of at least one case study related to the cement/concrete industry; (3) an overview of barriers and potential enablers of technology commercialization of environmental innovations.

Fig 1. Carbonation process at coal plant, transportation, and use of carbonated fly ash

First name: Alessandro **LAST NAME**: TANSINI

Topic: Energy consumption and CO_2 emissions from road vehicles

Course year: 2nd **Tutor(s)**: Prof. F. Millo

Academic context

[1] Tansini, A., Zacharof, N., Prado Rujas, I., Fontaras, G., "Analysis of VECTO data for Heavy-Duty Vehicles (HDV) CO2 emission targets", JRC Science for policy report, JRC Publications Repository, DOI 10.2760/551250, 2018
[2] Pavlovic, J., Tansini, A., Fontaras, G., Ciuffo, B. et al., "The Impact of WLTP on the Official Fuel Consumption and Electric Range of Plug-in Hybrid Electric Vehicles in Europe", SAE Technical Paper 2017-24-0133, 2017
[3] Arcidiacono, V., Tsiakmakis, S., Fontaras, G., Ciuffo, B. et al., "CO2MPAS: Vehicle simulator predicting NEDC CO2 emissions from WLTP", https://co2mpas.io

External collaborations

- European Commission's Joint Research Centre
- FEV Italia
- Hyundai Motor Europe

Highlights of the research activity

In recent years, simulation tools have been adopted in various regions of the world for the certification of gaseous emissions from road vehicles. During the 2nd year of my PhD I followed two main activities:
1. Analysis of VECTO data to support the proposal on CO_2 emissions standards for lorries
2. Experimental campaigns for the development of a simulation tool for hybrid electric vehicles

For the first topic the goal was to provide support to the European Commission with regards to the current Heavy-Duty Vehicles (HDVs) fuel efficiency considered in the CO_2 regulation, the impact of the different mission profiles and vehicle groups. For this purpose, the Joint Research Centre (JRC) was provided with VECTO (CO2 calculation tool for HDVs) simulation data from the manufacturers about the vehicles certified in year 2016. The data consisted mainly of the output from VECTO simulations, except some data that were not disclosed for confidentiality reasons, complemented with other vehicle characteristics (e.g. the cabin type that affects CdA) and information about the inputs (whether the input used to run the simulations were obtained according to the provisions of the HDV CO2 regulation or not). JRC developed a methodology that was used to understand the range of variation of specific energy losses (axle, gearbox, engine) and validate the data received by the manufacturer, or normalize them, in case of non-realistic figures produced by the use of default input values. The outcome of the exercise are reported in a JRC Science for policy report [4]. For the second topic, I have collected data about how energy is managed in hybrid powertrains, having the opportunity to test one full-hybrid and one plug-in hybrid. The campaigns required deep instrumentation of the vehicles and access to the vehicle communication line to derive information on the power split actuated between the ICE and the electric motor(s). The main goal was to derive the necessary data to define the ICE start/stop, the load point shift and the regenerative braking strategies. The data will support the development of a simulator for hybrid electric vehicles to be applied for potential regulatory purposes, which makes use of a generalized energy management strategy that is calibrated through experimental data.

