ECO DRIVE PUBLIC WORKSHOP

June 23-24, 2022

ANCONA, ITALY

UNIVERSITÀ POLITECNICA DELLE MARCHE

MicrodB

Contents

About ECO DRIVE

Over the next 30 years, as we shift towards Electric Vehicles (EVs), downsized IC (Internal Combustion) engines and hybrids with eco-powertrains will be central to the automotive sector. ECO DRIVE develops new technologies for the testing and simulation of eco-powertrains, addressing the complex challenges related to combustion noise, the irritating sound from electric motors, transmission-induced NVH (Noise, Vibration and Harshness) and driveline torsional vibrations, leading to new designs with improved eco-efficiency and NVH performance.

OBJECTIVES

The project offers a multi-disciplinary research-training program to the ESRs (Early-Stage Researchers), with the ultimate aim being to create a new generation of NVH professionals for the transport sector. The technical-scientific challenges are tough: to investigate highly innovative simulation, testing and signal-processing methods for advanced NVH analysis and the engineering of downsized IC engines, e-motors, and novel lightweight transmission systems, to validate and demonstrate the applicability of the developed approaches in an industry context, on both powertrain tests rigs and new vehicles. ECO DRIVE has 9 Beneficiaries from leading academic institutions, top research centres and Europe's premier vehicle producers. Together, they address the triple-I dimension of research training, being International, Interdisciplinary and Intersectoral. The ESRs profit from top scientific research guidance in combination with highly relevant industrial supervision through the secondment exchanges between the research organizations and the industry partners. The participating organisations gain from their involvement with top-level research; the ESRs receive outstanding Europe-wide training; and society benefits from a new group of young engineers trained in this exciting cross-disciplinary field.

BENEFICIARIES

KU LEUVEN

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

KIT Karlsruhe Institute of Technology

Fraunhofer IWU

UNIVERSITÀ POLITECNICA DELLE MARCHE

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SIEMENS

BMW GROUP

STELLANTIS

Timetable

ESR: Early-Stage Researcher Talk, IT: Industrial Talk.

Thursday, 23 of June

10h30–11h30	**Welcome and Registration**		
11h30–12h		**Konstantinos Gryllias** KU Leuven, Belgium	ECO DRIVE project presentation
12h–14h	**Lunch**		
14h–14:40	IT	**Martin Jeannerot** VibraTec, France	NVH of electric motors – Overview of VibraTec experience after (almost) 20 years
14:40–15h	ESR	**Xian Wu** KU Leuven, Belgium	Source separation and signal enhancement using a sparsely deployed array for condition monitoring of rotating machinery
15:20–15:40	ESR	**Muhammad Albezzawy** INSA Lyon, France	Advanced cyclo-stationary signal-processing methods for combustion/mechanical breakdowns
15:40–16h	ESR	**Kalasagarreddi Kottakota** MicrodB, France	Noise source localization during the Run Up/Coast Down
16h–16h20	**Coffee**		
16:20–17h	IT	**Olivier Sauvage** Stellantis, France	Noise and vibration new challenges in vehicles with electrified powertrains
17h–17:20	ESR	**Reza Jamali** UNIVPM, Italy	Increase the robustness of the subjective jury tests
17:20–17:40	ESR	**Vinay Prakash** Stellantis, France	Metamodels for linking powertrain design and NVH performance
17:40–18h	ESR	**Nicolo Salamone** SISW, Belgium	Advanced digital framework to improve eco-efficiency and vibro-acoustic vehicle comfort
19h	**Workshop Dinner**		

