Towards a reduction of noise emission of powered two-wheels – Part 1

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ABSTRACT

Transportation in urban areas is often synonymous of traffic congestion. In the last decade, this situation led users to give up passenger cars and incited them to adopt powered two-wheelers (PTW), better adapted to the traffic hazards. However, the question of the noise emitted by PTW remains a concern for the population. In France, these vehicles are quoted in second position in the opinion surveys relative to the transportation noise. The main objective of the French research project Ascoot (**A**coustique des **scoot**ers et des motocycles) is to propose solutions aiming to reduce the noise emitted by the most represented PTW in the current traffic. This paper summarizes the results obtained on the acoustical investigation of a panel of ten PTW (including an electric powered scooter). Global and third-octave noise analysis has been performed, relying on the classical Controlled Pass-by procedure, and on a determination of the directivity characteristics. Pass-bys at constant speed, with acceleration and deceleration have been considered, and the influence of mechanical parameters, as the engine capacity, is also analyzed. The noise emission of PTW has been finally compared with those of other means of transportation usually met in urban zones (light vehicles, medium heavy vehicles, buses, trams).

Keywords: Noise emission, powered two-wheels, electric powered two-wheels I-INCE Classification of Subjects Number(s): 13.3.3

1. INTRODUCTION

In a context of strongest traffic congestion in urban areas, using powered two-wheelers, particularly scooters, can be considered as an acceptable solution to avoid jammed traffic situations. In the past, many studies have been conducted on noise emission of means of transportation, however, few researches discussed the case of powered two-wheelers. In absence of information on the volume of powered two-wheels on the total traffic, this category of vehicles was not taken into account in noise prediction models. Noise emitted by powered two-wheelers remains a primary concern of the population : in a recent survey [1], these vehicles are quoted in second place – after light vehicles but before the heavy trucks - by 43% of French peoples claiming to be annoyed by transportation noise.

In January 2012, the French Ministry of ecology, sustainable development and energy published official statistics showing that the real fleet of powered two-wheels is more important than the carried out assessments to there [2]. Recent studies performed on the main parisian streets indicate that powered two-wheelers can represent up to 30% of the total traffic [3].

The purpose of this paper is to present some of the results obtained in one of the workpackages of the ASCOOT (Acoustique des SCOOTers) research project (2011-2015) whose objective was to assess noise

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emission of a panel of scooters representative of the french fleet (the scooters were selected on the basis of the best sales in France in 2010 [4]). This article describes the panel of scooters, the experimental device and the measurement protocol, and the calculation methodology of the emission laws of each vehicle. The analysis of three important parameters influencing noise of scooters is then presented. Finally, comparisons of noise emissions of the scooters to those of other typical urban means of transportation are investigated in the last part of the paper.

2. MEASURES AND METHOD

2.1 Vehicles

The tested vehicles panel consists of ten conventional scooters representative of the best statistics of sales in France during 2010 as well as an added electric-powered scooter. These scooters represent the production of several european and asian manufacturers [4]. For the sake of confidentiality, the vehicles are not identified in this article (see Table 1). This panel is composed of:

- Four scooters of 50 cc cylinder capacity : two 2-stroke engine scooters (2T) and two 4-stroke engine scooters 4-times (4T),
- Four scooters of 15 cc cylinder capacity,
- Two scooters of cylinder capacity exceeding125 cc.
- An electric-powered scooter, which is the electric version of a 50cc scooter developped by the same manufacturer.

Table 1 – Technical characteristics of the selected scooters.

Name	Engine capacity, cc	Engine	Power, kW
S50-2T-A	50	2T	4
S50-2T-B			4
S50-4T-C		4T	2.8
S50-4T-D			3.6
S125-A	125	4T	11
S125-B			11
S125-C			11
S125-D			9.5
M-A	400	4T	26
M-B	500	4T	35
E-Scooter	--	--	

The ten conventional scooters are fitted with a continuously variable transmission (CVT) which can change seamlessly trough an infinity number of effective gear ratios between minimum and maximum values. The transition between the ratios is progressive, depending on both engine- and vehicle speeds.

