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ACOUSTIC COMFORT IN CONVENTIONAL (ICE) AND ELECTRIC VEHICLES – ASSESSMENT METHODS & COUNTERMEASURES

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INTRODUCTION

WHAT IS NVH?

Measurement of vehicle noise and vibration from GMP (engine / admission / exhaust / gearbox), overhead noise, rolling noise (suspension, tire to ground contact, structurally transmitted) and other accessories such as GMV (Fan Motor Group), Compressor, Alternator, etc. These measurements are performed to ensure a level of acoustic comfort, and interventions are made during and after the project phases to ensure the desired acoustic levels and ensure market competitiveness.

Acoustic measurements are made with microphones positioned at standard vehicle-specific points, as well as vibration points, which are measured with triaxial accelerometers.

The vehicle noise is classified into interior and radiated exterior noise. And it influences on consumer's vehicle decision and traffic noise environment very much. In case of the vehicle exterior noise, it is related with traffic noise and in case of the interior noise, it is related with driver's and passenger's sensitivity quality. Because these influenced on drivers and traffic environment, so standards are restricted by the laws and regulated for the measurement. But, the existence standards measuring the only sound pressure level are limit to reflect consumer's sensitive aspects. [1]

Therefore, in this study, the aim is to understand the differences between ICE and EV vehicles acoustics, the differentials aspects that the passenger will "hear", and to put in place different countermeasures to different sources for each family of vehicles.

ELECTRIC MOBILITY IS EXPANDING AT A RAPID RATE

Electric car deployment has been growing rapidly over the past ten years, global sales of electric vehicles (EVs) in 2020 increased by 43% year on year to 3.24 million units (4.2 % of new passenger cars). This compares with a sales decline of 14% of the total passenger car market in 2020.

EV sales will continue to grow throughout the decade, forecasting that all EVs will represent 43% of all new cars sold in 2035. Figure 2:

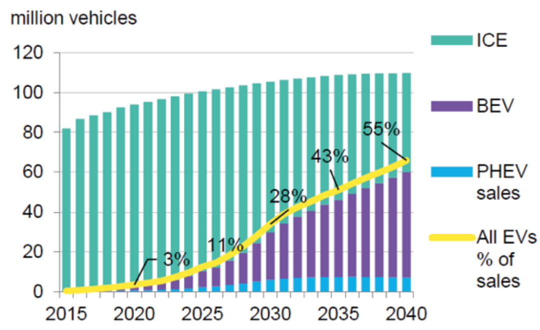


Fig. 2 – EV Sales and % Growth Forecast 2040

OBJECTIVE – GENERAL PURPOSE

2.1. Description of the experimental procedure for the study of automobile acoustics, according to (ISO 5128 – 1980), carrying out comparative experimental measurements in vehicles equipped with ICE and VE.

2.2. Know the acoustic behavior of the car in general, making special mention of the differences between a vehicle equipped with an Alternative Internal Combustion Engine and an Electric Vehicle, objectively, highlighting what a customer will "hear and feel" on both types of vehicles. [2]

