LIST OF MAIN RESEARCH TOPICS

PhD in AUTOMOTIVE ENGINEERING FOR INTELLIGENT MOBILITY

1. *Development of efficient and clean combustion systems for mobility (PROF. BIANCHI)*
2. *Modeling, Control and Testing of Advanced Powertrains (PROF. CAVINA)*
3. *Advanced design methods for an intelligent and efficient mobility (PROF. CROCCOLO)*
4. *Automotive Lighting and Sensing (PROF. CUCINOTTA)*
5. *Advanced Manufacturing Processes (PROF. FORTUNATO)*
6. *Energy storage systems and powertrains in electric or hybrid vehicles (PROF. DE MUNARI – PROF. CONCARI)*
7. *Electrical Machines and Drives for Green Transportation (PROF. IMMOVILLI – PROF. BARATER)*
8. *Innovative Two-Stroke Cycle Engines running on sustainable fuels (PROF. MATTARELLI – PROF. RINALDINI)*
9. *Development of neuro-inspired architectures for driver drowsiness detection (PROF. PAVAN)*
10. *Advanced Structural Modelling of Automotive components (PROF. PIRONDI)*
11. *Automotive Manufacturing System Design and Operations Management (PROF. REGATTIERI)*
12. *Electric Vehicle Charging Stations: power electronics and renewable integration – (PROF. RICCO)*
13. Dynamics and NVH of road and off-highway vehicles *(PROF. RIVOLA – PROF. MARTINI)*
14. Big Data for Interconnected, Safe and Sustainable Mobility (PROF. SIMONE)
15. Characterization and Modeling of Wide Band Gap (WBG) Semiconductor Power Devices for Automotive Applications (PROF. TALLARICO)
16. *Wireless Network and Communications for vehicular applications in Smart City scenarios (PROF. TARCHI – PROF. BAZZI)*

A SHORT DESCRIPTION OF EACH RESEARCH TOPIC FOLLOWS IN THE NEXT PAGES

Development of efficient and clean combustion systems for mobility – Prof. Bianchi

The research area of the Department of Industrial Engineering (DIN) at University of Bologna, aimed at the development and simulation of modern engines powered by renewable fuels, applies advanced numerical simulation tools to support the development of modern powertrain systems for automotive, heavy-duty off-road, two-wheels vehicle and maritime applications.

Research overview

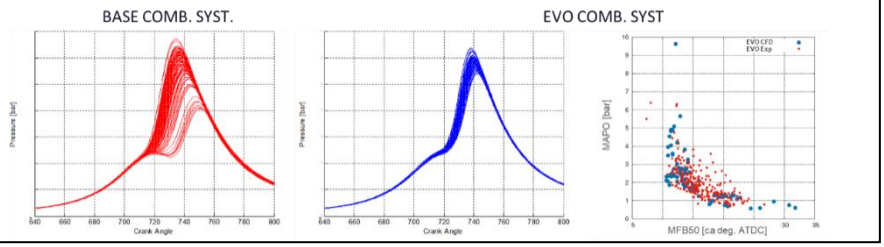
- Zero / one – dimensional modelling of fuel cells (PEM, SOFC) for the propulsion of hard-hybridized vehicles.
- Zero / one – dimensional modelling of modern engines (ICEs) fed by alternative fuel (renewable fuel, such as ammonia, hydrogen and green methane) for both automotive and maritime applications (short trip ferries).
- CFD modelling of fuel injection in vapor phase (example: hydrogen) and combustion process.
- Definition of the physical and chemical properties of fuels oriented towards CFD simulations.
- Definition and application of machine learning techniques for fast database definition and for complex optimization problems.
- Development and optimization of SI GDI/PDI Turbo-charged Engines fulfilling new emission regulations (according to WLTP, RDE cycle and Auxiliary Emission Strategy evaluation criteria), including lambda one operation on the full engine map.
- Development and optimization of SI naturally aspirated engine combustion systems.
- Development and optimization of CI DI engine combustion systems.
- Development and optimization of advanced combustion systems (GDCI,SACI, etc).
- Exploitation of new technologies to reduce the specific fuel consumption and the CO2 emissions in SI engines (Water injection, TJI concept)
- Modeling spray dynamics and spray wall interactions with emphasis on the Leidenfrost effect and the fuel droplet interaction with oil films.
- Development of fuel auto-ignition and flame laminar speed look-up table based on detailed chemistry solvers.
- 1D and 3D CFD multiphase simulation methodology to support the development of injection systems as well as the development of sub-models to predict the wall erosion risks induced by cavitation.
- Modeling heat transfer in ICE by using compressible non-isothermal wall function approaches.

Expertise # 1

CFD simulation of SI and DI CI combustion systems including abnormal combustion and recover of cycle-to-cycle variation effects, based on the use of most up-to-date chemical and physical sub-models

Industrial Case:
Series & Racing Engine Knock Mitigation

Topic:
Combustion System Knock Mitigation - Optimization (Intake/Spray/Temperature@IVC/Turbulence/Mixing)

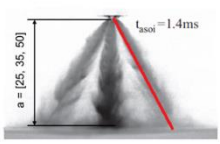


Expertise # 2

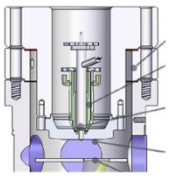
Simulation of spray dynamics, spray targeting and interactions with walls with modeling approach in-house developed and embedded in the engine simulation process.

Topic
Wall Film Model and Spray Interactions

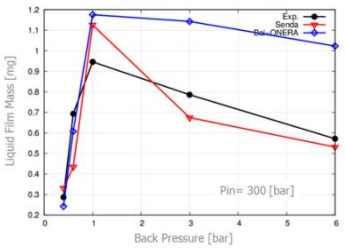
Basic Reserch
Assessment of CFD methodology for prediction of spray interactionand wall film



Distanze «a» rappresentative di early, average e late injection strategy



Wall Temperature	Back Temperature	Back Pressure	Injection Pressure	DOI
(K)	(K)	(bar)	(bar)	(ms)
303	[353, 413, 453]	[0.4, 0.6, 1, 3, 6]	[50, 150, 300]	[2.6, 1.5, 1.06]



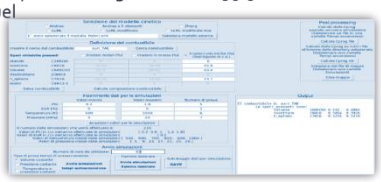
Expertise # 3

Development of auto-ignition time and flame laminar speed look up tables for any fuel including the effect of diluters, water or EGR.

Industrial Case:
Series & Racing Engine Knock Mitigation

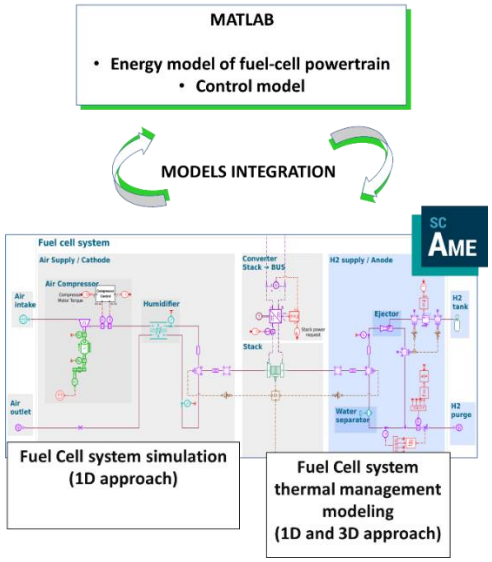
Topic:
Fuel Composition & equivalence ratio operation limit assessment

Tools:
The tools based on detailed chemistry solver outcomes (auto-ignition time look-up table and flame laminar speed correlations) allows to perform assessment of any fuel: from gasoline ULG95/98 to E20/E85, from methane to Formula One customer-tailored fuel



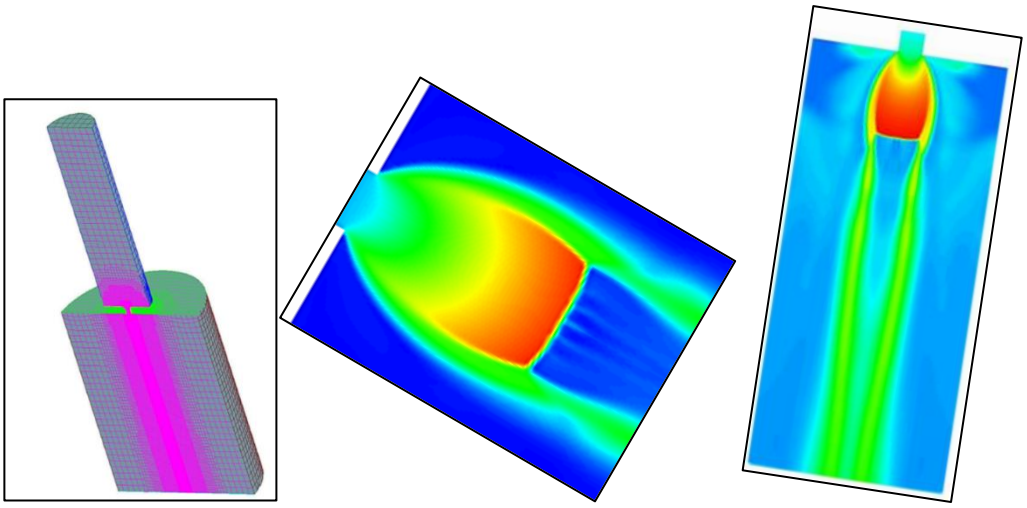
Expertise #4

Virtual analysis and optimization of Fuel Cell cooling, air and H2 supplying systems. Development of a 1D fuel cell system model, integrated into the overall powertrain model, including: a simple control system, a load profile that simulates a basic target trip, thermal management system, electrical part.



Expertise #5

CFD analysis of renewable fuels injection in vapor phase and combustion process in modern IC engines. Detailed analysis of under-expanded jets formed by means the injection of fuels in vapor phase under high-pressure difference conditions.



Expertise #6

Modeling from scratch of energy systems and devices with 0D/1D approach and complex physics for performance analysis, new conditions test, and design.

Modeling, Control and Testing of Advanced Powertrains – Prof. Cavina

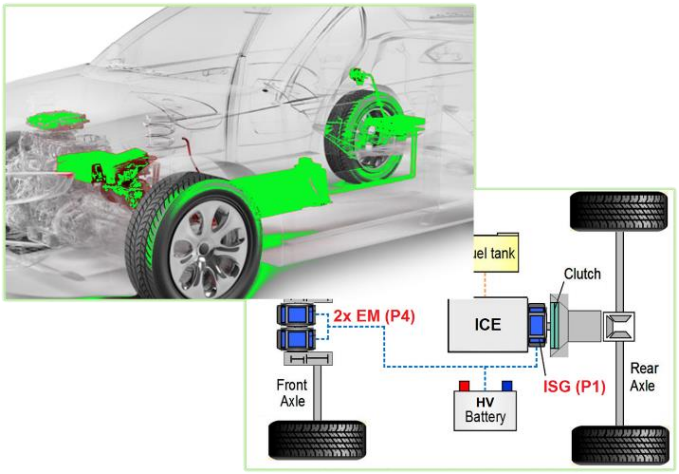
The development of innovative control systems for cleaner and more efficient powertrains for passenger vehicles is one of the main challenges of the next decades.