Friday, 24 of June

9h–9:20	**Arrival / coffee**		
9:20–10h	IT	**Arthur Hülsmann** BMW Group, Germany	NVH design of electric cars using dynamic substructuring
10h–10:20	ESR	**Rafael Dias** UNIVPM, Italy	Exploration of the state-space formulation for time domain dynamic substructuring applications
10:20–10:40	ESR	**Alessandro Zucchini** BMW Group, Germany	Modelling, design and testing of electric vehicle drivetrain acoustic
10:40–11h	**Coffee**		
11h–11:20	ESR	**Steve Mathew** INSA Lyon, France	Modeling and simulation of an electric powertrain NVH using angle time modeling
11:20–11:40	ESR	**Julian Staiger** KU Leuven, Belgium	The MSF approach in an industrial context
11:40–12h	ESR	**Khadijeh Farshi** KIT, Germany	Test-based method for targeted design of gearboxes with regards to lightweight specifications and acoustic behaviour
12h–14h	**Lunch**		
14h–14:40	IT	**Fabio Bianciardi** SISW, Belgium	The role of testing in the digital world
14:40–15h	ESR	**Lorenzo Mazzanti** SISW, Belgium	Smart Virtual Sensing for geared drivetrains
15h–15:20	ESR	**Navdeep Sharma** IWU, Germany	Simulation based sensitivity analysis of lightweight design concepts in terms of gearbox acoustics
15:30–17h	**ESR Social Activities**		

List of Abstracts – Talks

Thursday 23rd

NVH of electric motors – Overview of VibraTec experience after (almost) 20 years

Martin Jeannerot IT

VibraTec, France

Since the beginning of the 2000's, VibraTec is involved in the development of simulation and experimental analysis regarding electric motor NVH. The aim of this talk is to make a short reminder of the main technical hurdles that have been overcome up to now.

Electromagnetic simulation and mechanical simulation were two technical domains that were not able to communicate easily. One of the first breakthrough was the possibility to make them compatible in order to use the output from electromagnetic calculation (electromagnetic forces) as input for the mechanical model using rather different mesh strategy. The originality of VibraTec's approach is the possibility of analyzing the electrodynamic excitations (the forces) prior to the application on the mechanical model.

Since then, many electric motors have been studied: Permanent Magnet, Switch Reluctance, Induction machines, Brushless Direct Current… The presentation will give some examples of those different technologies. Finally, the latest state of the art on NVH and multiphysics optimization of electric motor topology will be presented.

Noise and vibration new challenges in vehicles with electrified powertrains

Olivier Sauvage IT

Stellantis, France

Electrified powertrains are today fully part of the acoustic landscape of people in their (new) vehicles – and have given major hopes for cleaner, more silent mobility technologies too. These hopes have quickly been converted into strong and often mandatory requirements for car designers and manufacturers, thus in the past years they have deeply changed many design rules, technical referential in the NVH engineering domain. Some of the associated technical and scientific challenges are then quite different from those associated with traditional internal combustion engines. In this introductive presentation we will give one general overview of the main NVH sources in BEVs, with details for some of our new specific NVH issues. This will also highlight the industrial context of the 3 upcoming PhD developments within this ECODRIVE MSCA-ITN project session.

Topic : NVH analysis of downsized IC engines and e-motors

Source separation and signal enhancement using a sparsely deployed array for condition monitoring of rotating machinery

Xian Wu

ESR

LMSD Division Mecha(tro)nic System Dynamics, Department of Mechanical Engineering, KU Leuven, Belgium
Dynamics of Mechanical and Mechatronic Systems, Flanders Make, Belgium

The occurrence of unexpected failures during the operation of a machine may result to sever accidents with human casualties, environmental pollution, and production losses. Thus, early and accurate fault detection and diagnosis are crucial in order to avoid unexpected machine downtime

Conventional vibration-based condition monitoring methods require the installation or integration of accelerometers into machine systems. However, this is not always feasible due to the costly installation or accessibility of the components. These drawbacks can be overcome by using contact-less sensors, such as microphones to monitor the operating condition of rotating machinery. The signature of the noise emitted from an operating machine can be used for the identification of the running conditions of the machine itself and the detection of anomalies. However, due to the complex sound field in real-world industrial environments, such as factories with multiple parallelly working machines, the measured acoustic signals are contaminated by reflections, reverberation, and background noise, which often result in a low signal-to-noise ratio (SNR). Hence, a solution to improve the SNR and separate the signal of interest is needed.

In this work, a methodology based on a data-augmented Minimum Variance Distortionless Response (MVDR) beamformer is proposed, performed on a sparsely deployed microphone array. First, the microphone channel which is located closest to the source of an unwanted noise is selected. Then it is rendered as the array response by being multiplied with the steering vector pointing to its location. The beamformer weights are calculated based on the augmented noise covariance matrix. The performance of the proposed methodology is evaluated in terms of the SNR improvement first on a simulated dataset and then on a real experimental dataset. The achieved results highlight the promising feasibility of this method for source separation and signal enhancement.