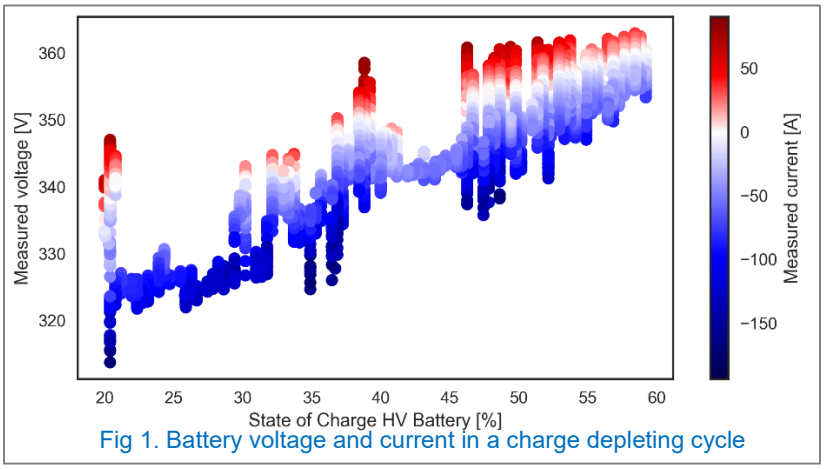


Fig 1. Battery voltage and current in a charge depleting cycle

First name: Anna Chiara **LAST NAME**: UGGENTI

Topic: Safety assessment of next generation nuclear systems

Course year: 3rd **Tutor(s)**: Prof. A. Carpignano, Prof. S. Dulla

Academic context

[1] GIF/RSWG, "An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear Systems", version 1.1 (2011)
[2] T. Pinna et al, Functional Failure Mode and Effect Analysis (FFMEA) for the DEMO cooling systems of the WCLL blanket model. Eurofusion report *EFDA_D_2JPQSG v1.0* (2015)
[3] E. Zio & N. Pedroni, Risk analysis – Uncertainty characterization in risk analysis for decision-making practice. Les cahiers de la sécurité industrielle (2012)

External collaborations

- European Project SAMOFAR (Horizon 2020)
- ENEA FUS (Frascati – Italy)
- LPSC/CNRS Grenoble

Highlights of the research activity

The current research activity in the nuclear field is focused on the development of nuclear facilities able to satisfy the current needs of safety, reliability and sustainability of energy sources. Safety assessment and risk analysis are recognized as a priority in the development of the next generation nuclear systems, whose innovative physics and technology and preliminary design stage demand a reconsideration of the safety philosophy currently applied to the existing nuclear stations.

In this framework, the European project SAMOFAR aims at furnishing the experimental proof of concept of the Molten Salt Fast Reactor (MSFR) and its safety assessment. For this purpose, the Integrated Safety Assessment Methodology (ISAM) has been selected and analysed as conceptual methodology, and a wide survey on risk analysis tools, international standards and best-practices have been performed, aiming at defining an operational procedure suiting MSFR analysis, including functional safety assessments. Well-established practices applying "Functional Safety" to conceptual systems do not exist; therefore a new method based on functional modelling has been proposed. This approach allows studying systems with a preliminary design, identifying functional deviations able to compromise safety, listing Postulated Initiating Events (PIEs) and recognizing lack of information, criticalities and necessity of supplementary provisions in the current design, with the aim of influencing the design from its earliest stages.

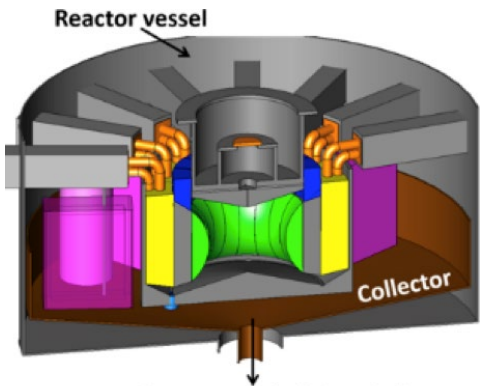


Fig 1. Schematic representation of the MSFR fuel circuit and cooling sectors

Successively, for selected accidental scenarios, the lines of defense method (LoD) has been applied to ensure that every accidental evolution of the reactor state is always prevented by a minimum set of homogenous (in number and quality) safety features before a situation with potentially unacceptable consequences might arise. The LoD helps to recognize the need of additional provisions to ensure the complete management of the accident or the importance of ensuring the availability of some existing components. In parallel, a critical evaluation of the nuclear safety assessment procedure has been carried on: the majority of current safety regulatory requirements is based on LWRs technology and necessitates changes to suit to a new spectrum of advanced nuclear plants that present a much larger range of risks variability (due different physical phenomena, plant responses associated with the reactor transients/accidents, use of different materials for the reactor fuel, moderator and coolant, etc.). Methodological and conceptual open points were identified: for example, the LWR risk metrics (core damage frequency –CDF- and large early release frequency –LERF-), do not suit many advanced nuclear reactors; as well concepts as physical barrier, the severe accident definition or the PSA role need to be reconsidered and represent important safety challenges for the acceptability of new generation plants.

First name: Blessing Onyeche **LAST NAME**: UGWOKE

Topic: Integrated Energy System Planning and Modelling for Nigeria

Course year: 1st **Tutor(s)**: Prof. S. Corgnati, Prof. P. Leone

Academic context

[1] Szabó S., Moner-Girona M., Kougias I., Bailis R., Bódis K. (2016) Identification of advantageous electricity generation options in sub-Saharan Africa integrating existing resources. NATURE ENERGY.
[2] Colombo E., Leone P., Taisch M., Cheli F.; Pinzone M.; Arrigoni A.; Chiasserini C.F, Boccardo P. (2017) Toward Smart and Integrated Infrastructure for Africa: An Agenda for Digitalization, Decarbonisation and Mobility Infrastructure Consortium for Africa. G7 INFRASTRUCTURE CONSORTIUM FOR AFRICA-BACKGROUND PAPER.
[3] Corgnati S.P., Fabrizio E., Filippi M., Monetti V. (2013) Reference buildings for cost optimal analysis: Method of definition and application. APPLIED ENERGY.