2.3. Perform vibration and noise level measurements and correlate them to the client's subjective perception.

2.4. Survey of external noise levels (compliance

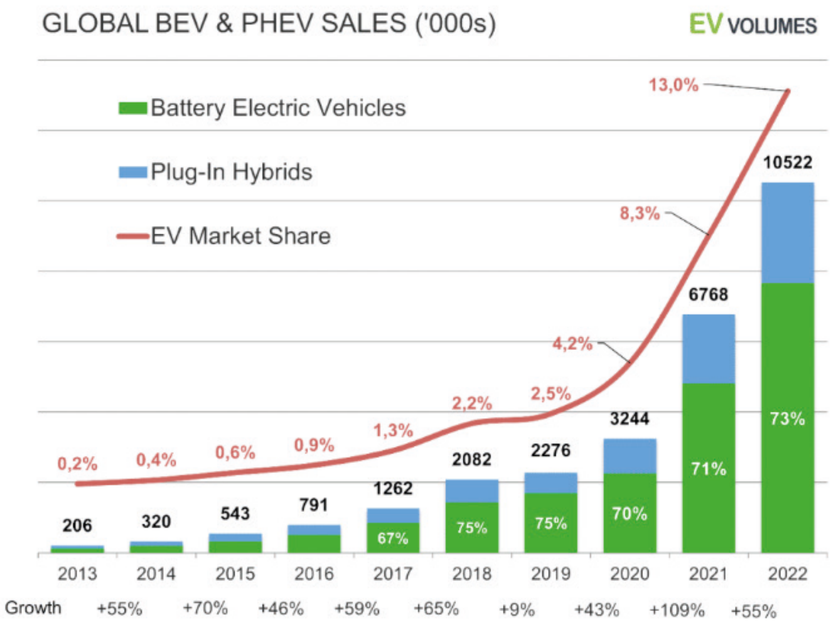


