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NOISE CONTROL FOR A BETTER ENVIRONMENT

Introduction of tire noise evaluation method under acceleration in semi-anechoic room

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ABSTRACT
The R51 test is a method of evaluating the vehicle pass by noise when the vehicle is accelerating. However, according to the latest R51.03, the contribution of tire noise is reported to increase by 40 ~ 50%. Therefore interest in tire noise during accelerating is also increasing. In this paper, an electric vehicle is used to evaluate the tire noise during acceleration. The semi-anechoic chamber is used for more robust tire noise test. The radiated sound power of tire under accelerated is measured and it is compared with the pass by noise test on ISO10844 road surface. In this study the drum radius effect is studied to enhance the correlation. The contact shape simulation on drum surface is studied and base on this result the bigger radius of drum is suggested to enhance the correlation. Finally the radius of drum is changed and re-test result shows the big drum radius is the better correlation than smaller.
Keywords: Pass by Noise, R51.03, Tire
I-INCE Classification of Subject Number: 72

1. INTRODUCTION

Vehicle noise is becoming an important requirement from the viewpoint of the customer due to the upgrading of the vehicle and improvement of the road condition. The importance of the noise of the tire which has more influence on the total vehicle noise during the constant speed driving. Especially due to the low noise vehicles such as electric vehicles, the contribution of tire noise has been increased more.(1) In addition, vehicle weight reduction and cost reduction have a sensitive effect on vibration and noise problems of Tire.

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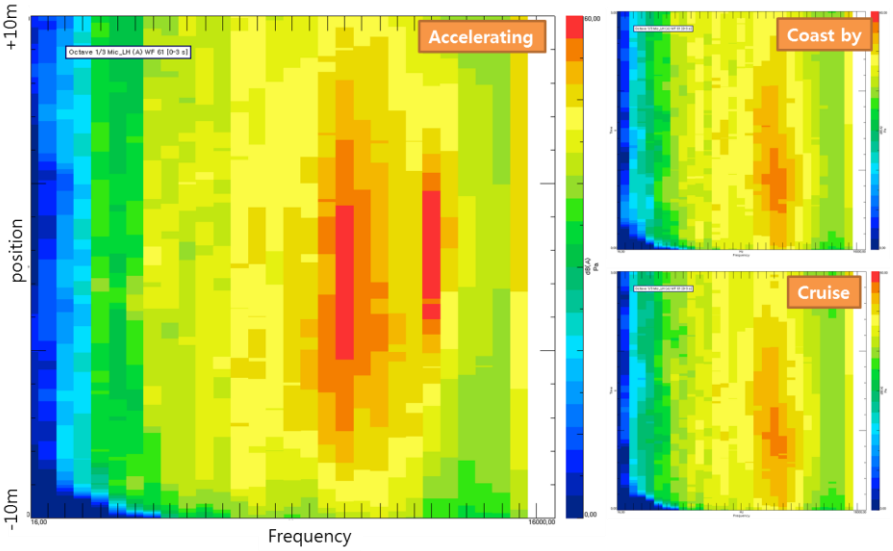
In addition, regulations on road noise are being reinforced in terms of living environment. Accordingly, improvement of external noises due to tires is required along with noise of engine, exhaust, etc. (2) Therefore various studies have been conducted to reduce such noise in the tire industry.

In this paper electric vehicle is used to test tire only noise in accelerating condition. First vehicle is tested at proving ground on ISO surface. Then residual noise of EV is checked with smooth tire and it is compared with normal tire. Finally it is tested on chassis dynamo in semi-anechoic room. The sound power of tire is measured in cruse, coast by, and accelerating condition and it is compared with PG test on ISO surface.