External collaborations

- Eni S.p.A
- Italian Ministry of Foreign Affairs and International Cooperation

Highlights of the research activity

The overall objective is to proffer a holistic, integrated and strategic energy system planning framework/ road map to better inform the decision making of stakeholders, policy makers and investors in the energy industry of Nigeria with focus on rural communities to achieve sustainable development. The methodology proposed for the bottom-up electrification of rural settlements entails locating, planning and operating standalone microgrids for rural applications in Nigeria, thus developing a unified framework/road map for rural electrification in Nigeria. The methodology comprises three broad categories from 1) rural community location and energy demand estimation through 2) scenario analysis and 3) energy system configuration to design and socio-economic impact of energy systems conceptualized.
At the end of the first year, research activities conducted have been mainly focused on the first and second broad categories of the methodology.
Firstly, by building upon the integrated low hanging fruit approach proposed by Szabo et.al. where the potential of existing energy infrastructure is analyzed and a significant
upfront investment has already been made, suitable locations were identified and selected.
Secondly, having identified the target locations, their potential for exploitation was then estimated using the methodology reported in IRENA, Mentis et al. and Gomez et al. Thirdly, robust and targeted energy demand estimation was carried out using the reference building approach which employs reference building models as characteristic and representative buildings in terms of functionality and geographic location of a building stock, including internal and external environmental condition.
Fourthly, the different customer segments which comprises adopters and imitators were evaluated, coupled with technology diffusion in the rural community through the identifying the topological characteristics of the prevalent social network of individual interactions with the accompanying social dynamics with the influence it exerts on the rapid spread and adoption of electricity from the installed off-grid in the selected localities.

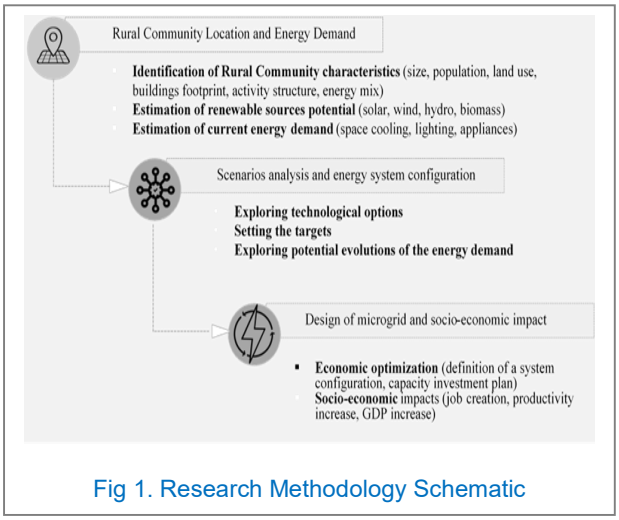


Fig 1. Research Methodology Schematic

First name: Oscar **LAST NAME**: VENTO

Topic: Fluid dynamics of internal combustion engines – Diesel injection systems

Course year: 1st **Tutor(s)**: Prof. A. Ferrari, Prof. A. Mittica

Academic context

[1] A. Ferrari, C. Novara, E. Paolucci, O. Vento, M. Violante, T. Zhang, A new closed-loop control of the injected mass for a full exploitation of digital and continuous injection-rate shaping, Energy Conversion and Management, Volume 177, 1 December 2018, Pages 629-639.
[2] A. Ferrari, C. Novara, E. Paolucci, O. Vento, M. Violante, T. Zhang, Design and rapid prototyping of a closed-loop control strategy of the injected mass for the reduction of CO2, combustion noise and pollutant emissions in diesel engines, Applied Energy, Volume 232, 15 December 2018, Pages 358-367.
[3] A. Ferrari, F. Paolicelli, P. Pizzo, Hydraulic performance comparison between the newly designed common feeding and standard common rail injection systems for diesel engines. ASME J. Eng. Gas Turbines Power, 138, p. 092801.

External collaborations

- Nanyue Fuel Injection Systems Co., Ltd.