Fig. 1 – Global BEV & PHEV Light Vehicles Deliveries

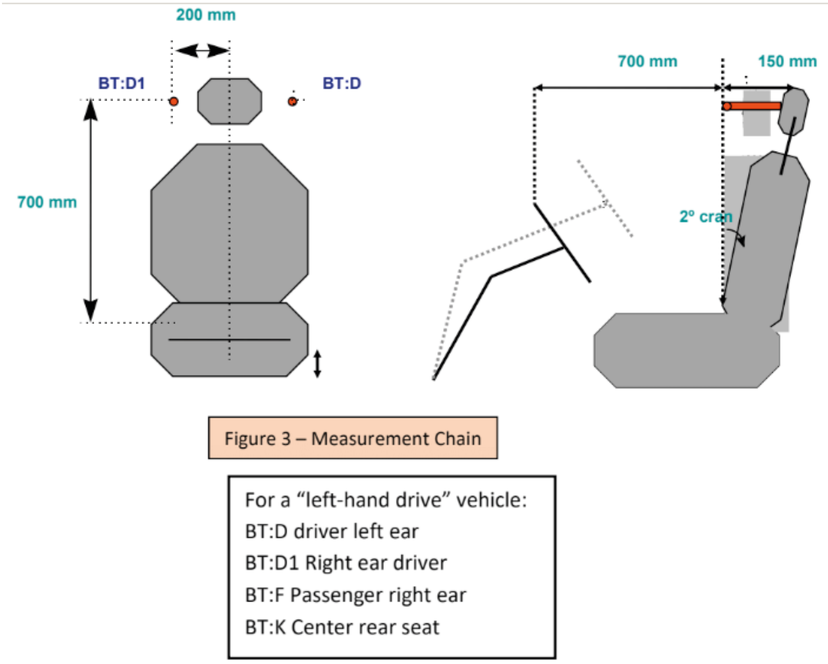
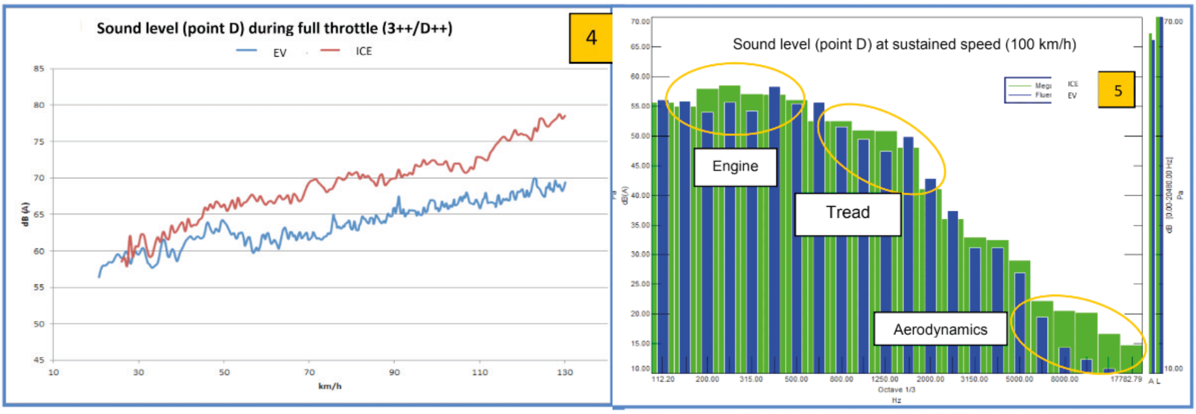
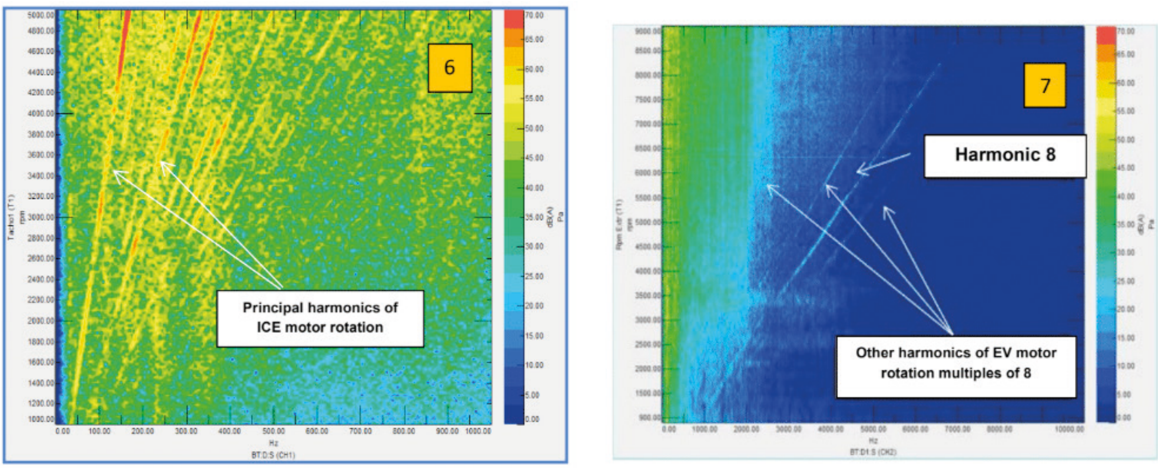


