ENERGETICS PhD PROGRAM

2013 ANNUAL REPORT

Editors: L. Savoldi Richard and P. Asinari
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 2013. The 2011 and 2012 editions of the Annual Report can be downloaded from https://didattica.polito.it/pls/portal30/sviluppo.scudo_new.visual?p_id_cds=301&p_id_sez=103

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First name: Maurizio

LAST NAME: ANDREATA

Topic: Study of new aftertreatment systems for diesel engines

Course year: 2nd

Tutor(s): F. Millo, F. Mallamo

Academic context


External collaborations

- FEV Italia S.r.l.
- GM Powertrain Europe
- BMW

Highlights of the research activity

Modern diesel engines play a key role in the CO₂ emission reduction thanks to their high efficiency. From Euro 5, wall flow particulate filter is mandatorily required for all European passenger cars. Diesel Particulate Filter (DPF) requirements will increase in the next years both for the introduction of particle number limit, requiring a better filtration efficiency, and for the need of integration with NOx aftertreatment systems. One of the major challenges, in the development of diesel particulate filter, is to guarantee the component safety under all the operating conditions and, in particular, during uncontrolled regenerations that may occur during the component life. This has to be achieved without an excessive reduction of the maximum filter soot loading in order to avoid drawbacks on fuel consumption and oil dilution. On the other hand, a too high maximum soot loading, in addition to higher risks in case of uncontrolled regenerations, could lead to a buildup of an excessive backpressure with consequent drawbacks on fuel consumption. A complete experimental investigation of all these parameters would result in a huge effort of time and economic resources. A complete 1-D engine and DPF model was developed. The 1-D engine model allows to determine the influence of the back-pressure (related both to a soot loading increase both to construction parameters changes) on fuel consumption over a great variety of driving conditions. The 1-D 2-layer regeneration model, on the other hand, allows to determine the maximum temperatures reached inside the filter as a function of the soot loading under different regeneration conditions. The results of these two models provide all the information to define the maximum filter soot loading that lead to the best tradeoff between fuel consumption, component safety and oil dilution.

The model was calibrated and validated with a large number of experimental data. Moreover three different substrates materials (Silicon Carbide, Aluminum Titanate and Cordierite) were investigated in order to evaluate the influence of different physical and geometrical properties on back pressure and maximum soot loading.
First name: Andrea LAST NAME: BARBARINO

Topic: Mathematical models and numerical solutions for core calculations

Course year: 3rd Tutor(s): Prof. S. Dulla, Prof. P. Ravetto

Academic context


External collaborations
- AREVA NP (Paris La Défense) – Section PEPDDF
- Université Libre de Bruxelles (ULB) – Prof. E. H. Mund

Highlights of the research activity

The PhD activity during 2013 has pursued the investigation of several aspects of neutron transport modeling. As in 2011 and 2012, the focus of this concluding year has remained on the improvement of the space and angular description on the neutron flux in reactor cores by means of effective calculation algorithms. All the branches constituting this PhD work has been addressed in 2013. From the point of view of the analysis of the performances of the Spectral Element Method (SEM) in neutron transport, a comprehensive overview has been completed using the manufactured solutions approach, deriving tailored analytical transport solutions and testing 1D even parity solvers imposing the challenging sources producing them. This framework allows to isolate the effect of the treatment of space (concerned by the application of SEM) and the bias introduced by the approximations on the model (second order) and the angular discretization. The results show excellent performances of the SEM method when compared to classical schemes.

Considering the implementation of SEM for involved geometries, the scheme has been applied to a typical assembly cell comprising a fuel pin, its clad and the surrounding moderator. Results, which use a second order model according to the latest tendencies in industry (pin-by-pin by means of nodal codes) has been validated with reference analytical diffusive solutions, finite elements calculations and consolidated transport algorithms (method of long characteristics, collision probabilities) via the code package DRAGON. A simplified, Monte-Carlo utility (following an object oriented paradigm) has been developed for validation, too. Results, again, demonstrate the validity of the method even if calculation times and memory consumption remain a major concern.

Considering the implementation of the AN model in AREVA software suites, the work has been continued on two commercial chains. Verification has been successfully carried out. The difficulties related to the fixed library format and the explicit reflector models have been only partially overcome.

Last, the studies of the ray effects have continued on the field of the time dependent problems, highlighting analytically the nature of space and time rays in $S_N$ type calculations.

Relative difference between diffusion and $A_2$ thermal flux values in a typical PWR commercial fuel pattern.
First name: Elisabetta
LAST NAME: BOELLA

Topic: Ion acceleration driven by intense laser pulse

Course year: 4th Tutor(s): G. Coppa and L.O. Silva

Academic context

External collaborations
• Instituto Superior Técnico (Lisbon, Portugal)

Highlights of the research activity

Ion acceleration driven by super-intense laser pulse is important field of research attracting an increasing effort. Motivations are to be found in the great applicative potential and in the perspective of investigating new physical regimes. Depending on the laser and target parameters, different physical phenomena are present. My work mainly focuses on Ion Shockwave Acceleration (ISWA) and on Coulomb Explosion (CE).

Ion Shockwave Acceleration
Recent experiments demonstrate the possibility to drive electrostatic shockwave in near critical plasmas. Such shocks are able to accelerate efficiently ions to energies suitable for medical applications [1]. To understand the physical mechanisms leading to shock formation and ion acceleration, one- and two-dimensional numerical simulations have been performed, using the shell code, a reduced electrostatic model, and OSIRIS, a state-of-the-art particle-in-cell code. A set of favorable plasma conditions, such as density and temperature, has been defined. A detailed study for the target has been performed, considering exponentially tailored and multilayer targets: optimal decaying length, ideal target size and number of layers have been individuated in order to reduce the energy spread of the beam and increment its charge. Moreover, the role of the laser has been investigated, analyzing the effects of the polarization and of a finite spot-size.

Coulomb explosion
The interaction of intense lasers with clusters, containing tens to thousands of atoms or molecules, can lead to the formation of completely ionized nanoplasmas that rapidly expand into vacuum [2]. In extreme situations, the laser field can be so powerful that all the electrons are immediately swept away, causing the explosion of the pure-ion cluster. Moreover, the presence of initial ion density disuniformities can produce shock shells that cause infinite compression of a finite amount of charge [3]. For the first time, we studied the dynamics of these phenomena with one-to-one three-dimensional calculations (as in a molecular-dynamics simulations). Results obtained from ensemble averages of the solution over a large number of different initial conditions have been compared with reference solutions for the Vlasov equation. We showed that collisionless kinetic theory, which is usually employed to study these phenomena, is not always the correct choice. In particular, while in the case of pure CE, even when the number of ions is small, kinetic theory provides the correct results, in the case of shock shell formation, the effect of two-body correlations has to be taken into account.

1 In collaboration with F. Fiuza, A. Stockem, R. Fonseca
2 In collaboration with A. D’Angola
First name: Roberto

LAST NAME: BONIFETTO

Topic: Computational modeling for nuclear fusion and fission applications

Course year: 3rd

Tutor(s): S. DULLA, L. SAVOLDI

Academic context


External collaborations

- CEA – Cadarache (France)
- Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), Hefei (P.R. China)
- ENEA – Brasimone (Italy)

Highlights of the research activity

Two computational tools developed at Politecnico di Torino and having a common structure are used to model components for nuclear fusion and fission devices.

Fusion applications: modeling of superconducting cables cooled by supercritical helium with the 4C code [1].

- First verification of the predictive capabilities of the 4C code cryogenic circuit module against experiments performed at HELIOS facility (CEA-Grenoble, France).
- Application of the 4C code to the assessment and mitigation of the ITER Toroidal Field Coils temperature margin reduction due to the enhanced nuclear radiation, including a sensitivity analysis on the thermal conductivity of the casing ground insulation (see Fig.1).
- Investigation of the thermal-hydraulic effects of the AC losses in the EAST Central Solenoid (CS) coil and assessment of the time constant of the strands coupling losses with the 4C code.
- Development of a simplified tool based on Artificial Neural Networks (ANN) for the assessment of the interaction between the magnets and the cryoplant in a tokamak, following the strategy adopted in [2].
  - First application and verification of the ANN capabilities using the 4C model of the HELIOS facility for the training/test runs.
  - Application to the ITER CS magnet and cooling system, modeled with the 4C code.