Highlights of the research activity

During my first year of PhD activity, I worked in a Proof of Concept project about the design of a closed-loop control of the injected mass for diesel engines. The control was based on a measure of two pressure signals in the high-pressure pipe that connects the rail and the injector. Research work started with the hydraulic characterization of an injection system of Euro 6 diesel engines with the standard control strategy. The innovative closed loop strategy for the injected mass control has then been implemented in a rapid prototyping hardware, which included a flexible electronic control unit. The hydraulic characterization of the injection system has been repeated in the presence of the innovative control strategy. The developed control can significantly improve the injected mass accuracy for the different thermal regimes. The error in the actuated injected mass was found to be below 1 mg for all the working conditions and the sensitivity of the injection performance to fuel temperature was significantly reduced. Also for Pilot-Main injection, an improvement for all the dwell time range was appreciated, especially in the short one: in this case, with the standard strategy, the error can be beyond 10 mg; with the developed closed-loop, it could be reduced below 2 mg. Another activity in which I was involved was related to the hydraulic characterization of a new type of injection system, called "Common Feeding", featured by a strongly reduction of the rail accumulation volume. Nanyue Fuel Injection Systems Co., Ltd, one of the main diesel injection systems factory in China, has prepared some rails with different accumulation volumes and a pump with a small delivery volume where the injectors can be directly connected. Results of the hydrualic characterization leaded to say that, for a light duty vehicle, the no-rail configuration can keep the standard performance and so it could effectively be used. I am performing a comparing analysis about the frequency dependent friction in the high-pressure circuit of a Common Rail system. The main objective of my work is to understand when the unsteady friction is necessary to be considered in numerical simulations of 1D pipes and how much it can improve the results, furthermore I compare the results of the various methods by using home-made and commercial numerical tools.

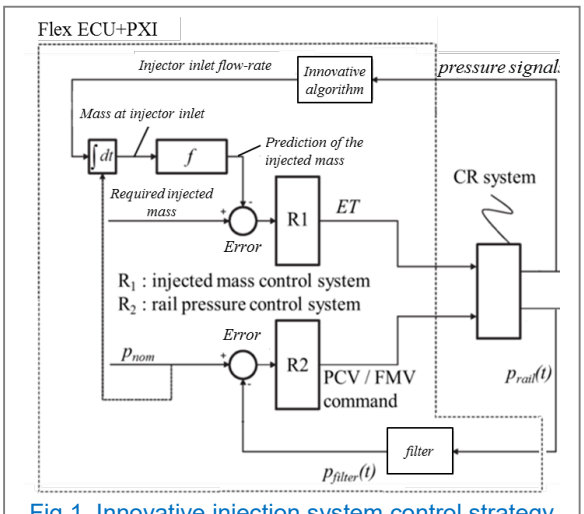


Fig 1. Innovative injection system control strategy

First name: Roberto **LAST NAME**: VITOLO

Topic: Reduction of fuel consumption and gaseous emissions from vehicles: implementation of non-conventional diesel combustion and development of an advanced central tire inflation system

Course year: 3rd **Tutor(s)**: Prof. S. D'Ambrosio

Academic context

[1] D'Ambrosio, S., Vitolo, R., "Potential impact of active tire pressure management on fuel consumption reduction in passenger vehicles", Proceedings of the IMechE, Part D: Journal of Automobile Engineering, Article in press, https://doi.org/10.1177/0954407018756776.
[2] D'Ambrosio, S., Mameli, E., Vitolo, R., Calaon, I., et al., "Fuel Consumption Reduction on Heavy-Duty and Light-Duty Commercial Vehicles through Advanced Central Tire Inflation Systems", SAE Technical Paper 2018-01-1334, 2018, https://doi.org/10.4271/2018-01-1334 (Accepted for publication on SAE International Journal of Commercial Vehicles).
[3] D'Ambrosio, S., Iemmolo, D., Mancarella, A., Vitolo, R., et al., "Performance and Emissions Comparison between a Conventional Euro VI Diesel Engine and an optimized PCCI Version", SAE Technical Paper 2018-01-0221, 2018, https://doi.org/10.4271/2018-01-0221.