Figure 3 – Measurement Chain



Figures 4-5: Comparisons of the mean pressure dB(A) at point D as a function of velocity (4) and for each third of an octave (5)



Figures 6 – 7: comparison of the spectrograms (point D): ICE engine (6) and VE (7)

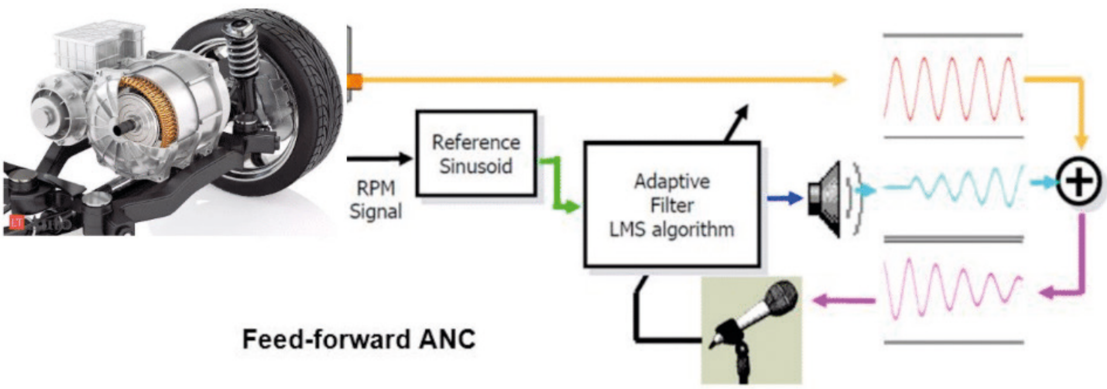


Figure 8 : ANC : with microphones : adaptative filter

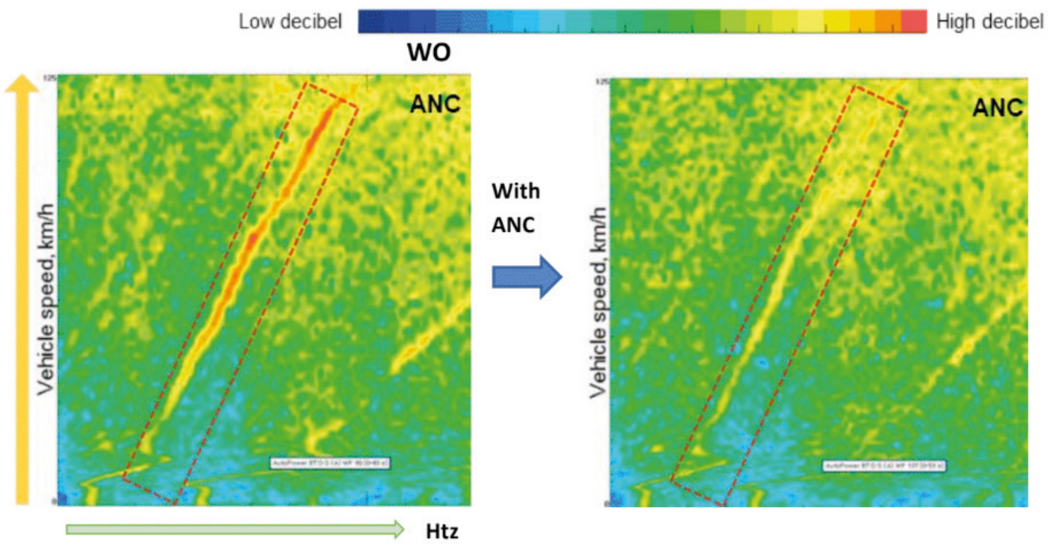


Figure 9 : Engine booming noise ANC : with microphones

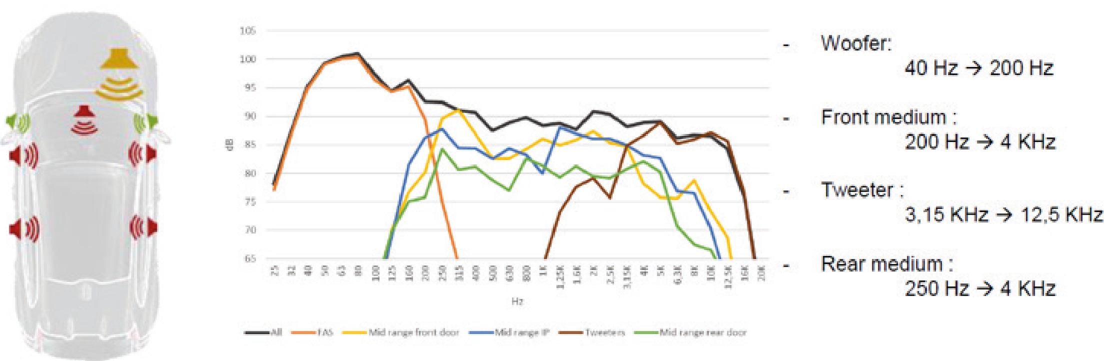


Figure 10 : Frequency analysis for the Sound System

with noise legislation).

2.5. Evaluate and propose engineering solutions for control / reduction of noise / vibration sources in vehicles.

2.6. Conduct comparative trials to evaluate cost reduction and quality improvement proposals.

MATERIALS AND METHODS: MEASUREMENT CHAIN (SEE FIGURE 3)

Registration according to the procedure to measure interior vehicle noise in BS 6086 1981 (ISO 5128 - 1980). BS 6086 requires:

- Microphones in a horizontal position and pointing their direction of maximum sensitivity in the direction that an occupant would normally face forward.
- Microphones at not less than 150 mm from the body or trim.
- Microphones must be mounted in such a way that they are not affected by vehicle vibrations.