- Further development of the NE module to reach the full 3D transient capability:
  - Extension of the coarse mesh nodalization of the core in the 3rd dimension (axial direction);
  - Implementation of the theta method for the transient calculation.
- Benchmark of the TH module against RELAP5-3D simulation on a simplified EBR-II geometry [3] to assess the model of the thermal coupling between the hexagonal assemblies.
External collaborations
- SWARCO MIZAR S.p.A. (Apprenticeship PhD)

Highlights of the research activity
Monitoring traffic flows on road infrastructures has increasingly become a more common practice. Diverse types of sensors and devices to count and classify vehicles have been tested and installed on European roads in recent years, contributing to the growing availability of several databases. Moreover, methodologies to assess energy consumption for transport and the consequent emissions require several data sets, which are not always available. Consequently, it is an interesting endeavor to investigate an approach that can model energy dissipation, beginning from fundamental mechanical rules and traffic monitoring data and related parameters. In addition to this, the presence of ITS can have a positive influence on traffic flows.

Starting from these assumptions, this research studies different scenarios based on actual and simulated data to estimate energy used in vehicular flow and how the energy consumed can change when the vehicular flow changes due to the influence of an ITS application. The approach presented in this study accounts uses both a mechanical model, and a traffic micro-simulation approach; both cases begin from the measurement of traffic flow parameters.

Differently from other studies the specific objective of this research, taking into account the apprenticeship framework, is to provide a tool for on-line energy consumption estimation, with a superior usability rather than extremely detailed models, and with direct advantages for on-field applications. From the analysis carried out in 2013, it is evident that an ITS-adjusted model has an accuracy that can be comparable with microscopic models, respecting the general approach of this work. In regards to the impact of ITS control, the reduction of energy consumption is considerable, particularly when considering a long period, even when accounting for standard motorway traffic.

Figure 1. Modelling and validation approach

[Diagram of modelling and validation approach]
First name: Silvia  
LAST NAME: CAMMARANO  

Topic: Daylighting design for energy saving in a building global energy simulation context  
Course year: 3rd  
Tutor(s): Chiara Aghemo, Anna Pellegrino  

Academic context  

External collaborations  
Bartenbach LichtLabor, Research&Development team, Aldrans/Tyrol, Innsbruck (AUT).  
References: Wilfried Pohl (wilfried.pohl@bartenbach.com)  
Robert Weitlaner (robert.weitlaner@bartenbach.com)  
David Geisler-Moroder (david.geisler-moroder@bartenbach.com)  

Highlights of the research activity  
In the field of lighting, a key factor to substantially reduce the energy consumption for electric lighting consists in a more widespread exploitation of daylight, associated with the use of the most energy efficient lighting technologies, including LEDs or electric lighting controls, in accordance with an increased and more conscious implementation of the building automation principles. Besides direct savings due to the exploitation of daylight, it has to be noted that an appropriate daylighting design approach can influence the global energy performance of a building as well as the interior visual and thermal comfort for the occupants. For this reason, it’s always necessary to account for the balance between daylighting benefits and energy requirements (control of solar gains). Within this frame the research activity has been focusing on three main aspects:  
- Analyzing limits and potentials of the current daylighting design practice and proposing synthetic information and tools to be used by the design team during the earliest design stage to predict the daylight condition within a space.  
- Analyzing the effect of a proper daylighting design on the energy requirement for electric lighting, associating with the use of efficient lighting technologies and control systems.  
- Assessing the influence of the energy demand for electric lighting on the global energy performance.  
The approach that was adopted relies on a parametric study. The global energy performance of several rooms’ settings was analyzed by first estimating, through simulations, the indoor daylight availability and the related energy demand for electric lighting and then using the latter as inputs for the calculation of the energy requirements for heating and cooling.
First name: Giulio LAST NAME: CERINO ABDIN

Topic: Local planning of biomass-to-energy systems

Course year: 2nd Tutor(s): Alberto Poggio

Academic context

External collaborations
- ENEA UTTS SALUGGIA
- CNR Ivalsa
- REGIONE PIEMONTE & IPLA

Highlights of the research activity

The use of biomass for energy production is becoming a key factor in order to reach the EU targets of 20% of energy from renewable sources by 2020. The use of wood biomass in residential applications has a significant share in some Italian regions, especially in rural areas. Nevertheless, an accurate estimation of the amount of biomass used for these purposes is not always available and it is not easy to undertake.

In the framework of the performed PhD activity, a new methodology to overcome this lack has been defined and applied.

The importance of the methodology in the planning activity is crucial, due to the need of a detailed database in order to proceed with the supply vs demand comparison activity.

Based on similar studies conducted in Politecnico di Torino (G.V. Fracastoro – M. Serraino 2011) a new methodology has been defined. Thanks to the availability of the detailed Piedmont Region census data has been possible to estimate the residential thermal energy needs. The availability of more detailed data has permitted to ride out some complexity of previous analysis.

The methodology has been defined in order to evaluate the demand of biomass of residential sector. The analysis has been completed with the industrial sector census performed during the first year of research activity.

First results have been obtained for the Province of Turin and Cuneo (Piedmont Region, Italy) for the year 2011. The energy from biomass supplied for residential heating purposes is approximately 241 kTOE. The amount of energy produced represents 21% of the total residential thermal energy needs (1,171 kTOE) for the considered area. The amount of biomass consumption related to the energy supplied to the residential sector is equal to 427 kTOE.

The study will be completed by the analysis of different biomass-to-energy pathways. According to the LCA (Life Cycle Assessment) methodology, the evaluation of the sustainability of the local biomass to energy supply chains will be carried out. Currently the study is focused on the LCI (Life Cycle Inventory) phase, collecting data from local forestry sites.
First name: Davide

LAST NAME: DRAGO

Topic: Design, development and testing of SOFC short-stacks with special heat pipes plates integrated with H$_2$ sources

Course year: 1$^{st}$

Tutor(s): Massimo Santarelli

Academic context


External collaborations

- FN Spa
- CNRS – CRETA
- DATE SA

Highlights of the research activity

The main activities were focused on the definition of the ‘ENERGY-BOX’, that is its design and modeling. With the term ‘ENERGY-BOX’ it was intended the system composed by an SOFC stack, heat pipes plates and an H$_2$ source (e.g., a tank containing metal hydrides).

The design activity was conducted with the aim to realize a geometry that could be elegant and functional at the same time. The structure was thought in order to respect the fundamental constraints for the correct operation of the stack.

The preliminary system modeling permitted to identify the optimal configuration of the ‘ENERGY-BOX’ (see the figure below). In particular were evaluated different design configurations in terms of electrical efficiency and thermal balance (i.e., the surplus heat generated from the SOFC stack and extracted with heat pipes plates has to be at least equal to the heat needed to desorb the hydrogen from the metal hydrides) starting from some assumptions made “a priori”.

![Figure. 'ENERGY-BOX' layout at low current density without the after-burner and with H$_2$ recycle.](image)

Another relevant activity still in progress consists in a legislative research about the actual European and international situation in terms of RC&S (Regulations, Codes and Standards) referring to household applications for fuel cells appliances. This study is included in an European project called “Ene.field” whose aim is to promote the cogeneration technology across the Europe through both trial tests and active presence in the creation of a better regulatory framework.
First name: Matteo  
LAST NAME: FASANO

Topic: Mass and heat transfer in nanoconstructs for biomedical and energy applications

Course year: 2nd  
Tutor(s): Pietro Asinari, Eliodoro Chiavazzo

Academic context

External collaborations
- Paolo Decuzzi, Department of Translational Imaging, HMRI, Houston (TX, USA)
- Fernando Bresme, Department of Chemistry, Imperial College, London (UK)
- Evelyn Wang, Mechanical Engineering Department, MIT, Cambridge (MA, USA)

Highlights of the research activity

A better physical understanding of mass and heat transfer at the nanoscale is essential for the rational design of novel nanoconstructs for biomedical (e.g. nanoparticles for targeted imaging or therapy) as well as for energy (e.g. thermal batteries) applications. Both nanoscale transfer phenomena are strongly influenced by solid-liquid nonbonded interactions occurring at the interface.