The research activity in the automotive and mobility sector is facing a great challenge in the powertrain area. Electrification, hybridization, development of advanced combustion systems, use of electronic-horizon information... are just some examples that require advanced and model-based control strategies to reduce energy consumption and pollutant emissions.

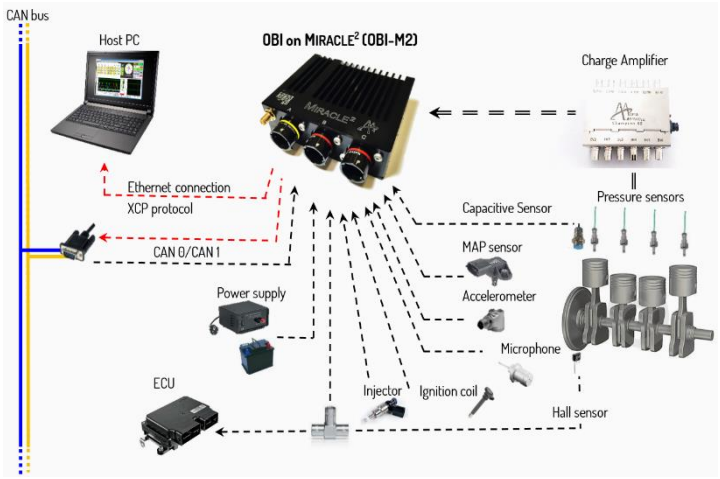
PHACTS (Pure & Hybrid Architectures Control Testing & Simulation) Research Group Overview

- Control-oriented modeling of advanced internal combustion engines and hybrid powertrain systems
- Rapid Control Prototyping implementation of innovative control functions, both at the test bench and on-board the vehicle
- Development and testing of innovative solutions for improving combustion efficiency (Water Injection, E-turbo solutions, Variable Compression Ratio, Low-Temperature Combustion Systems, After-treatment Systems…)
- Optimal energy and thermal management solutions for Hybrid Powertrains
- Development of E-Horizon functions for improving energy consumption, reducing pollutant emissions and increasing electric range of HEVs
- Control-oriented 1D engine modeling for Software In the Loop (SIL) and Hardware In the Loop (HIL) control and diagnostic functions development and validation
- Availability of 4 fully-automated test cells for ICEs and HEVs research and development projects

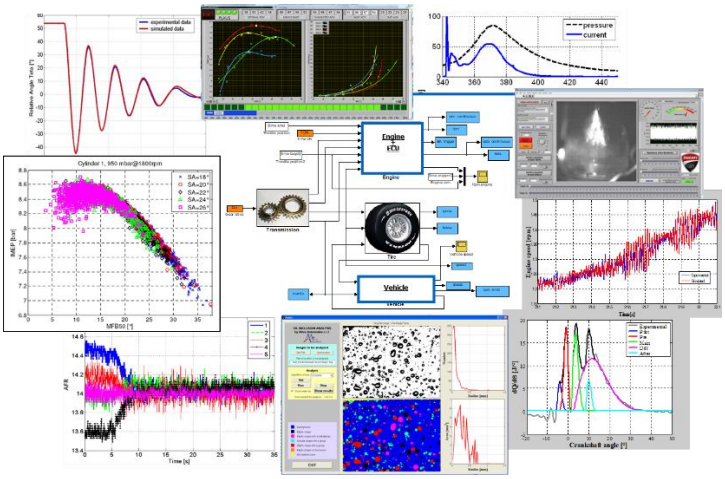
Expertise # 1 Development, validation and testing of innovative control strategies for internal combustion engines and hybrid powertrains



Expertise # 2 Self-developed Rapid Control Prototyping systems for immediate testing of new and complex control solutions, also based on innovative sensors and actuators (in-cylinder pressure sensors, ionization current, water injection, e-turbo, VCR, …)



Expertise # 3 Engine-powertrain-components analysis and modeling for calibration, control and diagnosis.



Advanced design methods for an intelligent and efficient mobility – Prof. Croccolo

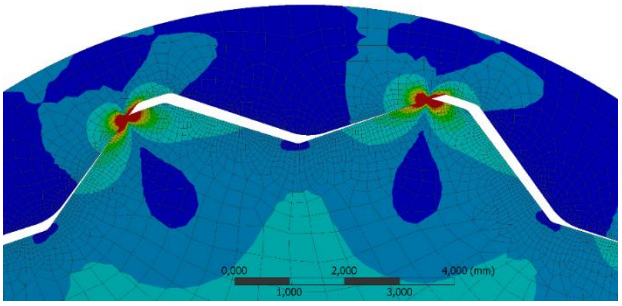
Development of advanced design methods for an intelligent and efficient mobility using modern tools of investigation and design

The Machine Design research area of the Department of Industrial Engineering (DIN) at the University of Bologna applies advanced simulation tools and investigation analyses (Finite Element Analysis, Design Of Experiment and Experimental Stress Analysis), to support the development of powertrain and chassis components and assemblies for automotive, heavy-duty off-road and motorbike applications.

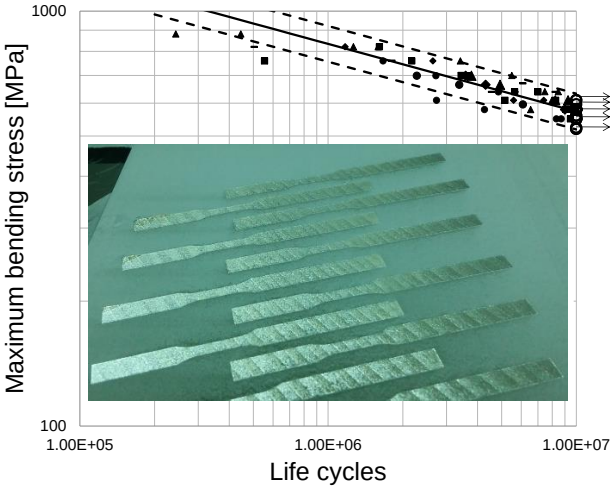
The Machine Design research overview

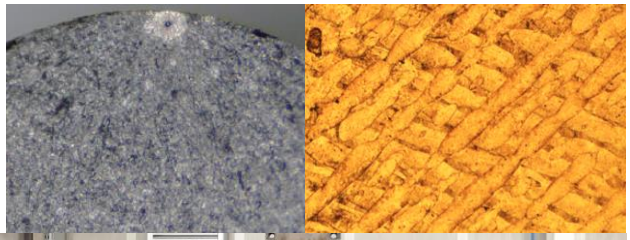
- Mechanical characterization of standard and innovative materials for vehicle body applications.
- 3d printed metals and plastics, composites, lightweight alloys.
- Characterization, design and optimization of structural joining devices, such as adhesives, threaded components, welds and shaft-hub couplings.
- Design and optimization of chassis body parts and assemblies, with an emphasis on suspension elements.
- Broad expertise in failure analysis of structural components, with capabilities of in-field measurements of strain, acceleration, residual stresses on automotive, heavy transportation, agricultural and earth moving machinery components.
- FEA techniques applied to characterization, design, optimization and failure analysis of automotive components, assemblies and complete vehicle bodies.

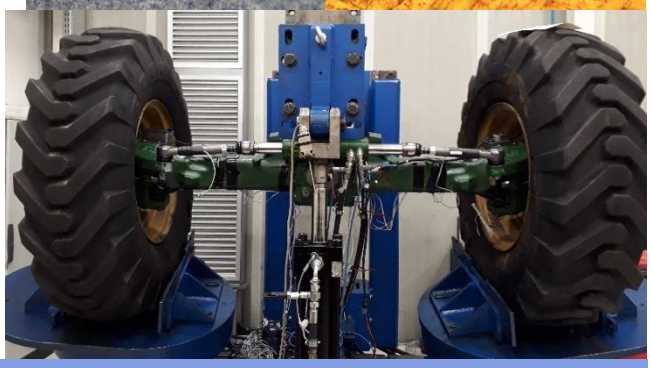
Expertise # 1 Structural Joining Methods: design and optimization of any kind of structural joint. Thorough experience on contact and fretting-fatigue issues. The group relies on dedicated test benches for static, dynamic and tribological characterization, commercial and self-developed FE tools for the design of structural joints.



Expertise # 2 Mechanical characterization of innovative materials. The group has a long-term experience with regard to fatigue characterization of additively manufactured high strength steels and Aluminum alloys, including as well last generation stainless steels. The effects of processing and post-processing techniques have often been addressed. The group relies on International cooperation, fatigue testing machines, equipment for surface texture, fracture and microstructure analysis, devices for not-destructive testing, specific tools for statistical assessment.

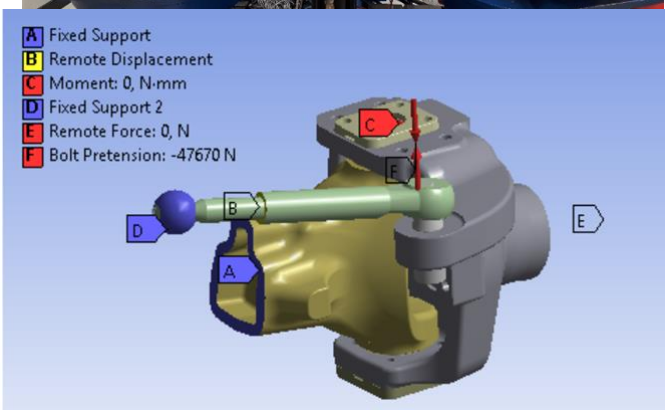






Expertise # 3

Design and optimization of chassis body parts: steering system optimization, failure analysis on chassis body and transmission components, design to cost and in field/laboratory measurements. The group has a long term experience in cooperating with important international players in the field of automotive and off-road machinery. The group relies on dedicated test equipment for strain, acceleration and residual stresses measurements.



Automotive Lighting and Sensing – Prof. Cucinotta

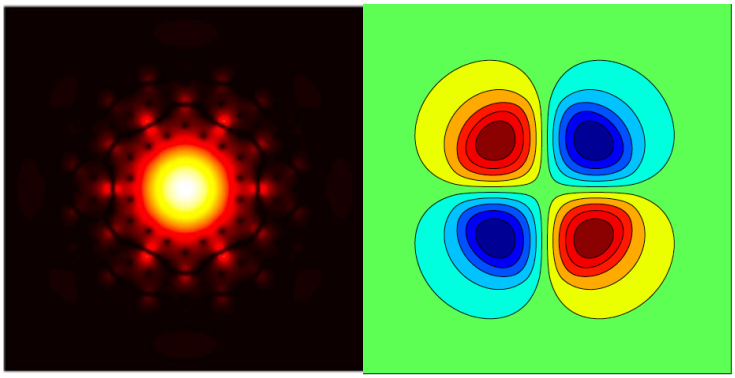
Solutions for automotive lighting and sensor integration to support advanced driver assistance and automated driving

The research field deals with the methodologies and techniques for electromagnetic modelling and photonic device design, covering all aspects from the material properties to the application level.
The research activity is focused on the study and design of fiber lasers as well as electromagnetic field propagation is standard and specialty optical fibers.