2.2 Measurement setup

The test facility offers open-field acoustic measurement conditions. The test track surface is dense asphalt concrete 0/10, representative of road surfaces used in French urban areas. Pass-by noise measurements were performed with the vehicles running in both directions in various real use conditions. Two acoustic devices were implemented simultaneously on a distance of 20 m along the track, leading to complementary information on the scooters noise emission (Figure 1). The pairs of infrared cells / reflective plates allow to estimate the speed of the scooters in the way of each acoustic device. The engine speed is determined continuously using an amperometric clamp fixed on the spark plug cable.

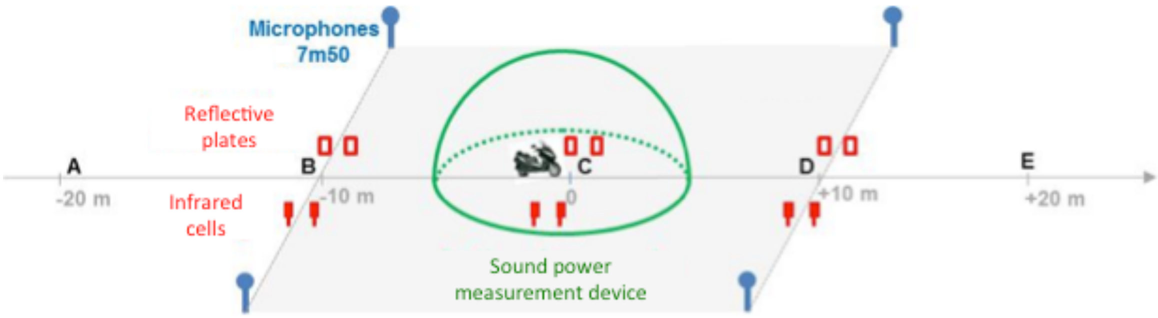

Figure 1 – Measurement setup

2.3 Standard 7.5 m microphone measurement (CPB)

Four microphones, facing each other on either side of the track in pairs, are set up 7.5 metres from the track centre and 1.2 metres high. The two microphone pairs are within 20 metres of each other along the track. The procedure carried out is similar to Controlled Pass-by standard [5,6] extended also to pass-bys with acceleration or braking: in each configuration, the third-octave (frequency range 50 Hz to 10 kHz) and global maximum A-weighted noise pressure levels on each microphone are recorded. Results which do not exceed background noise by more than 10 dB(A) were discarded. This requirement happens to be difficult to fulfil at the lowest speeds when the electric scooter was investigated.

2.4 Sound power- and vertical directivity measurements

The method used by IFSTTAR to determine the noise characteristics of road vehicles (e.g. sound power and vertical directivity of noise emission) [7] has the advantage to be used on moving vehicles. It consists in measuring the sound pressure levels in seventeen points spread over a hemisphere of radius 4.57 m (see Figure 2).

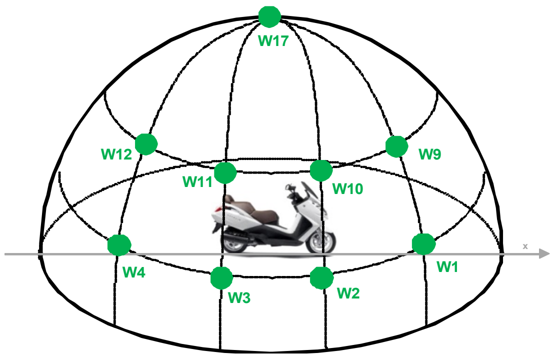

Figure 2 – Sound power measurement

For each vehicles pass-by, sound power level (L_{WA}) is calculated from noise pressure levels (L_p) measured by each of the seventeen microphones when the vehicle is located in the centre of the hemisphere. These noise levels are associated with each corresponding elementary area, and L_{WA} is calculated as follows:

$$L_{wA} = 10 * log\left[\sum_{i=1}^{17} \frac{S_T/17}{S_0} 10^{Lp(i)/10}\right] \quad (1)$$

where S_T is the total area of the hemisphere and S_o is the reference area (1m^2).

This device also allowed us to determine the directivity in the two horizontal planes where the microphones are located (1.08 m and 3.23 m height in accordance with Figure 3)

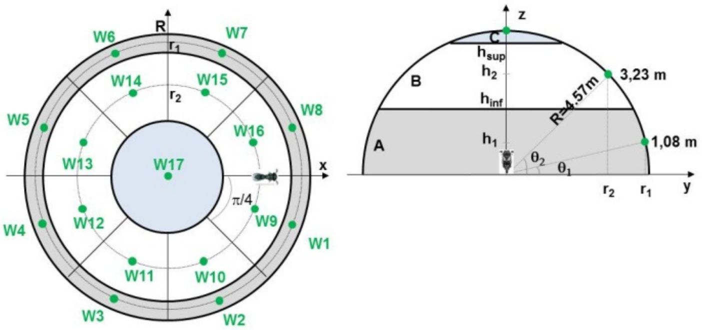

Figure 3 – Location of microphones on the hemisphere.