First, classical Molecular Dynamics (MD) is used for investigating water transport in the proximity of several nanosized solid surfaces (i.e. within nanopores or around nanoparticles, nanotubes and proteins), according to different surface functionalizations (i.e. hydrophobic/hydrophilic) and physical conditions. Results (Fig. 1) show that the self-diffusion coefficient $D$ of water in nanoconfined geometries is reduced respect to bulk conditions. $D$ is primarily influenced by geometrical features and scales with a parameter $\theta$, representing the ratio between the volume of confined water, which is defined by the solvent accessible surface and a characteristic length of confinement $\delta$ depending on surface chemistry, and the total one. The $D(\theta)$ relationship is then interpreted using a random walk approach combined with thermodynamic estimates of transition probabilities. The $D(\theta)$ scaling law can be applied, for example, for a more systematic design of novel contrast agents for MRI, where a $D$ reduction implies a better image contrast.

Second, water diffusion in nanoconstructs also play a role in ruling the solid-liquid nanoscale heat transfer, where modeling guidelines are needed for optimizing the design of nanofluids for thermal therapies or heat transport in thermal batteries. As a matter of fact, the bottleneck in nanoscale phononic heat conduction is the thermal boundary resistance, which defines the thermal impedance between different materials. Hence, non-equilibrium MD simulations are used to model heat transfer at solid-liquid interface and to predict the characteristic thermal boundary resistance, according to different surface functionalizations (i.e. bonded/ nonbonded, hydrophilic/hydrophobic coatings) or solvent conditions (i.e. confinement, thermodynamic state).

Finally, MD is applied for studying thermal properties of large networks of carbon nanoparticles, which may have a critical impact in novel more compact and efficient thermal storage systems. Several configurations consisting of sole and pairs of carbon nanotubes characterized by different geometries and number of C-O-C bonded interlinks, are considered. Results show that CNTs with short overlap length and a few bonded interlinks already present a remarkable enhancement in the overall transmittance of the nanoconstructs, which also prove the importance of solid-solid interface for optimizing heat transfer at the nanoscale.
First name: Domenico          LAST NAME: FERRERO

Topic: Design, development and testing of SOEC-based power-to-gas systems for conversion and storage of RES into synthetic methane

Course year: 1st              Tutor(s): Prof. M. Santarelli

Academic context

External collaborations
- Risø-DTU laboratories
- Delft University of Technology

Highlights of the research activity
The research activity is focused on the design and testing of a SOEC-based Power-to-Gas system. To achieve this goal, the activities have been structured in experimental and modeling. The objective of the initial part of the research is the study of the performance of Solid Oxide Electrolysis Cells in stationary and dynamic conditions and the modeling at cell level, before the development of stack models for system design and analysis.

SOC testing: current-voltage characteristics and impedance spectra have been measured in reversible single-cell SOFC/SOEC operations with H₂/H₂O and CO/CO₂ mixtures and for different electrode materials. Galvanostatic and fast dynamic long-term tests have been performed on single-cells in SOEC mode to investigate degradation. Dynamic testing is the first step in the study of SOEC systems for Power-to-Gas applications integrated in networks with high penetration of Renewable Energy Sources. Tests with real renewable-based load profiles will be performed. The effect of pollutants (H₂S) on SOEC operations has also been assessed.

Electrochemical single-cell modeling: a 1-D full-cell electrochemical model has been developed and validated on the experimental data collected in SOC testing. The model simulates current-voltage characteristics of a cell in SOFC/SOEC operations taking into account the electrochemical processes occurring at the electrodes together with the mass transport of gaseous species. The model identifies kinetic parameters and relates them to electrode materials and reactions. The results of the model are consistent with experimental values reported in literature in single electrode and full-cell studies. The application of the model as a diagnostic tool to support experimental cell characterization has been proposed.

Thermal modeling: a 2D FEM full-cell thermal model has been developed. Simulation of the temperature distribution inside a cell has been performed using the coupled thermal and electrochemical models.
First name: Rocco  
LAST NAME: FUSO

Topic: Development of innovative control strategies for hybrid powertrains

Course year: 1st  
Tutor(s): Prof. F.Millo & Ing. M.Cisternino

Academic context

External collaborations
- General Motors-Powertrain Europe

Highlights of the research activity
The Sailing Mode allows the best exploitation of the kinetic energy of the car. By enabling such a feature the clutch is automatically disengaged, so the car can move forward by inertia, decreasing fuel consumption due to the engine switch-off. The advantage in terms of fuel consumption comes from the use of the kinetic energy of the car in order to overcome the rolling and aerodynamic resistances. If the driver request, made through the accelerator or brake pedal, results to be different from the ‘natural’ vehicle deceleration, the clutch is engaged immediately to take advantage of engine contribution. The efficiency of this feature depends on the driving style.

The increasing hardware and software complexity (IN/OUT from the mode cannot be properly managed by the driver) makes more convenient this technology on an hybrid powertrain. Usually these powertrain architectures are already equipped with a proper hardware to remotely disengage the conventional internal combustion engine. Moreover the presence of a second source of power (for example an electric motor) allows additional features able to assist the sailing, for example a smooth engine restart.

In the framework of a continuous improvement of the fuel economy, the main car manufacturers are actually investigating the base logic of this functionality.

During this first PhD year a specific system controller has been developed in order to extent as much as possible the sailing events on the next generation driving cycle, the WLTP (Worldwide harmonized Light vehicles Test Procedures). The controller performance have been evaluated in the UnifiedModel environment, a Simulink-based system simulator developed by GM.

In order to prevent the lack of perceived safety by the driver, the introduction of new S&S technology as sailing requires ad hoc calibration, vehicle by vehicle. Calibration is important in order to prevent too frequent entry into sailing, because such a behavior results in different decelerating responses as well as fast worsening of the driveline components.

For this reason, once the model was developed all the key parameters have been tuned for a specific target vehicle. The analysis were performed via DoE methodology.
First name: Elisa                 LAST NAME: GUELPA

Topic: Modeling strategies toward multiple scenario applications and fast simulations: Application for fire safety engineering

Course year: 1st Year              Tutors: V. Verda, R. Borchiellini, A. Sciacovelli

Academic context
[2] Janice L. Coen et al., WRF-Fire: Coupled Weather-Wildland Fire Modeling with the weather Research and Forecasting Model
[3] A. Stepanov, J. M.G.Smith, Modeling wildfire propagation with Delaunay triangulation and shortest path algorithms

External collaborations
- Università degli Studi di Torino
- Selex Galileo
- Elbit

Highlights of the research activity

Reducing of computational cost is often necessary in the engineering sector in order to model topologically complex systems, perform sensitivity analysis and for real time modeling. The PhD work is focused on low computational time methods for treatment of complex domain systems, in particular wildland fire modeling and experimental analysis. The first part of the research activity developed in the 1st PhD year concerns a literature review of wildfire. In particular the available models for the simulation of wildland fires behavior have been reviewed and compared in term of type of input data, level of details, accuracy of results and computational cost. A major issue is poor accuracy associated to computationally cheap models, while physical-based models do not allows one to compute large domain in reasonable time. This aspect will be tackled during the following PhD years. In particular possible hybrid models will be investigated.