Advanced cyclo-stationary signal-processing methods for combustion/mechanical breakdowns

Muhammad Albezzawy

ESR

Laboratory of Vibration and Acoustics, INSA de Lyon, France

The characterization of sound sources is a common problem in acoustics. This characterization aims to localize, identify, and rank sound sources. Acoustic Imaging techniques have been successfully utilized for this purpose. However, If a composite field exists, where the contributions from incoherent sources overlap in both the spatial and the frequency domains, no definite phase value can be assigned at any point on the hologram plane, and hence sources can be hardly identified by acoustic imaging. Therefore, Source Separation techniques have been used as a preprocessing step to separate the contributions of incoherent sound sources before performing Acoustic Imaging. Sound Source Separation techniques are divided in two categories. The References techniques and the Blind Source Separation techniques. The aim of the PhD is to improve these techniques in terms of the effectiveness and robustness in situations where correlated, noisy, or no references exist. The target was quite accomplished for the category of the References techniques, where we introduced an original technique that can deal with the situation of a large set of correlated and noisy references, and it was formulated to deal with the MIMO systems hence it can process multiple outputs concurrently.

Noise source localization during the Run Up/Coast Down

Kalasagarreddi Kottakota

ESR

MicrodB, France

In the automotive industry, spectral and pseudo-temporal acoustic imaging is a popular method for identifying noise sources. However, because the resulting vibro-acoustic phenomenon during a run-up or coast-down is a function of the rotational speed of shaft rather than absolute frequency, this common technique cannot be directly applied to rotating machinery. The measured responses from a run-up/coast-down are non-stationary in nature, with amplitude and frequency modulation of the signal. Therefore, this needs the development of an acoustic imaging method for the identification of noise sources in the non-stationary environment. The order analysis is a well-established diagnostic tool for examining a machine with significant and high speed variations. It can extract orders, which are rotational harmonics, as well as study critical frequencies, tonal components, and so on. Combining the order tracking techniques with the microphone array processing reveals the localization of noise sources specific to the orders, allowing the identification of the dominant sources. Therefore, the presentation discusses the need for developing a tool for sound source localization in non-stationary regimes, as well as the value addition to the current acoustic measurement technique from an industry standpoint.

Increase the robustness of the subjective jury tests

Reza Jamali

ESR

Università Politecnica delle Marche, Italy

Sound is becoming a crucial part of the product design process. Today, customers don't look only into product functionality specifications, but more often demand high-quality sound in addition to other aspects. The most accurate way to rate sound quality is by performing a jury test that aims at identifying relations between the sound of a product and the quality perceived by the jurors. Jury tests consist in asking questions about the sound quality perceived directly to people acting as jurors. The output provided by jurors are gathered and analyzed to calculate specific scores, e.g. pleasantness or annoyance that are used to rate products in terms of sound quality performance. The disadvantage of a jury test is that it requires a lot of time and human resources, and it can be affected by uncertainty linked to the involvement of the jurors. To overcome this problem, jury tests results can be correlated to objective sound quality metrics. The logic behind performing subjective to objective correlation centers on the concept that one can possibly replace subjective testing with more objective characterizations of the stimuli. By doing this, one can reduce subjective testing that is costly from a time, equipment, facilities, and general logistics standpoint. In order to have a robust correlation between objective and subjective metrics, the latter ones obtained as result of the jury test, the jury test itself must have a sufficient level of accuracy and reliability. On that account, if the involvement of the jurors could be measured, this parameter could be used as a weighing function for the subjective metrics. A good candidate for the evaluation of juror's involvement is the physiological response to the sound stimulus provided to the juror during the jury test and this response can be measured by performing an Electroencephalogram (EEG) simultaneously to the jury test itself.

