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SOUND APPROVAL TEST FOR ELECTRIC VEHICLES: RESULTS OF PASS-BY TESTS

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ABSTRACT

The Directive 70/157/EEC sets out the guidelines to perform the required sound tests on the sound approval process for motor vehicles. The test known as “pass-by” defines the procedure, based on the ISO 362 standard.

This article presents the results obtained from different pass-by tests carried on a hybrid electric vehicle running in electric mode at different speeds. The purpose of the study is to define the vehicle behaviour and the sound performance compared to a conventional ICE vehicle.

RESUMEN

La Directiva 70/157 / CEE establece las directrices para realizar las pruebas de sonido necesarias en el proceso de homologación sonora para vehículos a motor. La prueba conocida como "pass-by test" define el procedimiento de ensayo, establecido de la norma ISO 362.

Este artículo presenta los resultados obtenidos de los diferentes ensayos “pass-by” en un vehículo híbrido, funcionando en modo eléctrico a velocidades diferentes. El propósito del estudio es definir el comportamiento del vehículo y el rendimiento de sonido en comparación con un vehículo convencional (gasolina).

INTRODUCTION

The pressure on the society to dispose of more silent vehicles is higher than ever; the customers demand more silent interior sound for the sake of driving comfort and the society constantly put pressure on the automotive industry to reduce the exterior noise level due to an increasing noise pollution in urban areas.

As a consequence, the automotive industry demands for validated experimental methods and tests to be able to assess a vehicle’s acoustic performance as early as possible in the development process of new vehicles. One well know test that should be use to study the acoustic behavior of new generation vehicles is the well-known pass-by test [1][2], even though the standards that defined the testing methodology have been partially changed recently [3]. However, up till now, pass-by test has only been used for ICEVs (Internal Combustion Engine Vehicles).

One such problem is the different noise signature of an electric engine compare to an ICE which makes uncertain the results of the classic pass-by test. The main objective of this paper is to analyze the results of the pass-by test in a HEV (Hybrid Electric Vehicle), comparing the results with sound levels emitted by a conventional ICEV.

NVH problems in electric vehicles

Even though electric and hybrid vehicles, when using the electric motor, are more quite than traditional ICE vehicles, several new NVH problems are coming up suddenly [4]. In terms of noise, three main reasons can be distinguished:

- No masking effect due to the ICE yields noise from various components as the HVAC system (Heating, Ventilation and Air Conditioning), the transmission, oil/water pumps etc.,
- New noise sources, like the electric engine itself. These new noises might be perceived as annoying because of its tonality and high frequency components.
- The rolling noise becomes the major noise source, giving that ICEVs and HEVs emit similar levels of sound at high speed [6][7].

Two other NVH problems that follow with the electrification are:

- The safety for pedestrians and other sensitive groups like children and blind persons. The low exterior noise level from the HEVs at low speeds (at which the tire noise and flow induced noise are low) makes them difficult to identify which make them a moving risk.
- Brand specific and model characteristic sound becomes a challenge to achieve with an electric engine.

MATERIALS AND METHODS

Test configuration and instrumentation used

A series of road tests was performed to reach the objective of the study. The methodology used in the tests was founded in the specifications described in the Directive 70/157/EEC, based in the pass-by test described in the ISO 362 standard.