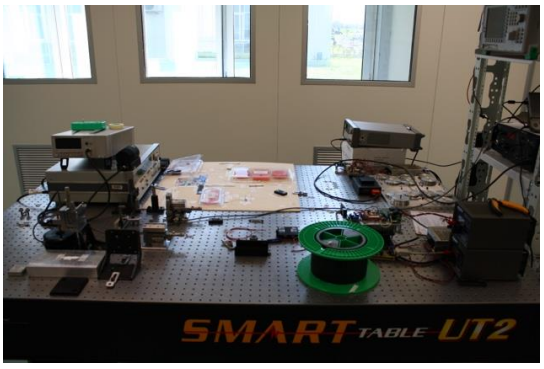
The research field overviews:

- Fiber lasers
- Fiber sensors
- Design of active and passive optical components, like LEDs, lenses, splitters, power dividers
- Antenna design
- Study of vehicular electromagnetic propagation
- Optical components experimental characterization

Expertise # 1
Numerical modeling of standard
and specialty optical fibers



Expertise # 2 Experimental characterization and design of optical components. High resolution spectral measurements in the range 350-1750nm.



Advanced Manufacturing Processes – Prof. Fortunato

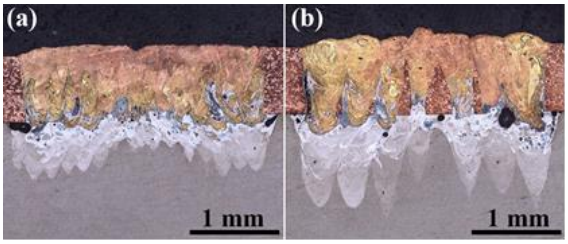
The development of innovative manufacturing processes for the fabrication of new and more efficient components for e-mobility is one of the main challenges of the next decades.

Manufacturing technologies have a fundamental role in the coming years, namely, to make new products related to e-mobility more reliable, with greater performance, and at a lower cost. Electric mobility, in fact, requires products completely different in shapes and materials, and consequently, new tools and new manufacturing processes must be developed in the coming years so that the growing demand for electric cars can be satisfied. In the upcoming years, manufacturing technologies will play a crucial role in producing new products for the e-mobility sector that are more reliable, perform better, and cost less. Electric mobility requires products completely different in shapes and materials, and consequently, new tools and manufacturing processes must be developed to meet the growing demand for electric cars.

Research Group topics:

- Feasibility study of the processes and characterization of automotive components' technological properties
- Design, modelling and numerical simulation of innovative manufacturing processes of automotive components
- Optimization and control of process parameters to improve vehicle performance
- Determination of the effects of process parameters on real industrial cases
- Economic and environmental evaluation of new technologies in order to reduce energy consumption, environmental impact and process costs

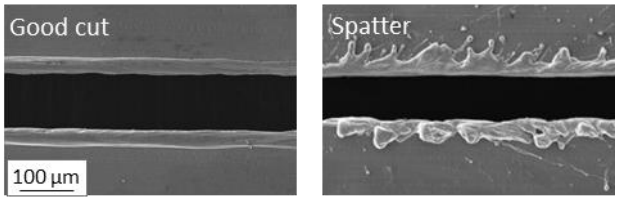
Expertise #1 Laser welding of automotive vehicle batteries



The increasing demand for complex and integrated products needs to combine dissimilar materials to obtain different characteristics. For example, in electric and electronics applications, such as hybrid engine batteries in the automotive propulsion industry, it is useful to combine the electrical conductivity of copper with the low density of aluminum. The process optimization involves microstructural, mechanical, thermal, and electrical analysis in order to enhance the final battery performance.

Expertise #2 Laser cutting of battery electrodes

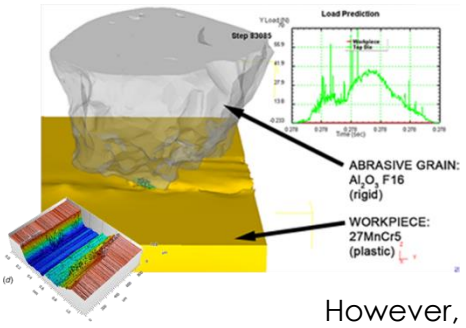
Coated Al and Cu current collectors are employed for the production of Li-ion batteries, functioning as cathodes and anodes. Several different coatings and collector thicknesses are currently on the market, and more are being developed. The increasing demand and the need for net zero-defect cutting quality are driving industrial production to seek fast, reliable, and flexible technologies while simultaneously adapting the process to new electrode geometries and materials. Different manufacturing processes are able to cut electrodes, but laser-based cutting processes are currently considered the most valid alternative to conventional methods for increasing productivity. Cut quality and the presence of defects such as burrs, clearance width, and heat-affected zone must be analyzed to assure battery performance.



Expertise #3 Laser drying of batteries electrodes

The drying process of the coated electrodes represents the most energy-intensive and, thus, the most cost-intensive process step in electrode manufacturing. At the same time, the residual solvent content is a major factor influencing the subsequent cell performance. Nowadays, the drying of anodes is done using a furnace, and it represents nearly 30% of the overall energy consumed per kWh Li-ion battery produced. Research has already confirmed the positive effect of introducing laser drying of the slurry, but efficient and reliable removal of the solvent still needs to be clearly understood and assessed. The main goal is to identify efficient solvent evaporation with laser process parameters and the best trade-off between the production rate and electrode defects.

Expertise #4 Dry grinding of automotive gears and permanent magnets rotors



Grinding is the preferred choice for finishing automotive gears and rotors because of its high productivity and capability to machine heat-treated or brittle parts with high geometric accuracy and surface quality. Material removal processes for rotors' permanent magnets are particularly challenging due to their high hardness and brittleness, and the grinding process is crucial for reaching the dimensional tolerances requested by the product. However, the heat generated during grinding is particularly challenging in terms of superficial defects such as burns on the gear's surface or the loss of the magnetic and mechanical properties of permanent magnets. For these reasons, grinding remains a machining process that requires a high quantity of lubricant with significant costs, health implications, and environmental risks in gear production. The feasibility of dry grinding must be assessed by first identifying threshold grinding parameters for avoiding defects and then optimizing cutting parameters to obtain the desired components' accuracy.

Expertise #5 Additive manufacturing of high-performance metal components

3D printing of metal components allows the manufacture of high-performance components that can be adapted to all situations of use. In particular, it can allow the manufacture of customized electric motor rotors, the manufacture of copper components with low weight and low electrical resistance, and, moreover, the development of new light alloys with high mechanical resistance. The main research interests are new materials and process optimization for new product designs.

Energy storage systems and powertrains in electric or hybrid vehicles - Prof. De Munari – Prof. Concari

Energy storage systems are crucial components of electric and hybrid vehicles, determining their efficiency and overall performance. The primary goal in this field, is to maximize the stored energy and increase the useful life of batteries. For this reason, the research interest in Battery Management Systems (BMS) has been remarkably increased in the last years. The BMS plays a key role for an efficient, safe, and reliable operation of a battery pack. It guarantees continuous control and monitoring, evaluating the cells' State-of-Charge (SoC) and the State-of-Health (SoH) indicators to prevent cells to work outside the safe operating area and avoid overstress situations leading to premature failure and safety risks. These indicators cannot be directly measured and can only be predicted from measurable parameters such as cell voltage, current, and temperature, that must be continuously acquired and processed to estimate such useful indicators. Many battery SoC evaluation approaches, with different levels of accuracy and implementation complexity, have been studied and reported in the literature and other are expected in the future, especially considering the impressive growth of Artificial Intelligence methods, that can be exploited and used also in this field.

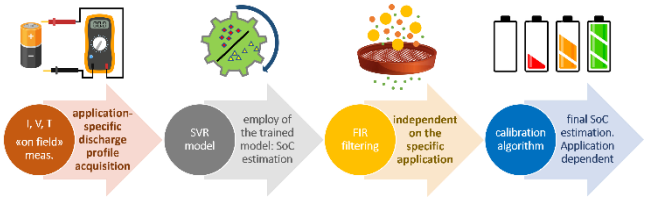
The necessity to move towards a more sustainable mobility also calls for more efficient vehicles, which still fulfil dynamic requirements with limited weight. Model-based design plays a key role in the effort to minimize vehicle weight while maximizing energy efficiency and performance. Given the number of variables and constraints that comprise the model of a vehicle, multi-objective optimization techniques must be employed. The same techniques can be used as sizing methods for hybrid energy storage systems (HESS) suitable to determine the combination of any number of primary storage systems (such as batteries and supercapacitors), each with its specific power and specific energy characteristics, that is optimal in terms of mass.

The research field overview:

1) Battery cell measurements and characterization, including innovative techniques (e.g. impedance measurement);
2) Study of algorithms to evaluate SoC and SoH with a particular focus on the possibility to hardware implementation of them;
3) Implementation on Field Programmable Gate Arrays (FPGAs) or microcontrollers based embedded systems of SoC, SoH evaluation algorithms;
4) Study of digital signal processing techniques to improve the accuracy in estimation, compensating for the lower computational capability that usually affects embedded processors in comparison with more powerful CPUs;

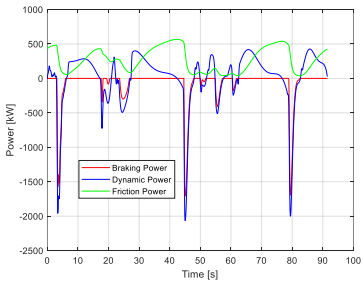
5) Model-based design of electric and hybrid powertrains with the aim of optimizing efficiency and/or performance through multi-objective optimization techniques;
6) Optimization of HESS to minimize its weight while meeting the required specific power and energy ratings.

Expertise # 1 developing of Data Driven Models for SoC and SoH estimation based on both AI and digital processing algorithms. Implementation of them on FPGA/microcontroller based embedded systems

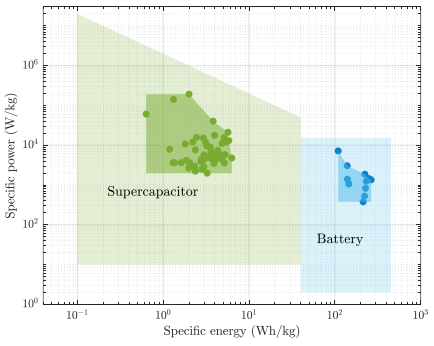


Expertise # 2 Measurements and characterization of battery cells. Measurement bench is available including a climate chamber for measurements at different temperature ranges.

Expertise # 3 Development of electric and hybrid powertrain models and multi-objective optimization for efficiency and performance.



Expertise # 4 Optimal sizing of HESS given power and energy constraints. Minimization of weight by the optimal combination of batteries, supercapacitors, and other energy storage options.