Metamodels for linking powertrain design and NVH performance

Vinay Prakash

ESR

Stellantis, France

In recent years, a great emphasis has been put on engineering the acoustic signature of vehicles that represents the overall comfort level for passengers. In the automotive industry, we rely heavily on numerical simulation or approximation methods to replace expensive and time-consuming real-world experiments. Such numerical methods are not useful when we are in the early-design stage where very little to no information is available about the different design parameters. Furthermore, the predictive assessment of the vehicle's NVH (Noise, Vibration and Harshness) response is even more challenging due to the highly uncertain behavior that arise from manufacturing tolerances, natural variability in material properties and conditions employed during the physical testing procedures. Owing to such vibroacoustic variability in production cars and various uncertainties in modelling processes, probabilistic metamodels or surrogates can be useful to estimate the NVH dispersion and assess different NVH risks. In contrast to black-box models, these grey-box metamodels mimic physical behaviors and shall aid as a design space exploration tool during the early-stage design process to support NVH optimization.

An automotive OEM (Original Equipment Manufacturer) such as Stellantis N.V. carries out NVH test campaigns on a regular basis for different needs and diagnosis. These measurement databases constitute different noise contributions such as aerodynamic noise (wind-tunnel test), tire-pavement interaction noise (rolling noise), and noise due to electric motors (whining noise). The first two noise contributions, aerodynamic and the tire-road noise, contribute towards the masking effect which lie in the broadband frequency regime. This research work proposes a global NVH metamodeling technique for mapping the operating input conditions to these broadband noises exploiting the Bayesian framework that takes into account the prior (domain-expert) knowledge about complex physical mechanisms. Both parametric and non-parametric Bayesian Hierarchical models are investigated to represent the level of uncertainty. Additive models based on Gaussians and b-splines along with physical laws are used to model the dependency of sound pressure level (SPL) on predictor variables which are further validated using k-fold cross-validation. Semi-analytical e-NVH models are realized with the help of open-source library Pyleecan and the probabilistic modelling is carried out with the help of a Python package PyMC3 that utilizes No-U-Turn sampler (NUTS). Several different diagnostic tools have been explored to assess the convergence of MCMC sampling process. For model evaluation and comparison of the predictive accuracy, we used Bayesian cross-validation (Leave-one-out, LOO).

Advanced digital framework to improve eco-efficiency and vibro-acoustic vehicle comfort

Nicolo Salamone

ESR

Siemens Industry Software, Belgium

The recent government's commitments in reducing greenhouse gas emissions are affecting the automotive world that is pushing for new and advanced eco-driving solutions that aim to efficiently balance energy consumption and performance. Automotive industries need also to face other questions, such as the noise exposure in the cities, that is leading to more stringent noise regulations. Moreover, the challenge to introduce specific noise signature is not straightforward in this era of powertrain electrification and hybridization. From the perspective of optimizing eco-powertrain acoustic comfort, it is important to assess the impact of control parameters that positively influence the noise and vibration behavior. Nevertheless, changing these control parameters primarily affects the powertrain performance. Multipurpose control optimizations are necessary to optimize different aspects and find trade-off solutions for efficiency and comfort. A virtual engineering platform that enables the optimization in an early-stage car design is presented. The proposed digital framework relies on a real-time co-simulation of a multi-domain 1D model, that simulate the vehicle performance, and of an acoustic model, which is based on data measured on an existing vehicle or on a virtual component assembly. The model interaction allows the user to evaluate the in-cabin acoustics through a Driver-In-the-Loop environment in realistic driving situations.

Friday 24th

NVH design of electric cars using dynamic substructuring

Arthur Hüelsmann

IT

BMW Group, Germany

Frequency-based substructuring (FBS) can bridge the gab in full-vehicle responsibility between the conception phase and full-vehicle hardware testing in the V-Model describing the vehicle development process. Substructures can be exchanged during rebalancing of subsystem conception and targets.

FBS and component-based Transfer Path Analysis (TPA) methods are used to analyze the drivetrain acoustics of an electrical vehicle. The models can be purely measurement-based or hybrid, based on experimental data as well as on simulation data from FE-models. The entire transmission chain is build modularly, starting from the electrical engine over a double elastic mounting with an axle carrier to the interior. Various elastic mounts are characterized using an inverse FBS approach. The excitation by equivalent forces, the mount models, the coupling of the electrical drivetrain with the rear axle carrier only and the full-vehicle synthesis showing acceleration and sound pressure level results are validated one by one. Parameter variation or variants comparisons are powerful applications of this method.

