Pass by Noise Test Site Variability

Byoung Sam Kim*
(논문접수일 2005. 5. 2, 심사완료일 2005. 5. 23)

Abstract

The objective of this paper is to compare the site-to-site variability of ISO 10844 pass by the noise test sites. In order to investigate the site-to-site variance of test surfaces, European commercial tires are tested at seven different test sites. Three Korea test sites and four Europe test sites are selected. The pass by noise test is done according to a 2001/43/EC regulation. Although the ISO surface has a very specific track composition, it does not reduce the variation of pass by noise measurements over the surface of test sites. This paper shows that the test results of pass by noise level are different depending on the test sites. The correlation obtained in this work is able to predict the pass by noise level for certain test site using the data measured from another test site. The prediction value is range with an error within 1dB(A).

Key Words : Pass by Noise(가속주행 소음), Tire(타이어), ISO Surface(ISO 도로표면), 2001/43/EC Regulation(2001/43/EC 법규), Sound Pressure Level(음압레벨)

1. Introduction

Statistics show that over ninety percent of the population has suffered from vehicle traffic noise(1). Among them, about twenty to twenty-five percent suffered at a much serious level. It has been well recognized that such an environmental pollution needs to be abated if not totally eliminated. In order to quantify progress toward such abatement, an international standard(ISO362) of measuring drive-by noise emitted by rapidly accelerating road vehicle was established in 1994 mainly to address urban traffic noise. The test standard requires the use of intermediate gears with full utilization of the engine power available. Over the last decade, the world has witnessed steadfast improvements of vehicle noise for components such as engine, transmission, exhaust and intake. Such improvements have consequently elevated the need to further reducing tire generated noise not only for highway but also urban traveling. In addition, the european parliament and council put into effect a directive for regulating vehicle pass by noise in 1992 that lead to an amended one in 1997. The latest directive will affect all replacement

* Department of Automobile and Machinery, Suncheon First College (anvkbs@sunchecn.ac.kr)
주소: 540-260 전라남도 순천시 덕월동 산 9-3

tires to be imported to its member states from 1 October 2005[2]. Unlike the vehicle drive by noise measurement required in ISO362, the pass by noise in the directive is measured with gear selector set at neutral position and engine switched off.

Studies have shown that vehicle pass and tire pass by noise are affected by the interaction of tire and road surface. Schumacher[3] studied noise deviations among SAE sealed, SAE unsealed and ISO10844 surfaces. His study showed that a maximum Sound Pressure Level (SPL) deviation is 9.2dB(A) in pass by condition and a maximum SPL deviation among the three standard road surfaces is 5.7dB(A) in pass by condition. Osman[4] investigated the SPL difference of different tire types on several road surface conditions.

In order to evaluate the effect of Korean and European road surfaces on tire pass by noise, a study on a group of tires between some Korean and European ISO10844 road surface was conducted. For this investigation, three of the Korean and four of the European ISO surface sites were chosen. The tire pass by noise on each road is measured and the pass by noise level is determined by regression analysis.

2. Measurement Equipment and Method of Pass by Noise

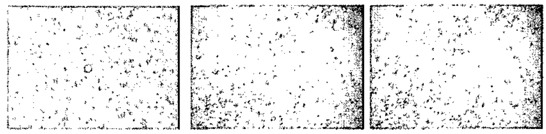
2.1 Test Surfaces(ISO 10844)

Table 1 shows details of test road surfaces, both Korean and European. Figure 1 shows the Korean roads. It is visibly clear that the granular sizes of these road surfaces are different. Table 2 shows conditions of road regulated by ISO 10844. The regulation of ISO 10844 has limits of maximum and minimum value according to each test item. Therefore, although some roads meet the regulation of ISO 10844, the noise deviations between road surfaces are still possible.

This paper studied the deviation of pass by noise among the seven certified ISO road surfaces. And pass by noise is predicted through road variations.

Table 1 Test Site

Road surface	Area	Remarks
Europe 'A'	Germany	ISO
Europe 'B'	U.K.	ISO
Europe 'C'	Northern Germany	ISO
Europe 'D'	Spain	ISO
Korea 'A'	In-cheon	ISO
Korea 'B'	Dae-gu	ISO
Korea 'C'	Gog-sung	ISO



(a) Korea 'A' (b) Korea 'B' (c) Korea 'C'

Fig.1 The Surface of the Test Road

Table 2 ISO 18044 Limits for Test Items

Items	ISO
Air void contents	< Max. 10% < Average 8%
Sound absorption	< 10%
Texture depth	≥ 0.4mm
Proportion of aggregate	Mass of stone(S ≥ 2mm) : 50.5% ± 5 Mass of sand(0.083<S<2mm) : 40.2 ± 5 Mass of filler(S>0.083mm) : 9.3% ± 2

2.2 Measurement Setup and Test Tires

In this study, pass by noise is measured according to regulation 2001/43/EC. Table 3 shows the types and sizes of test tires. These include five sets of various tread pattern tires and one set of blank tread tires.

