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The effect of electric vehicles on urban noise maps

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ABSTRACT

The electric vehicle is the best-positioned alternative to the ICE conventional vehicle become of, among other reasons, its environment friendly properties. One of its most significant properties is its quiet electric engine which can be a good tool for decreasing noise pollution in cities.

In this respect, the electric vehicle can be acoustically assessed from different points of view; on the one hand, as a moving point source, its detectability or annoyance for pedestrians can be studied, and, on the other hand, as part of the traffic flow in a road its effect on the whole noise map. In this paper the effect of introducing a flow of electric vehicles into real urban traffic has been studied and quantified. For this purpose, experimental procedures were used to add to the NMPB ROUTES noise prediction model of the electric vehicle as a potential noise source in the traffic flow. Several conditions have been analysed and was evaluated the change in the number of citizens exposed to diverse ranges of noise levels.

1. Introduction

Sales of electric (EV) and hybrid electric (HEV) vehicles have increased in recent years, and they have become more common in urban fleets. Electric technology, in addition to reducing the emission of polluting gases, also impacts on the noise maps of the cities. The absence of mechanical noise is expected to significantly reduce noise levels in urban areas, having a positive effect on noise maps. According to Directive 2002/49/CE [1], a noise map is a graphic designed for the global assessment of noise exposure in a specific area due to different noise sources or for overall predictions for such an area. EU Member States are required to produce strategic noise maps for their main cities (and other infrastructure and industrial sites). The main objective is to make a general diagnosis of noise pollution that can lead to action plans and noise management that can be implemented in terms of action plans and acoustical planning. There are several models for making noise maps. Some use empirical models, based on experimental approaches, but most of the models are based on the physics of propagation of sound outdoors implemented in a theoretical sound power generation model that changes with the characteristics and number of traffic sources. In none of those models, is the potential presence of electric vehicles considered.

This paper presents the assumptions and experimental tests developed to integrate the EV as a noise source in a traffic noise prediction model, as well as the expected effect of those vehicles on a noise map under different traffic conditions.

2. Methodology. New model and influence of warning sounds

To be able to develop computational noise maps, it is necessary to use a prediction model that simulates the real conditions of the area of study. With this purpose and taking in account the recommendations of the European Directive, the French official noise prediction model, NMPB ROUTES has been used to evaluate noise levels as a function of traffic flow conditions.

The French model needs different inputs to develop the simulation, the main ones are:

- Flow of light vehicles per hour (weight < 3.500 kg).
- Flow of heavy vehicles per hour (weight > 3.500 kg).
- Speed of both types of vehicle.
- Boundary conditions.

After introducing the parameters into the model, it provides the sound pressure level (dB(A)/hour) along the area of simulation, taking into account reflections and the effect of elements such as barriers, buildings or green areas.

In order to introduce electric vehicles into the noise prediction model, it is necessary to know the sound power level emitted by an electric vehicle and to develop an algorithm to model the sound level depending on the source's speed.

The modelling process was carried out based on an initial assumption "The acoustic behaviour of an electric vehicle could

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be assumed as a conventional internal combustion engine (ICE) vehicle without mechanical noise", supported by some experimental measures of several ICE and EVs under coast-by and pass-by conditions [2], see Figs. 1 and 2.

In order to implement this assumption in the French noise traffic prediction model, a careful study of the algorithms used in the model for obtaining the sound power level of different noise sources was made. According to the guidelines of the model, noise produced by a vehicle is divided into two main independent sources [3,4], see Eq. (1) and Fig. 2:

- The engine and other mechanical sources.
- Tyre/road source, rolling noise (aerodynamic sound is considered part of this source).

$$L_A(V,R,p,a) = L_{rolling}(V,R) + L_{engine}(V,p,a) \quad (1)$$

where
- L_A is Pass-by level of the vehicle (dB(A)) [3],
- R is the road platform surface category,
- p is the road gradient (%),
- V is the speed of the traffic flow (km/h),
- a is the traffic flow type (steady speed, acceleration, deceleration).