The role of testing in the digital world

Fabio Bianciardi

IT

Siemens Industry Software, Belgium

A global digital revolution is truly underway across many industries. In the automotive domain, we observe a very dynamic transition toward electrification and autonomous driving, which is impacting largely the overall way engineers are developing their vehicles. Electrification brings new powertrain concepts, innovative lightweight materials, with a drive toward higher efficiency and extended range. In this context the requirements of the testing activities are changing and the biggest challenge for test engineering teams is to support the continued drive for developing innovative products and to meet critical product requirements.

We are witness of a strong acceleration in terms of time to market along the vehicle development cycle, a drive to reduce prototypes and to perform more and more numerical simulations. All this can be done in an efficient way by having a strong link between test and simulation, so that test can enrich and validate simulations, enabling the so called virtual digital twin. Testing also gives critical insight into balancing between conflicting performance criteria and delivering upon critical product performance.

In this keynote, SISW will discuss how advanced in-depth testing remains crucial in qualifying how designs perform through the full product lifecycle.

Exploration of the state-space formulation for time domain dynamic substructuring applications

Rafael Dias

ESR

Università Politecnica delle Marche, Italy

Nowadays, dynamic substructuring is mainly explored in frequency domain. Yet, some applications would profit from time domain analyses (for instance, real-time substructuring). Due to the suitability of state-space models to deal with problems posed in time domain, the group of dynamic substructuring techniques named state-space substructuring seems to be promising to extend the applicability of this concept into time domain. However, this family of methods is still under investigation, not being so well established in literature as the frequency based ones. Therefore, we decided to investigate this kind of methods to develop state-space substructuring (SSS) techniques, which are suitable for analyse components rigidly connected or connected by means of a connecting element. Furthermore, we intend to produce methods that merge the advantages of the previously presented ones. As greater milestone, we are seeking to increase the global knowledge and interest of the engineering community in the field of SSS methods by demonstrating the value of these approaches to tackle challenging non-stationary applications, e.g involving time-varying loads. An interesting outcome will be also the possibility to adopt SSS in time-domain component-based TPA approaches.

Modelling, design and testing of electric vehicle drivetrain acoustic

Alessandro Zucchini

ESR

BMW Group, Germany
Department Mechanical Engineering, Katholieke Universiteit Leuven, Belgium

The aim of this PhD project is to develop methods to predict the structure borne noise transmission and the overall sound pressure level at the driver's ear in future electric cars. The prediction includes the transmission of the structure borne noise from the excitation from the electrical drive train (electromagnetics and gear whining noise), through the elastomer mounts and the chassis to the driver's ear. Various FRF's (frequency response functions) describing the dynamic behavior of different subsystems of the vehicle are coupled using dynamic substructuring to predict the vehicle behavior. The PhD thesis will improve the methods themselves (such as a higher frequency range, simulation of rubber mounts or mechanical acoustical transfer function of the car body) as well as apply them to derive a better understanding of structure borne electrical drive train acoustics.

Topic : NVH analysis of lightweight transmission systems and drivelines

Modeling and simulation of an electric powertrain NVH using angle time modeling

Steve Mathew

ESR

LaMCoS, INSA de Lyon, France

Electrification of vehicles has radically changed how the Noise Vibration and Harshness (NVH) performance of a vehicle is perceived due to the introduction of tighter NVH constraints. Electric engines are now moving in the direction of higher speed and larger torque to achieve a very large range of high-performance operating conditions, leading to non-stationary operating conditions. Therefore, predicting accurately the non-stationary loads and deformations during these regimes is of utmost importance. In recent years, multiphysics modeling simulation techniques have played an increasing role in designing, developing, and optimizing powertrain NVH at component and system levels. Understanding the interactions between the excitations due to the elements' geometries and the various interactions among the elements and their consequences on measurable quantities representative of dynamic behavior (acceleration, speed, etc.) necessarily involves the implementation of numerical models.

