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20 YEARS OF RESEARCH ON ACOUSTICS AND VIBRATIONS AT MIGUEL HERNANDEZ UNIVERSITY OF ELCHE

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ABSTRACT

The Miguel Hernandez University of Elche (UMH) is a public and young university located in Alicante province, in the southeast of Spain, founded in December 1996 and which started its academic activities in the course 1997/1998. In the earliest beginnings of the UMH, a very small group of researchers of the Mechanical Engineering teaching area had the motivation of creating a working line focused on research on acoustics and vibrations. That fact led, in 2005, to the foundation of the Acoustic Engineering and Vibrations Laboratory of the UMH (LIAV-UMH). Since then, the members of the LIAV-UMH group focus their research lines mainly in the field of sound emissions and vibrations of road traffic and environmental acoustics, which results have naturally led to the knowledge transfer and collaboration with different entities and companies. In the current year, 2025, the LIAV-UMH celebrates its 20 years of research. This is why this paper summarizes the scientific trajectory followed by the group from its creation to the present days, showing the different working lines, developed research projects and knowledge transfer activities.

Keywords: *vehicle noise, tyre road noise, traffic noise prediction model, warning sound, metasurface.*

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1. INTRODUCTION

Noise pollution has been perceived throughout the history of civilisations as a nuisance that reduces the quality of life of people exposed to high noise levels. Noise exposure may lead to negative consequences that might vary from difficulties for holding a conversation, to sleep problems and disturbances in the performance of activities that require concentration, or even variations in the nervous system. In the last decades, different policies have been developed to control and reduce environmental noise. In this respect, the European Commission's Green Paper on 'Future Noise Policy' was a first step towards a common noise policy in the European Union [1]. Subsequently, in 2002, the publication of the European Directive 2002/49 on Assessment and Management of Environmental Noise [2], provided the main legislative framework to address noise reduction in Europe. The Directive established a common approach to avoid and prevent exposure to environmental noise through noise mapping and action plans. However, almost two decades after its publication, it was shown that noise from road traffic was still the noise source that affected the largest number of people [3]. This is still the case today, as reported in the European Environment Agency's latest publication [4] on exposure to transport noise in the European Union, which highlights the fact that the number of people exposed to high levels of road traffic noise remains high and is likely to increase in the coming years. Thus, it is estimated that about 113 million people are affected by traffic noise levels of at least 55 dB(A) over extended day-evening-night periods (Lden). This emphasises the need to designate and protect more quiet zones both in cities and in areas outside cities.

The motivation for environmental awareness has always been one of the main concerns of the group of the Acoustic

Engineering and Vibrations Laboratory of the UMH (LIAV-UMH), and what led the team to start research in environmental acoustics and noise and vibration control. In that context, the LIAV-UMH group began its work in 2005. Currently, the group is integrated by a team of seven researchers and several collaborators. All the members of the group are professors and lecturers of the Mechanical Engineering Teaching Area of the Department of Mechanical Engineering and Energy of the UMH, and their lines of work have been oriented towards acoustic engineering and applied vibrations, as well as offering a practical approach to the transfer and provision of services to companies and public and private entities.

The work of the group members is currently framed within the University Institute for Engineering Research of Elche (I3E - https://i3e.umh.es/en/), within the research lines of the Energy and Mechanics Unit. This article mainly describes the research trajectory of the group, focusing on the priority lines of research.

2. FIRST STEPS: TOWARDS STUDYING ROAD TRAFFIC NOISE AND VIBRATION CONTROL

Strategic noise maps are the tool that allows the global assessment of noise exposure of the population in a given area. In this sense, the beginnings of the group coincided with a period when the study of noise mapping was a trending topic.

In this line, one of the first works of the group that received public funding (Generalitat Valenciana, GV05/100, 2005-2006), focused on the development of a prediction model of night-time traffic noise based on the vehicles' sound directivity. The research also allowed the study of the horizontal sound directivity of vehicles travelling at high speed [5] (2009). To this end, work was carried out to establish a methodology capable of providing information on the sound distribution of a noise source in its main plane of emission, based on the proposal of different configurations of microphone arrays [6] -a linear antenna with uniformly distributed microphones (ULA) and a linear antenna with proportionally distributed microphones (PROP)-, in different orientations with respect to the vehicle's driving line. The results of this work yielded very interesting conclusions and led to the registration of a patent for an acoustic speedometer system [7].