External collaborations

- FPT Industrial (FPT Motorenforschung AG research center in Arbon)
- IVECO / CNH Industrial
- FCA – Balocco Proving Ground

Highlights of the research activity

The research project aims to develop two different technologies devoted to reduce toxic emissions and greenhouse gases emissions, from vehicles propelled by internal combustion engines, aiming at applying both of them on the same vehicle to demonstrate their combined effect. More in detail, the research project has involved the implementation of an advanced diesel combustion strategy aiming at a NOx-less and soot-less combustion, and the development of an automatic system for smart management of tire inflation pressure.
The former activity has shown the potentialities of premixed charge compression ignition (PCCI) combustion on the reduction of NOx and particulate, but also highlighted the weakness of this kind of combustion in terms of engine-out emissions of HC and CO and in terms of increased fuel consumption. The increase of HC and CO emissions could be effectively compensated by proper after-treatment devices, and the increase of fuel consumption can be partially neutralized by the reduced need for regeneration of the DPF. The study has been first performed by working on a standard on-market diesel engine, and later extended to an experimental version of the engine. Experimental figures related to fuel consumption and gaseous emissions from steady-state tests have been analyzed for both the engine configurations.
Additional benefits can be achieved with a reduction of the vehicle energy demand, e.g. through the abovementioned device for tire pressure management (ACTIS). A dedicated software tool has been developed to account for the effect of tire pressure on fuel economy. The system can reduce fuel consumption up to 1.55% on a reference annual mission for a light commercial vehicle, and up to 2.24% if the baseline case is a misused one. Additional benefits are the reduction of NOx, tire wear and non-exhaust particulate emissions. A preliminary design of the system for commercial vehicles has been developed. Experimental data from the test-bench activity on the PCCI project have been used to simulate the combined effect of the two technologies on a light-duty commercial vehicle.

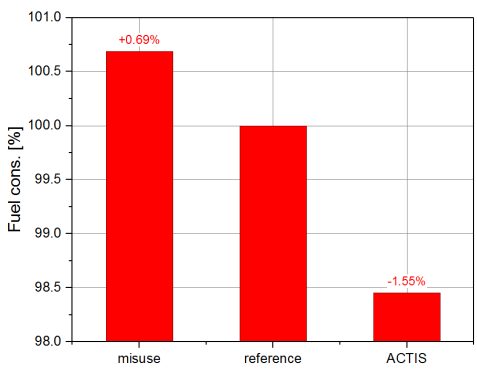
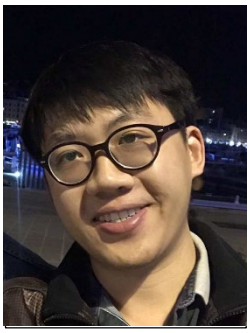


Fig 1. Effect of tire pressure management on the annual fuel consumption of a light commercial vehicle



First name: Haosheng **LAST NAME**: WU

Topic: SOLPS modelling for AUSDEX Upgrade L-mode detachment in presence of a High Field Side High Density region

Course year: 2nd **Tutor(s)**: Prof. F. Subba

Academic context

[1] [1] S. Potzel, et al., A new experimental classification of divertor detachment in ASDEX Upgrade, *Nuclear Fusion*, **54**(1): 013001(2013).
[2] L. Aho-Mantila, et al., Assessment of SOLPS5.0 divertor solutions with drifts and currents against L-mode experiments in ASDEX Upgrade and JET, *Plasma Physics and Controlled Fusion*, **59**(3): 035003 (2017).
[3] F. Reimold, et al., The high field side high density region in SOLPS-modeling of nitrogen-seeded H-modes in ASDEX Upgrade, *Nuclear Materials and Energy*, **12**: 193-199 (2017).

External collaborations

- Max Planck Institute for Plasma Physics, Garching
- ITER Organization

Highlights of the research activity

My research activity in the 2nd year focused on modeling the High Field Side High Density (HFSHD) region [1] in AUG L-mode detached plasmas. The HFSHD region is tightly contact with the neutral particle distribution, which is associated with recombination and ionization that affects the prediction/simulation of divertor target power load. SOLPS5.0 is the modelling code and mainly includes B2.5 fluid plasma solver and EIRENE Monte-Carlo neutral particle code. B2.5 is based on Braginskii equations and calculates the plasma parameters like density, velocity and temperature. Through coupling with EIRENE, which describes the neutral-ion reactions and provides particle and energy source for B2.5, SOLPS (B2.5-EIRENE) can simulate the edge plasma behavior. SOLPS5.0 modelling of AUG #21700 (t=2.7s) discharge has been finished. The fluid boundary conditions used for B2.5 are identified from experiments, like input power, the ion flux through the core boundary and sheath boundary conditions at the divertor targets etc. The input parameters related to EIRENE are from experiments and previous benchmark cases, like gas puffing rate, pumping rate and reactions types etc. At current state, the transport coefficients are from previous simulations [3]. The electron temperature and density profiles at outer midplane, the ion flux at outer targets, the electron density in the divertor volume are compared with experimental data to test the overall modelling setup. Drifts (ExB and diamagnetic) and currents play an important role in the distribution of plasma and detachment asymmetry. Thus, their effect on the formation of the HFSHD region is investigated through SOLPS5.0. They change the spatial plasma extent as well as the radial and poloidal gradients of the high field side high density.