Electrical Machines and Drives for Green Transportation – Prof. Immovilli – Prof. Barater

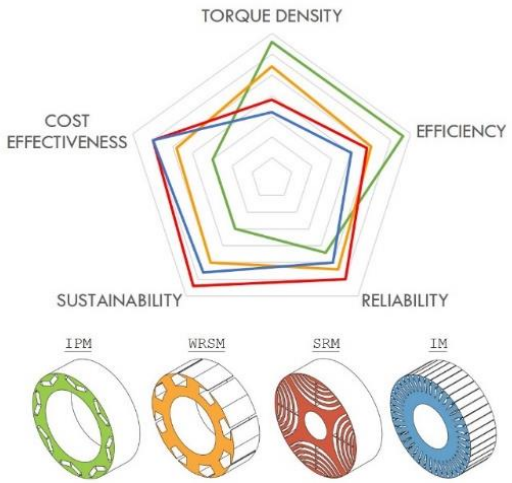
Research and Development of Electric Machines, Drives and Power Converters for electric vehicles

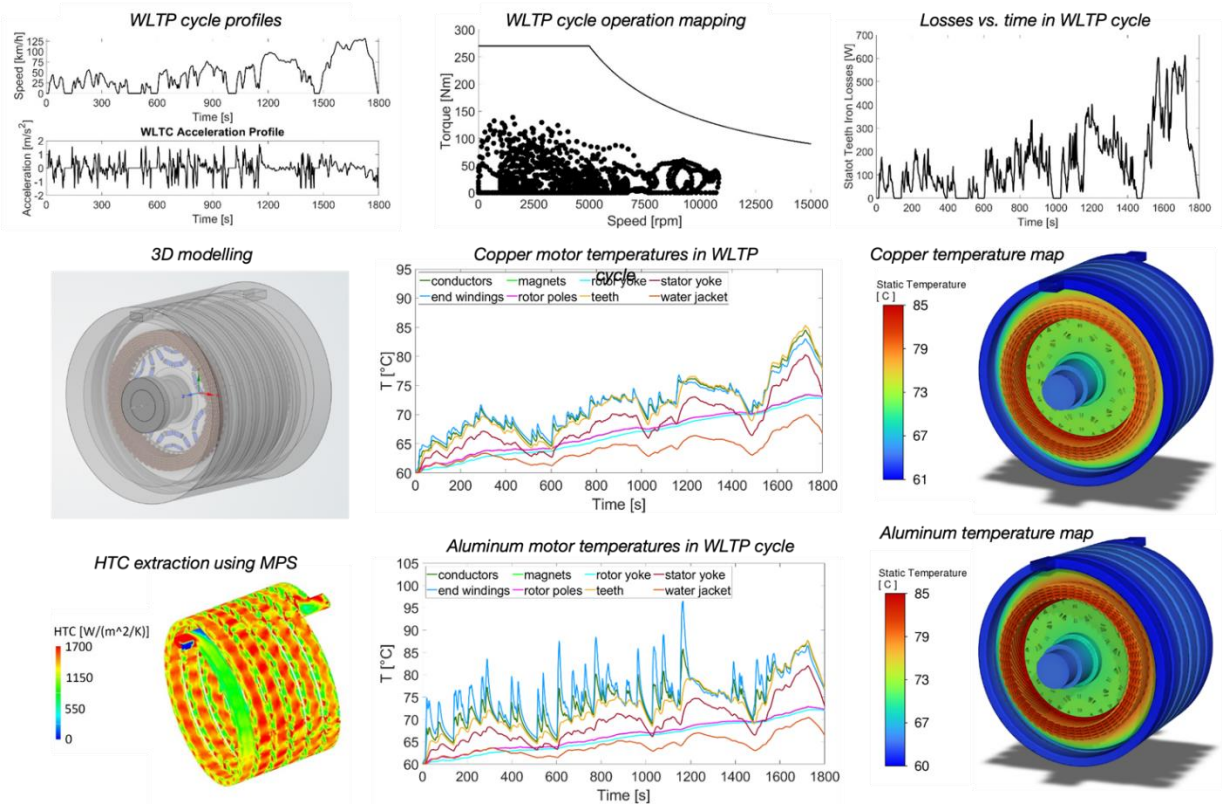
The research relies on analytical modeling, numerical simulation and analysis tools, to optimize and improve the performance of electric drives in transportation application as well as the associated electric vehicle subsystems.

Research overview

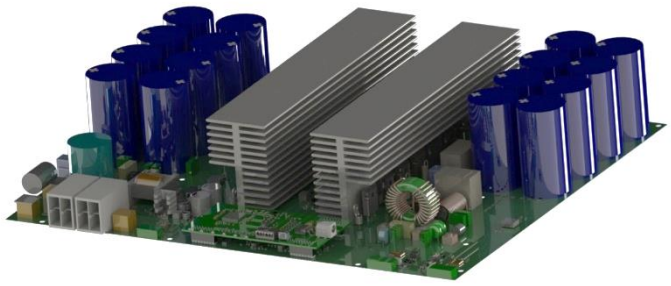
- Study, modeling and design of the various electrical components constituting full electric or hybrid powertrains. Particular importance is given to the analysis and modeling of electric machines and power converters that best suited the performance of the different type of vehicles.
- Investigation of new coils and windings forming methodologies and fabrication techniques, as well as cooling systems and machines topologies to increase power density, sustainability and reliability in high speed electric motors for traction applications
- Study and design of electrical drives for high-speed motors, and their control via wide-bandgap-based inverters (SiC, GaN), which can achieve very high switching frequency and maximize power density. Research of DC/DC converters able to integrate and exploit performances of different storage technologies
- Study, identification and modeling of the main stress factors responsible for aging and failure of electrical motors and passive magnetics driven by PWM converters assessing the effect of the joint action of electrical stress and environmental factors (changes in temperature, pressure, humidity) on the aging of insulation system. Detection of electromechanical faults, such as localized bearing faults with the mechanism of propagation of the failure signatures, through the harmonic study of phase currents (MCSA)

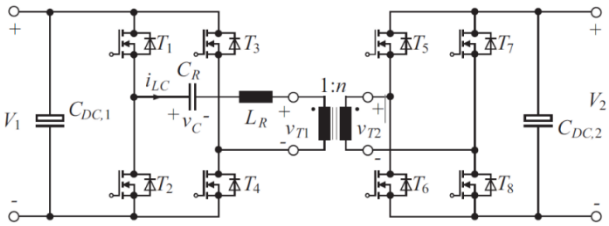
Expertise # 1 Design and FEM modeling of electrical machines



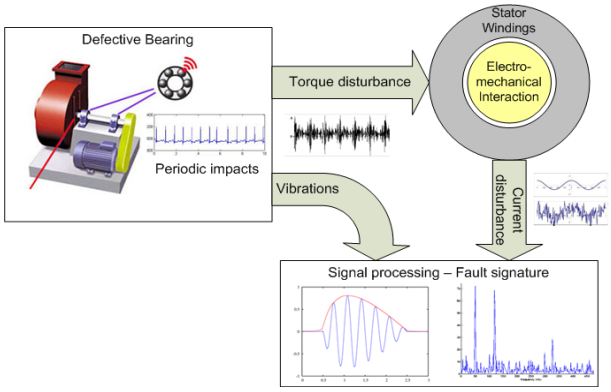


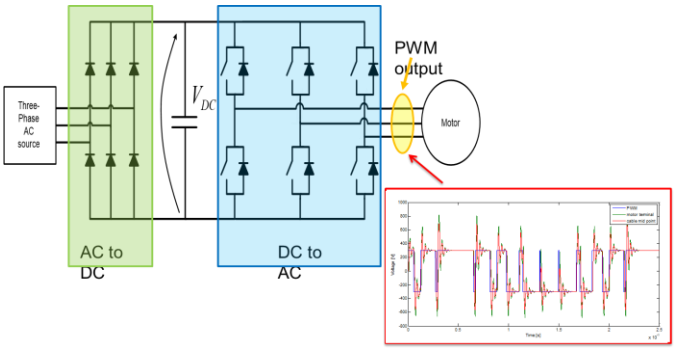
Expertise # 2 Design and development of high-performance power electronics converters based on Wide Bandgap Semiconductors

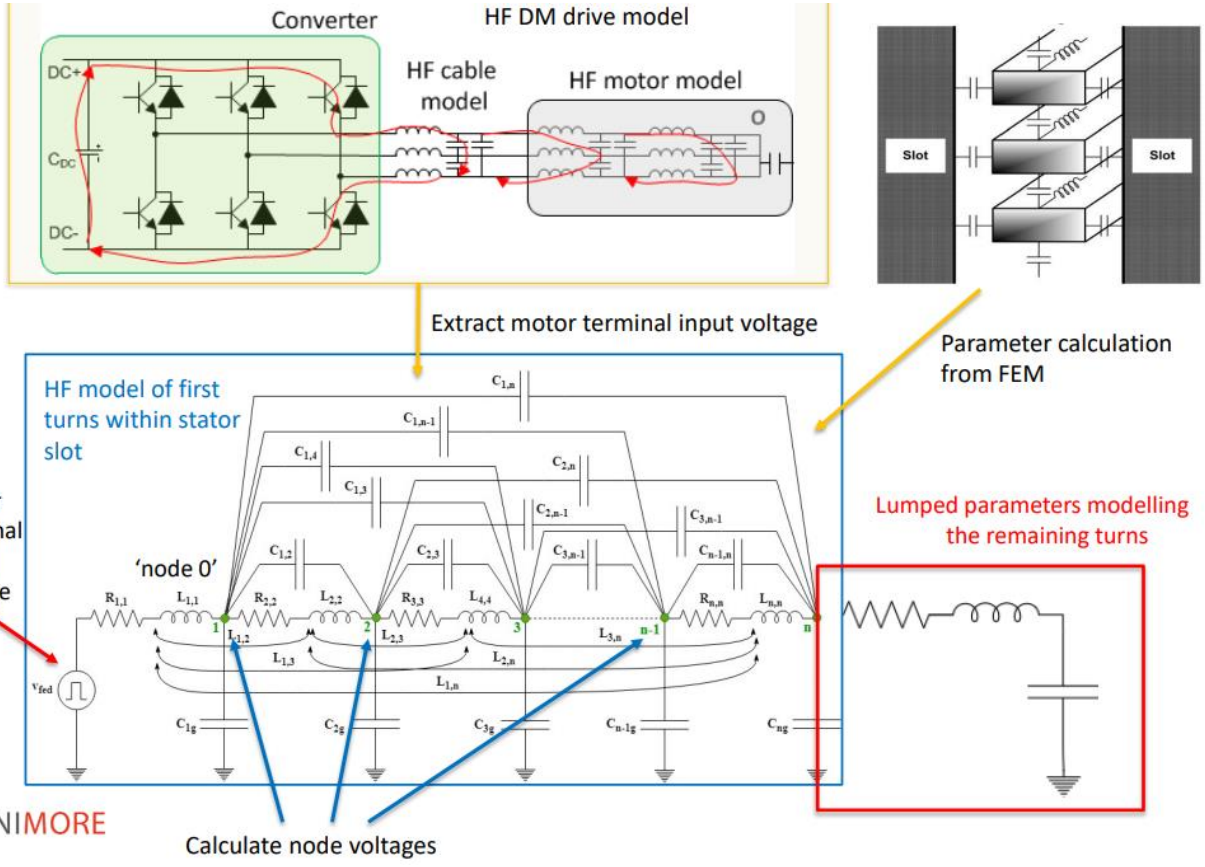




Expertise # 3 Fault diagnosis of electric machines and drives







Innovative Two-Stroke Cycle Engines running on sustainable fuels – Prof. Mattarelli – Prof. Rinaldini

The goal of this project is to explore the potential of the two-stroke cycle applied to innovative design concepts and utilizing sustainable fuels, with particular reference to hydrogen.