WildFire Dynamic Simulator (WFDS), the most common physical-based software, elaborated at the NITS, has been used in order to model simple fire propagation problems. Some reduction order methods useful for treating complex domains have been investigated including multi-scale models and proper orthogonal decomposition. A complex network model often necessary for multi-scale approach has been built and tested [1]. A multi-scale model has been used in order to analyze an advection-diffusion problem [2]. Furthermore entropy generation analysis, which can be used in order to find preferential propagation paths of ignited fires, has been conducted. An application to a transient problem has been conducted to test this approach [3].

First name: Arash        LAST NAME: HADADIAN

Topic: Energy losses and efficiency of electrical-based apparatuses

Course year: 1st        Tutor(s): Prof. M. Chiampi, Dr. M. Zucca

Academic context

External collaborations
   • (INRIM Electromagnetism Dep., Electromagnetics engineering)

Highlights of the research activity

Devices devoted to energy harvesting and based on magnetostrictive materials have been the object of my recent studies. Indeed magnetostriction is a property shown by every ferromagnetic material. It consists in a dimensional variation induced by a external magnetic field, which change the material magnetization. In the other words when a time variant stress is applied to a magnetostrictive material, this latter reacts changing consequently its magnetic permeability which is so called “Villari effect”. As result the Villari effect can be exploited for energy harvesting applications and for damping. In a long and thin material sample, where a magnetic field variation and thus the magnetization change happens axially, the maximum relative variation in length induced in the sample is called saturation magnetostriction \( \lambda_s \). Alloys based on iron and rare earths like Dysprosium and Terbium, or doped with Gallium, or FeSiB alloys, exhibit a large magnetostrictive effect and are able to exert high mechanical actions induced by the magnetization change. For deeply studying this phenomena and to investigate of the parameters influencing the performance of the vibrational energy harvester tow setups have been made and developed in INRIM. In the setups some special parameters should be considered, measured or estimated: static preload to the active material; dynamic vibrational force acting on the magnetoelastic material and the velocity close to the measurement point; electrical power on the electrical load; device performance and efficiency. My contributions in the first setup are as follow: data acquisition and elaboration; use of the Preisach FEM-MM code to simulate the results starting for the measured time profile of the force excitation; comparison between measurements and simulations. As a result one extended abstract was prepared for next Intermag Conference May 2014, Dresden, Germany. In the second setup the performance and behavior of the strip amorphous material are investigated. My collaboration in the second one are as follow: helping to install the setup, collaboration to making the measurement, use of the Preisach FEM-MM code to simulate the results starting for the measured time profile of the force excitation; comparison between measurements and simulations. A second abstract concerning this latter activity is under preparation.
First name: Imran  LAST NAME: KHAN.

Topic: Fault Detection Analysis in Building Energy Systems through Data Mining Techniques

Course year: 2\textsuperscript{nd}  Tutor(s): Prof. S. Corgnati, Ing. A. Capozzoli

Academic context

External collaborations
- Telecom Italia
- ENEA Italy

Highlights of the research activity

The field of fault detection and diagnosis (FDD) applied to building energy performance is relatively new compared to other applications. FDD involves two steps: detecting a fault, then isolating and diagnosing it. In FDD two types of modeling approaches, forward (classical) and data driven (inverse) are used and their application depends on the availability of data and the purpose of the investigation. This research based on empirical data driven approach using data mining techniques applied on hourly and sub hourly consumption data of whole building energy systems. Starting from first year work, the research plan consists of following activities:

i) Data Cleaning i.e. missing data, sensor and input errors; ii) Data Sampling- case selection conditions; iii) Independent Variables screening/selection by analyzing different variables i.e. temperature, solar radiation, working hours, people presence, etc. using sensitivity analysis to check their significance on energy consumption; iv) Analyzing energy consumption patterns for under study buildings using different data mining techniques along with outliers’ detection methods to detect abnormal consumption and identify potential savings. Pattern recognition techniques are used to find structures in data set and are advantageous in finding anomalies in data if applied properly. In brief the following tasks have been completed during this year research;

a) An article has been published in Energy Procedia, volume 42, in which we applied three different data mining techniques on real building energy data for fault detection.

b) We also published a report for ENEA, Italy, which was the continuation of our work of previous year.

c) We have proposed an innovative integrated approach for fault detection and an abstract of that study has been submitted for a conference. We are also working on energy certification data and investigating the applicability and effectiveness of other data mining methods for fault detection and energy optimization.
First name: Sabino
LAST NAME: LUISI

Topic: Numerical characterization of Knocking Sensitivity in VVA Gasoline Engines

Course year: 3rd
Tutor: Federico Millo

Academic context

External collaborations
- CRF (Fiat Research Center)

Highlights of the research activity
The PhD activity of the third year has been focused on the experimental investigation of compression ratio modularity under knock limited conditions: such a modulation was obtained through a proper intake valve timing.

The analysis was performed on two different turbocharged 1.4 liter VVA (Variable Valve Actuation) [1] gasoline engines with 4 in-line cylinders and 16 valves.

The innovative layout of the induction system allows to vary continuously the effective compression ratio in order to enhance the knocking resistance and consequently the fuel conversion efficiency. It includes the possibility to introduce EGR (Exhaust Gas Recirculation) and also modulate the engine displacement using two or three cylinders so as to maximize the fuel conversion efficiency. This particular flexibility is exclusive of MultiAir system, patented by FIAT, and represents a new challenge in the emission reduction of gasoline engines. Its characterization was carried out during the first and the second year of PhD.

The first step of such an investigation was the characterization of the knocking sensitivity as a function of the effective compression ratio. The experimental activity was conducted on two engines, one PFI (Port Fuel Injection) and one GDI (Gasoline Direct Injection) in order to assess the effect of the in-cylinder direct injection on knocking occurrence. The full load curve and different load sections at constant speed were chosen to study the phenomenon. At high engine loads the knock mitigation was obtained delaying the closure of the intake valves and thus realizing a controllable Miller cycle with a reduced compression ratio. In the tested cases the thermal efficiency was increased of 10% at part load and 15% in full rated power. After the experimental optimization of the compression ratio a Knocking zero dimensional model was implemented. The knocking model is based on the evaluation of the autoignition time as a function of the in-cylinder temperature and pressure [3]. The only calibration variable is the polytropic coefficient of the unburned mixture: it was found that this coefficient depends mainly on the engine speed. The results show good agreement with the combustion process featuring a new methodology to evaluate the combustion behaviour of VVA gasoline engines with different compression ratios.
First name: Marco

LAST NAME: MARCHETTI

Topic: Development of Transport Methods for Multiphysics Simulation:
SIMMER/PARTISN and SIMMER/VARIANT coupling

Course year: 2nd

Tutor(s): S. Dulla

Academic context

External collaborations
- Karlsruhe Institute of Technology (KIT)

Highlights of the research activity
The research activity deals with the solution of the neutron transport equation. Two main threads can be identified:
- Static transport – Variational Nodal Method (VNM) with heterogeneous nodes
- Time dependent transport - Coupling fluid-dynamics and neutronic codes
  - Coupling SIMMER code and PARTISN code
  - Coupling SIMMER code and VARIANT code

The VNM has been extended to include the treatment of heterogeneities in each direction (i.e. XYZ) and implemented in the VARIANT module, included in the SIMMER code. The two main areas of application of this technique are:
- Modeling small-scale heterogeneities
- Using very big nodes in low-importance regions

With respect to the first, the method has been applied to a typical 17x17 PWR fuel assembly. Here the heterogeneities appear on a small scale, with the radius of each fuel pin being as small as 0.5 cm. We found that the multiplication coefficient k-eff is effectively predicted. As a second area of application, we considered the possibility to reduce the number of nodes in a computation by using big nodes that straddle different materials, e.g. steel reflectors in the periphery of the reactor. This method allows to achieve a reasonable accuracy and to reproduce the flux behavior within each heterogeneous node rather well.