2.5 Experimental methodology

2.5.1 Constant speed pass-bys

Constant speed pass-bys ranged on [v_{min}, v_{max}] speed range in 10 km/h steps where:

- v_{min} = 10 km/h whatever the cylinder capacity of the scooter
- v_{max} = 45 km/h for scooters of 50 cc cylinder capacity and the electric-powered scooter,
- v_{max} = 90 km/h for scooters of 125 cc cylinder capacity
- v_{max} = 110 km/h for the scooters exceeding 125 cc cylinder capacity.

2.5.2 Acceleration pass-bys

For the test during acceleration, the scooter was either stopped 10 m before the center of the hemisphere and pulled away with full acceleration until the exit of the measurement area (point A or D on Fig. 1 depending on the direction of travel), or arrived at constant speed (10, 20 or 30 km/h for scooters of cylinder capacity 50 cc and the electric-powered scooter, 30, 50 and 70 km/h for the scooters of cylinder capacity exceeding 50 cc) and began to accelerate hard 10 m before the center of the hemisphere until the exit of the measurement area.

2.5.3 Deceleration pass-bys

The measurement protocol used in this study in deceleration conditions specifies that the scooters arrive at constant speed (45 km/h for scooters of 50 cc cylinder capacity and the electric-powered scooter and 90 km/h for the scooters of higher cylinder capacity) and begin to decelerate (without braking) 10 meters before the center of the hemisphere (point A or D on Fig. 1 depending on the travelling direction).

3. RESULTS

Results presented in this paper relate only to global noise emission, however it should be kept in mind that third-octave band analysis, which isn't described here, was also performed in the [50 Hz – 10 kHz] frequency range.

Whatever the driving condition, noise emission laws are determined by quadratic regression on the maximum sound pressure levels at 7,5m :

$$L_{Amax}(v,r,s) = \alpha_{rs} + \beta_{rs} log\left(\frac{v}{v_{ref}}\right) + \gamma_{rs} log^2\left(\frac{v}{v_{ref}}\right) \quad (2)$$

or by quadratic regression on the power noise levels :

$$L_{WA}(v,r) = \theta_r + \vartheta_r log\left(\frac{V}{V_{ref}}\right) + \mu_r log^2\left(\frac{V}{V_{ref}}\right) \quad (3)$$

where α, β, γ, θ, ϑ and ϑ are the regression coefficients, r is the running condition (constant speed, acceleration, deceleration) and s is the considered side of the scooter (left, right).

An example of noise emission laws is given in the case of the scooter S125A (Figure 4). Information on the noise emission laws of the other scooters can be found Fig. 8. The comparison between the noise emitted by the electric-powered scooter and the « equivalent » conventional 50 cc scooter shows that substantial noise reduction can be expected with this type of motorization, whatever the running conditions (10-15 dB) – cf. Fig. 5

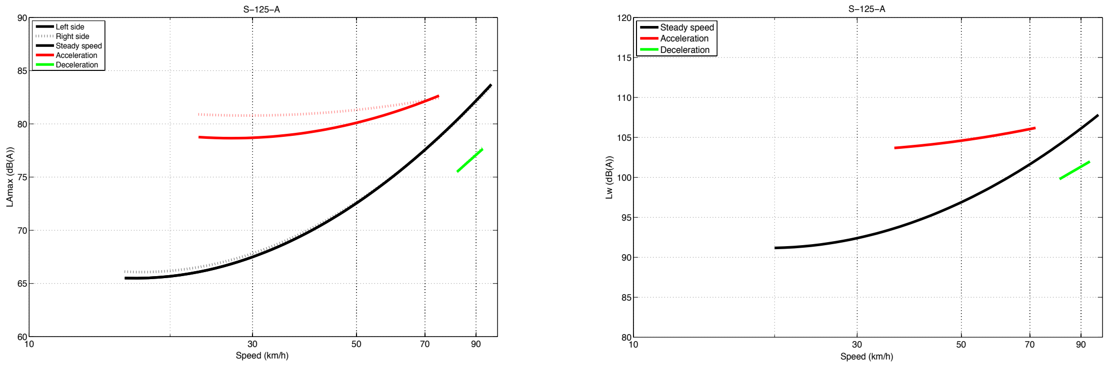

Figure 4 – S125 noise emission laws. Left graph : L_{Amax}. Right graph : (L_{WA})