Research overview

- Study on Hydrogen–Diesel Dual Fuel combustion by means of CFD-3D simulation and experiments, carried out on conventional CI 4-stroke engines (background for the application to the 2-stroke cycle)

- Theoretical and experimental development of a single cylinder opposed piston SI engine running on Hydrogen for industrial applications (targets: 20 kW, BTE>40%)

- Development of a new Direct Injection 2-stroke motorcycle engine with the support of CFD-1D and 3D simulations. The engine will have the following features: twin cylinder, supercharged, forced lubrication with oil sump, loop scavenging with piston controlled ports, low-pressure direct injection, variable geometry of both scavenge and exhaust ports, EURO V compliant.

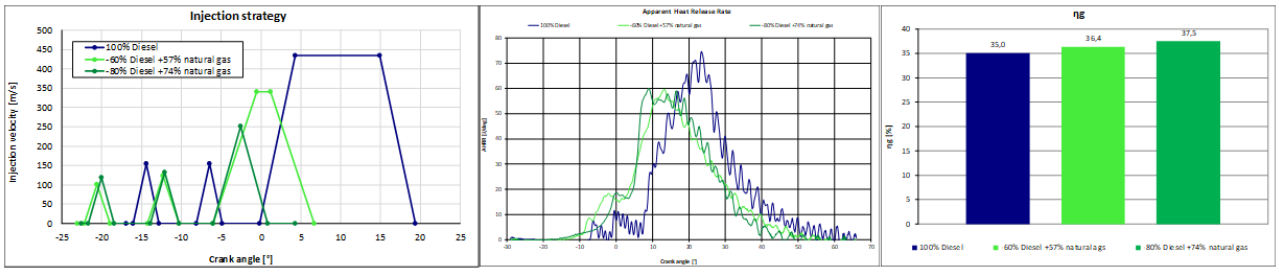
- Development of a parallel hybrid powertrain for a high performance motorbike, including the above mentioned 2-stroke engine, running on E-Fuels or bio-fuels.

Expertise # 1

Development and experimental calibration of a Natural Gas – Diesel Dual Fuel combustion system

Industrial Case: 4-stroke, 4-cylinder, 2.8L turbocharged Diesel engine, EURO IV compliant

Topics: achieve a regular, efficient and clean combustion when substituting up to 90% of Diesel fuel with Natural Gas

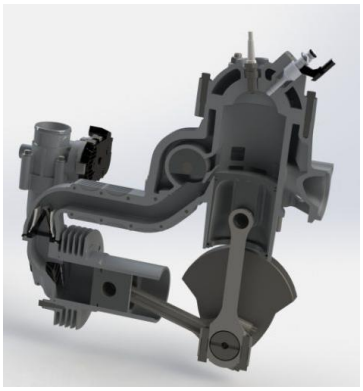


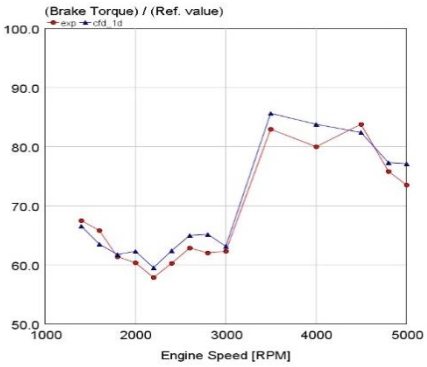
Expertise # 2

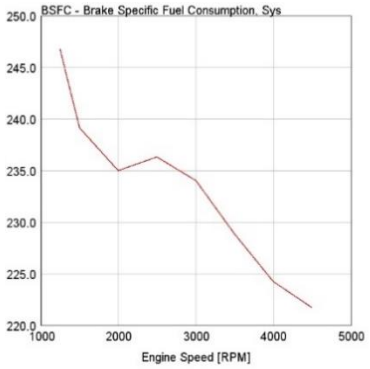
Development of a compact, clean and efficient GDI 2-stroke engine for Range-Extender application (30 kW at 4500 rpm)

Industrial case: PRIMAVIS Range-Extender, single-cylinder, 0.5 liter, loop scavenging with external piston pump

Topics: optimization of the scavenging and combustion system by means of integrated CFD 1D and 3D simulations; experimental calibration of the prototype

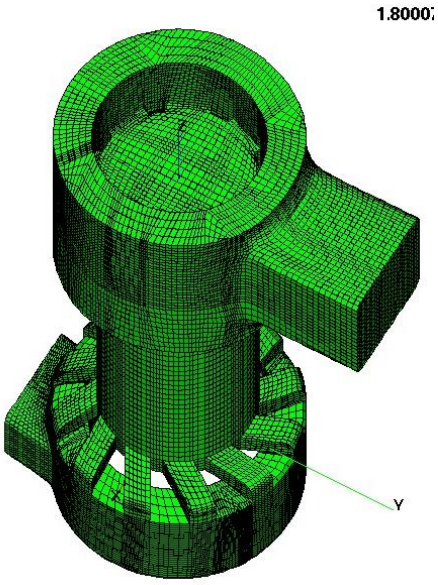


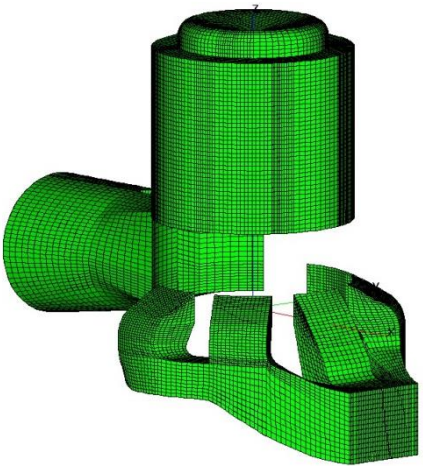


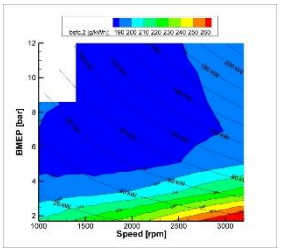


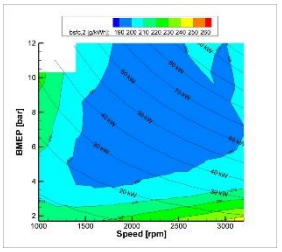
Expertise # 3

Theoretical study for the development of an opposed piston and a loop scavenged CI engines, in cooperation with General Motors









Development of neuro-inspired architectures for driver drowsiness detection – Prof. Pavan

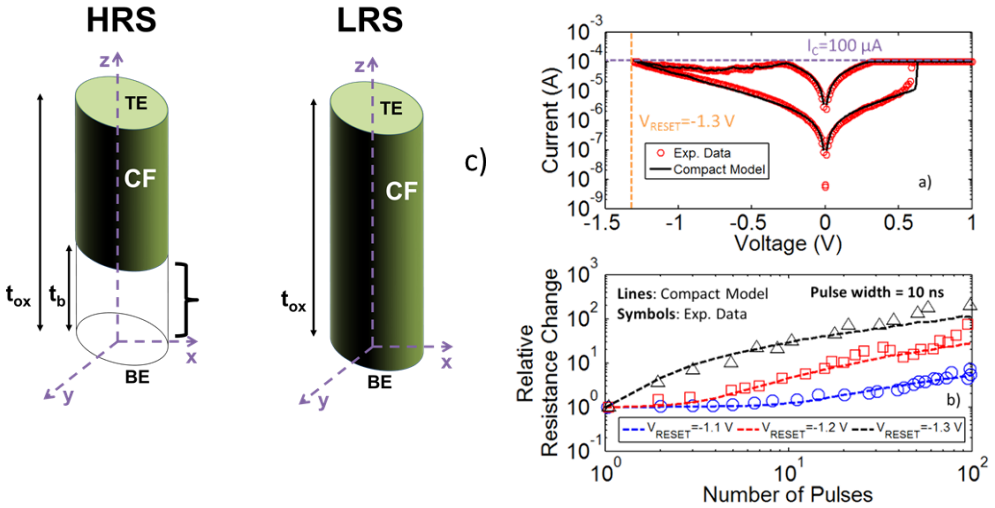
The *micro and nano electronics* research group at University of Modena and Reggio Emilia applies advanced characterization methodologies and simulation tools to support the development of neuro-inspired architectures based on resistive switching devices (RRAM) to detect driver drowsiness.

Research overview

- Development and optimization of characterization methodologies of RRAM.
- Development and optimization of RRAM-based neuro inspired compact models.
- Development and optimization of innovative RRAM based neuro inspired architectures.
- Implementation of neuro-inspired algorithms to identify driver drowsiness monitors.
- Validation of neuro inspired algorithm results.
- Verification of electronic performance of neuro-inspired architectures.

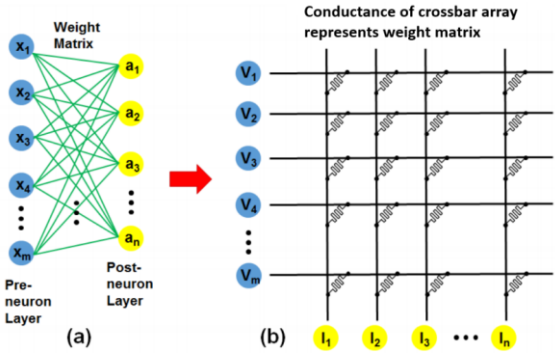
Expertise # 1

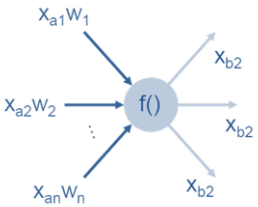
Simulation of RRAM devices, both at physical level and compact models



Expertise # 2

Design of neuro-inspired architectures.

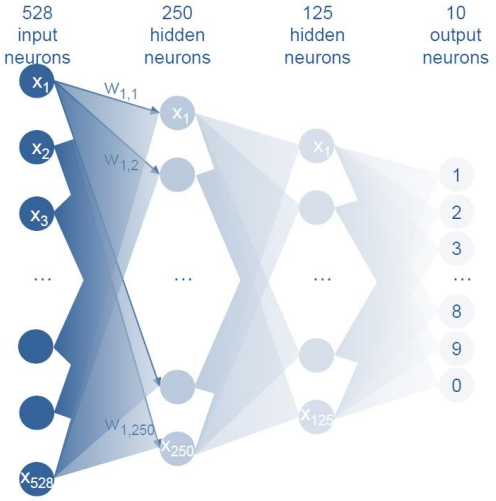




$$x_{bi} = f(\Sigma\, x_{ai} w_i)$$

Expertise # 3

Development of dedicated neuro inspired architecture to detect driver drowsiness.



Advanced Structural Modelling of Automotive components – Prof. Pirondi

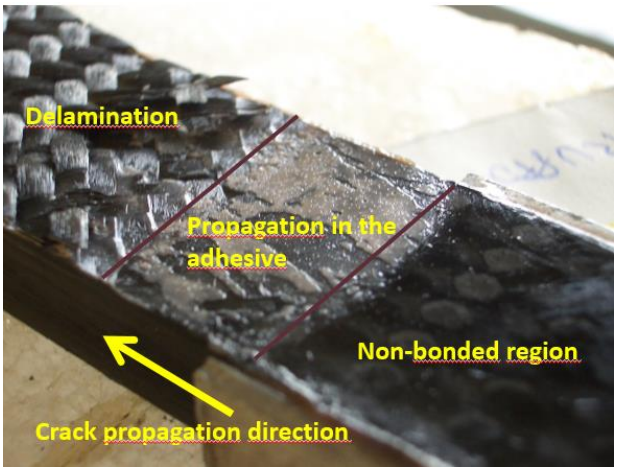
Development and optimization of lightweight, energy-saving components for automotive industry

The Machine Design research area of the Department of Engineering of Industrial Systems and Technologies (DEIST) at the University of Parma applies advanced experimental and simulation methods such as Non-linear Finite Element Analysis, Fracture testing, Experimental Stress Analysis, to support the development of single- and multi-material assemblies for the development of energy-saving components.

