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A STUDY OF NOISE SOURCE LOCALIZATION IN MOTORCYCLES

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ABSTRACT

In civilized and developing countries, the number of the motorcycles in transportation systems is increasing day by day. With the growing demand of the motorcycles, the noise caused by these vehicles has constituted an important role in the noise pollution. On the other hand, the drivers are suffering from the permanent damages that are generated by the motorcycle noise. For overcoming these drawbacks, the first necessary is to determine the noise sources in motorcycles. The purposes of this study are the determination of the noise sources in motorcycles by sound intensity method and investigation of the effects of the motorcycle noises on the drivers. Firstly, sound levels were measured at idle mode and at three different engine speeds for investigated motorcycle by using the sound intensity probe. Besides these measurements, the sound levels were also captured at the ear level with and without a helmet. Then the results were analyzed by taking into the consideration of the helmet usage and the driving speed.

Keywords: Motorcycle Noise, Sound mapping, Sound Intensity I-INCE Classification of Subjects Number(s): 72, 78

1. INTRODUCTION

Transportation is one of the main ingredients in the daily life of the citizen. Besides, traffic problems begin to appear by increasing the number of vehicles on the roads. Thus, people choose public transport or smaller vehicles rather than automobiles. Motorcycles may be seen good choice for the metropoles as well as in country yards because of their functionalities, practical usages and fuel economy. However, motorcycles are not perfect, since they generate emissions and noise pollution. The motorcycle noise is limited by the regulations for the noise pollution (1). On the other hand, the regulated amount of the noise can still affect the motorcyclist as well as the habitants. Thus, noise localization and the transmission path from the sound source to the receiver have importance.

The noises caused by industrial machines may permanent health damages on humans. Medical as well as occupational health and security professionals have investigated noise and hearing protection. The noise exposure of motorcyclist was studied on the last decades (2, 3). Using earplugs might be good choice for reduction noises that receives the motorcyclist, however, not all of drivers willing to use and carry earplugs, thus improving the helmet design seems as best option (4) In order to good helmet design by the mean of acoustics, the noise characteristics must be determined. For that reason, the motorcycle, which can be seen as the major part of the noise source and may generates noise pollution not only for the motorcyclist but also for the urban, has to be investigated for noise localization.

The localization of the noise may be performed by mapping the sound source. In order to plot sound maps, the sound intensity measurements seem as the best option. There is not large number of the studies that contain the noise localization of the motorcycles by intensity methods. Yong and Feng (5) described holographic sound intensity method and compared the method with traditional intensity method. Yunus et. all. (6) investigates the usage of the intensity method for the noise control in the automobile industry with combination of the vibration analysis.

In this study sound intensity probe is used for the determination of the sound intensity on the

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selected side of the motorcycle. The motorcycle was driven on its stand in laboratory conditions for four engine speed which were specified as experiment cases. The sound intensities were measured for the cases in order to observe the effect of the driving speed. Thus, the plotted sound intensity maps show the noise concentrated regions on the motorcycles and lead to specify the main noise sources. In addition to all sound pressure levels at ear level on both sides were measured in this study for the observation the noise that receives motorcyclist. After that the simulation results were analyzed according to helmet usage condition and driving speed.

2. THEORY

Sound can be described as the pressure propagation in the medium. Sound intensity, which is a vector quantity, in contrast with sound pressure, may be defined as net flow of acoustic energy at a given position (7). The attempt of the measuring intensity has historical background as early as 1932 by Olson (8). Clapp and Firestone (9) and Tschultz (10) developed "acoustic wattmeter" for measuring the acoustic energy flow. However, the problems such as adjusting and calibrating these types of instruments, lead drawback the usage of these techniques. In order to overcome limitations of the early techniques, cross-spectral methods were developed (11, 12). For steady state fields, the time average acoustic intensity can be defined as (11):

$$I = \frac{1}{T}\int_0^T p \cdot u dt = \overline{p \cdot u} \qquad (1)$$

Where T is the averaging time, p is the instantaneous pressure and u is the instantaneous velocity at the same position. One may calculate the velocity in one direction by integrating the acceleration that is corresponding to the pressure gradient and density of the fluid as Euler formulation:

$$u = -\frac{1}{\rho}\int \frac{\partial p}{\partial r} dt \qquad (2)$$

Then, with using the finite difference approximation, particle speed can be written according to the pressures at points (A and B) have distance Δr (7):

$$u_r = -\frac{1}{\rho \Delta r}\int (p_B - p_A) dt \qquad (3)$$

The sound intensity can be calculated with using above Eq.3 and the mean pressure $(p_B + p_A)/2$ between two points as:

$$I = \overline{p \cdot u} = \overline{\frac{1}{2\rho \Delta r}(p_B + p_A)\int (p_B - p_A) dt} \qquad (4)$$