Table 4 shows the types of equipment used. Sound level meters were calibrated using piston phone. Two sound level meters are located on each 7.5m sideway from center of vehicle lane, and the height of the meters was 1.2m above ground(see Fig. 2). The conditions of atmospheric temperature and wind velocity are measured at 1.2m above ground. The temperature of road surface

Table 3 Test Tire

Tire Size	Use	Tread Pattern	Application
175/70R13	All Season	Block type	A-PTN, B-PTN
195/65R15	All Season	Block type	C-PTN, D-PTN
205/55R15	All Season	Block type	E-PTN
205/60R15	All Season	Smooth pattern	Plain-PTN

Table 4 Measurement Instruments

Instruments	Model	Usage
Sound level meter & microphone	B&K 2236	- Noise measurement. Time : F-charact. Frequency : A-charact.
Pistone phone	B&K 4220	- Calibration of SLM.' 94dB(A) at 1kHz
Speedmeter	-	- Measurement of vehicle speed
Temperature sensor & wind measurement device		- Measurement of meteorogical conditions

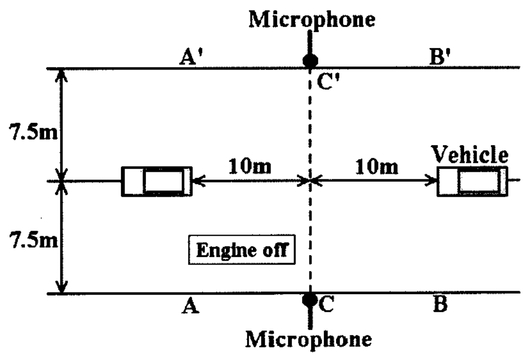


Fig. 2 Schematic Diagram of Pass by Noise Test

was measured at a position that was not under direct light. Test data were recorded at the atmospheric temperature ranges of 5°C~40°C and the road surface temperature ranges of 5°C~50°C. Maximum wind velocity throughout the test was kept at 5m/s. Ambient noise was kept at least 10dB(A) lower than the measured noise.

2.3 Test Method and Condition

As shown in Fig. 2, the test vehicle has traveled along a straight line marking the centerline of the test lane. At the time the front of the test vehicle reached the line of A-A', the gear selector was shifted to neutral position and the engine switched off. Test vehicle coasted through the designated test lane. During this time, test data including SPL, vehicle velocity, and ambient temperature were recorded.

For tests using passenger car, the velocities of the test vehicle were maintained at between 70 and 90km/h. At least 4 measurements were made at the vehicle speed of less than 80km/h. And at least 4 measurements were made at the vehicle speed of over 80km/h. The inflation pressures and load conditions of the test tires were controlled to adhere to the specifications prescribed in the directive. Table 5 shows the test conditions of the directive for test tires. The measurement conditions satisfied the regulations during this test.

3. MEASURED RESULTS AND ANALYSIS

3.1 Determination of the Pass by Noise Level

Regression analysis was used in order to extract the pass by noise at the velocity of 80 km/h, and then the results were corrected for temperature.

The extracted pass by noise levels using regression analysis were obtained by the following equations.

$$L_R = \bar{L} - a\bar{v} \quad (1)$$

Where $\bar{L}$ is the mean value of the noise levels L_i, measured in dB(A): $\bar{L}=\frac{1}{n}\sum_{i=1}^{n}L_i$ n is the measurement number ($n \geq 16$). $\bar{v}$ is the mean value of logarithms of speed v_i : $\bar{v}=\frac{1}{n}\sum_{i=0}^{n}v_i$ with $v_i=\log\left(\frac{v}{v_{ref}}\right)$, v_{ref} = 80km/h.
a is the slope of the regression line in dB(A) :

$$a=\sum_{i=0}^{n}\frac{(v_i-\bar{v})(L_i-\bar{L})}{\sum_{i=0}^{n}(v_i-\bar{v})^2}$$

Table 5 Pass by Noise Test Condition in ECE Regulations

Size	Load(kg)	Pressure(kg/cm2)
175/70R13	333~380	1.6~2.1
195/65R15	431~492	
205/65R15	543~620	