The Machine Design research overview

- Mechanical characterization of metallic, polymeric and composite materials.
- Characterization, design and optimization of structural joints, with focus on co-cured, co-bonded and secondary bonded single- and multi-material joints.
- Design and optimization of chassis body parts and assemblies, with an emphasis on suspension elements.
- FEA techniques applied to material behavior modelling and identification, design, optimization and failure analysis of automotive components and assemblies.

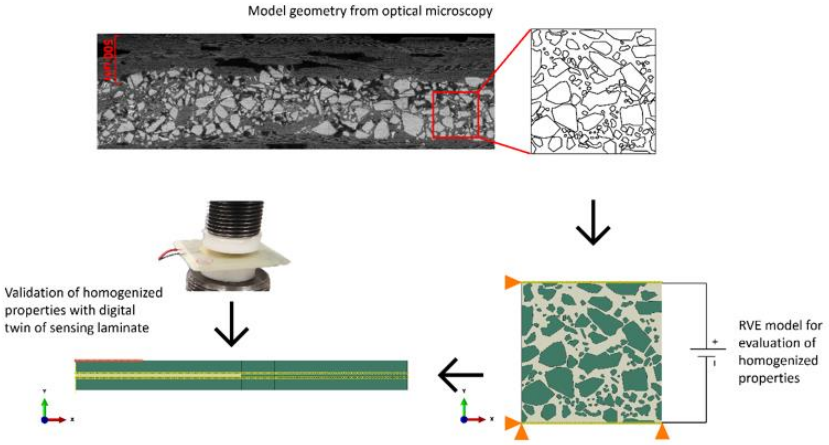
Expertise # 1 Structural Joining Methods for lightweight structures: design and optimization structural joint with special emphasis on co-cured, co-bonded and secondary bonded single- and multi-material joints and joint use of theoretical modelling, numerical analysis and testing



Expertise # 2 Simulation of the rolling resistance of pneumatic tyres. Expertise gained working in close collaboration with a tyre manufacturer, with the development of routine that, starting from the elastic stress-strain distribution in a pneumatic tyre retrieved by a quasi-static FE simulation, applies a linear viscoelaticity model and outputs the rolling resistance

Expertise # 3

Prediction of mechanical behavior of materials based on a meso-scale representation: theoretical and FE-based simulation methods applied to to a Representative (RVE) or Statistical Volume Element (SVE) of a material with multi-phase microstructure to identify the overall mechanical behavior from that of the single phases. The group relies on dedicated test equipment for strain, acceleration and residual stresses measurements.



Automotive Manufacturing System Design and Operations Management – Prof. Regattieri

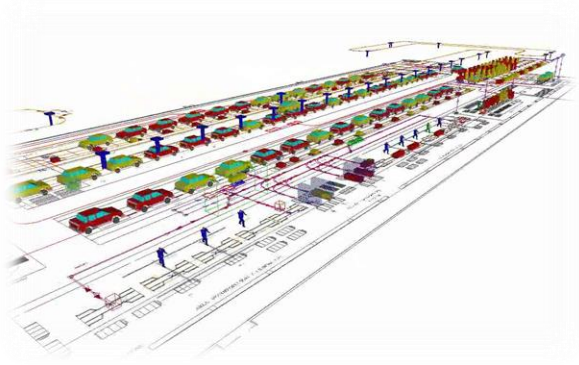
The efficient design of Manufacturing Systems and the correspondent management of the Supply chain play a fundamental role in modern Automotive companies. The Industry 4.0 perspective offers innovative approaches potentially disruptive in comparison with methods traditionally used.

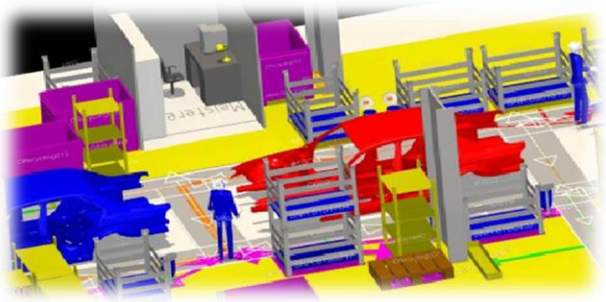
The research activities about manufacturing systems in the Automotive sector are facing big challenges due to new requirements by the markets, to the high level of global competition and to the new available technologies in the Industry 4.0 era.
The Automotive Manufacturing System Design Group (AMaSyDeG) working at the Department of Industrial Engineering @ University of Bologna is fully engaged in this context.
Main Research areas are:

- Innovative design methods for automotive manufacturing systems
- New material feeding systems for job shop and assembly lines
- Manufacturing Lines balancing innovative criteria
- New systems (based on Artificial Intelligence) for advanced training of operators
- Innovative track and trace methods for Material flow
- Workstation organization and design based on lean principles.
- Ergonomic design of the workstation.

The "next gen" research tracks opened at AMaSyDeG, are listed in the follow.

Expertise # 1 DESIGN OF INNOVATIVE AUTOMOTIVE MANUFACTURING SYSTEM
Feasibility study and development of innovative manufaturing solutions (i.e. Automatic Vehicle System – AGV, Flexible Manufacturing Systems, Collaborative Assembly systems, quality control system based on AI solutions, etc.).
Manufacturing system design (i.e. foundry, job shop, powertrain assembly, final car assembly, etc.)
System simulation for new plant design or for re-design of as-is manufacturing systems with the use of the digital twin (virtual simulation and commissioning of plant).

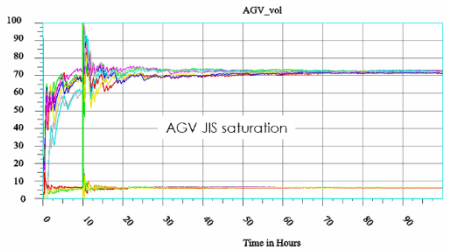


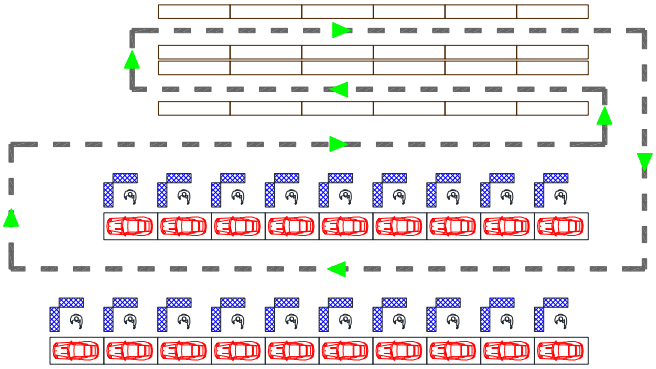


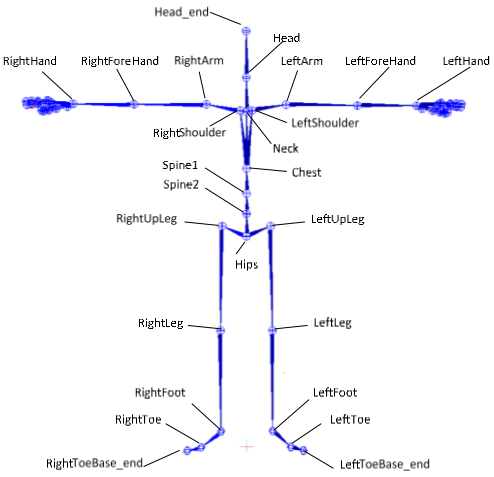
Expertise # 2 DESIGN AND OPTIMAL MANAGEMENT OF INNOVATIVE SOLUTIONS FOR LOGISTICS AND SUPPLY CHAIN

Development of Assembly lines innovative balancing methods, components al location and line feeding design, innovative inventory control with ANN algorithms.

Supply chain optimization (inbound/outbound)

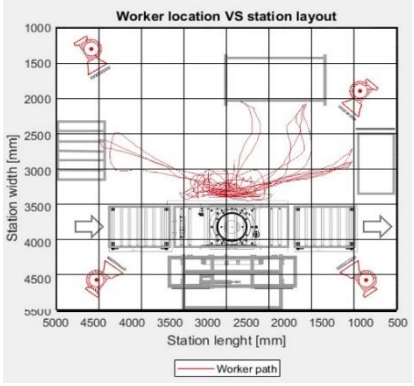


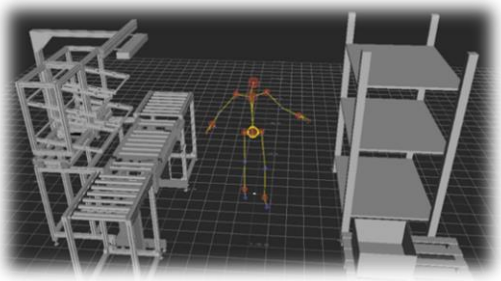




Expertise # 3 INNOVATIVE SOLUTIONS FOR WORKSTATIONS IN AUTOMOTIVE MANUFACTURING SYSTEMS

Material flow innovative track and trace. Augmented reality for material feeding support. Augmented reality for assembly support. Virtual training of operators. Workstation organization and design based on lean principles. Ergonomic design of the workstation. Automatic work measurement with 3D camera based technology





Electric Vehicle Charging Stations: power electronics and renewable integration – Prof. Ricco

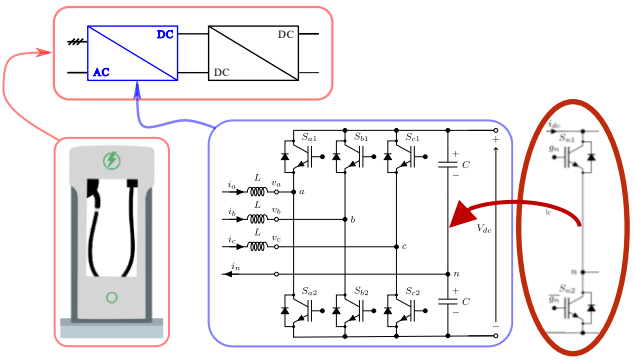
The research activity is focused on the study, design, and optimization of power electronic converters topologies and modulations as well as their control for on-board and off-board electric vehicle chargers.

The integration of renewable sources with electric vehicle charging plays a fundamental role in ensuring truly sustainable and pollution-free mobility. In this context, research activities focus on optimized charging management methods through smart-charging, V2G and V2X techniques, and energy management for integration with photovoltaic and storage systems.