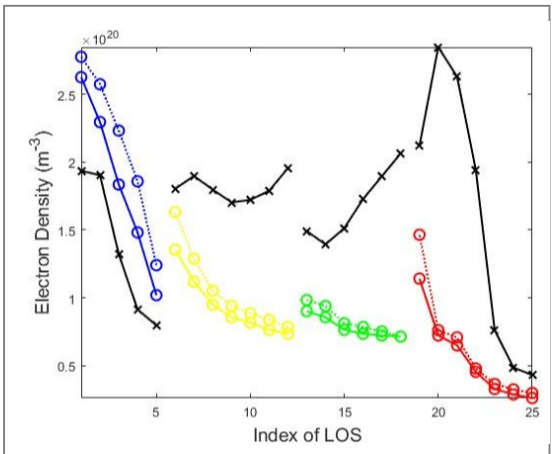


Fig 1. Divertor volumen n_e, color solid lines for drifts case, color dash lines for non-drift case, black lines are for experimental data.

First name: Alessandro **LAST NAME**: ZANELLI

Topic: Modeling and simulation of innovative electrified diesel propulsion architectures

Course year: 2nd **Tutor(s)**: Prof. F. MILLO

Academic context

[1] MILLO, F., ROLANDO, L., FUSO, R., MALLAMO, F., Real CO2 emissions benefits and end user's operating costs of a plug-in Hybrid Electric Vehicle, APPLIED ENERGY, vol. 114, pp. 563-571, http://dx.doi.org/10.1016/j.apenergy.2013.09.014
[2] MILLO, F., FERRARO, C.V., ROLANDO, L., Analysis of different control strategies for the simultaneous reduction of CO2 and NOx emissions of a diesel hybrid passenger car. In: INTERNATIONAL JOURNAL OF VEHICLE DESIGN, vol. 58 n. 2/3/4, pp. 427-448, ISSN 0143-3369, http://dx.doi.org/10.1504/IJVD.2012.047393
[3] MILLO, F., BADAMI, M., FERRARO, C.V., ROLANDO, L., Different Hybrid Powertrain Solutions for European Diesel passenger cars, SAE INTERNATIONAL JOURNAL OF ENGINES, vol. 2, pp. 493-504, ISSN 1946-3936, http://dx.doi.org/10.4271/2009-24-0064

External collaborations

- General Motors Global Propulsion Systems
- Gamma Technologies LLC, www.gtisoft.com
- Roechling Automotive Italia S.r.l., https://www.roechling.com/it/automotive/

Highlights of the research activity

Nowadays OEMs are facing the challenge of producing vehicles that meet more and more challenging fuel economy and emissions targets. Powertrain electrification may represent a viable technology to achieve those targets by using several hybrid architectures. Additionally computer-aided software tools to run simulated test of powertrains plays an important role in the optimization of fuel consumption, performance and reducing pollutant emissions. My research activities started with the development of a comprehensive vehicle and powertrain model with the aim to assess the potentialities of different diesel hybrid architectures.
The increased electric power available in a mild hybrid powertrains can be exploited by the introduction of electrified auxiliaries. This year I focused my attention on the impact of an electric charging device, a so-called electric supercharger (eSC) on the powertrain model. This component, installed in line with the series production turbocharging system, can be used effectively as supplementary charge device when necessary. A rule based control system has been defined for the eSC activation and proper regulation during driving cycles and vehicle acceleration manoeuvers with the aim to evaluate the impact of the eSC on vehicle performances. Additionally, the development of an innovative energy management methodology of the powertrain with the aim to control the eSC as well as the entire powertrain system on the basis of the Equivalent Consumption Minimization Technique (ECMS) has been proposed. This integrated powertrain and eSC energy management showed an impact on eSC activation and consequently on the electric energy provided to this electric auxiliary.