The second part of the research work has been focused on time-dependent problems. The SIMMER code is a coupled fluid-dynamics/neutronics code, where the fluid-dynamic module is parallelized, while the neutronic module is not. Therefore, it has been proposed to couple the thermal-hydraulic module of SIMMER with the PARTISN code, a parallel $S_n$ code, with the aim to establish a SIMMER version with a parallel neutron kinetic module. We tested that version in some cases, finding good agreement with the standard SIMMER code. The reduction of computational time can be as high as 30%. The coupling between SIMMER and VARIANT can also be considered as an alternative to other $S_n$ codes. The main problem is that VARIANT code is rather slow in some situations, however we can benefit from the heterogeneous version of VARIANT we developed (see above) to speed-up the computations by reducing the number of nodes.

Fig1. Reactivity for a FR ULOF transient, comparison SIMMER with SIMMER/PARTISN
At present, some calculations are performed with the neutronic module ECCO as a basis for the new estimation, whose safety implications are obvious, must be solved by introducing SIMMER, as verified in the international benchmark on Phenix CR withdrawal tests [3]. This incorrect heterogeneity effect [2].

The work is preparatory for the second and more central part of the research activity, which deals with the performance analysis. The correction has been validated using both the Molten Salt Reactor and Phenix designs, and the correction set is profitable also from the result precision point of view.

The result of the work done in 2013 is a correction to the SIMMER code that will perform a part of the cross-section collapsing inside the calculation itself, therefore decoupling the energy structures of the libraries and of the transport code. In this way, libraries with much higher number of groups can be provided without hindering performance and at least part of the collapsing is performed with consideration of the real geometry of the problem under exam. Hence, the correction set is profitable also from the result precision point of view.

The correction has been validated using both the Molten Salt Reactor and Phenix designs, and the performance analysis demonstrated a 30% reduction of the computational time with a \( k_{\text{eff}} \) discrepancy from the reference smaller than 10 pcm.

The work is preparatory for the second and more central part of the research activity, which deals with the heterogeneity effect [2]. The latter causes an overestimation of the control rod (CR) weight calculated by SIMMER, as verified in the international benchmark on Phenix CR withdrawal tests [3]. This incorrect estimation, whose safety implications are obvious, must be solved by introducing a correction technique.

At present, some calculations are performed with the neutronic module ECCO as a basis for the new technique development.
First name: Grazia
LAST NAME: MONNI

Topic: Special Instrumentation for Two-Phase Flow
Course year: 3rd Tutor(s): Prof Bruno Panella, Prof. Mario De Salve

Academic context

External collaborations
- SIET S.p.A.

Highlights of the research activity
The design of nuclear reactors requires to carry out integral and separate effect tests on simulation facilities, as well as to perform safety systems verification and safety code validation. As part of the safety assessment and licensing procedure for nuclear power plants (NPPs), a wide range of analyses must to be carried out to analyze the system response during a wide variety of accident scenarios and transients, including operational transients, large and small break loss-of-coolant accidents (LOCAs) and anticipated transients without scram (ATWS). Reliable two-phase instrumentation is therefore essential for the connection between analysis and experiment especially in the nuclear safety research where accident scenarios have to be simulated in experimental facilities and predicted by complex computer code systems.

In the frame of the LP1 program “Reattori evolutivi INTD”, focused on small and medium nuclear reactors, the thesis consists on the development of special instrumentation and on the development of models, based on the analysis of experimental data, that are able to interpret the measurement signals for many possible two-phase conditions. During the first year activity the instruments suitable to be used in simulation facilities for the two-phase mass flow rate measurement, have been selected based on a detailed analysis of the state-of-arts on the available instrumentation. The selected instruments have been experimentally/theoretically analyzed and different possible combinations (Spool Piece - SP) have been evaluated.

The research work allows to identify a reference SP made up of a Venturi Flow Meter and an impedance sensor. More in detail, two different SP have been modeled: Venturi and Wire Mesh Sensor (WMS) in an horizontal configuration and Venturi and Electrical Capacitance Probe (ECP) in a vertical configuration. The instruments combination allows the measurement of the mass flow rate of the phases with a good accuracy and the identification of the internal structure of the flow (flow pattern, interface evolution, characteristic frequency and void fraction profiles), fundamental not only for the correct interpretation of the SP response, but also for the development/improvement of the two-phase models used in computer code simulation.

Figure 1. Mass flow rate of air and water estimated using the model of the SP Venturi and ECP.
**First name:** Marta  
**LAST NAME:** Nervo

**Topic:** Transport methods in nuclear reactor kinetics

**Course year:** 2nd  
**Tutors:** Profs. S. Dulla, P. Ravetto

**Academic context**


**External collaborations**
- ENEA-Casaccia
- IAEA
- INFN

**Highlights of the research activity**

Analysis of pulse experiments for heterogeneous subcritical systems (FREYA project) have shown that spatial and spectral effects cannot be neglected, as well as the effect of heterogeneity [1].

In the framework of subcritical system analysis an innovative on-line reactivity monitoring method has been proposed for power nuclear reactors. It is based on the classic point-kinetic model of reactor physics and it allows a real-time monitoring of the reactivity during operation of a nuclear reactor [2]. At first, such method has been assessed for source-free system according to the following steps:

- Application to a point-like reactor for validation, sensitivity analysis and study of the experimental uncertainty effects;
- Adoption of a 1D dynamic model for the investigation of spatial effects, considering spatially and spectrally localized perturbations;
- Benchmark against a full 3D model with uniform system perturbation.

As a second step, the method has been extended to subcritical source-driven system (IAEA collaboration) [3]:

- Validation, sensitivity analysis and analysis of the experimental uncertainty effects of the method, as for the source free system;
- Spatial and spectral effects investigation adopting a 1D model of source-driven lead-cooled fast reactor associated to a multi-group energy structure of the system (4-group and 49-group).

Further applications of the reactivity monitoring method

- Interpretation of pulsed experiments simulated with a 1D model;
- Application to real measurements of pulsed experiments (INFN collaboration) performed in the subcritical facility under study in the framework of the FREYA project (ENEA collaboration);
- Interpretation of measurements in other subcritical source-driven facilities (e.g. YALINA) [4].

The assessment of the method has proved its capability to promptly detect the reactivity changes for both source-free and source-driven nuclear systems. More efforts will be devoted to assess the technique for a wider types of experiments to prove its efficiency for real applications in power nuclear reactor operations.
First name: Michel | LAST NAME: NOUSSAN

Topic: Simulation models for biomass-fired power plants

Course year: 2nd | Tutor(s): Alberto Poggio

Academic context

External collaborations
- ENEA – UTTS Saluggia
- Regione Piemonte

Highlights of the research activity
The main target of the research activity is the development of an integrated model for the simulation of biomass-fired CHP systems. The tool has to deal with multiple aspects, in order to take into account the different issues related to energy production from wood biomass.

The use of wood biomass for energy production is currently increasing, due to the interest of energy production from renewable sources. A sustainable use of wood biomass usually requires a small or medium size power plant, and the combined heat and power production is essential in order to reach acceptable efficiencies. Moreover, a careful design of the plant needs a detailed operational analysis, as the operational conditions in some situations can strongly differ from design conditions.

The research activity has been focused on biomass power plant simulation and optimization considering different aspects, such as the wood biomass heterogeneous characteristics, the fluctuating heat demand profiles (obtained from the real operation of a district heating system over several years), the simulation of the heat storage systems in order to match the heat demand, the analysis of different CHP units and their size optimization with respect to the maximum heat demand of the users.

The main technology for small size CHP production from wood biomass is currently the ORC (Organic Rankine Cycle). Different ORC parameters have been simulated, comparing the performances of different fluids (R245fa, MDM, MM, toluene) and variable system configurations. Also some real plants already in operation have been analyzed in detail, in order to perform a comparison between operation performances and design conditions of the units.
First name: Valerio     . LAST NAME: NOVARESIO

Topic: Modeling and experimental characterization of a SOEC stack for syngas production

Course year: 2nd       Tutor(s): Prof. M. Santarelli

Academic context
[1] Christopher Graves, Sune D. Ebbesen, Mogens Mogensen, Klaus S. Lackner, Sustainable hydrocarbon fuels by recycling CO2 and H2O with renewable or nuclear energy, Renewable and Sustainable Energy Reviews, Volume 15, Issue 1, January 2011, Pages 1-23, ISSN 1364-0321, 10.1016/j.rser.2010.07.014.