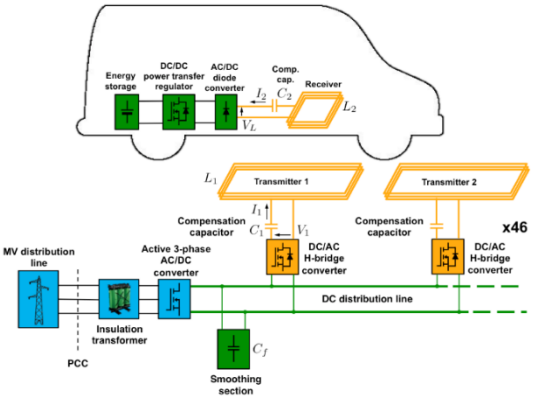
Main research topics of the group:

- Onboard (AC charging) and offboard (fast and ultra-fast) chargers
- Design and control of three-wire and four-wire active front-end topologies
- Design and control of isolated back-end topologies (especially Dual-Active Bridges)
- Optimization of efficiency, weight, footprint, and harmonic pollution
- Multiport power conversion for the integration of renewable energy sources and battery energy storage
- Multi-level power converters for the direct connection to the MV AC grid
- Static and dynamic wireless power transfer (WPT) for electric vehicle charging
- Electric vehicle charging infrastructure and its communication protocols.
- Forecasting methods of EV fleet charging demand based on statistical and data-driven approaches (machine learning)
- Photovoltaic technology and energy prediction algorithms
- Modeling and optimal sizing methods of charging hubs integrated with stationary storage and photovoltaic systems
- Development of Charging Management System (CMS) to control the power consumption of large EV fleets for smart charging (SC), Vehicle-to-Vehicle (V2V), Vehicle-to-Load (V2X) and Vehicle-to-Grid (V2G) applications
- Energy Management System (EMS) for optimizing power balances within charging hubs with photovoltaic (PV) + stationary storage systems (BESS).

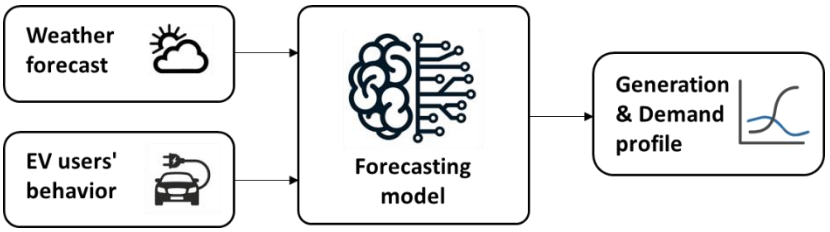
Expertise # 1 The group has experience in innovative power electronic converter topologies, both front-end and back-end, to optimize the bill-of-material, efficiency, harmonic pollution, weight and footprint. The expertise also includes developing advanced low-level modulation techniques and high-level control strategies. These skills are fundamental to enhancing power converter efficiency and ensuring fault-tolerant capabilities in both onboard and offboard chargers.



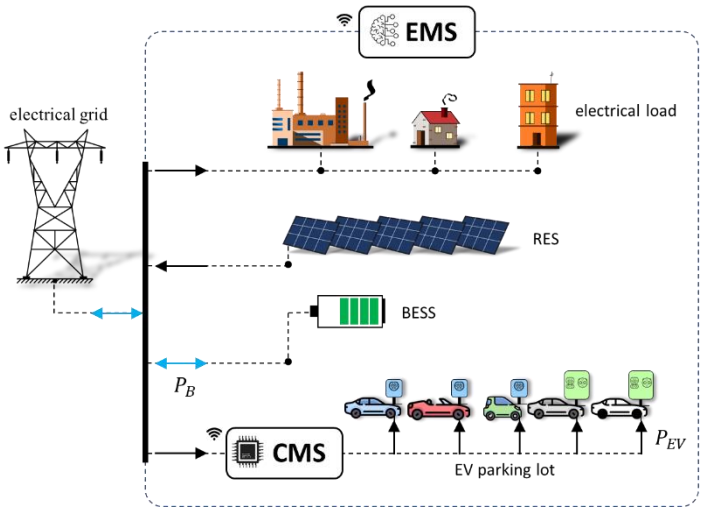
Expertise # 2 Study and design of wireless power transfer (WPT) for both static and dynamic electric vehicle charging. The expertise includes determining technical requirements and solutions, designing the power electronics, and ensuring compliance with human exposure limits.



Expertise # 3 Development of advanced methods for modelling photovoltaic systems, battery storage systems, and electric vehicle charging behaviour. Real-time forecasting of PV generation and charging station demand profiles.



Expertise # 4 development of energy management systems (EMS) based on optimization and forecasting methods to integrate renewable sources with electric mobility and charging management systems (CMS) to optimize the EV power demand in large charging hubs. The expertise of the group includes optimization techniques to achieve Smart Charging solutions, also considering bi-directional power flows.



Dynamics and NVH of road and off-highway vehicles – Prof. Rivola – Prof. Martini

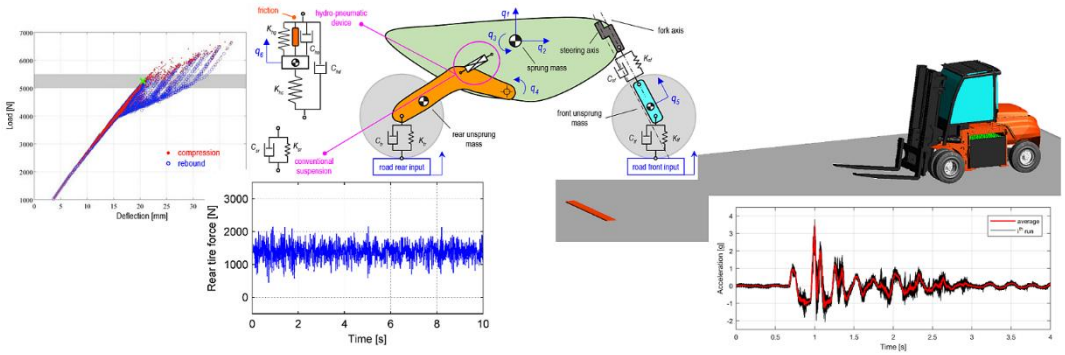
Development of innovative analysis tools and design strategies to enhance the dynamic performance and vibration response of vehicles

The research relies on numerical simulation and analysis tools, experimental vibration measurements and advanced signal processing techniques to investigate and improve the dynamic performance of full-vehicles, as well as to assess and limit vibro-acoustic issues related to vehicle subsystems

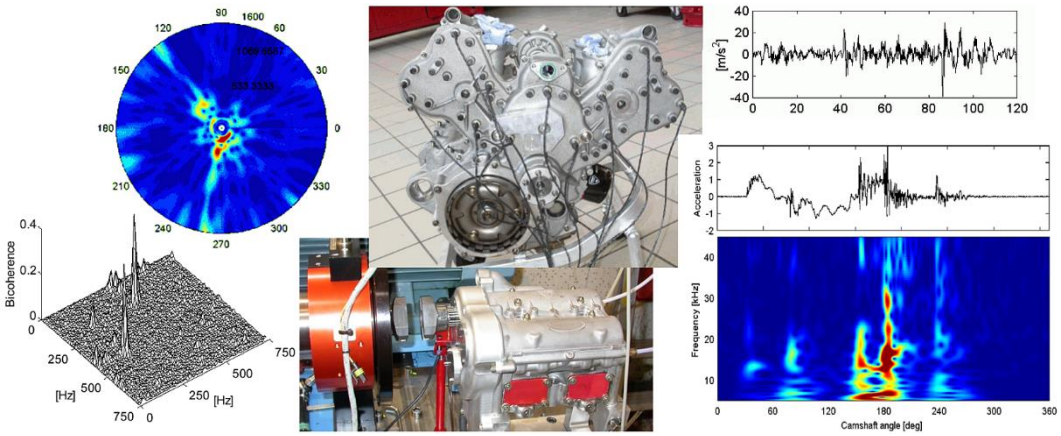
Research overview

- Development and validation of flexible multibody models to perform virtual tests for evaluating the (elasto-)dynamic behavior of full vehicles and/or parts/assemblies/devices for automotive applications (e.g. suspension systems and drivelines)
- Identification of vibration sources by designing and performing experimental campaigns for vibration measurements on test benches and/or in real operating conditions
- Development of effective design solutions for reducing noise and vibrations in automotive drivelines and mechanical transmission systems
- Implementation of algorithms for vibration monitoring and diagnostics of innovative drivelines for electric cars and industrial vehicles for material handling
- Definition of advanced algorithms for the synthesis of laboratory test profiles to perform vibration-based highly accelerated life tests (HALT) on automotive components
- State estimation and parameter identification with advanced techniques (e.g. Kalman filters and machine learning algorithms) for high-performance vehicles and racing applications

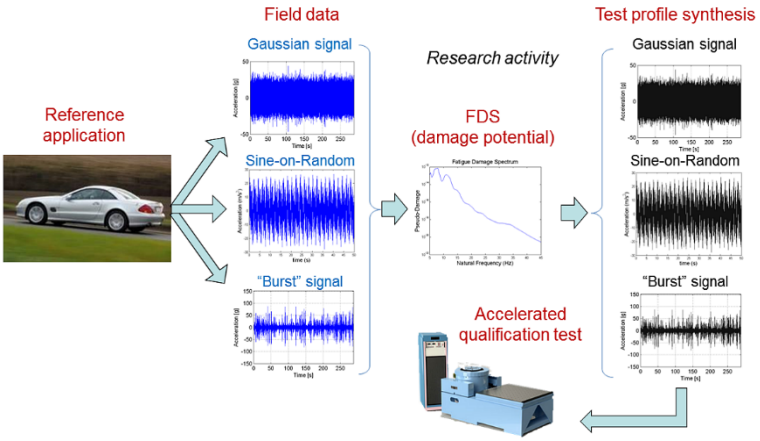
Expertise # 1 Development of elastodynamic models for the virtual testing of full vehicles and assemblies/devices for automotive applications



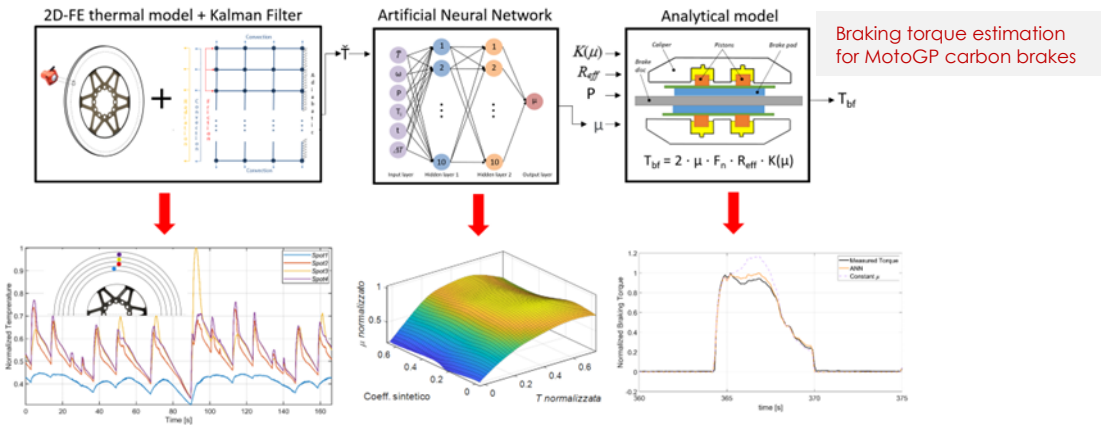
Expertise # 2 Experimental measurements for vibration source identification and fault detection/diagnosis



Expertise # 3 Synthesis of laboratory profiles for vibration-based HALT tests on automotive components



Expertise # 4 State estimation and parameter identification with advanced techniques for high-performance and racing vehicles



Big Data for Interconnected, Safe and Sustainable Mobility – Prof. Simone

The emerging paradigm of Big Data has recently garnered significant global interest, particularly in the sectors of transportation and automotive industries. The integration of disruptive technologies and new concepts, such as the Smart City, enhances the transport data life cycle. In this context, Big Data is considered an innovative solution for the transportation sector, enabling efficient management of the data required to provide smarter, safer and more efficient means of transportation, as well as allowing users to personalize their travel experience.

