DETECTABILITY OF ELECTRIC MOTORCYCLES

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Abstract

Electric and Hybrid Electric Vehicles (EVs and HEVs) seem to be the key for the total reduction of noise disturbance and pollution in urban areas. However, the use of EVs/HEVs has shown the danger of a "quiet" transport system in urban environments. This phenomenon occurs specially at low speed regimens, where the propulsion system noise overcomes the noise produced by aerodynamics and tyre/road contact. The problem has been addressed in different scientific papers and a new regulation is being prepared regarding this topic. Nevertheless, current works solely focus on four-wheeled vehicles while leaving out mopeds and motorcycles.

This paper analyses the detectability of different motorcycles, with electric and internal combustion engines, at the speed of 20 km/h. For that, a group of listeners were polled. The subjects had to detect the presence of a vehicle in a pass-by mode test. The study was made by means of an acoustic simulation with the help of a software tool. The results underscore the risk posed by electric two-wheeled vehicles.

Keywords: motorcycle, electric vehicles (EVs), internal combustion engine, detectability, reaction time.

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1 Introduction

Electric and Hybrid Electric Vehicles (EV and HEV) may provide a short-term solution to reduce gas emission in cities guaranteeing a good air quality in urban areas. Worldwide demand for HEVs will advance rapidly and nearly 8 million are expected in 2020 [1]. Moreover, the use of electrical engines as propulsion systems considerably reduces the emitted noise comparing internal combustion ones. This coincides with an increasing awareness around the issue of the environmental noise. The World Health Organisation is reporting that traffic noise is responsible for over 20,000 deaths each year via resulting heart problems or reduced sleep quality.

However, the very low noise levels in EV or HEV may pose a danger to pedestrians and cyclists, since their proximity may be unnoticed. Thanks to the tyre/road noise, EV and HEV may generate a sufficient noise level to warn pedestrians under some driving conditions. According to [1], in an analogous situation, a HEV is two times more likely to be involved in a pedestrian crash than an internal combustion engine vehicle (ICEV). To overcome this problem, vehicles will be provided with an Acoustic Vehicle Alerting System (AVAS). Nevertheless, several questions such as the level of noise generated by the warning sound system and the features of this sound, need to be solved in order to avoid the increasing of the environmental noise pollution. These questions have already been discussed in the literature. K. Yamauchi, in [2], compares the level of different warning sounds to be detected in a number of urban background noises. E. Parizet et al., in [3], study the detectability of different designed warning sounds comparing the reaction time between people with normal vision and people visually impaired. These works underscore how useful the warning sounds can be. For that reason, different Government Administrations are drafting specific regulation for the use of AVAS.

Up to now, all efforts have been focused on four-wheeled vehicles. However, the question arises as to what happens with electric two-wheeled vehicles. Mopeds and motorcycles are used almost exclusively in urban areas, where quiet vehicles most directly affect the road safety. In the same way, its lower price compared to four-wheeled vehicles suggests a faster increase on the demand.

The noise emitted by two-wheeled vehicles differs considerably from the cars. On the one hand, the tyre/road noise will be less due to its number and smaller size. This may result in a high influence of the engine to the total noise emitted by the motorcycle. Therefore, it is reasonable to believe that the use of electric engines considerably decreases the noise emitted by mopeds and motorcycles. Thus, the pedestrian safety is compromised.

This paper proposes a first approach to the detectability of two-wheeled vehicles. The study analyses the acoustic behaviour of different mopeds, comparing the internal combustion vehicles with the electric ones. A group of 30 people were polled using an auditory test conducted in a laboratory. The results highlight a significant difference between both propulsion systems. The noise emitted by an electric motorcycle is substantially less than the noise emitted by other with an internal combustion engine.

2 Experimental Procedure

A group of five mopeds was selected for the auditory tests: two with pure electric propulsion, two with internal combustion engine, and one with an hybrid system. In the latter case, the electric mode and the internal combustion mode were analysed separately, allowing to compare the behaviour of both systems with the same boundary conditions.

Figure 1. Internal combustion (left) and electric (right) mopeds.