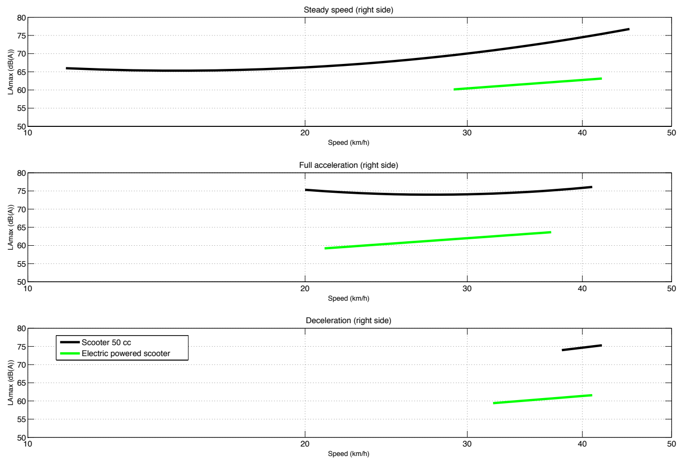

Figure 5 – Comparison of the noise emitted by the electric powered scooter and the 50cc conventional scooter.

4. NOISE EMISSION ANALYSIS

The analysis of the results allowed to identify parameters which have an influence on L_{Amax} or L_{WA} levels. The influence of three of these parameters is presented here:

- the scooter side (dissymetry of noise emission)
- the engine capacity,
- the running condition : effect of acceleration on the acoustic power level

4.1 Dissymetry of noise emission

The emission laws depicted Figure 4 in the case of the scooter S125-A shows that the emission noise levels are higher on the right side of the vehicle. This dissymetry is maximal at low speed and decreases up to become negligible at high speed. It becomes also more marked in acceleration running condition than at steady speed. This dissymetry in the noise emission, caused by the presence of a muffler located on the right side of the ten scooters, reaches 1.8 dB for decelerating scooters, 2.4 dB at constant speed and 3.1 dB for accelerating scooters (Figure 6).

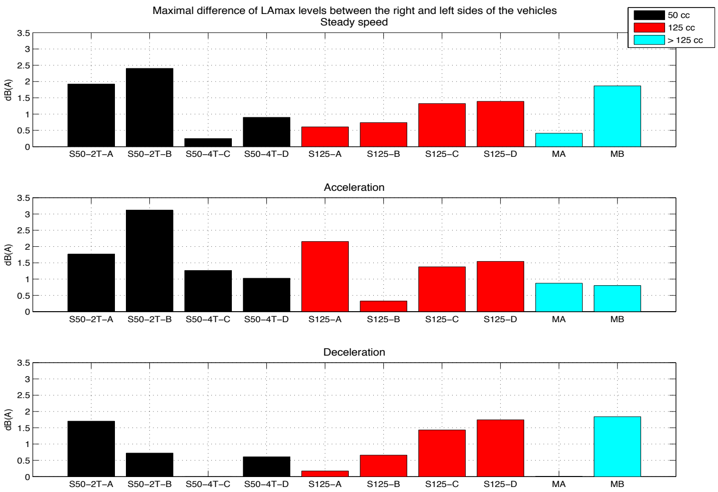

Figure 6 – Dissimetry of the noise emission of scooters for constant speed, acceleration and deceleration running conditions.

The dissimetry of the noise emission depends also on the type of motorization : the scooters fitted with a two stroke engine show a more accentuated dissymetry than those fitted with a 4 stroke engine. On the other hand, this dissymetry doesn't depend on the engine capacity of the vehicle. Figure 7 shows relative levels for speeds minimum and maximum for each stage of the S50 - 2T scooter - B which introduces strongest asymmetry. These polar patterns are represented by taking for reference 0 dB (A) the noise level measured by the microphone located at the top of the hemisphere (microphone referenced W17 in Fig 2). During deceleration, only the diagram rated at the maximum speed is represented. These diagrams analysis confirms that the noise emitted by this scooter is higher at the right side. Moreover noise emissions are more important to 1.08 m in height and the rear of the vehicle.