Final result shall be normalized to a test surface reference temperature θ_{ref} by applying a temperature correction, according to the following :

$$L_R(\theta_{ref}) = L_R(\theta) + K(\theta_{ref} - \theta) \tag{2}$$

where θ is the measured test surface temperature, θ_{ref} = 20°C

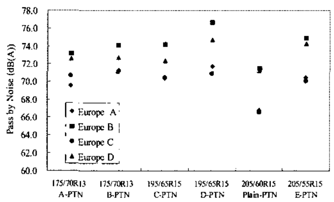
For the automobile tires,

K = -0.03dB(A)/C for $\theta > \theta_{ref}$, K = -0.06dB(A)/°C for $\theta < \theta_{ref}$,

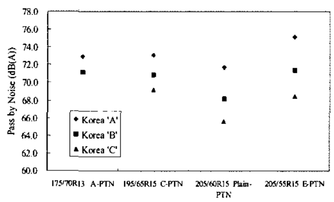
3.2 Result Analysis

3.2.1 Effect of Tire Size

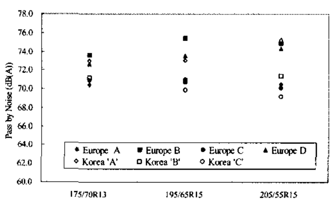
As shown in Figs. 3(a) and 3(b), there are deviations of pass by noise level between test sites for the same set of tires. However the relative differences between the various tire sizes for each test site were virtually identical among all seven test sites.



(a) Pass by Noise on the European Road



(b) Pass by Noise on the Korean Road



(c) Pass by Noise according to Tire Size

Fig. 3 The Results of Pass by Noise

It was also observed in Fig. 3(c)that the pass by noise level increases with tire section width. Tires of type A-PTN(A-tread pattern type) and type B-PTN(B-tread pattern type) are designed for compact vehicles and tires of type C-PTN(C-tread pattern type) and type D-PTN(D-tread pattern type) are designed for standard and full-size vehicles. Type E-PTN(E-tread pattern type) designs are directional tread pattern for high-speed driving and type F design is blank tread. It was expected that the blank tread tires generated the lowest pass by noise level among the seven tread pattern designs. Not only so, production tread pattern design does influence the sound level of pass by noise. The test results here confirm what has been known all along.

3.2.2 Effect of Road Surface

Table 6 compares the pass by noise on the seven test surfaces. The maximum difference among these sound levels is 4dB(A). Such a difference is believed to be influenced by the porosity, or the ability of sound absorption, of the test surface.

It is concluded from the measured data that for the tread patterns and tire sizes tested the maximum difference observed in pass by noise level is 3.5dB(A) as shown in Table 7. The same table also shows that the difference in pass by noise level between various road surfaces for the same set of tires ranges from 3 to 6dB(A). It suggests that road surface texture, porosity and other factors have greater effect on pass by noise level than variations in tire tread pattern and sizes.

3.2.3 The Deviation of Pass by Noise among Road

Table 8 shows the deviation of pass by noise level

Table 6 Data Summary by Tires and Test Site(unit : dB(A))

Size		175/70R13		195/65R15		205/55R15	205/60R15
PIN		A	B	C	D	E	F
All Site	Avg.	71.7	72.3	71.6	73.5	72.2	68.9
	Max	73.2	74.1	74.2	76.7	75.2	71.7
	Min.	69.6	71.1	69.9	70.9	69.2	66.5
	Diff.	3.6	3.0	4.3	5.8	6.0	5.2
	s.d	1.4	1.4	1.6	2.7	2.5	2.5

tested on each road from the one measured on an European test site labeled 'A'. The highest pass by noise level was produced on the other European test site 'B'. The domestic test site 'C' generated the lowest noise level. The difference of the pass by noise levels between Europe 'B'(the highest) and domestic 'C'(the lowest) was 4.8dB(A). Current European directive governing the noise emission determination requires that digits after the decimal point of the pass by noise level be disregarded. And since the error of measurement is ± 1dB(A), the effect of the test surface variation is a much greater measurement uncertainty and cannot be ignored.

Also, pass by noise level can be predicted from deviation of among roads as shown Table 9. Table 9 shows an error between predicted and measured pass by noise levels relative to Europe 'A' surface. It is in average 0.9dB(A). Pass by noise level of each road can be extracted within error range because 0.9dB(A) value is lower than 1dB(A) that is measurement error.

4. Conclusions

The following conclusions have been arrived according to the above experimental study:

(1) Pass by noise level increases with tire section width.
(2) Tire size and tread pattern design can influence pass by noise level.