In order to determine the detectability of different motorcycles a psychoacoustic test was performed. For that, a real scenario was simulated in a laboratory: a pedestrian standing on the sidewalk, at a distance of 3 meters from the centre of the traffic lane, prepared to cross the road. Different sounds from mopeds were presented to the listener in a pass-by mode, simulating the movement of the motorcycle in both directions. The two-wheeled vehicles approached the listener individually, at a constant speed, covering a distance of ±30 meters from the pedestrian. In order to increase the realism of the simulation, the motorcycles were presented under certain background noise conditions. Subjects must indicate, by pressing a button, the moment they perceived the vehicle approaching.

To evaluate the detectability of vehicles, the sound sample from each moped was obtained in a pass-by test. The samples were used during the auditory tests in order to reproduce the sound event more accurately. Recordings were made by means a HeadAcoustic HSM III dummy head, with a sample frequency of 44100 Hz and a bit depth of 16 bits with noise shaping algorithm. A fifth order high-pass filter with cut-off frequency of 22 Hz was used during the acquisition. The dummy head was situated 3 meters from the centre of the traffic lane. The sound acquisition was made from ±30 meters from the dummy head.

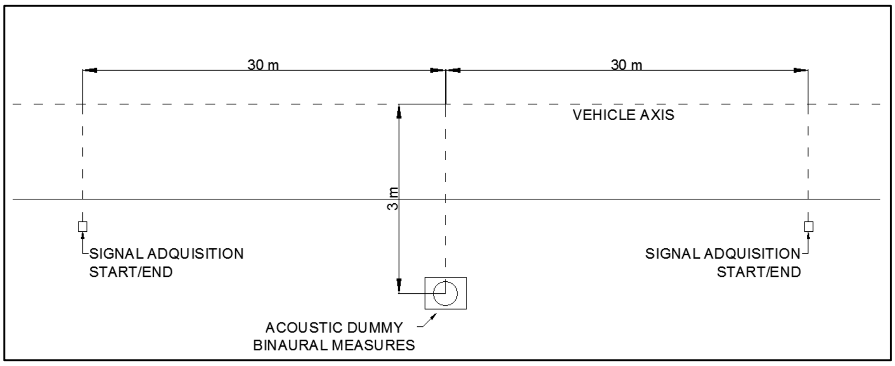

Figure 2. Pass-by test configuration for sound samples acquisition.

To study the behaviour of the vehicles at different speeds, the tests were conducted at 10, 20, 30, 40 and 50 km/h. During the event, the sound pressure level emitted by each motorcycle was measured using a Sound Level Meter B&K Type 2250. The device was situated 80 cm from the dummy head recording the level from the pedestrian point of view. Vehicle speed was determined by means of a set of photocells located on one side of the road. The measurements took place at the University Miguel Hernández of Elche, on a traffic lane with an asphalt characterization G20 + S20.

Acquired sound samples were processed and conditioned to be used on the detectability tests. Samples were analysed and listened carefully in order to discard those useless. Some audio files presented different background noises that can somehow affect the validity of the samples and the detectability results: wind, birds, barking, aircraft or other vehicles. These samples were filtered or even removed. In order to eliminate a part of the signal fluctuations caused by wind, all samples were filtered by a 5-th order Butterworth high-pass filter with cut-off frequency of 80 Hz.

The binaural sound samples were obtained with an acoustic dummy head using diffuse field equalization. This equalization allows to correct the effect of the head in the acquired signals, making possible the comparison between the measures provided by conventional microphones. To carry out the psychoacoustic tests, the diffuse field equalization must be removed so that the signals represent accurately the event. Likewise, the use of headphones during the detectability tests may affect the accuracy of the emitted signal with respect to the real sound. The frequency response of headphones can change the spectral content of the sample and thus, must be corrected. An inverse filter from the headphones impulse response was used to solve the aforementioned effects.

The background noise used in the auditory tests was obtained from the superposition of the noises emitted by several idling vehicles. The resulting signal presented an equivalent sound pressure level of 61 dB(A).

A software tool was implemented to perform the detectability test. The application emitted different sound samples over a constant background noise. Samples were presented individually and randomly, and the time between sound events varied between 1 and 20 seconds. Each sound was played six times - three in the left-right direction and three in the opposite - making a total of 36 sound events by subject. User had to indicate the approach of a vehicle by pressing a key, obtaining at the end of the test the time response for each sound sample.