External collaborations
• DTU Risø Campus research center (Frederiksborgvej 399, 4000 Roskilde, DK).
• Acacia Cleantech S.r.l. (Corso Castelfidardo 30/A, 10129 Torino, IT)

Highlights of the research activity

The PhD activity is devoted to the modeling and experimental characterization of an innovative SOEC stack and developing a new stack diagnostic technique. Firsts two years are focused on modeling (code development/validation and simulations) while the last year is more dedicated for experimental work.

Solid oxide electrolytic cell (SOEC) stack is one of the typical field where different time and space scales are involved. Usually in literature one can found cell level detailed analysis finalized to improve materials design and electrochemical performances or to study degradation phenomena; on the other hand many CFD macro model are developed to study temperature and species distribution. CFD macro models usually neglect detailed geometry informations in order to reduce the computational domain. This approach makes possible to obtain good results for global or integral variables, but fails when details have to be considered.

The second year of activity has been devoted to the simulation of many stack geometries using the code developed during the first year (a code based on the open source framework OpenFOAM, that can perform electrochemical impedance spectroscopy EIS using partial differential equations). The simulations were focused on impedance due to the mass transport. Differences between geometries can be shown in the low frequency impedance arc. Variations in impedance magnitude and phase are related to geometric variations, incipient degradations or fluid path’s occlusions. This code can be used as a diagnostic tool in order to monitoring the stack performances. The code is now also ready to be coupled with the open source tool Cantera in order to consider complex reactions mechanisms.

SOEC stack optimization is also performed considering the cost variable. The stack and the complete system are been decomposed in base element and a cost matrix was generated. Coupling this matrix and the CFD optimization routines is possible to obtain a more effectiveness stack, even if is not the most efficient one.
First name: Davide   LAST NAME PAPURELLO

Topic: Biogas from dry anaerobic digestion of organic waste, production characterization, cleaning section for innovative SOFC feeding

Course year: 3rd   Tutor(s): Prof. M. Santarelli

Academic context


External collaborations
• Edmund Mach Foundation (FEM – San Michele a/A (TN), via E.Mach 1 – 38010)
• SOFCpower spa (Mezzolombardo (TN), Viale Trento, 115/117, c/o BIC – I – 38017)

Highlights of the research activity
A pilot plant energy generation system was built using a digester, a blower, a gas cleaning section and a gas compressor coupled with a gas cylinder tank buffer and a SOFC 500 $W_e$ stack. An anaerobic digestion pilot plant was fed by domestic waste collected from the local municipalities. The biogas volumetric flow produced was around $1 m^3/h$ with an outlet pressure above 4 mbar. The low biogas outlet pressure required a blower to feed a gas cleaning section filled by activated commercial carbons. A compressor system brings the biogas from 80 mbar to 11 bar while 16 gas cylinders are filled to realize a buffer for the SOFC stack feeding. A commercial 500 $W_e$ SOFC stack is built from Sofcpower with 40 Ni-anode based cells. The biogas trace compounds content was investigated using a PTR-MS mass spectrometry instrument before and after the gas cleaning section. Aside from sulfur compounds, aromatic and terpenes compounds are detected. The principal pollutant compound detected in the biogas stream was $H_2S$ with concentrations that range from 30 to 100 ppm(v). The SOFC stack was directly fed by the biogas produced using a c-POx reforming system and worked for more than 400 h at 200 $W_e$. Maximum SOFC performance were achieved in galvanostatic mode at 54% FU with an electrical efficiency above 35% and electrical power above 500 $W_e$. 
First name: Pietro
LAST NAME: PIZZO

Topic: Development of innovative diagnostic tools for fuel injection systems (FIS) and design of new measurement devices for hydraulic test benches.

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

Academic context

External collaborations
• Rabotti s.r.l.

Highlights of the research activity
In the first part of the activity, the research of Dr. Pizzo has been focused on the development of a 1D model of a fuel injection system. A new generation solenoid injector has been considered and the model has been developed by means of the Amesim commercial tool. It has been validated comparing numerical results with experimental data, which had been acquired at the hydraulic test bench of the Energy Department.

The validated model has been used to investigate the internal fluid dynamics in different operative conditions and the effects of modifications of the high-pressure circuit on the system performance have been examined. An analysis of pilot-main and main-after injection-fusion events is being performed. The general objective is to improve the knowledge about the injection dynamics.

The model of the fuel injection system has been applied to develop a flow-meter that can detect the instantaneous flow-rate in high-pressure liquid flows. The time history of the liquid flow-rate in a high pressure pipe can be calculated by means of the momentum and continuum equation applied between two points located at fixed distance and at which the instantaneous pressure is experimentally known. As a first step a simplified momentum equation has been implemented by means of the Matlab commercial tool and the results has been compared to that of the Amesim model. The following step will be the implementation of all the terms of the momentum and continuum equation.

In the second part of the activity, a review on the state of art of gasoline injection systems has been carried out. It is aimed at analyzing the evolution of direct and indirect fuel injection system for gasoline engine from the earliest to the latest systems providing a comprehensive description of the components and modifications performed during the years. The review will be submitted for publication to a selected journal.
First name: Laura                      LAST NAME: RIEETTO

Topic: Energy systems integration: from building scale to urban scale

Course year: 1st          Tutor(s): Prof. G.V. Fracastoro, Prof. V. Verda

Academic context

External collaborations
- Europe-China Clean Energy Centre (EC2)
- Regione Piemonte

Highlights of the research activity

The research activity is inserted in a wider project, the Europe-China Clean Energy Centre (EC2), a five-year cooperation project started in 2010. The goal of this alliance is to promote a cleaner energy sector in China and to support the Chinese Government in decision-making in this field.

EC2 proposes to actuate some demonstration actions in the Xinjiang Region in the City of Urumqi, so at the moment I am working on data collection on energy production, energy grids and energy demand of that site. Among the focus areas of the Sino-European project there are three items related to our research activity:

- Energy efficiency in residential, commercial, tertiary and industrial sectors;
- Renewable energy sources;
- Sustainable distribution systems.

My PhD project will consist in modeling the energy production system, the thermal network and the demand side to carry out an overall optimization (energy production plants + distribution networks + buildings demand, considering economic, environmental and energy parameters within a multi-objective analysis.

At the moment my attention is focused on the energy efficiency of buildings and in particular on energy consumption estimation using commercial software for the prediction of energy demand based on quasi-stationary calculations.

A study whose aim is to estimate how much the geometrical simplifications of a model that reproduces a more complex real building influences energy consumption results is in progress. The results will be employed to decide which will be the most suitable procedure to estimate the energy consumption of the buildings in Urumqi and which data input precision can be acceptable.
First name: Uktam  
LAST NAME: SALOMOV

**Topic:** Pore-scale mesoscopic modeling of transport processes in electrodes for high temperature PEM fuel cells

**Course year:** 2nd  
**Tutor(s):** prof. P. ASINARI

**Academic context**


**External collaborations**

- Prof. D. Jones, Charles Gerhardt Institute for Molecular Chemistry and Materials, in Montpellier, France (within the ARTEMIS project 2012)
- Prof. Dr.-Ing. Sabine Roller, Applied Supercomputing in Engineering German Research School for Simulation Sciences, Aachen University, Germany
- Prof. F. Alcaide-Monterrubio, Unidad de Materiales para Energía, Energiarako Materialeen Unitatea, Materials for Energy Unit, CIDETEC - IK4, Spain

**Highlights of the research activity**

Despite the tremendous progress in PEM fuel cell technology, namely development of the phosphoric acid doped PBI-based high temperature (> 100 °C) PEMFC with improved properties [1], degradation issues still remain. Loss of phosphoric acid, especially in high current density and elevated temperature (> 160 °C), through different processes like capillary transport, diffusion, membrane compression, evaporation and leaching by condensed water during shutdown and cold start, is thought to be one of the major mechanisms of degradation [2]. Deep insight into this degradation mechanism comes through pore-scale modeling of the mass transport phenomena, which provides the detailed information available at the microscopic scale. The morphological model presented in [3] was developed as the first step towards modeling of such degradation mechanisms in pore-scales.