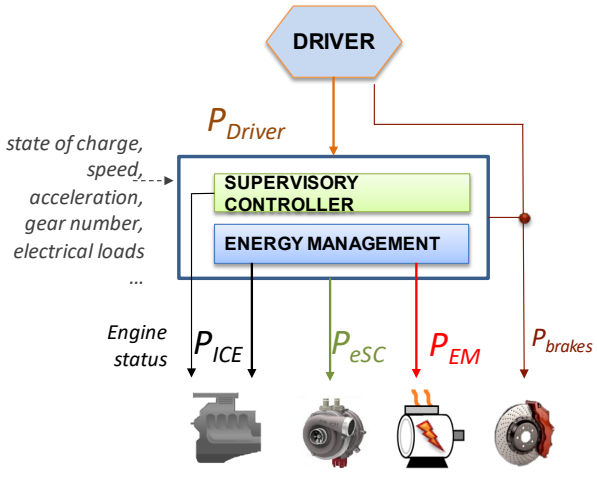


Fig. 1 Integrated eSC and powertrain ECMS control

First name: Andrea **LAST NAME**: ZAPPATORE

Topic: Modeling innovative HTS conductors for fusion applications

Course year: 1st **Tutor(s)**: Prof. L. Savoldi

Academic context

[1] Zappatore A, Heller R, Savoldi L and Zanino R 2017 Modelling of the test of the JT-60SA HTS current leads *Cryogenics* **85** 78-87
[2] Zappatore A, Heller R, Savoldi L and Zanino R 2018 Assessment of the performance of a 20 kA REBCO current lead *Cryogenics* **95** 95-101
[3] Wolf M J, Fietz W H, Bayer C M, Schlachter S I, Heller R and Weiss K P 2016 HTS CroCo: A Stacked HTS Conductor Optimized for High Currents and Long-Length Production *IEEE Trans. Appl. Supercond.* **26** 6400106

External collaborations

- Karlsruhe Institute of Technology (KIT)
- ENEA

Highlights of the research activity

During this first year of PhD, the predictive and interpretive model validation on HTS currents leads operation activity has been carried on from the work started during the Master thesis. The work, carried out in collaboration with the Karlsruhe Institute of Technology (KIT), aims at the improvement of the CURLEAD code for the thermal-hydraulic analysis of HTS CLs operation. The code has been developed several years ago at KIT and adopted for the design of various HTS CLs. However, for some designs, the agreement between the measured and computed results was not satisfactory. For this reason, additional components of the CL have been included in CURLEAD, leading to a good agreement between the measured and computed results [1], [2]. The validation has been carried out before and after the tests, i.e., predictively and interpretively.
During the last months, the development of a thermal-hydraulic model for HTS conductors has started, in collaboration with Karlsruhe Institute of Technology (KIT). The modeling activity is focused on a novel HTS conductor concept for future fusion magnets, based on the HTS CrossConductor (CroCo) idea [3].
A 2D thermal-model of the conductor cross-section developed in STAR-CCM+ was coupled with a 0D electrical model, in order to properly account for current redistribution during quench propagation, see Figure 1. The main outcome of this work was the qualitative assessment of the thermal response of the conductor undergoing different thermal disturbances. In case of slow transients, the temperature can be considered uniform on the cross-section, while in fast transients the temperature gradients within the conductor cross-section are not negligible.
In addition, a 2D electro-thermal model in the direction along the conductor was developed in the COMSOL Multiphysics environment. The aim was to investigate the relevant time-scales at the tape and stack level during the initiation and propagation of the quench. It was shown that during quench initiation the HTS stack can have very different temperature with respect to the surrounding copper, therefore the two solid regions, for each strand, must be considered separately.
The 1D simplified model needed to analyze thermal-hydraulic transients, in magnets designed with these kind of conductors, is under development.