3 Results

3.1 Sound Pressure Level

The analysis of the sound pressure level emitted by the tested vehicles at diverse speeds showed a significant difference between electric and internal combustion motorcycles. The results highlighted a behaviour similar to that observed on four-wheeled vehicles [5]. As the vehicles speed increases, the noise generated by aerodynamics and tyre/road contact increases. At speeds above 50 km/h, the noise produced by these phenomena had a greater contribution than noise generated by propulsion system on the total sound emitted by the vehicle. Therefore, at high-speed regimes, the sound pressure level generated by an electric moped will be similar to that produced by an internal combustion model.

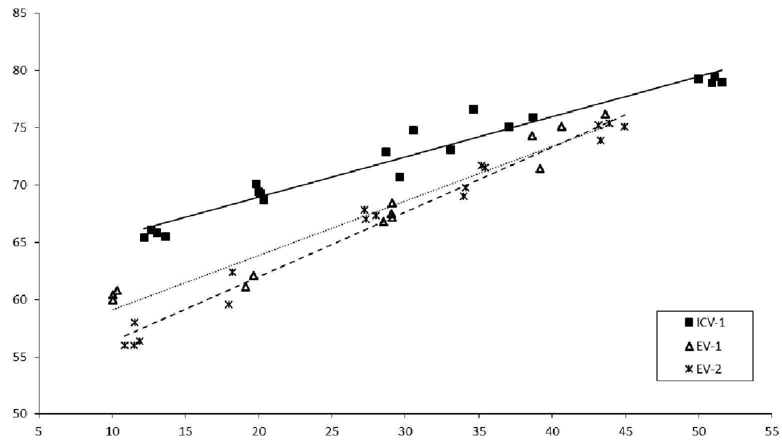

Figure 3. Maximum Sound Pressure Level emitted by mopeds with power smaller than 7 kw at different speeds.

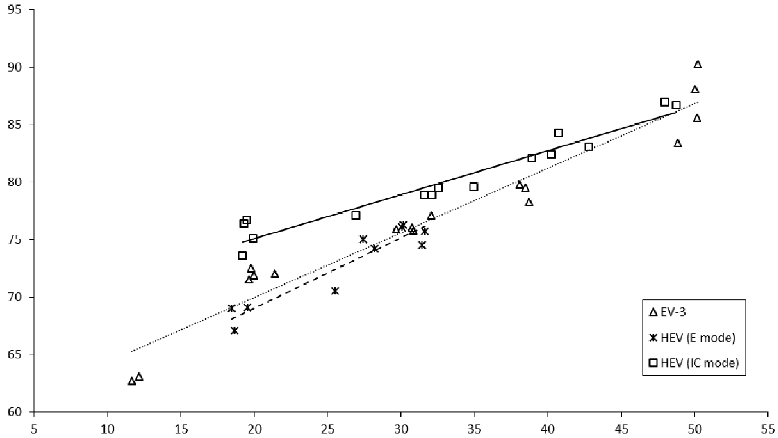

Figure 4. Maximum Sound Pressure Level emitted by mopeds with power greater than 7 kw at different speeds.

Previous graphs represent the sound pressure level obtained during the tests. The results were separated into two groups according to the power of the motorcycle. Mopeds with smaller engine capacity generated a sound pressure level significantly lower. In all cases, the level of noise generated by the two-wheeled electric vehicles was lower than the sound produced by the internal combustion models of the same group. Focusing on the hybrid motorcycle, the difference between the level produced by the motorcycle running in electric mode and the internal combustion mode, at 20 km/h, was approximately 5 dBA. This gap decreased for higher speeds. Quiet vehicles may be masked by the environmental noise and therefore, present a risk for pedestrians.

A spectrum analysis showed the appearance of harmonic frequencies in electric motorcycles. These components were linked to the vehicle speed, changing their value as the velocity increases.