This method is called Direct Method and needs to time integrations. On the other hand, Fast Fourier transform can be used for intensity calculation by frequency domain (11, 12). By using cross spectral method, intensity can be calculated for a given direction as (7):

$$I = -\frac{1}{\omega \rho \Delta r} \operatorname{Im} G_{AB} \qquad (5)$$

Where ω is the angular velocity, G_{AB} is the imaginary part of the cross spectrum. This method is named as Indirect Method and commonly used in modern measurements. These methods are applicable for limited frequency bandwidth (or wavelength) hence Δr has to remain relatively too small. The Indirect Method leads to usage equipment configuration that is subjected to measure sound pressure in two points in same direction in Frequency Domain. It should be noted that, Indirect Method needs digital processing for calculations. The definition of the sound intensity enables to calculate sound power of the sound sources by discrete point measurements (13), by scanning surface measurements (14, 15). In this study discrete point measurements were preferred for noise localization procedure.

3. EXPERIMENTS

Presented study has two experimental rigs. The first rig was set up for the noise localization of the motorcycle with sound intensity measurement. The second rig was prepared for measuring sound pressure levels on driver ear level. The motorcycle used in the measurements was fixed on its stand. All measurements were held in laboratory conditions with acoustic shielding base and a sound absorption panel was positioned left side of the motorcycle for avoiding reflecting sounds, see Figure 1. The front and the rear side of motorcycle remain free field for the ventilation.

Figure 1 – Experiment setup

3.1 Sound Intensity Measurements

In order to perform noise localization of the studied motorcycle, sound intensity measurements were taken into consideration. A measurement surface was divided to 15 x 15 cm^2 measurement area, 10 in vertical, 16 in horizontal direction. The measurement grid was located 25 cm from the gear box casing and parallel to the right side of the motorcycle. Afterwards, B&K Type 3599 Sound intensity probe kit was used for the discrete point intensity measurements on grid. The probe has two microphones in a direction facing each other, the spacing between microphones was chosen as 12mm. Selected frequency bandwidth was specified as 20Hz-10kHz. For every measurement 3 second time averaging was performed. RMS (Root Mean Square) Spectrums of the intensities on 1/3 octave band from every measurement area were captured. The driving speeds were idle, 2000 rpm, 3000 rpm, 4000 rpm and the sound intensity maps for the driving cases were generated. These cases were chosen to simulate motorcycle driving in the crowded traffic and with slow speed.

3.2 Sound Pressure Level Measurements

The aim of the sound pressure measurement was to determine the sound levels that transmits to driver ear on drive conditions. For that purpose, B&K Head and Torso Unit was used to simulation of the human ear hearing. B&K four channel analyzer and PULSE software were combined to data acquisition and signal processing. The experiment was performed for the several engine speed such as idle speed, 2000 rpm, 3000 rpm and 4000 rpm with and without helmet on the unit. The first gear was chosen for each driving speed, except idle one since it was neutral. Three measurements for each case were captured. Then averaged frequency spectrums were calculated to observe sound pressure levels at ear level.

4. RESULTS

Firstly, the sound intensity results that lead noise localization of the studied motorcycle are mentioned in this section. The captured intensities on the 1/3 bands were used for calculating the total intensity for the measurement area. The calculated sound intensity maps for different engine speeds were shown in Figure 2. From the figure, the increasing intensity levels according to the engine speed can clearly be observed. The noise is concentrated in the downside as expected. It can be said via intensity maps that the engine and the transmission box is the main sources of noise. The exhaust system follows the couple.