This research aims to describe a simplified coupled dynamic model of the electric powertrain to evaluate the vibroacoustic behavior of an electric powertrain under non-stationary conditions with no assumption of the machine's operating speed. The developed numerical model is based on the angular domain approach, which introduces explicitly the machine's free body rotation degrees of freedom allowing simulations in non-stationary operating conditions. Integration of ball bearing modeling, gear modeling, and the electric motor modeling that invokes the effects of all the components' geometry provoking interactions in the rolling element-races normal forces, modifying the gear mesh forces, and establishing couplings between electromagnetic and mechanical forces in the electric motor leading to perturbations of the angular speed. As an example, taking into account the gyroscopic effect in a non-stationary model of a Jeffcott rotor may be shown to introduce a weak difference in the two radial directions for loads and displacements. The expected results will provide a base model which can be a tool for phenomenological analyses and can be easily extended into more complex models of bearings, gears, casings, and motors.

The MSF approach in an industrial context

Julian Staiger

ESR

Katholieke Universiteit Leuven, Belgium

Within this industrial context, proper design of drivetrains and their subcomponents, such as gears and bearing, has a crucial role in ensuring efficiency and timely maintenance. Monitoring the behaviour of these systems during operative conditions is fundamental to guarantee reliability and performance. To properly address these issues, it's of paramount importance to obtain an accurate estimate of contact forces and strains acting on gears and bearings during operative conditions. However, accurate and cost-effective measurement of these quantities is rarely possible with experimental methods, due to the intrusive nature of sensors, cable management or labour-intensive maintenance. FE or multibody simulations on the one hand are accurate but computational costly. Employing model-based hybrid deterministic-stochastic techniques such as augmented Kalman filters on the other hand offers the practitioner to access the states of interest by combining multiple measurements and high-fidelity numerical process models. Currently for all AKF approaches used the sensor behaviour is ideal in terms of frequency characteristics, i.e. the measurement matrices are linear and time-invariant. This limits the combination possibilities of sensors employed for estimation. With the newly developed Multifrequency Sensor Fusion (MSF) Kalman filter approach high fidelity process models are combined with low complexity sensor models. The MSF-KF can be used to enhance prediction quality or to start using low-cost sensors for brought band force identification problems.

Test-based method for targeted design of gearboxes with regards to lightweight specifications and acoustic behaviour

Khadijeh Farshi

ESR

Karlsruhe Institute of Technology, Germany

Identification of noise sources in the lightweight powertrain and characteristics of these noises is necessary to remove or decrease annoying noise aspects for drivers. It is important to note that considering only sound pressure level and overall vibration is not enough, psychoacoustic characteristics of noise such as sharpness, roughness, loudness, and tonality need to be considered. These metrics can be used to prioritize, which of the noises are most annoying to drivers. To do this, a correlation between the NVH measurements and human perception will be done, by mapping measured noises to psychological factors such as comfortability via the psychoacoustic analysis.

Developing a test-based method for noise optimized gearboxes, by considering lightweight specifications and psychoacoustic metrics, is the main purpose of this project. The possible design parameters for lightweight gearboxes and their impact on the acoustical behaviour will be extracted. The potentials of a psychoacoustic based approach by utilizing psychoacoustic metrics to decrease the negative impact of these acoustical phenomena have not yet researched sufficiently. Development of an approach to handle the conflict between lightweight design and NVH behavior and identification of metrics to best specify said noise are going to be addressed in this project.

Smart Virtual Sensing for geared drivetrains

Lorenzo Mazzanti

ESR

Siemens Digital Industries Software, Belgium
Department Mechanical Engineering, Katholieke Universiteit Leuven, Belgium

The knowledge of the contact forces and resulting strains gears and bearings is of paramount importance to gain insights into the state and the performance of complex transmissions system. Despite its high relevance, the correct evaluation of contact forces and full strain fields is rarely achieved with today's available sensors. This means that simulation tools such as Finite Elements or (flexible) Multibody Dynamics simulations are used to derive these quantities – although only in an approximative way. However, due to the complexity of the contact phenomena in gears and bearings, these local quantities are often inaccurately predicted, which forces engineers to oversize their designs.

This research project focuses on the development and validation of an estimation-based Virtual Sensing technique that makes it possible to accurately assess contact forces and strain fields (e.g., at the tooth root or on the bearing raceways) by combining a few well-positioned and easily accessible sensors (e.g., strain gauges and accelerometer) with advanced numerical gear-contact models.