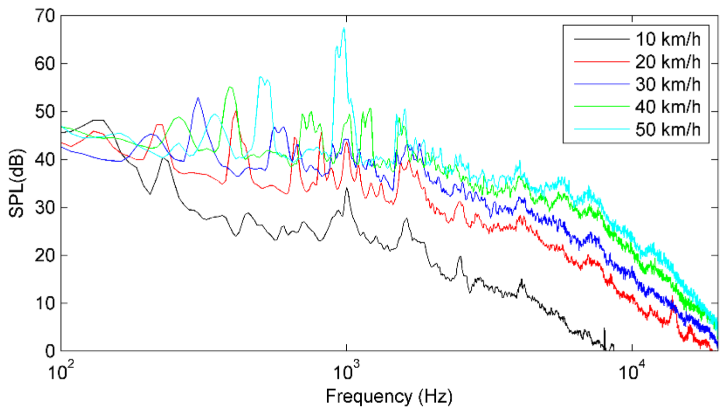

Figure 5. Evolution of the frequency spectrum with the speed for an electric moped.

The appearance of tonal components may result in an increase of annoyance perceived by driver and pedestrians.

3.2 Detectability

The detectability test was conducted on a group of 30 people with an average age of 25. Most of them were students from the University Miguel Hernández of Elche and the University of Alicante. The test was performed with motorcycles at 20 km/h. The results showed higher reaction times for those vehicles with an electric propulsion system.

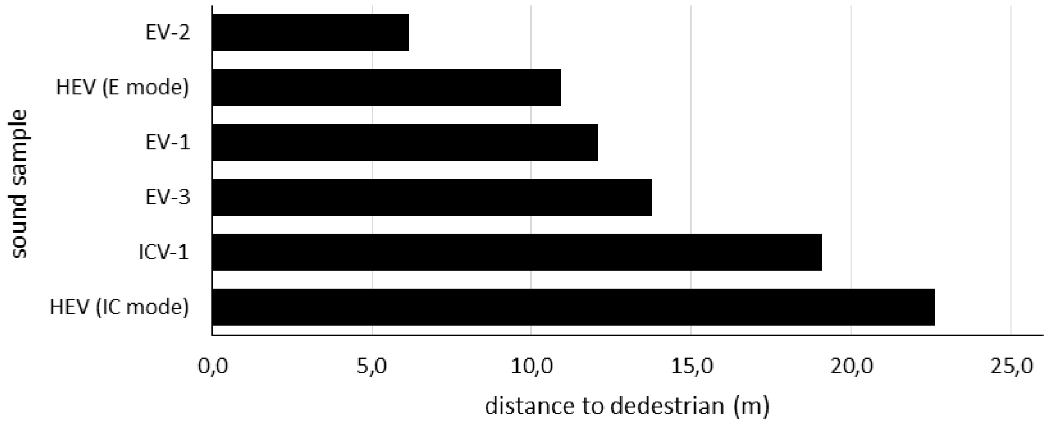

Figure 6. Distance to pedestrian for different two-wheeled vehicles.

The minimum time difference between electric and internal combustion motorcycles was 1 second, which means a distance of 7 meters. Electric vehicles were detected at a shorter distance from the pedestrian, representing an increased risk of accident. EV-2, under background noise conditions used during the test, was detected at an average distance of five meters from the pedestrian. The distance was smaller than the stopping distance required for motorcycles at the speed of 20 km/h. Regarding the hybrid moped, the difference between both operating modes, electric and internal combustion, was reflected in a detectability delay of approximately 2.3 seconds. The results confirm how the propulsion system affects the vehicle detectability.

4 Conclusions

Preliminary results revealed a significant difference between the sound pressure level generated by the electric and internal combustion motorcycles at low speeds. As the velocity of the vehicle increased, the difference between both propulsion systems was reduced. At high speeds, the noise produced by aerodynamics and the tyre-road contact resulted more important.

The observed level difference resulted in a decrease of the detectability for electric vehicles. Therefore, there is a real risk for pedestrians in front of the incorporation of this kind of vehicles to the urban traffic. It should be noted the difference obtained for an hybrid moped in both operating modes. For the same vehicle, reaction time provided a difference of more than 10 meters between electric and IC modes.

The results shown in this study were obtained under a particular background noise characteristics. Modifications of this conditions, like the use of urban environment with higher levels of noise, should result in a decrease on time reactions. These changes could involve not to detect some of the vehicles tested. According to the results, the need of an alerting system in two-wheeled vehicles must be considered.

Acknowledgements

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