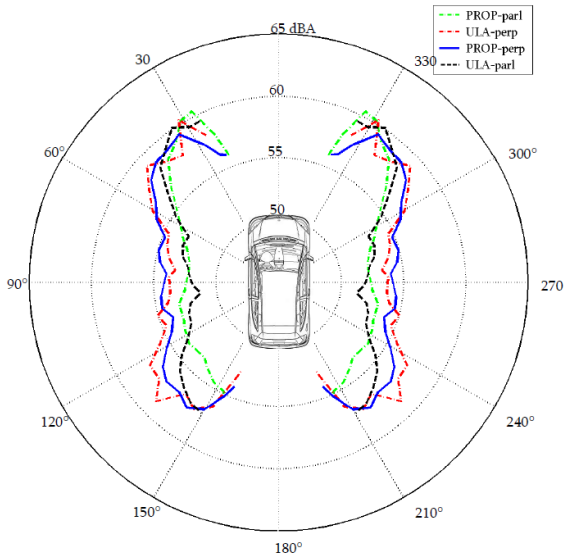

Figure 1. Polar plot of the sound level obtained with each of the proposed antennas [5].

During this first period, members of the group also collaborated in a much larger project (Generalitat Valenciana, GVEMP06/011, 2006), which included other researchers, for the construction of a drum-type tyre testing machine, Fig. 2. The machine allows to perform load/speed tests for new and retreaded passenger car and commercial vehicle tyres according to UNECE regulations 30, 54, 108 and 109, and rolling resistance tests according to ISO 28580.

Figure 2. Tyre testing facility at the UMH.

3. TYRE/ROAD NOISE AS A FOCUS OF ATTENTION IN VEHICLES

The results obtained in that first stage on the sound directivity of vehicles led the group in the subsequent years to open one of its main current lines of work: the study of tyre/road noise. Initially, work was carried out on the development of new measurement methodologies to assess tyre/road noise, the novelty of which laid in the evaluation of sound emission through a standardised engineering method (ISO 3744), to determine the sound power level in the tyre/pavement interaction [8], Fig. 3.

In a first phase, two methodologies were designed for evaluation on track [9] (2013): Alternative Coast-By (A-CB) [10] and Alternative CPX (A-CPX) [11], inspired by the traditional CB and CPX methodologies, but with the result of obtaining the sound power level of the set of sources formed by the four tyres of a vehicle rolling on a pavement (A-CB), and the sound power level of the interaction of a single tyre rolling on the pavement (A-CPX). One of the conclusions drawn from this phase of work was that the tyre/road sound power level of a complete vehicle can be calculated from the energetic sum of the tyre/road sound power level of each individual tyre that comprises a vehicle [12].

At the time when the group had the tyre testing facility in operation, two analogous methodologies were developed for the study of tyre/road noise on a drum testing machine [13] (2018): Alternative Drum methodology (A-DR) [14,15] and Alternative CPX Drum methodology (A-CPX-DR) [16].

4. THE INCORPORATION OF ELECTRIC VEHICLES INTO ROAD TRAFFIC

In parallel to the line related to tyre/road noise, the group also began another of its major fields of work: the study of the effect generated by the inclusion of electric vehicles in noise maps. At this point, in the early years work was carried out on adapting the NMPB-Routes 2008 road traffic noise prediction model to the presence of electric vehicles [17] (2014). The group's work was collected in different publications - some of them of relevant impact [18] - where, among other conclusions, it was possible to gather that the noise emitted by an electric vehicle can be compared with that emitted by an internal combustion vehicle without mechanical noise, when both circulate at speeds above 50km/h.

The study of the NVH (Noise, Vibration and Harshness) of electric vehicles was a very important topic in the early period of the introduction of electric vehicles into vehicle fleets - and it remains so today. That led to the group's participation in the COST Action TU1105 'NVH analysis techniques for design and optimisation of electric vehicles' (European Union, Cost Action TU1105, 2012-2016). As a result of the joint efforts of the members of the Action consortium, a comprehensive catalogue of NVH-related technologies for electric and hybrid vehicles was compiled [19].