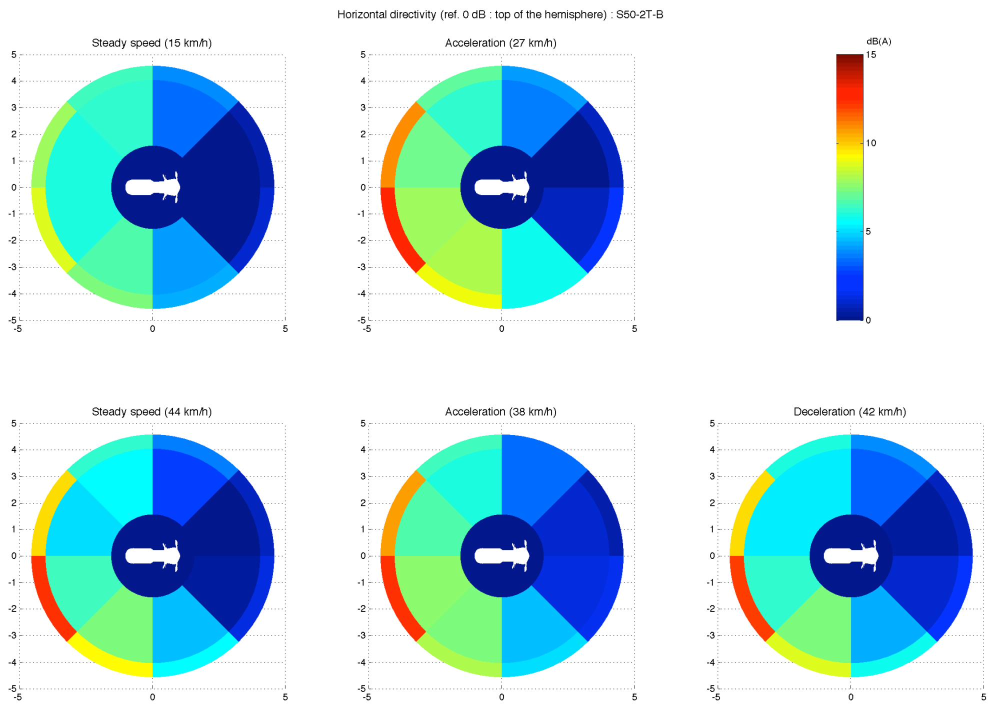

Figure 7 – Dissimetry of the noise emission of scooters for constant speed, acceleration and deceleration running conditions.

5.2 Influence of the engine size

Figure 7 shows the distribution of the maximum sound pressure levels, represented in the form of clouds representing each a family of scooters of same engine size. The influence of the engine size on L_{Amax} levels depends on the the vehicle speed.

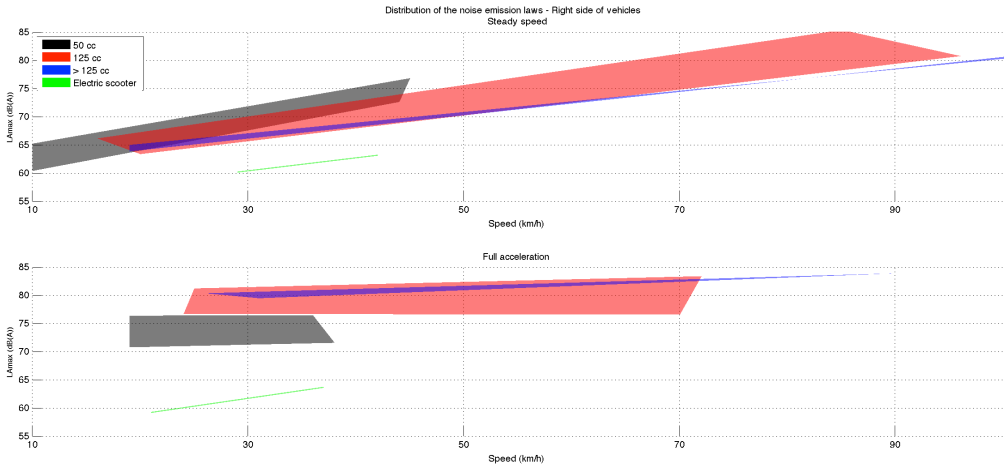

Figure 7 : Influence of the engine size on the L_{Amax} levels.