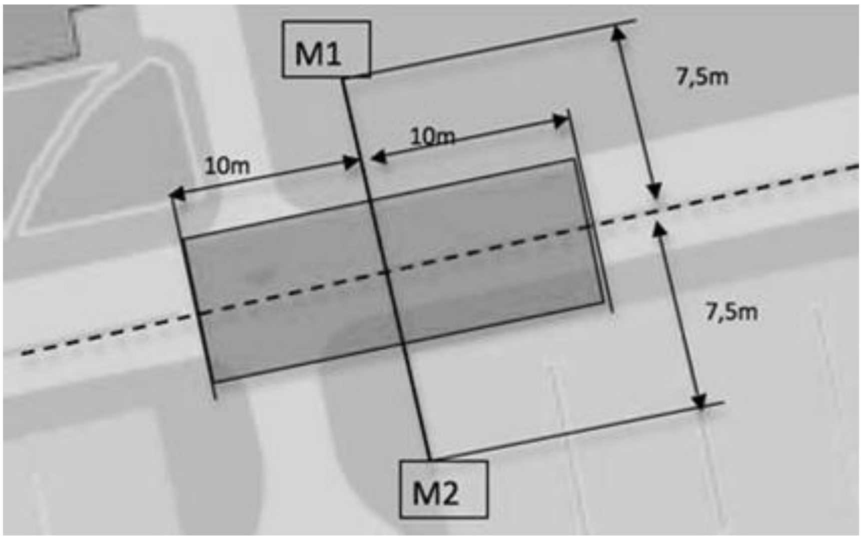

Figure 1. Pass-by test configuration for sound samples acquisition.

The vehicle used for the measurement was a HEV, Toyota Prius. The vehicle's driving conditions throughout the test were the same as for the Pass-By test: the vehicle approaches and circulates by the test area at a constant speed, figure 1. The vehicle was tested for the following reference speeds, running in electric mode: 10 km/h, 20 km/h, 30 km/h, 40 km/h and 50 km/h, and twenty pass-by tests were measured.

The sound pressure levels emitted by the vehicle were recorded by two microphones located at 7.5m from the test track axis, and at 1.2m height. The two microphones utilized were 1/4-inch Bruel & Kjaer model 4935, connected to the 24 bit 16 channel IMC Cronos Compact data acquisition system, operating at a sampling frequency of 25 kHz, and with a Fast time weighting. Photoelectric sensors connected to the data acquisition system recorded the vehicle speed, and the meteorological conditions and road temperature were periodically recorded during the test. During the test, it was registered the background noise.

The tests were conducted on a paved asphalt test area composed of a 20 cm thick subbase of graded aggregate, a 20cm thick base course of graded aggregate, and a surface course consisting of two layers, 5cm G-20 and 4cm S-20 with barren porphyry, and sprayed with prime and tack coats, figure 1. A 20m long section of this road was selected, upon which the test instrumentation was set up. The selected section was clear of obstacles within a 50m radius.

Figure 2. Detail of the asphalt

NOISE EMISSION OF ELECTRIC AND HYBRID-ELECTRIC VEHICLES

The external noise emitted by ICEVs is composed of two main components: the powertrain noise and the tyre/road (rolling) noise [5].

The powertrain noise depends on the engine revolutions, whereas the rolling noise depends on the speed of the vehicle. Both components are influenced by the driving conditions: constant speed, acceleration, deceleration or braking. The driver behaviour has also an effect on the emitted noise. It is well known that, for ICE vehicles, powertrain noise is prevailing mainly at low speed or under acceleration, whereas rolling noise is the main source at high speed [6]. These components are classically assessed through standard procedures by using the maximum noise level at vehicle pass-by in specified conditions, recorded at 7.5 metres from the track centre and a height of 1.2 metre (ISO 362-1, 2009). This process is performed per frequency band (generally third octave or octave) and over the whole audible frequency range (global levels), taking into account the A-weighting response. To evaluate the change in frequencies, figures 3, 4 and 5 show the spectrum of the same hybrid-electric vehicle (Toyota Prius) tested at different speeds and running in electric mode.