Therefore, to be able to model the sound level emitted by the EVs, only the tyre/road noise source (rolling noise) has been considered, removing all mechanical noise sources from the algorithm that calculates the power level of an EV. As is done with other types of vehicle, the power level of an EV was evaluated as a function of traffic speed and added to the general algorithm of the French model, see Eq. (2).

Fig. 1. Pass-by test of an electric vehicle.

$$L_Awi = 10 * \log 10((Evl + 10 * \log 10Q\,vl) + (Evh + 10 * \log 10Q\,vp) + (Eve + 10 * \log 10Q\,ve)) \quad (2)$$

where
- Ev(i) sound power emitted for each category of vehicle ((dB(A)/veh)) (l - light vehicle, h - heavy vehicle, e - electric vehicle),
- Qv(i) average flow rate for each category (veh/h).

Before developing the general study about the effect of electric vehicles on real noise maps, it must be commented that special attention has been paid to urban speed, <50 km/h, as above that speed the contribution of rolling noise is similar to the total noise of ICE vehicle, see Fig. 3.

a. Free field traffic lane with electric vehicles

The first step of this work was to analyse the noise emitted by a free field traffic lane of vehicles and assess the variations in the emitted sound pressure levels by changing the proportion of electric vehicles in the traffic flow.

With this objective, a road with a constant traffic flow of conventional ICE vehicles was implemented, simulated and validated with real traffic noise measurements, Fig. 4.

To evaluate the effect of electric vehicles on these conditions, the proportion of electric vehicles in the total number of light vehicles was varied, Eq. (3), and the sound level emitted by the traffic lane was calculated.

$$QTotal - lightV = (1 - N\%) * Qlight - ICEV + Qlight - EV \quad (3)$$

where
- N% percentage of electric vehicles,
- QTotal – lightV, total traffic flow of light vehicles (veh/h),
- Qlight – ICEV(i), average flow of ICE vehicles (veh/h),
- Qlight – EV(i), average flow of electric vehicles (veh/h) according to:

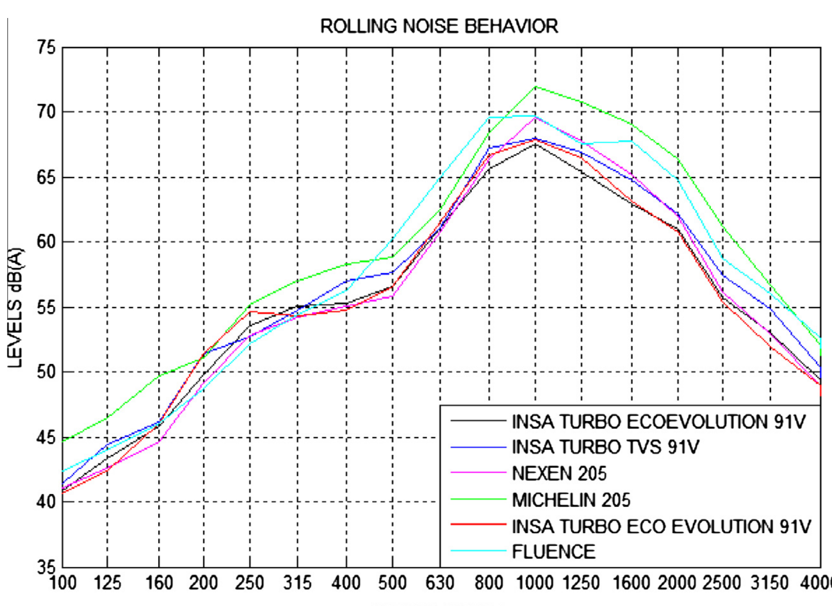

Fig. 2. Comparison of sound emitted by an electric vehicle vs ICE vehicles tyre/road noise.