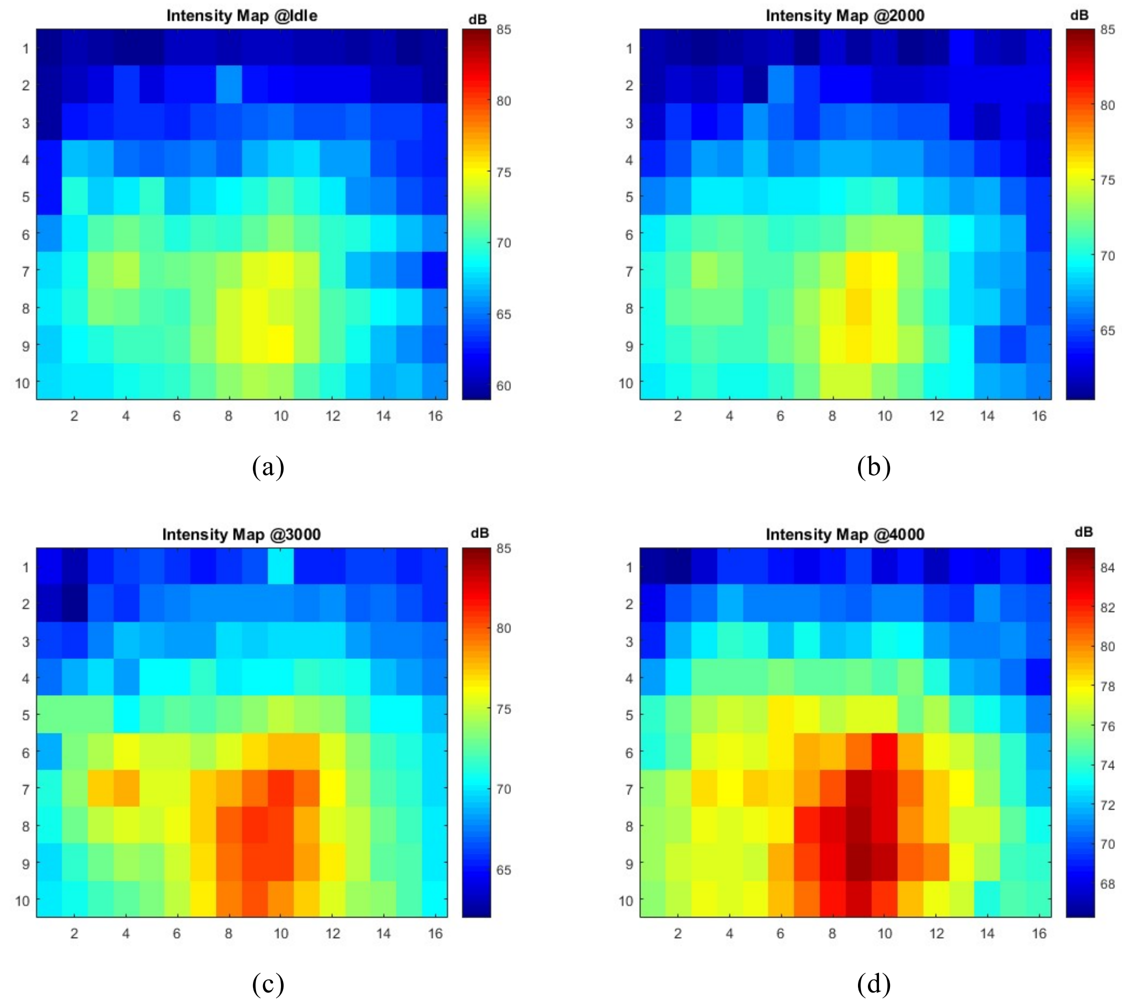

Figure 2 - Sound Intensity Maps for (a) idle speed, (b) 2000 rpm, (c) 3000 rpm, (d) 4000 rpm.

The sound pressure levels that measured on ear level were plotted for left and right ear simulations in Figure 3. It can clearly be said that sound pressures on the low frequencies that is detected at ear level are greater than the higher frequencies for every engine speed. The helmet usage decreases the sound levels on every engine speed especially after 2000 Hz. The sound pressure results of left and right ears are in good agreement. It should also be noted that, studied motorcycle has exhaust pipes on both sides, thus amount of the exhaust system in total noise can be assumed symmetric on the both sides.