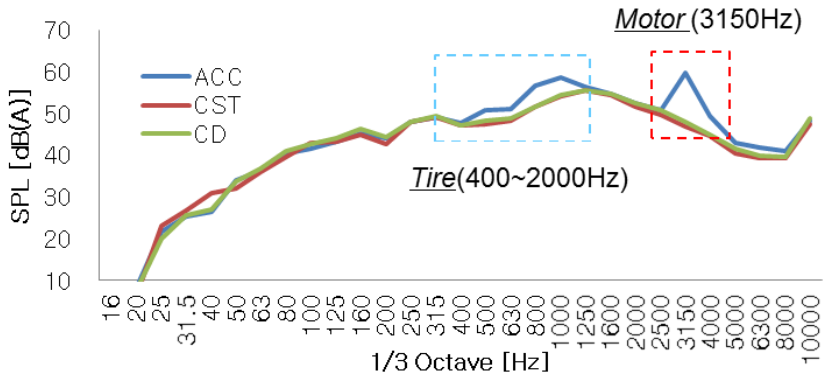
2. TEST METHOD

2.1 Pass by Noise test at proving ground on ISO road

Pass by noise is analysed versus vehicle position. (Figure 1) Test at Cruse, coast by, and accelerating condition are done and results are compared. In accelerating condition, around 1kHz and 3kHz sound is increased. As we compare it with result of coast by test, 3kHz sound is from the electric motor. Around 1kHz sound is from the tire tread noise and accelerating condition makes this pattern induced noise higher.



a) Colormap analysis



b) 1/3 octave band spectrum at center position

Figure 1. Noise Spectrum analysis of three different operating condition

2.2 Residual Noise of Electric Vehicle

To make the tire noise minimize, the smooth tire is used with EV and also normal pattern tire is tested. Two operating condition - Cruise and Accelerating (2.8m/s^2) - are tested. Residual noise is calculated with smooth tire (Table 1) and it is 58.5dB. The difference with normal pattern tire noise is 8.2dB in acceleration condition. Therefore EV is useful for tire noise test under accelerating condition.

Table 1. Residual noise calculation

Accelerating (A)	Coast by (B)	Convert dB to Power			Residual Noise
		ⓐ	ⓑ	ⓐ-ⓑ	
62.7	60.6	0.000745	0.000459	0.000286	**58.5**

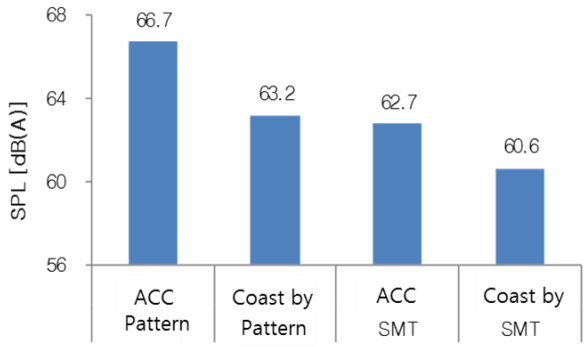


Figure 2. Pass by noise level of pattern tire and smooth tire

2.3 Pass by Noise test on chassis dynamo in semi-anechoic chamber

As you know it is difficult to control test condition in PG testing. Especially this pass by noise is very difficult. Driver needs to control vehicle position, and starts full acceleration on exact timing, and meets the target speed at microphone position. Therefore for tire design change study, the more robust indoor noise test in anechoic chamber needs to be developed. Vehicle speed is controlled same as field condition by chassis dynamometer. This dynamometer drum diameter is 1.707m and the drum surface is steel spray coating. Test tire is placed at only front left position and smooth tire is used at the other 3 positions. Sound power calculation is followed by ISO 3745 standard (3). Considering the limitation of shape, only 5 microphones are used like Figure 3.

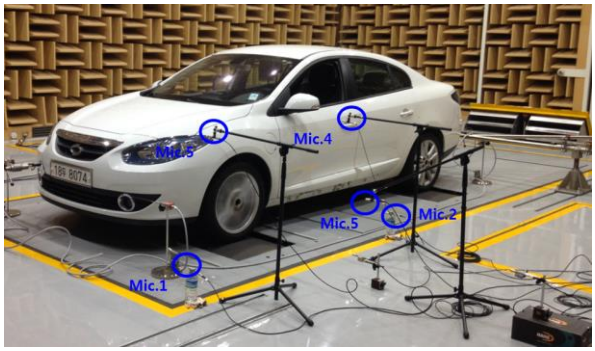


Figure 3. Indoor noise test method on dynamometer

The next is correlation result between indoor and outdoor field test. 4 different pattern - smooth, summer, all season, and winter pattern - are tested and the result is in

Figure 4. Tire ranking and spectrum is similar but has some different. Green dot line in Figure4 is spectrum trend of indoor sound power. And same line is applied field sound pressure spectrum. As spectrum is compared, field test is higher than indoor below 630Hz. But above 2.5 kHz field test is lower than indoor. When we compare the min-max value in Figure 5, the indoor test result variation is larger than PG. There are many different between indoor and outdoor test but the surface difference and contact shape difference can be main root cause factor.