During the report period, we have investigated how the distribution of catalyst (Pt) electrochemical active surface area (ECSA) can change flow field at the catalyst layers and how this manipulation by flow field near membrane can be used as a mitigation strategy for phosphoric acid loss and crossover of reagents through membrane. While velocity gradient is directly related to the component of pulling stress on phosphoric acid, by probing different distributions we have found the optimal configuration where this stress is highly reduced compared to conventional quasi-homogeneous distribution of ECSA (see Fig.1). For this purpose we have performed direct numerical pore-scale Lattice Boltzmann simulation of the fluid flow through CL with different ECSA distributions. Moreover, a three-dimensional macroscopic model of the membrane electrode assembly (MEA) has been developed to analyze how the proposed mitigation strategy affects the polarization curve and hence the performance. The proposed distribution of ECSA may greatly improve durability by mitigating the phosphoric acid loss, at the price of only 9.3% reduction in efficiency at high current densities (see Fig.2).
First name: Fabio                LAST NAME: SABA

Topic: Towards the development of a National Standard for Thermal Energy and its application to smart heat meter calibration

Course year: 1st                Tutor(s): Prof. M. Masoero, Dr. V. Fernicola

Academic context

External collaborations
• INRIM (Istituto Nazionale di Ricerca Metrologica)

Highlights of the research activity
The activities I’ve carried out during the 1st year of my PhD regard:
• a Monte Carlo analysis of the uncertainty propagation in reference thermal energy measurement resulting from the use of a classical thermodynamic model formerly chosen for thermal energy calculation; the results obtained in terms of uncertainty propagation have been discussed in a technical report written on July 2013 (F. Saba, Technical Report n°12/2013, “Mathematical model and uncertainty propagation for the INRIM Thermal Energy Standard”, INRIM);
• the estimation of the uncertainty propagation in water mass flow rate measure, focusing on the uncertainty contribution associated with different water density calculation models; the results of this work have been presented and discussed at the International Congress of Metrology (C. Marinari, F. Saba, “The INRIM Water Flow Rate Primary Standard revamping”, 16th International Congress of Metrology, October 2013, Paris).
• a computational thermal-fluid-dynamic analysis for some possible working conditions of the instrumented and hydraulically-reconfigurable mock-up, which is under development at INRIM laboratories in order to simulate a real thermo-hydraulic system for the validation of novel smart thermal energy transducers; the CFD analysis has been carried out in order to assist the design phase and to evaluate the effects due to the possible working regimes of the mechanical ventilation system and installation patterns of water radiators on the mock-up walls.

Another activity I’m performing is related to the thermal-fluid-dynamic matching between the two separate hydraulic circuits which make up the system used for reference thermal energy measurement. The target of this activity is to ensure that the reference and the under test thermometers belonging to different hydraulic circuits are exposed to the same heat transfer conditions as in an ideal non-separate hydraulic circuit configuration. The exposition of the temperature transducers to a water flow rate represents an innovation in the calibration procedure of the thermal energy meters widely used in central heating systems.
First name: Mahrokh
LAST NAME: SAMAVATI

Topic: Design and development of Solid Oxide Electrolyser based systems for emission free synthetic liquid fuels generation

Course year: 1st
Tutor(s): Prof. M. Santarelli

Academic context

External collaborations
• Department of Energy Technology, Royal Institute of technology (KTH), Stockholm, Sweden

Highlights of the research activity
The project is about integrating a renewable energy system with a complex plant devoted to the production of synthetic hydrocarbon fuel in an emission-free configuration, via a solid oxide electrolyser which will be a good solution to the renewable energy resources problems due to their intermittent nature. Such a system allows storing the excess produced power in the form of high value synthetic hydrocarbon fuels without having adverse effects on the environment. The generated fuels can be further used in different applications such as transportation and/or chemical industry. In order to achieve the objectives of this study, the total system was broken into three different subsystems, Solid Oxide Electrolyser system, Pyrolysis and gasification system, Fischer-Tropsch Conversion system. The Solid Oxide Electrolyser system and Pyrolysis and gasification system have been modeled using ASPEN Plus software (Aspen Tech). A process flow sheet containing all of the components that would present in an actual system was created. The modeling results showed a good compatibility with the ones from literature.

Figure 3- system schematic
First name: Roberto \hfill LAST NAME: TAURINO

Topic: Innovative seal for aircraft engines

Course year: 1\textsuperscript{st} \hfill Tutor(s): E. Campagnoli, P. Maggiore (DIMEAS)

Academic context


External collaborations

- GE Avio S.r.l.

Highlights of the research activity

In the first year research work was focused on three main activities:

- bibliographic research was carried out in order to point out the main physical phenomena characterizing labyrinth seals. A special focus lied on abradable labyrinth seals with honeycomb stator since they are currently used in Low Pressure Turbines. Research results show how the identification of an optimal solution can be made evaluating three different aspects: fluid dynamics performances, heat exchange containment and the rubbing behavior control. Moreover, other phenomena like thermal stability, corrosion and windage effect have to be taken into account.

- analytical correlation, provided by GE Avio S.r.l., evaluating labyrinth seal leakage performances was investigated. The global sensitivity method known as The Morris Method was used. The results provide an overview on the parameters influencing more the leakage and identify honeycomb cell size as the most affecting. The adoption of honeycomb seal in place of smooth seal increases the mass leakage flow and demonstrates how this solution advantages cannot be found investigating only the seal fluid dynamics.

- flow behavior inside labyrinth seals was investigated by means of Computational Fluid Dynamics (CFD). Numerical results compared with numerical solutions and experimental measurements available in literature are in good agreement. On the basis of this comparison it is possible to state that developed numerical models are capable to predict the discharge coefficient for smooth and honeycomb labyrinth seals. A particular investigation was performed in order to evaluate two different approaches to resolve boundary layer. The use of analytical wall functions was identified as the best compromise in terms of computational cost and solution accuracy.

![Percentage error below 2\% respect to experimental data]

Figure 1-4 Numerical results and comparison with experimental data
First name: RAFFAELLA

LAST NAME: TESTONI

Topic: Modelling of radionuclides transport phenomena in environmental matrices for Safety Assessment

Course year: 1st

Tutor(s): Prof. M. De Salve and R. Levizzari (ENEA)

Academic context


External collaborations

- ENEA

Highlights of the research activity

The research topic are Safety Assessment studies, which aim to properly foresee and manage the environmental impact of Nuclear activities. Safety Assessment mainly relies on detailed sites characterization, in order to collect data to be processed with a suitable software (e.g. Modflow, Hydrus, AMBER) and predict the evolution of the potential contamination, and to investigate environmental impact of analyzed activities.

My research is focused on preliminary Safety Assessment study of the Saluggia area, where several nuclear facilities are present: nuclear reprocessing plant Eurex, waste ponds to collect radioactive effluents, research reactor Avogadro, etc. Through collaboration with ENEA Saluggia Center, several data related to geology, hydro geological characteristics, etc. have been collected. These data have been used to develop simulations models by means of Modflow software, which simulates dynamics of the groundwater and transport of the contaminants in the aquifer as result of an accidental event.

Firstly, site model has been calibrated from the point of view of streams characteristics and pressure head; then, model has been used to develop “critical” scenario and to evaluate contaminants dynamic in the aquifer.