At constant speed, the lower the engine size of a scooter is, the noisier the vehicle is : for a given speed, the engine speed reached by low-sized engine scooters is higher than that achieved by scooters of greater engine capacity. In acceleration runing conditions, a scooter is even noisier that its cylinder capacity is strong : for a given speed, the engine speed reached by high-sized engine scooters is significantly higher than that of a 50cc scooter.

5.3 Influence of full acceleration load

Acceleration causes an increase of the noise level compared to a scooter running at a similar instantaneous speed during a steady-speed pass-by. This increase of L_{Amax} is maximal at low speed and decreases to become negligible when the vehicle reaches its maximum speed. The increase of the L_{Amax} is significant especially at lower speeds for which the torque is high : it reaches 9 dB (A) for 50cc scotters, 16 dB (A) for 125cc scooters, 14 dB (A) for scooters exceeding 125cc (Fig. 8).

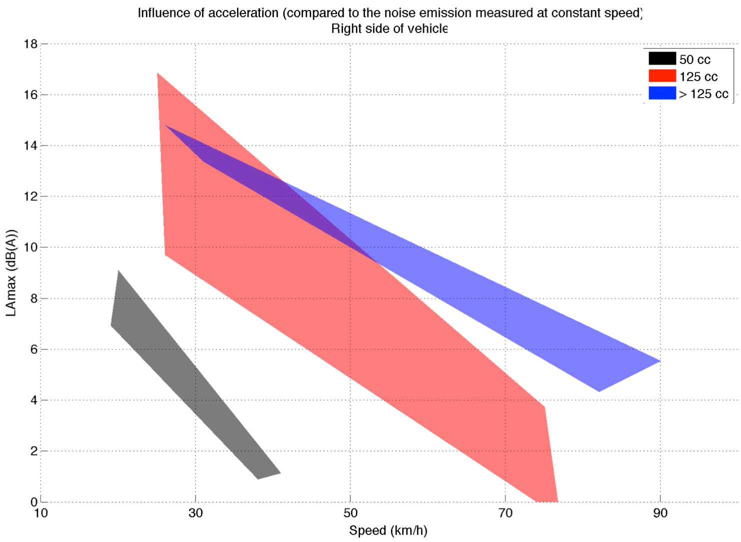

Figure 8 : Increase of the L_{Amax} levels due to acceleration (ref. L_{Amax} level at constant speed).

5. THE POWERED TWO-WHEELS : A VERY NOISY VEHICLES ?

5.1 Comparison at steady speed and acceleration using the L_{Amax} index.

It seemed interesting to compare noise emission of powered two-wheelers to those of other means of transport frequently used in urban areas, such as light vehicles, heavy goods vehicles, buses and trams. For each category of scooters (50cc, 125 cc and scooters exceeding 125 cc), L_{Amax} levels measured on the louder size have been averaged. The comparisons were established as follows :

- For passenger cars and heavy trucks, L_{Amax} levels are given by the NMPB08 prediction method [8,9] for a R2 road surface corresponding to the road surfaces used in urban areas.
- For buses and trams, L_{Amax} levels have been determined in the frame of previous studies ([10] for buses, [11, 12] for trams).

A steady speed, scooters are less noisy than a heavy truck regardless of their engine size. On the other hand, if the 50 cc scooters are more noisy than a light vehicle (+ 4.2 dBA at 45 km/h) and are as noisy as buses, L_{Amax} levels of 125 cc scooters are equivalent to those of passenger cars at low speed and are noisier at 90 km/h (+3,9 dBA). The scooters of engine size exceeding 125cc are a little less noisy than a passenger car (Fig. 9).