Main Research areas are:

- Road asset management
- Pavement management systems
- Monitoring of people behaviour and movements
- Cooperative Intelligent Transport Systems C-ITS
- V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) interactions
- Driver behaviour
- Road safety

Expertise #1 Mobility has emerged as one of the most investigated field of Big Data applications in the context of Intelligent Transport Systems (ITS). The group has expertise in the management of floating big data for managing the sustainable mobility matters such as cell phone data, floatig car data (FCD) and data on public transportation.

Expertise #2 The use of big data in the mobility field is coherent with the common definition of five-V-paradigm: Value – which information we can extract from data; Velocity – speed of data collection and processing; Volume – the amount of data obtained; Variety – typology and structure of data; Veracity: reliability of data. The reliability of data is still one of the more crucial point in the field of ITS.

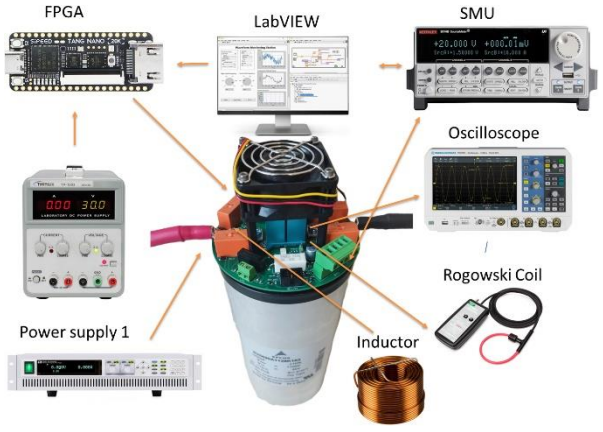
Expertise #3 The development of automated driver assistance systems (ADAS) and various sensors installed on connected vehicles (CVs) has surged in recent years. The proliferation of these vehicles within network systems can offer innovative monitoring strategies and enable real-time assessment of road network quality, which can be integrated into a comprehensive road asset management framework.

Characterization and Modeling of Wide Band Gap (WBG) Semiconductor Power Devices – Prof. Tallarico

The adoption of Wide Band Gap (WBG) semiconductor power devices in automotive technology is pivotal for enhancing the efficiency and performance of electric vehicles (EVs). Their superior efficiency and compactness contribute to increased driving range and faster charging times, crucial factors for widespread EV adoption. However, further development and improvement of WBG devices are necessary to accelerate this transition, ensuring even greater efficiency, reliability, and cost-effectiveness in automotive applications.

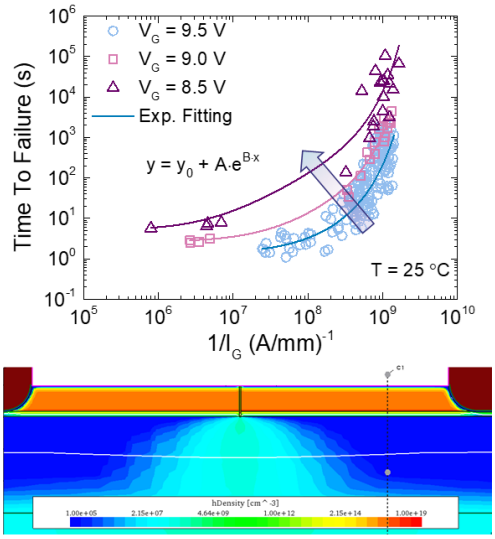
Research overview:

- Development of experimental setups aimed at testing performance, reliability and robustness of WBG power devices;
- Implementation of advanced techniques for accelerated stress/reliability tests;
- Experimental characterization of wear out effects and of the underlying microscopic mechanisms in WBG power devices;
- Semi-empirical modelling of the devices degradation by means of accelerated stress tests and TCAD (Technology Computer-Aided Design) physics-based simulations;
- Design and prototyping of power circuits specifically oriented to the *in-situ* analysis of the wear out affecting WBG power devices.

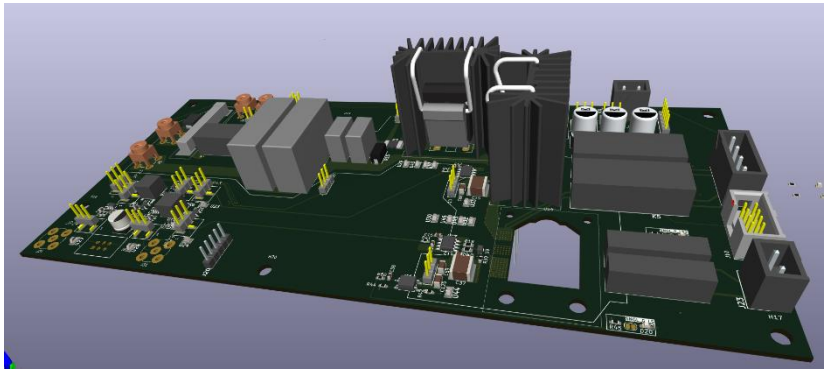


Expertise # 1 Development of experimental setups for testing the performance, reliability, and robustness of Wide Band Gap (WBG) power devices is essential for accelerating their commercialization and widespread adoption in various applications, including automotive, renewable energy, and power electronics. These setups typically involve specialized equipment and procedures to accurately assess the electrical, thermal, and mechanical characteristics of WBG devices under different operating conditions, driving continuous improvement and innovation in WBG semiconductor technology.

Expertise # 2 Characterization and modeling of Wide Band Gap (WBG) power devices are fundamental steps in understanding and optimizing their performance and reliability for various applications. Characterization involves systematically measuring and analyzing the electrical, thermal, and reliability properties of WBG devices under different operating conditions. Modeling plays a crucial role in predicting and optimizing the behavior of WBG power devices. By combining experimental characterization with advanced modeling techniques, devices design can be optimized, improving reliability, and accelerating the adoption of WBG semiconductor technology in various high-performance applications.



Expertise # 3 Designing and prototyping power circuits specifically oriented to the in-situ analysis of wear-out affecting Wide Band Gap (WBG) power devices is crucial for understanding device degradation mechanisms and improving their reliability and lifespan. These circuits are tailored to monitor key parameters such as temperature, voltage, current, and gate signals during device operation, providing valuable insights into degradation processes occurring in real-time. Additionally, in-situ analysis provides valuable data for developing predictive models and simulation tools to forecast device degradation and optimize device designs for long-term reliability.



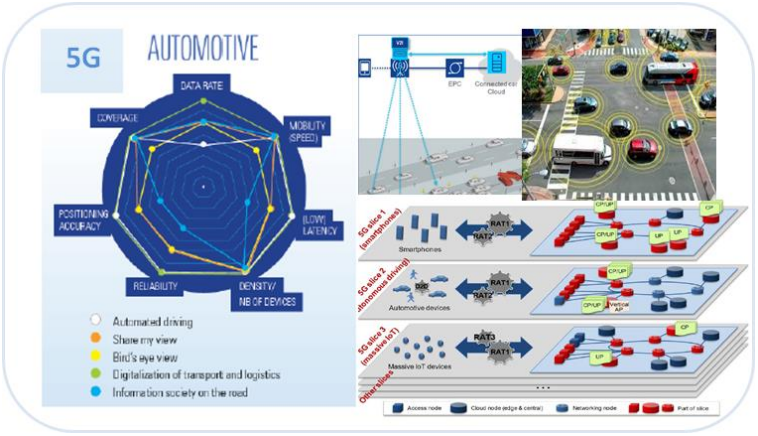
Wireless Network and Communications for vehicular applications in Smart City scenarios – Prof. Tarchi – Prof. Bazzi

The Telecommunications research field deals with the methodologies and techniques for information processing and transmission over wireless and wired media across communication networks, covering all aspects from the physical layer to the application level. The research activity is focused on the study and design of wireless communication systems and networks, as well as radio navigation systems for vehicular and roadside applications.

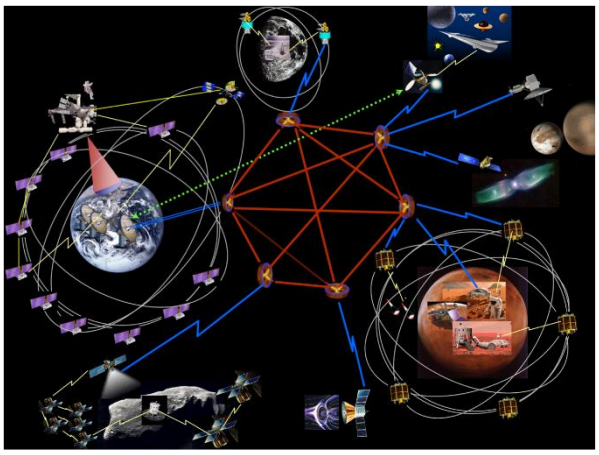
The Telecommunications research field overviews

- ICT for intelligent transportation systems and smart cities
- Network technologies for vehicular transportation: Software Defined Networking, Network Function Virtualization and Network Slicing Solutions for Vehicular Networks
- Delay-/Disruption-Tolerant Networking
- Vehicular Mobile edge computing and fog computing scenarios
- Vehicle-to-Everything communication technologies, including Vehicle-to-Vehicle, Vehicle-to-Infrastructure, Vehicle-to-Network and Vehicle-to-Vulnerable Road users.
- Cellular-V2X, including 5G for vehicular scenarios.
- Satellite and Terrestrial hybrid solutions for vehicular networks
- Wireless Sensor Networks for vehicular systems
- Energy efficient wireless systems for vehicular applications
- Multimedia networking for vehicular applications
- Satellite and terrestrial localization systems
- Big Data for mobility
- Machine learning techniques applied to vehicular transportation.
- Advanced methodologies for safety enforcement
- Information and signal processing for vehicular communication systems
- Study and development of vehicular electromagnetic propagation and channel modeling.

Expertise # 1 The group has experience in network architecture, protocols, and algorithms to be applied in the automotive context taking into account the specific requirements of the vehicular context in terms of latency, density, and safety. The emerging concepts of virtualization and slicing are of high interest for the group to design 5G controlled.



Expertise # 2 Delay-/Disruption-Tolerant Networking (DTN). DTN is a new architecture designed to cope with "Challenged" networks, i.e., networks affected by ling delays, link disruptions and network partitioning, where traditional TCP/IP architecture cannot work effectively. Challenged networks include space networks, but also vehicular networks. DEI has a long and well-established experience on DTN.



Expertise # 3 Wireless communications for vehicular networks, with emphasis on the main technologies that are available as state of the art, covering both direct communications and communications using the cellular infrastructure. Concerning direct communications, this includes both the IEEE 802.11p/bd, with the related American and European protocol stacks, and the 4G and 5G cellular-vehicle-to-everything (C-V2X) sidelink defined by the 3GPP. The expertise extends to minor alternative or additional solutions, such as visible light communications.