Figure. Evaluated pressure head [meter above sea level] during transient simulation in Saluggia area.
First name: YIFEI                      LAST NAME: TONG

Topic: CO2 Reduction Technologies for ICEs

Course year: 1st                Tutor(s): Mirko Baratta, Ezio Spessa

Academic context

External collaborations
- CRF (Centro Ricerche Fiat)

Highlights of the research activity
Training phase of the 1D and 3D simulation software GT power and Star CD/CCM+

Take part in the CORE (EU VII FP) and BiomethAir Projects. Several preliminary work has been done for the twin air engine (2-cylinder, fuel with CNG-compressed natural gas) of BiomethAir project, investigations were made to focus on the variation of injection timing influence on the cylinder to cylinder A/F ratio. Also the similar simulations were made with the decreased boost level.

Several simulations were made for the engine (a heavy duty engine with 6 cylinders, fueled with CNG-compressed natural gas) in CORE project for the part Cursor 8, part load conditions with EIVC (early intake valve closing) strategy. A sweep of spark advance with different fi2 angles were simulated through GT power.

Notice that the application of VVA (EIVC here) control strategy is quite new for CNG engines, very few literatures till now have made investigations on that.

Based on the steady state data obtained through previous work done, preliminary modeling for the transient conditions were made for the part Cursor 8 of the CORE (EU VII FP) project. VVA(variable valve actuation) strategies has been imposed into the model. Currently the transient model is still under development and improvement.

The target is to simulate a transient in which the target load profile is imposed to the engine and an expected engine speed profile should be come up as an output. Till now the model has been tunneled to be able simulate with a fixed engine speed target and a fixed load profile input to the engine.

![Figure 1. Transient engine model with intake valve lookup profiles control for VVA(variable valve actuation) strategy](image-url)
First name: Jacopo LAST NAME: TONIOLO

Topic: Energy Monitoring in buildings: benchmark and control improvement

Course year: 4th Tutor(s): Marco Masoero

Academic context

External collaborations
• Cardiff University, Welsh School of Architecture, prof. Ian Knight and Afroditi Konidari
• University of Porto, prof. Jose Luis Alexandre.
• Almaviva (I.T. Italian Company, 24'000 employees, 730 M€ turnover)

Highlights of the research activity

The research activity during 2013 was carried out defining specific energy benchmarks for tertiary system buildings. The innovation of the work is represented by the large amount of specific data available (hourly energy consumption data on: HVAC, lighting, PC, etc…) and the time span (about 2 years). Those data are taken from about 100 existent building during normal operation. Results achieved comprehend Supermarket and Office monthly energy benchmarks.

Figure 5: Electric consumption (kWh) of two equal HVAC system (VRF). Poor control on the left, optimized control on the right.
First name: Mattia  
LAST NAME: VENDITTI

Topic: A comprehensive methodology for energy management of hybrid electric vehicles

Course year: 3rd  
Tutor(s): Ezio Spessa

Academic context
[2] Stuttgart International Summer School-FKFS.

External collaborations
- GM Powertrain Europe
- Centro Ricerche Fiat
- AVL-Graz

Highlights of the research activity
The main activity dealt with the optimization of the layout and of the control strategy of different types of hybrid electric vehicle (HEV) equipped with compression ignition engines. A series HEV, five types of parallel HEV and one series-parallel HEV have been studied.

The layout of each vehicle has been optimized by means of the Optimal Layout Tool (OLT), which aims at finding the optimal design that minimizes the powertrain cost, including the fuel cost over the vehicle life, with the constraint of guaranteeing the vehicle performance of the conventional vehicle, namely maximum vehicle velocity, 0-100 km/h acceleration time and gradeability. An additional constraint has been introduced for the hybrid vehicles, that is, the maximum distance that has to be covered in pure electric mode. All the different architecture designs, generated by OLT, have been evaluated on the basis of their optimal performance. To this end, two benchmark optimizers have been developed to identify the optimal control strategy that minimizes the cost function. The first is based on DP-theory, while the second is derived from the GA theory.

The gear number and the working mode that determines the power split between the motors of the vehicle have been set as control variables of the problem. Two rule-based and a static optimization tool have been developed in addition to the benchmark optimizers. They have been trained over a specific driving cycle and assessed in other conditions to estimate the cycle-dependency. Two innovative contributions have been introduced to speed-up the computational operations. First, the equations of the vehicle model have been written in such a way to enable a coarser time grid to be used without sacrificing the accuracy of the results, considering separate formulations for the left and right sides of each node of the time grid. Second, a configuration matrix has been introduced in order to store the main outputs of the vehicle model for any possible configuration of the model control variables during the pre-processing stage; the optimization tools do not therefore require the vehicle model to be evaluated during the optimization process, as it is sufficient for them to read the configuration matrix. The simulations have been carried out to test the improvements of each vehicle in several driving missions, i.e. the NEDC, the FTP and the Artemis Urban, Road and Motorway driving cycles, in terms of fuel consumption and NOx emissions.
First name: Luigi          LAST NAME: VENTOLA

Topic: Innovative surface coatings for high heat transfer efficiency

Course year: 1st          Tutor(s): P. Asinari , E. Chiavazzo

Academic context

External collaborations
- Center for Space Human Robotics IIT@Polito, Istituto Italiano di Tecnologia, Turin, Italy.
- INRIM Nanotechnology group. Turin, Italy.

Highlights of the research activity
During the first year of research activity, experimental evidences have been studied on the potential of direct metal laser sintering (DMLS) in manufacturing flat and finned heat sinks with a remarkably enhanced convective heat transfer coefficient. To the best of our knowledge, this is the first study where artificial roughness by DMLS is investigated in terms of such thermal performances.

On rough flat surfaces, we experience a peak of 73.0% for the convective heat transfer enhancement (62.7% on average), while, on rough (single) finned surfaces, the best performance is found to be 35.4% (32.5% on average). Experimental data are obtained by a sensor purposely developed by us with maximum and mean estimated tolerance intervals of ±7.0% and ±5.4%, respectively.

Following the ideas from [ref 1] and [ref 2], we propose that heat transfer close to the wall is dominated by eddies with a size depending on the roughness dimensions and the viscous (Kolmogorov) length scale. An excellent agreement between the experimental data and the proposed analytical model is finally demonstrated.

Convective heat transfer of three different rough flat surfaces (average roughness Ra for each sample is provided in the legend). Smooth sample (Ra = 1 µm) with identical geometry was used as reference. Point are experimental data, whilst lines are prediction according the model.
First name: Elisa  
LAST NAME: VIGLIANI


Course year: 2nd  
Tutor(s): Prof. Marco Badami; Ing. Paolo Segreto

Academic context

External collaborations
• Comau S.p.A – Grugliasco (Italy); Apprenticeship PhD

Highlights of the research activity

The research work is focused on the analysis of technical solutions that can improve energy efficiency in the industrial sector and, in fact, particular attention has given to the combined heat and power (CHP) production. An energetic and economic analysis of eleven CHP industrial power plants, installed in Italy, has been performed. The novelty of this work is that a double set of data has been used for each power plant: design data and operational data of a full working year. In the analysis, the effect of two consecutive legislations (the Italian Directive, issued in 2002, and the current European Directive) on the evaluation of primary energy savings (PES) has been studied; it appears that EU Directive is generally more severe than the old Italian one. The evaluation of the primary energy savings of CHP power plants is particularly relevant for the accessibility to economic subsidies foreseen by Italian legislation. An economic analysis, based on the simple payback time (SPB) of the plants, has also been carried out, considering the effect of incentives on the economic profitability of the CHP plants; it is worth to noting that economic subsidies lead to a significant reduction of the SPB.

Among the Best Available Techniques for energy efficiency, together with the CHP production, the waste heat recovery from industrial processes has an important role in the improvement of industrial plants efficiency. In particular, the research activity deals with the application of a small-scale Organic Rankine Cycle to the exhaust flow exiting from a melting furnace actually in operation. The thermodynamic model of the ORC has been implemented with Engineering Equation Solver (EES) and the first and second law performance analysis have been carried out. The research activity is focusing on extending the system considering also a district heating system and an heat pump; the aim of the work is the improvement of the simulation model in order to carry out the thermoeconomic analysis of the system, using the method of Exergetic Cost Theory, with different operative modes of the furnace.