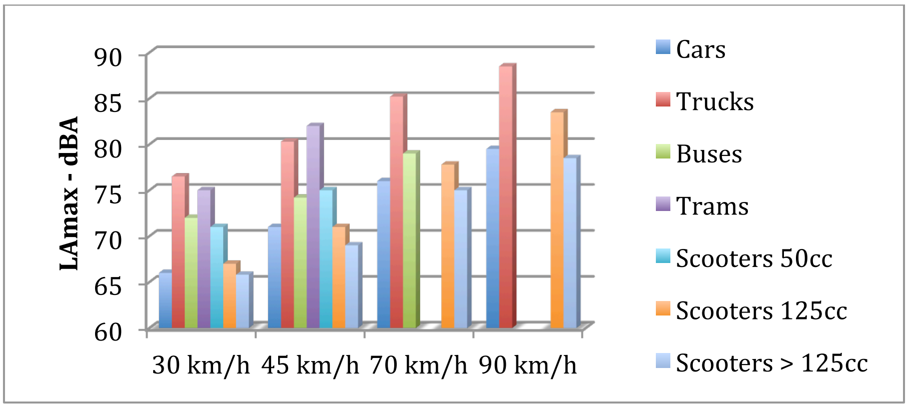

Figure 9 – Comparison of noise emitted by powered two-wheels and other means of transportation (L_{Amax} - steady speed)

In acceleration running conditions, scooters are more noisy than passenger cars regardless of their engine size and the speed. The differences are more important at low speed: + 7.8 dBA at 30 km/h and + 3.6 dBA at 70 km/h for 125cc scooters. At 30 km/h, the noise emissions of 125 cc – or exceeding 125cc scooters are equivalent to those of a heavy truck, and are higher than those of buses. However they remain less noisy for acceleration at higher speeds (Fig. 10).

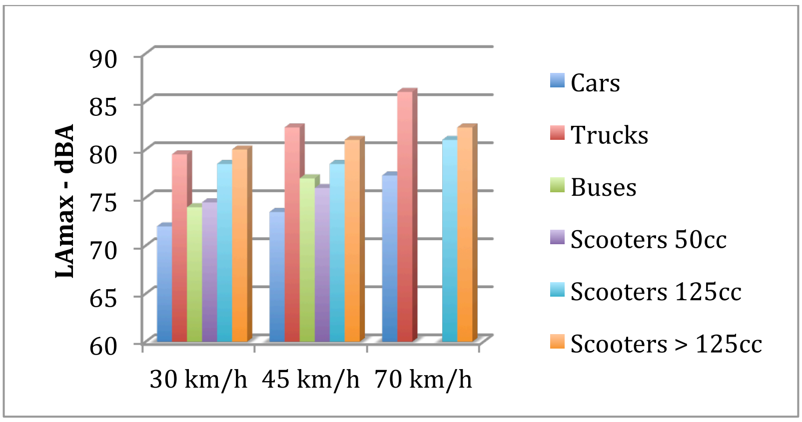

Figure 10 – Comparison of noise emitted by powered two-wheels and other means of transportation (L_{Amax} - acceleration)

5.2 Comparison at steady speed using the spatial sound exposure level (L_{Ax})

The spatial sound exposure level (LAx) of a moving source is defined as follows :

$$L_{AX}(v) = 10log\left[\int_{-\infty}^{+\infty} \frac{p^2(x)}{p_0^2}\frac{dx}{x_0}\right] = L_{Amax}(v) + 10log\left[\int_{-\infty}^{+\infty} s(x)\frac{dx}{x_0}\right] \quad (4)$$

where s(x) is the relative acoustic signature of the source. It was showed in a previous study [13] that this term doesn't depend on the speed in the case of a moving point source.

This index offers two advantages :

- The real directivity of the source is taken into account
- The physical meaning of this index is close to the real exposure of a local resident during the considered vehicle pass-by.

To establish the comparison, the integral in eq. (4) was calculated over the distance [x_{min}=-30m, x_{max}=+30m] in order to avoid errors due to background noise.