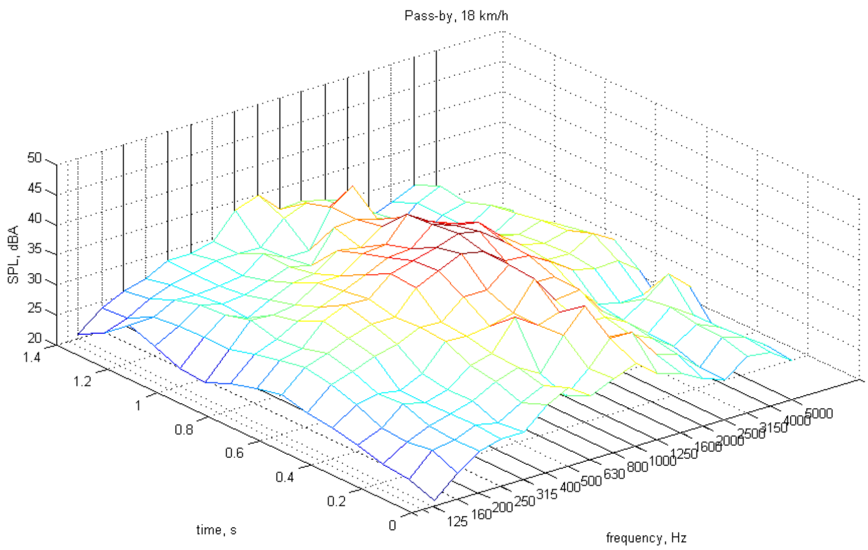

Figure 3. Spectrogram of tested HEV at 18 km/h

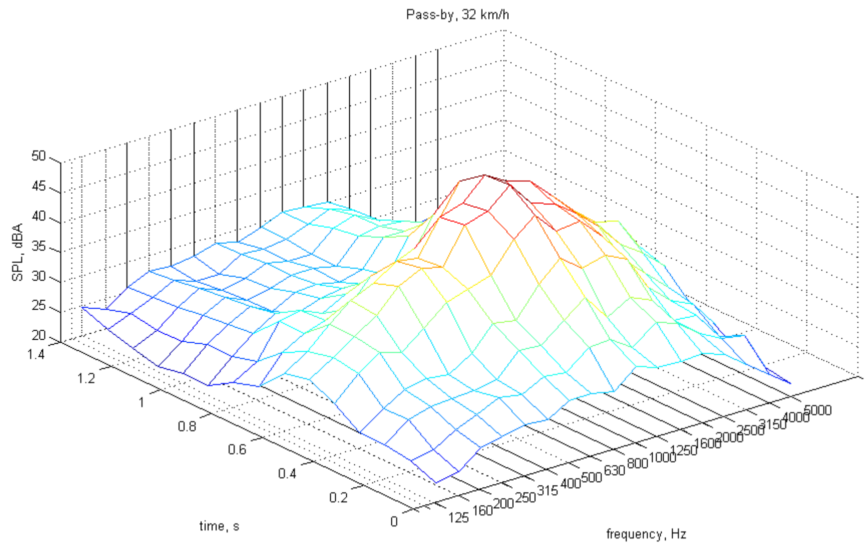

Figure 4. Spectrogram of tested HEV at 32 km/h

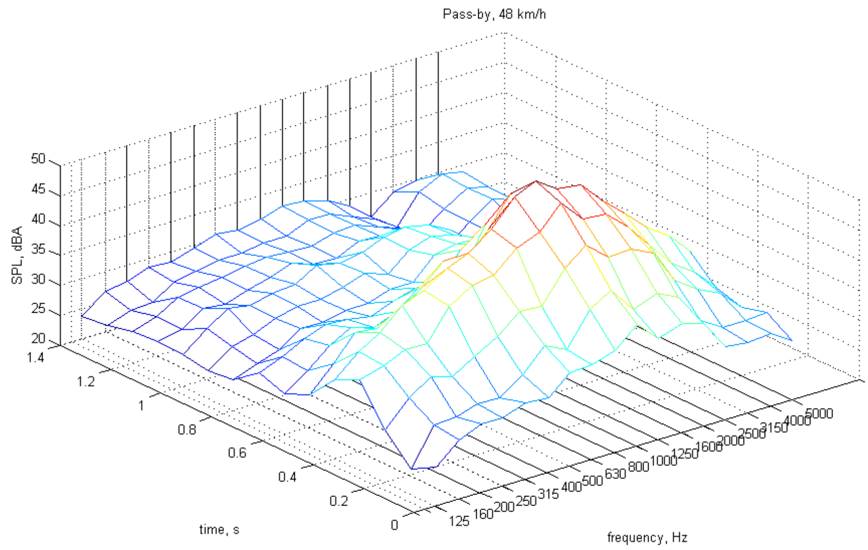

Figure 5. Spectrogram of tested HEV at 48 km/h

Figures 3, 4 and 5 show how change the frequency distribution during the test due to the speed of the vehicle. In all cases, main peak of energy is located between 1 and 2 KHz.

PASS-BY TEST RESULTS

According to the ISO 362, the maximum sound level is the index measured and the result of the pass-by test. Figure 6 shows those sound levels measured[1], as well as the sound levels measured in previous works (of ICEV tested)[7].