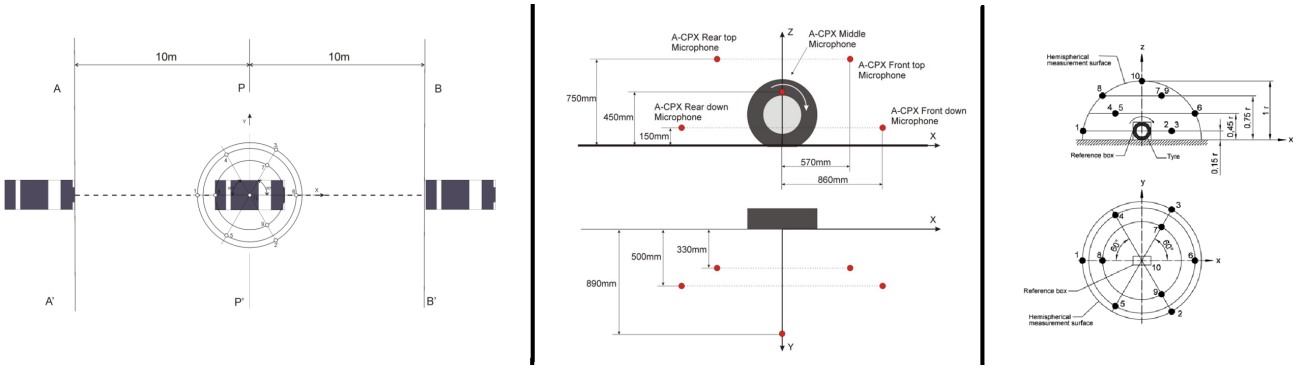

Figure 3. Configurations of the alternative methodologies designed by the LIAV-UMH group for evaluation of sound power level of tyre/road noise [9,13]. Left: A-CB tests. Center: A-CPX. Right: A-DR.

5. WARNING SOUNDS: PEDESTRIANS AT POTENTIAL RISK

The experience that the group was acquiring in the NVH of alternative vehicles was focused on the study of their acoustic detectability. In this field, the group had the opportunity to work on different projects. Among them, one of the most noteworthy was the collaboration with ONCE (Spanish National Organisation for the Blind), in a project (Generalitat Valenciana, GV/2017/004, 2017-2019) whose objective was to improve the detection, localisation and identification of the warning sounds of electric vehicles through the perception of blind people. To this end, the emotional response of the test volunteers to different warning sounds was studied, as well as the detectability of these sounds through the analysis of detection times.

More recently, the work carried out in the group has focused mainly on the development of numerical models of mechanical systems that can help to improve the sound detectability of alternative vehicles [20] (2023). In this field, the modelling of the noise generated by a tyre either when it impacts against the ground in free fall or when it impacts against elements external to the vehicle, such as a speed bump or a pothole in the pavement, has been studied. The model developed by the group is solved in two steps: a dynamic analysis of the contact of the tyre with the element against which it impacts, through FEM modelling; and a subsequent BEM analysis of the sound field generated in the environment, based on the vibration of the tyre surface as a sound source.

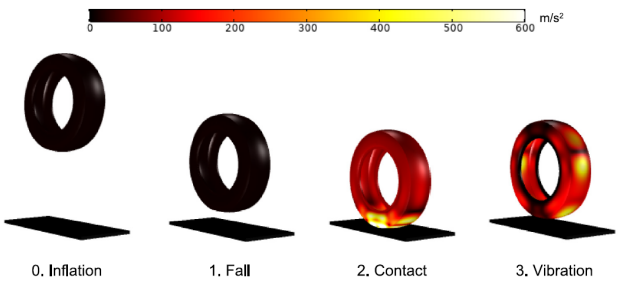

Figure 4. Phases of a transient analysis in a FEM simulation of a tyre impacting a flat, rigid, and reflective surface [20,21].

6. CURRENT RESEARCH IN THE GROUP

The experience accumulated by the group to date has allowed us to identify the need for further research into aspects related to the detectability of electric and hybrid vehicles in particularly sensitive environments in low-speed traffic conditions. To this end, the group is currently exploring the potential that metasurfaces may provide for this solution (Generalitat Valenciana, CIGE/2022/1, 2023-2024). The term 'rolling metasurface' was coined by the team [22] to refer to a surface pavement design modified in its geometry, which confers different properties to those provided by its original textural characteristics (micro, mega and macro texture), and which is capable of generating controlled sound emission and propagation when a tyre circulates on this pavement. Previous work in this line [23], has led the team to continue investigating this proposal.

Finally, the group is also currently exploring the sound directivity capabilities of a low height stepped directional acoustic barrier (SDAB) system. The aim of the design of this barrier is to create an interference to sound propagation in the transverse direction, but at the same time to allow sound transmission at a certain angle in both horizontal and vertical planes [24].

7. CONCLUSIONS

The LIAV-UMH group has focused its work over the last 20 years in the field of applied acoustics and vibrations, especially in the area of vehicle acoustics, with the development of methodologies and characterisation of the sound emission of conventional vehicles, as well as electric and hybrid vehicles; the study of tyre/road noise; environmental acoustics, with the improvement of traffic noise prediction models, development of noise maps and experimental studies of traffic noise emission sources; acoustic studies of sound sources, with special attention to studies on the control of noise measurement installations in MOTs; development of vibration behaviour models for road and rail vehicles; among many others. This article covers only part of the group's work, the most closely related to its research work.

The group's research strategy for the coming years will continue to focus on the search for solutions to improve urban environments in terms of noise emissions. To this end, the group intends to continue collaborating with institutions and entities, both public and private, national and international, with the ultimate aim of achieving results

with a social impact that can be transferred and implemented in practice.

8. ACKNOWLEDGMENTS

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