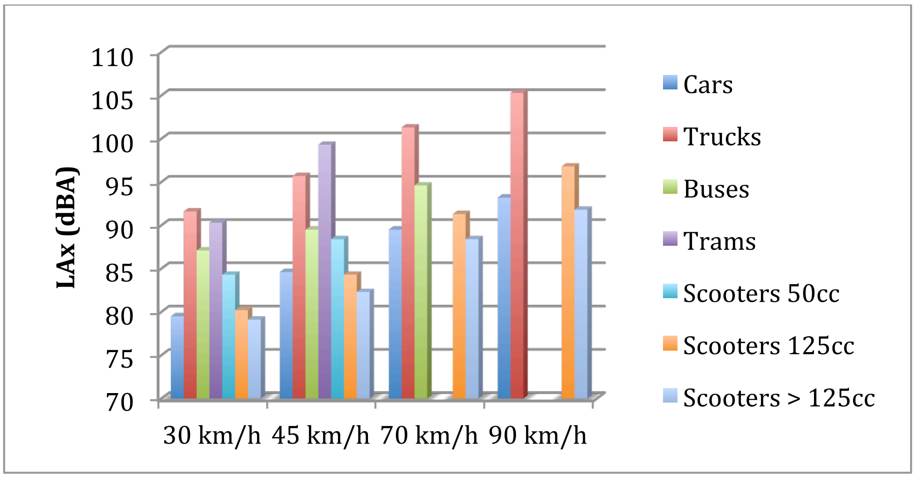

Figure 10 – Comparison of noise emitted by powered two-wheels and other means of transportation (L_{AX} - steady speed)

The trends observed in § 5.1 remain identical when considering the averages between the powered two-wheels and the cars, it confirms that these vehicle can be considered as point sources. However, the gaps are more marked in the case of large-sized vehicles, it justifies the fact of taking into account the complete signature of these vehicles.

6. CONCLUSIONS

This study compares the noise emission of a panel of conventional and electric powered scooters. Emission laws, represented by a quadratic regression based on the logarithm of the speed, have been established for each scooter at various running conditions. The analysis of the obtained results allowed to identify parameters influencing noise emissions from such vehicles. The influence of three of these parameters was presented in this article. The noise emitted by each of the ten scooters of the panel is higher on the right side where the unique exhaust system is positioned. This disymetry is maximal at low speed and decreases to become negligible at high speed. The influence of engine capacity of the scooters on LAmax levels depends on the speed of the vehicle. At steady speed, a scooter is even noisier as its cylinder capacity is low. When accelerating, a scooter is noisier as its cylinder capacity is high. LAmax levels of the conventional scooters were compared with those of urban mean of transportation. Scooters are generally noisier than passenger cars but quieter than heavy trucks. However, scooters exceeding 125cc can be less noisy than a passenger car at steady speed and as noisy as a heavy truck with acceleration at low speed. The noise increase due to acceleration is significantly higher for scooters than for the other categories of vehicles.

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REFERENCES

1. Lambert J., Philipps-Bertin C, Les nuisances environnementales des transports : résultats d'une enquête nationale, Les Collections de l'INRETS, Rapport n°278 (2009).
2. Ministère de l'Écologie, du Développement Durable et de l'Énergie. Les deux-roues motorisés au 1er janvier 2012. Chiffres & statistiques n° 400 (2013).
3. CETE Ile-de-France, Étude du trafic des deux-roues motorisés en Ile-de-France, 37p (2012).
4. Etat de l'art, bruit des deux-roues motorisés, livrable du lot1 du projet ASCOOT rapport ASCOOT-11R1L1, 61 p (2011).
5. ISO 362-1:2007, « Measurement of noise emitted by acceleration road vehicles – Engineering method, Part1 : M and N categories » (2007).
6. NF S31-119-2, « Caractérisation in situ des qualités acoustiques des revêtements de chaussée – Mesurages acoustiques au passage – Partie 2 : véhicules maîtrisés (2000)
7. Hamet J.F, Bruyère J.C, Pachiaudi G. Puissance et directivité acoustiques du bruit de contact pneu/chaussée, méthode de mesure, rapport INRETS NNB 8601, 48 p (1986)
8. NMPB08 - Calculation of sound emissions from road traffic. Methodological guide - SETRA (2009)
9. Hamet J.-F, Besnard F., Doisy S., Lelong J., Le Duc E. : New vehicle noise emission for French traffic noise prediction. Applied Acoustics, 71, 9, pp. 861-869 (2010)
10. Lelong J., Leclercq L., Dynamic evaluation of the noise emitted by a bimodal (passenger cars/buses) traffic flow. Proc. Internoise 2003, Jeju, Korea (2003)
11. M.-A Pallas and al. Bruit et vibrations dus aux tramways : émission et perception (Rapport INRETS n°279, 2009)
12. Lelong J., Pallas M.-A., Chatagnon R. : Noise emitted by trams - Part 1 - Investigations on emitted noise. Power, vertical directivity and localization of noise sources. Proc. of Internoise 2007, Instanbul, Turkey (2007).
13. Hamet J.-F. Niveau de bruit d'un véhicule au passage : L_{eq} ou L_{pmax}. Utilisation de la signature acoustique pour valider la relation entre ces deux quantités. Actes INRETS n°36 (1994).