[1] After some corrections due to the background noise

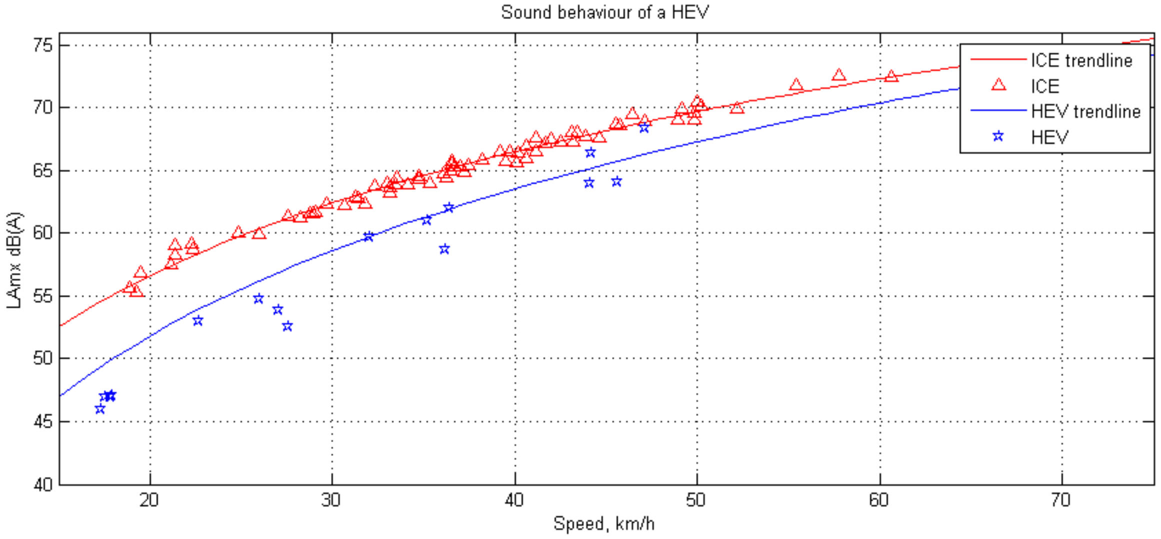

Figure 7. Results of HEV and ICEV and logarithmic trendlines

CONCLUSIONS

As a conclusion, this paper shows the frequency behaviour of a hybrid electric vehicle tested under the conditions defined by ISO 362 (pass-by test) and running in electric mode. The results confirm that the general spectrum emitted during the test increase the sound level at the frequencies between 1 KHz and 2 KHz, being the frequencies traditionally related with the rolling noise.

As the same time, it was study the sound pressure level of a hybrid electric vehicle depending on the speed during the test and those results were compared with the ICE levels, achieving two main conclusions:

- Back ground noise affects significantly the results of the measured, and, due to the low level emitted by the HEV running at low speed, some measurements were rejected or corrected.

- HEV tested at speeds near 50 km/h emitted level closed to the level emitted by an ICEV.

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REFERENCES

[1] ISO 362-2:2009. Measurement of noise emitted by accelerating road vehicles -- Engineering method. Part 2.

[2] ISO 362-1:2015. Measurement of noise emitted by accelerating road vehicles -- Engineering method -- Part 1.
[3] R. de Abrantes; A. L. S. Forcetto; R. M. Araújo. A eficácia da norma ISO 362:2007 para o controle do ruído de veículos pesados. SIMEA 2015, Brazil.
[4] Linus Falk Lissel. Pass-by noise contribution analysis of electric vehicles. KTH Engineering Sciences. Master of Science Thesis Stockholm, Sweden 2013
[5] Marie-Agnès Pallasa; Michel Bérengierb; John Kennedyc; Phil Morgand; Sara Gasparonie; Reinhard Wehre. Noise emission levels for electric and hybrid vehicles — First results of the FOREVER project. Transport Research Arena 2014, Paris.
[6] Hamet, J.-F., Besnard, F., Doisy, S., Lelong, J. &Le Duc, E. (2010), New vehicle noise emission for French traffic noise prediction. Applied acoustics, 71, 861-869.
[7] Campello Vicente, Hector. Adaptación del modelo de predicción de ruido de tráfico rodado NMPB-ROUTES 2008 a la presencia de vehículos eléctricos. PhD thesis, Miguel Hernandez University, Spain, 2014.