Simulation based sensitivity analysis of lightweight design concepts in terms of gearbox acoustics

Navdeep Sharma

ESR

Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik, Germany

The transport sector is being subjected to increasingly stringent regulatory guidelines pertaining to environmental emissions. The response of automotive manufacturers has been to move development efforts towards exploiting lightweight designs that help reduce fuel emissions. However, the development of downsized subsystems has its own noise management challenges, as thinner and lighter structures are by vibro-acoustic principles, more prone to NVH problems. For example, higher flexibilities of lighter gear blanks, shafts and housings can cause larger tooth misalignments, which can lead to higher system excitations and a worsened NVH performance in gearbox systems.

The influence of lightweight design choices for different gearbox components is planned to be studied in the current project using simulations coupling MBD and FEM/BEM techniques. The excitation path from the gear-mesh forces as the source, to the final acoustic radiation, is virtually evaluated. Metrics such as transmission errors, bearing loads and housing surface-velocities are analysed to rank the dynamic contribution of problematic components.

Simulation-based sensitivity analyses and parameter studies on design choices for different components can help identify the risks and capabilities of light-weighting measures. Novel design concepts and the use of acoustically promising materials (e.g. metal foam structures and metamaterials) can then also be explored in the same simulation environment.

Useful Information

ECO DRIVE public workshop will be held at the **Faculty of Engineering** of **Ancona**, in Aula Azzurra "Mario Giordano" (see access information below).

The **workshop dinner**, free of charges, will be held at Ginevra Restaurant, a panoramic restaurant at the top of Seeport Hotel with beautiful views of the port of Ancona and the historic part of the town. The restaurant is in the city centre, close to the main hotels in Ancona, therefore it can be easily reached on foot.

Adress : Ginevra Restaurant, Rupi di Via XXIX Settembre 12, 60122 Ancona.

How to get to the Faculty of Engineering of UNIVPM ?

The workshop will be held at the premises of the Faculty of Engineering of Ancona. The full address of the Faculty is :

Facoltà di Ingegneria
Università Politecnica delle Marche
via Brecce Bianche
60131 Ancona
tel. 071 2204708 (carer)

HOW TO REACH THE FACULTY

By Plane

From "Raffaello Sanzio" airport to the centre of Ancona :

- take the Aerobus Raffaello shuttle to Ancona. The bus runs every day from 7 am to 10.30 pm (according to the flights' timetable), it stops at Ancona Railway station and Piazza Cavour (town centre) and the journey takes about 30 mins. Tickets can be purchased onboard. The price is € 5,50.
- take the train from Castelferretti to Ancona railway station and then # 1/4 bus to Tavernelle. Check `https://www.trenitalia.com/` for times and fares.
- take a taxi (`www.ctftaxi.it`, `www.taxifalconara.it`)
- rent a car

- AUTONOLEGGIO MAGELLANO +39 071 9157086,
- AUTOVIA +39 071 9188038,
- AVIS +39 071 52222,
- EUROPCAR +39 071 9162240,
- HERTZ +39 071 2073798,
- LEASYS +39 071 9716163.

By Car
Take the A14 Bologna-Bari motorway, turn off at Ancona Sud, then follow the signs to Ancona and turn off at "Università".