Through the Siemens PLM Software, the LMS TestLAB Durability Acquisition program, we made a temporary recording during the Road Test. Although Standard BS6086 requires recording at various constant speeds in the range of 60-120 km/h, from idling to full load, it has been chosen to make a measurement in 3rd gear from idling to full load and another at a sustained speed of 100 km. /h. The application is built around three basic steps, which constitute a typical RLDA (road load data acquisition) process: establish channels, measure, and validate.

a. Results: Comparative graphs of the average pressure dB(A) at point D as a function of speed and for each third of an octave (Figures 4-5) and comparative spectrograms (pt. D) for both types of motor are shown (Figures 6-7)

CONCLUSIONS

1. FULL THROTTLE: The noise level difference between the two vehicles at full throttle can be up to 8 dB. This marked contrast is due to the predominant presence of the heat engine when requesting its maximum performance, and it is more noticeable the higher the engine rotation speed - Figure 4

2. The **main source of noise is the combustion engine**, proportional to its speed of rotation and with levels above 70 dB(A) for some low harmonics. In the spectrograms those narrow bands where the sound emission is concentrated are clearly observed. It is maximum near the limit of rotation (5000 rpm) – Figure 6

3. In the case of the **EV there are no major sources of noise**. At low speed the rolling noise predominates while from 80 km/h the aerodynamic noise becomes important. The spectrogram shows the absence of intense low-frequency noise, but the 48th harmonic (and multiples of 8) does stand out, originating in the rotor (8-pole) – Figure 7

4. In conclusion, the **electric vehicle enjoys greater acoustic comfort** compared to its combustion equivalent, but at the same time requires more demanding work in reducing noise not linked to GMP, present in all types of automobiles.

COUNTERMEASURES

GLOBAL INSULATION

- Design check

Sound proof : leakage, hole, sealing gap

Sound absorption : absorbing material (foam, felt, ..)

- Specification for insulators: Thickness & Insertion loss are key to define a good insulator for each noise. Insertion Loss (IL), i.e.: the difference between the steel equipped with "soundproof" and the "bare" steel. IL must be provided from supplier for each thickness (for 5. 10, 15, 20, 25,…mm).

- IL forecasts for each area of dash and for total dash (based on flat samples IL, with above relationship)

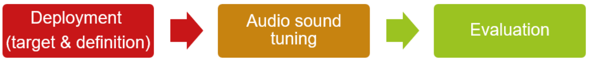
ACTIVE SOUND DESIGN: ANC, ACTIVE NOISE CANCELLATION (EV VEHICLES)

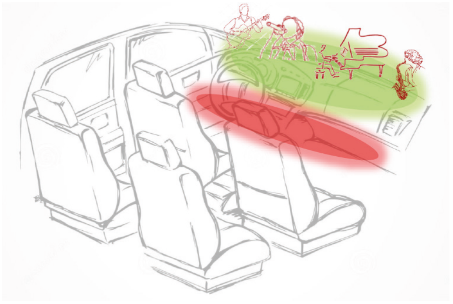
The 1rst EV experience is the absence of noise. However, EV customers are becoming much more sensitive to road noise…

The vehicle measures the vibrations entering the chassis. Based on these measures, and the current noise measured in the cabin, it generates a sound inside the cabin, that will cancel the current road noise for better driving comfort.

AUDIO SOUND QUALITY

Manage frequency responses to create listening comfort for both the driver and the passengers: see below strategy for application:





Each of the parts of the Sound system has a contribution in frequencies as seen in Figure 10:

REFERENCES

1.- Qian, Kun & Hou, Zhi-chao. (2021). Intelligent evaluation of the interior sound quality of electric vehicles. Applied Acoustics. 173. 107684. 10.1016/j.apacoust.2020.107684.

2.- Etienne Parizet , Karl Janssens, Pedro Poveda-Martínez, Andreia Pereira, Jakub Lorencki and Jaime Ramis-Soriano. NVH Analysis Techniques for Design and Optimization of Hybrid and Electric Vehicles. Chapter 4. Sound Quality of Electric vehicles. Nuria Campillo-Davo and Ahmed Rassili, ISBN 978-3-8440-4356-3, Shaker Verlag Publications (2016)