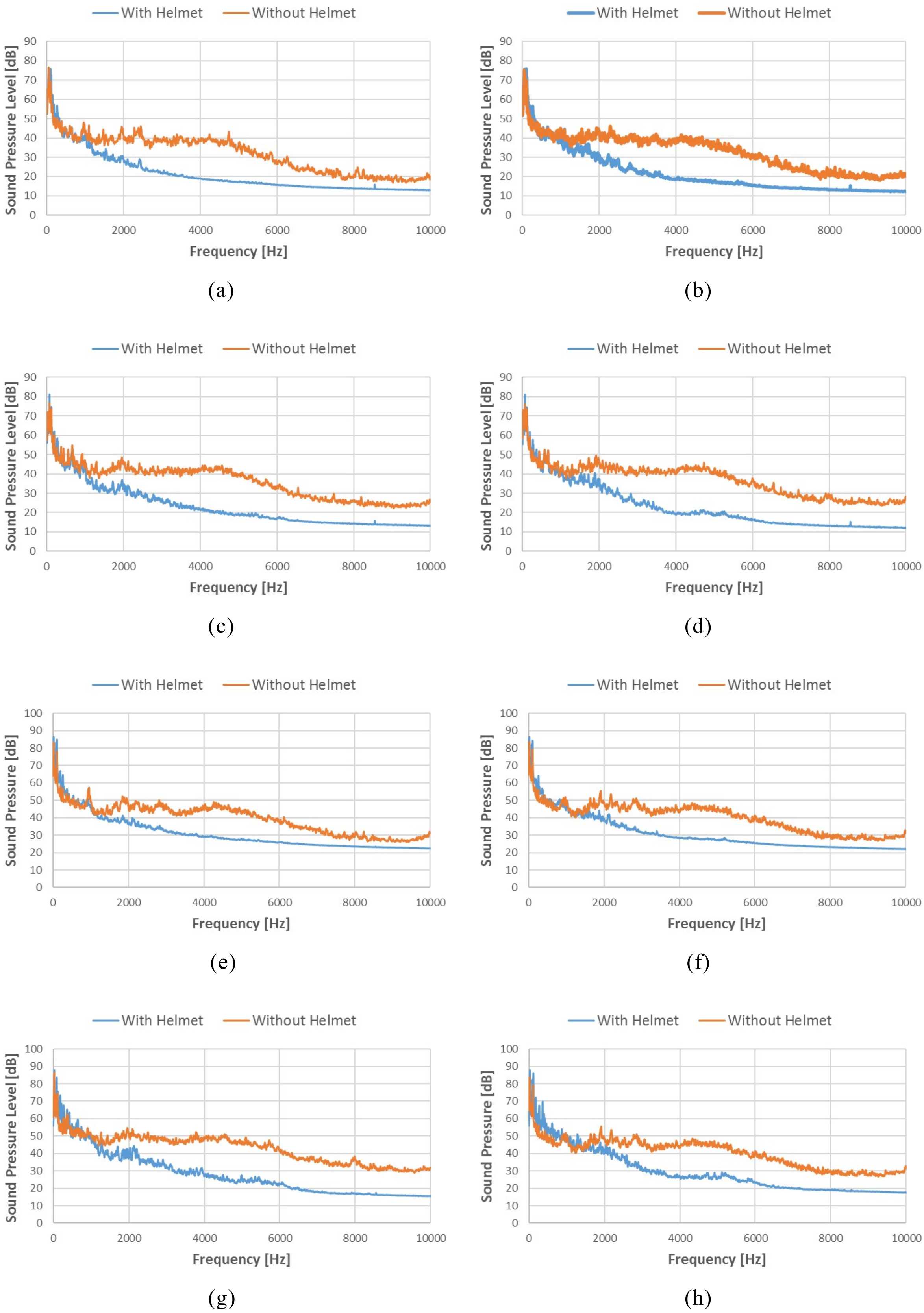

Figure 3 - Sound Pressure Levels at idle speed from (a) left ear and (b) right ear, at 2000 rpm from (c) left ear and (d) right ear, at 3000 rpm from (e) left ear and (f) right ear, at 4000 rpm from (g) left ear and (h) right ear.

5. CONCLUSIONS

In presented study, describing the noise source localization the motorcycle for several driving speed is aimed. It was also studied to measure sound pressure levels for the simulation of the drivers' ear to define the effects of intensity. The results were analyzed with helmet usage conditions.

The noise localization was performed via discrete intensity method on the defined measurement grid that is located on the right side of the motorcycle. The intensity maps for every studied driving speed were plotted. It is observed that the intensities were concentrated about engine and transmission box region, and increases with the driving speed. The exhaust system output was the following noise source. It can also be seen that the intensities on the upper part of the measuring area remain greater, regarding to noise source region. Thus for the inspected cases, the receivers close to this area, i.e. car drivers in the traffic or the animals, may suffer from the motorcycle noise.

The noise levels from right and left ear were analyzed and the results espouse assumption that the noise source was symmetric. On the other side, the helmet usage decreases the sound levels after 2000 Hz, it can clearly be said that the noise reduction is more effective in high frequencies. In future researches, the measurements may be focused on smaller surface and measurement areas engine and transmission region for the determination of intensity on component basis.

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