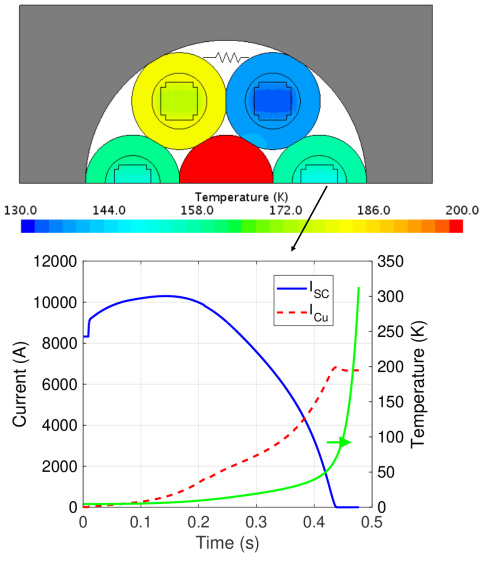


Fig 1. (top) Temperature map of during quench of the CroCo conductor and (bottom) current evolution in one of the HTS strands

First name: Tantan **LAST NAME**: ZHANG

Topic: Fluid dynamics of internal combustion engines – diesel injection systems

Course year: 2nd **Tutor(s)**: Prof. A. Ferrari

Academic context

[1] Ferrari A, Novara C, Paolucci E, Vento O, Violante M, Zhang T. Design and rapid prototyping of a closed-loop control strategy of the injected mass for the reduction of CO2, combustion noise and pollutant emissions in diesel engines. *Applied Energy*, 232, pp. 358-367.
[2] Ferrari A, Novara C, Paolucci E, Vento O, Violante M, Zhang T. A new closed-loop control of the injected mass for a full exploitation of digital and continuous injection-rate shaping. *Energy Conversion and Management*, 171, pp. 629-639.

External collaborations

- Nanyue Fuel Injection Systems Co., Ltd

Highlights of the research activity

The first research activity conducted by me has been to investigate the influence of the diesel Common-rail injector setup on digital and continuous injection rate shaping performance. In this activity, fluctuations in the injected quantity as the electrical dwell time is varied have been analyzed. Meanwhile, as the dwell time is reduced to values well within the injection fusion zone, the cycle-to-cycle dispersion of the injected mass again improves and this enables effective continuous injection rate shaping performance also for the solenoid injectors. In order to analyze the reasons behind this behavior, a 1D model of a solenoid fuel injection system has been established and validated. This model then has been applied to perform parametric analyses on the injector setup. Several key parameters have been changed in order to realize more efficient injection rate-shaping schedules. Two typologies of state-of-the-art injectors have been tested and the results have been analyzed; in particular, the connection between the mini-rail integrated in the injector with the injection rate phenomena in the short dwell time working zone has been deepened.
The second activity consists of a benchmark between Bosch and Zeuch method based flowmeters for the measurement of the fuel injection rate. During this study, the theoretical backgrounds of those two types of flowmeters have been analyzed. By applying those two typologies, injection rates under different working conditions have been tested and differences in the results have been found. Afterwards, by applying a Riemann, 1D numerical model of the hydraulic circuit of the flowmeter based on the Bosch method, it has been studied that the cause and the effect relationships between the features of the flowmeter hydraulic circuit and the possible alteration in the measured injected flowrate pattern.

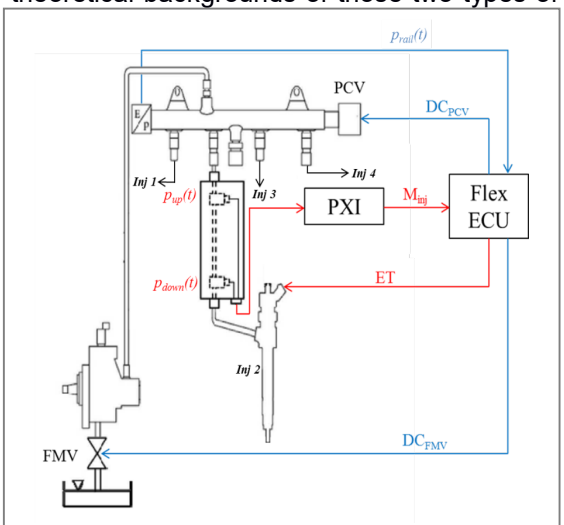


Fig 1. Experimental layout of the prototypal injection system

The last study carried out is related to a rapid prototyping hardware that is able to evaluate the effectively injected quantity of every injection. It was obtained by adding pressure sensors on the rail-to-injector pipe. Different methods have been tested. In a first technique, the fuel mass flow-rate along the rail-to-injector pipe can be obtained. Then a correlation between this pipe flow-rate and the injected flow-rate has been determined in order to be able to control the injector fueling. Another method is based on the time frequency analysis of the pipe pressure signals in order to find the corresponding time instants at which the injector needle opens and closes the nozzle. Once those instants have been determined, the injected quantity can be predicted. The prototyping hardware based on these theoretical backgrounds has been realized and the experimental results are satisfactory for single injections and pilot-main injections.