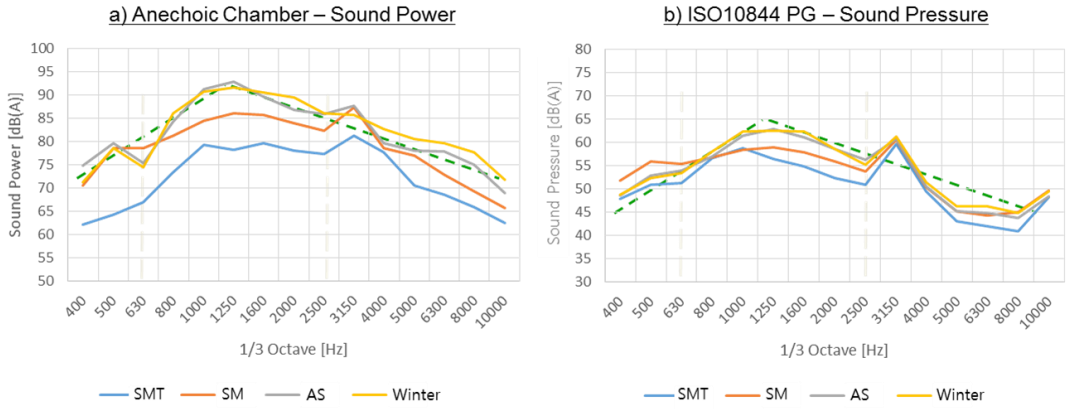


Figure 4. Spectrum comparison between Anechoic test and PG test

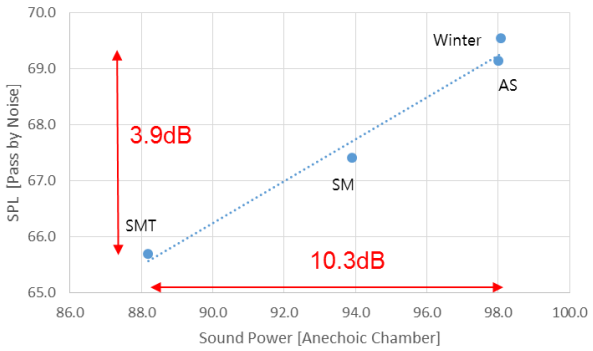


Figure 5. Correlation between Anechoic test and PG test

3. IMPROVE TEST ENVIRNMENT

3.1 Consideration of tire contact shape

The contact shape is important factor to control tire performance and it is also closely related with tire noise too. But the contact shape on the curved drum surface is not the same as the shape on the flat surface in Figure 6. It is the simulation result of 22/45R18 tire. Contact shape length, width, and area are changed with respect to drum diameter. As flatness is increase, contact shape is bigger. In the first test, 1.707m diameter drum is used for indoor simulation test. In the second test we changed the drum diameter to 3.0m. It will be much similar foot shape than 1.707m drum.

3.2 Consideration of road surface

The road surface is important factor to control tire performance and it is also closely related with tire noise too. Different type of road surface make the big difference in tire noise. Even though the ISO road surface, the noise level is different. In the first

test, steel spray coating surface is used. In the second test we changed to resin replica road surface (Figure 7). It is copy road of ISO road surface.