Table 7 Data Summary by Tires Size and Pattern(unit : dB(A))

Tire	Road Surface in Europe				Road Surface in Korea		
	'A'	'B'	'C'	'D'	'A'	'B'	'C'
175/70R13'A'	69.6	73.2	70.7	72.6	73.0	71.2	-
175/70R13'B'	71.3	74.1	71.1	72.7	-	-	-
195/65R15'C'	70.4	74.2	70.5	72.4	73.1	70.9	69.9
195/65R15'D'	71.4	76.7	70.9	74.7	-	-	-
205/55R13'E'	70.5	74.9	70.1	74.3	75.2	71.4	69.2
Average	70.7	74.6	70.7	73.3	73.8	71.2	69.6
Max.	71.7	76.7	71.1	74.7	75.2	71.4	69.9
Min.	69.6	73.2	70.1	72.4	73.0	70.9	69.2
Diff.	2.1	3.5	1.0	2.3	2.2	0.5	0.7

Table 8 Differences between Test Roads for Europe 'A'(unit : dB(A))

Tire	Road Surface in Europe				Road Surface in Korea		
	'A'	'B'	'C'	'D'	'A'	'B'	'C'
175/70R13'A'	0.0	3.6	1.1	3.0	3.4	1.6	-
175/70R13'B'	0.0	2.8	-0.2	1.4	-	-	-
195/65R15'C'	0.0	3.8	0.1	2.0	2.7	0.5	-0.5
195/65R15'D'	0.0	5.0	-0.8	3.0	-	-	-
205/55R13'E'	0.0	4.4	-0.4	3.8	4.7	0.9	-1.3
205/60R13'F'	0.0	4.7	-0.2	4.5	4.9	1.4	-0.3
Average	0.0	4.1	-0.1	3.0	3.9	1.1	-0.7
S.D	0.0	0.8	0.6	1.1	1.1	0.5	0.5

Table 9 The Errors between Experimental and Estimated Data(unit : dB(A))

Tire	Road Surface in Europe				Road Surface in Korea		
	'A'	'B'	'C'	'D'	'A'	'B'	'C'
175/70R13'A'	0.0	0.5	1.2	0.0	0.5	0.5	-
175/70R13'B'	0.0	1.3	0.1	1.6	-	-	-
195/65R15'C'	0.0	0.3	0.2	1.0	1.2	0.6	0.2
195/65R15'D'	0.0	0.9	0.7	0.0	-	-	-
205/55R13'E'	0.0	0.3	0.3	0.8	0.8	0.2	0.6
205/60R13'F'	0.0	0.6	0.1	1.5	1.0	0.3	0.4
Average	0.0	0.7	0.4	0.8	0.9	0.4	0.4

(3) Road surface has major influence to pass by noise level.

(4) The order of influence is as follows: road surface, tread pattern and tire size.

(5) Variations of pass by noise levels among certified ISO test surfaces up to 6dB(A) has been observed. Likely causes are air void density and sound absorption of test surfaces.

(6) Pass by noise among roads is extracted from deviation of pass by noise of each road. We can calculate it similarly error range of used experimental equipment.

References

(1) European Community, 1996, *Future Noise Policy by European Commission Green Paper Book*, Brussels, November.

(2) European Community, 2001, "Tyre/Road Noise Emission," Directive 2001/43/ EC, L211/33~L211/46.

(3) Schumacher R. F., 1995, "SAE and ISO Noise Test Site Variability," SAE Paper 951361.

(4) Osman, M. M and May, D. N., 1980, "Relative Influence of Pavement Texture and Tire type on Pavement/Tire Noise," SAE Paper 800282.

(5) Hieronimus, K. and Hellener, G., 1991, "Reduction of Car Sound Emissions by means of Systematic Development Work," *Unikeller Conference 91*, pp. 15/1~15/38.

(6) Hong, D. P. and Kim, B. S., 1992, "Prediction of Sound Radiation from Tire Tread-band Vibration," Proceedings of 1'st International Conference on Motion and Vibration Control, Yokohama, pp. 1006~1013.

(7) Walker, J. C., 1981, "Noise Generated at the Tyre-Road Interface," PH. D. Dissertation, Aston University, Birmingham.

(8) Ewald, D., Pavlovic A. and Bollinger J. G., 1970, "Noise Reduction by Applying Modulation Principles," *The Journal of the Acoustical Society of America*, Vol. 49, No. 5, pp. 1381~1385.

(9) Waters, P. E., 1974, "Commercial Road Vehicle Noise," *J. Sound and Vib.*, Vol. 35, No. 2, pp. 155~222.

(10) Yoon, M. C., Cho, H. D., Kim, S. K., Kim, Y. K. and Cho, H. G., 2001, "A Study on the Modeling and Analysis of Chatter in Turning Operation," *Transactions of The Korean Society of Machine Tool Engineers*, Vol. 10, N0. 4, pp. 76~83.