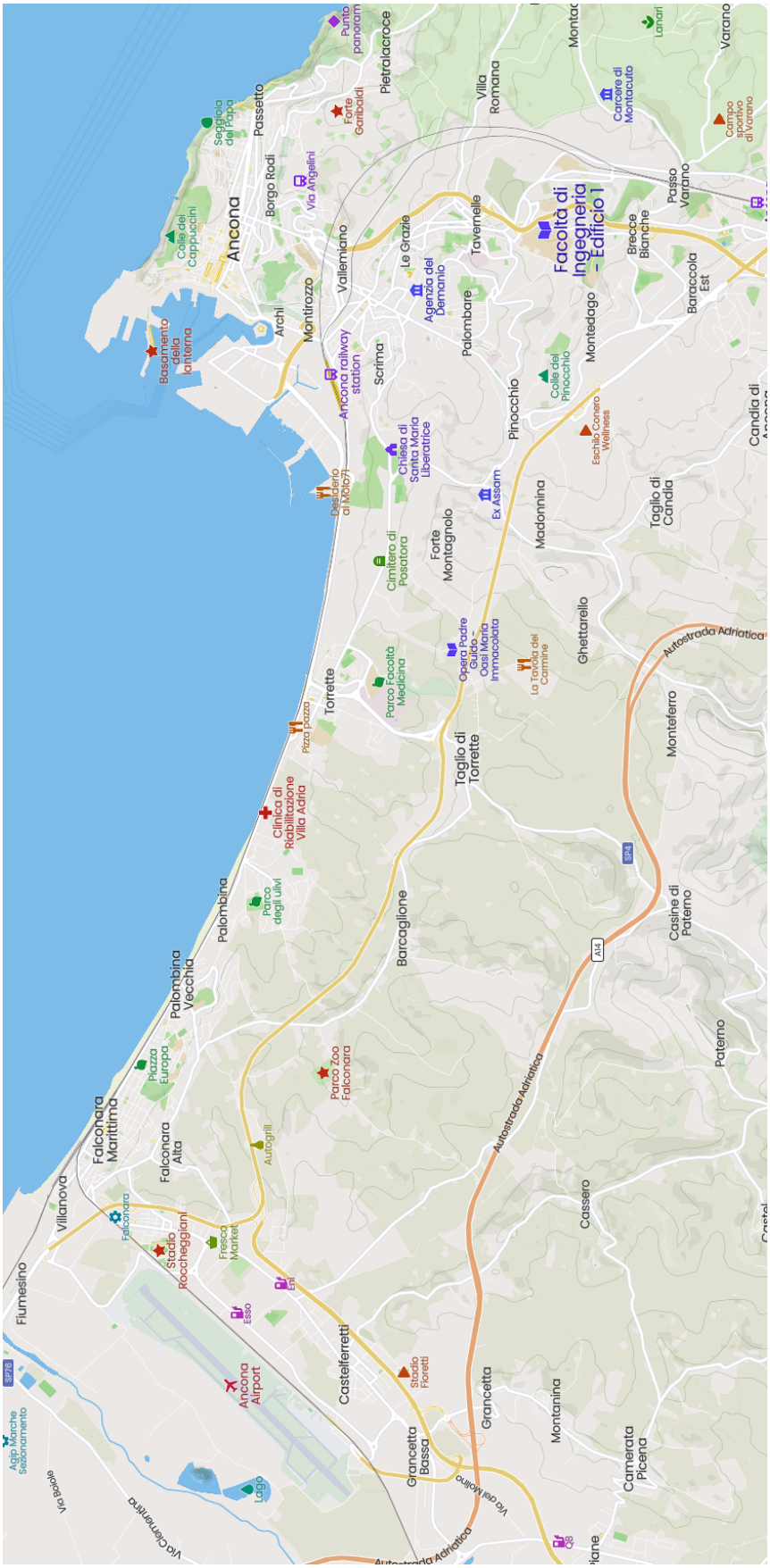
By Train
From Ancona Railway Station, take # 1/4 bus to the Faculty terminal in Tavernelle.

By Bus

- # 46 bus leaving from Piazza Cavour (in the town centre) and stopping right in front of the main gates of the Faculty. The bus runs every 10/15 mins and the journey takes about 10 mins.
- # 1/4 bus from the town centre to the Faculty terminal in Tavernelle. Bus # 1/4 runs every 7 mins and the journey takes about 20 mins. The bus stops at Piazza Cavour, Piazza Kennedy (near the Muse theatre) and Ancona Railway station.

Bus tickets can be bought through the app mycicero (`http://www.mycicero.eu/`) or from newsagents. Some buses sell tickets onboard.

MAP OF ANCONA



HOW TO REACH AULA AZZURRA

To reach Aula Azzurra, enter the main gates to the Faculty of Engineering and the Montedago campus (A), go straight on past the fountain, take the third on the left. Aula Azzurra is in Building 3 (3). As you enter the building, the workshop room is on the ground floor on the right.

Partner Institutions

This public workshop is part of the ECO DRIVE project, funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 858018.

Italian Association of laser velocimetry and invasive diagnostics

European Automotive Research Partners Association, Belgium