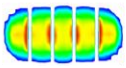
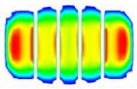
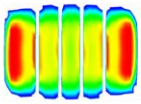
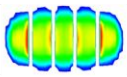
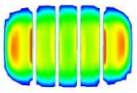
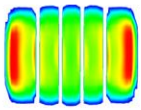
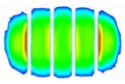
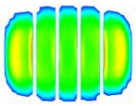
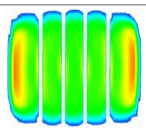
I.P. 2.2 kg_f/cm^2		320 kg_f (60%)		534 kg_f (100%)		748 kg_f (140%)	
Drum ø1.707	Length (mm)	84.2		116.3		139.0	
	Width (mm)	174.2		188.8		196.4	
	Area (cm^2)	114.1		172.1		227.0	
Drum Ø3.00	Length (mm)	96.6		121.0		149.0	
	Width (mm)	173.6		188.3		196.1	
	Area (cm^2)	122.9		185.9		245.1	
Flat	Length (mm)	104.9		140.8		171.0	
	Width (mm)	171.9		187.6		195.5	
	Area (cm^2)	134.3		209.5		276.7	

Figure 6. Contact shape with respect to drum diameter

	< Before >	< After >
Diameter	1.707m	3.00m
Surface	Steel Spray Coating	Resin Replica Road (ISO10844)

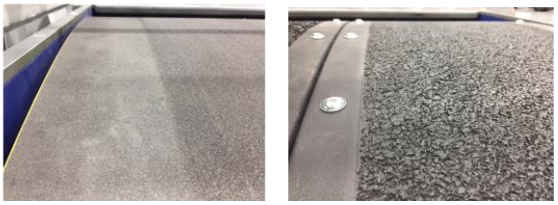


Figure 7. Suface changes

3.3 Improvement result

Correlation test is done again and smooth tire is not used. Tire size is 225/45R17. Three summer tires, one all season tire, and two winter tires are used.

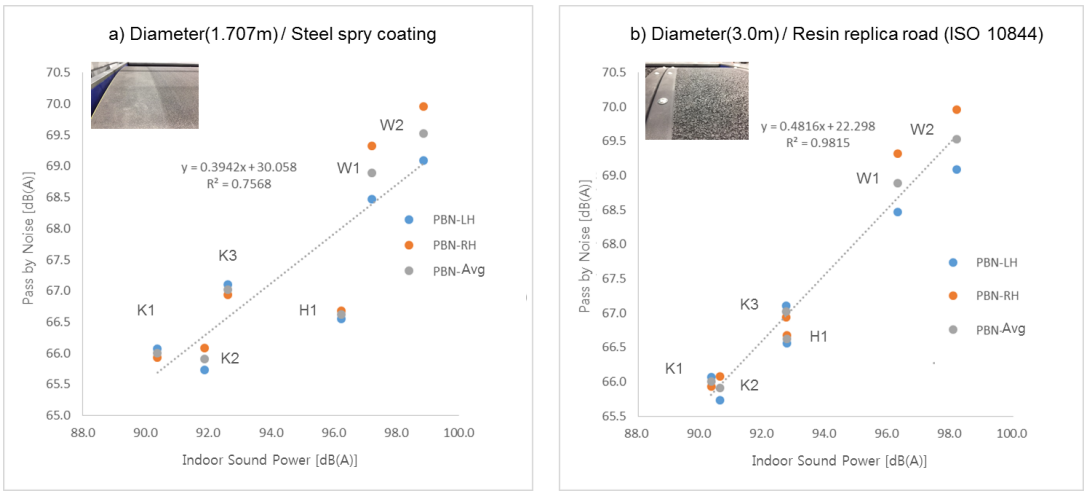


Figure 8. Improvement correlation of indoor sound power and pass by noise

The result is in Figure 8. The correlation between indoor sound power test and PG is getting better when the diameter and surface are changed.

4. CONCLUSIONS

In this paper radiated sound power of tire under accelerated is measured and it is compared with the pass by noise test on ISO10844 road surface. To enhance the correlation, the contact shape and contact surface are considered to be improved. Base on the contact shape simulation, 1.707m diameter drum is changed into 3.0m. And steel spayed coating surface is changed into resin replica road surface to make surface characteristics to be more real ISO road. Finally it shows the better correlation by improvement test condition.

5. REFERENCES

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3. ISO 3745, "*Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for anechoic rooms and hemi-anechoic rooms*" (2012)