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NOISE SOURCE IDENTIFICATION OF KOREAN HIGH SPEED TRAIN

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Abstract

This paper deals with the noise source identification of the Korean High Speed Train (KTX) at the maximum commercial speed of 300 km/h. Typical pass-by noise sources and their frequency characteristics are investigated, it is primarily aimed at investigating the location and characteristics of the low frequency noise (60 Hz~100 Hz) related sources, however. This low frequency range noise has become an issue in the interior of the KTX, especially at passing through the tunnels with slab track system. For the purpose of identifying the main noise sources the results from the microphone array tests are analyzed in relation to the remarks from analytic studies which have been done with the intention of understanding the aerodynamic source mechanism and rolling mechanism. The acoustical image shows the low frequency noise sources mainly at the position of the under part of the train and the related source mechanism are discussed.

1. INTRODUCTION

The main issues in the noise research on korean high speed train since its revenue service can be outlined as following : Pronounced tonal noise components of interior noise inside the tunnels installed with slab track systems, which seemed to become more considerably at train speeds higher than 270 km/h. There was a need to examine this phenomenon not only to keep the noise level within the noise specification for the KTX train, in which the permission level is given as an overall level, but also it was apparently audible to the passengers as a sort of booming noise. The possible source mechanisms will be mentioned later, it is a problem which depends on various structures and factors simultaneously. Therefore as reduction measures focusing on reduction of the interior noise, several objects come into question, one case is shown.
As next issue the high speed trains on the kyung-bu line has to satisfy the environmental noise standards level which is reduced for the 15 years after the revenue service. Furthermore the accurate measuring and identification technology of the main noise sources in consideration of the train speed is in demand to keep in step with the development of the new high speed trains with raised train speed. As an input material for the propagation simulation and mitigation measures more precisely.

On the basis of these considerations the processes to examine the problems and results are shown and discussed.

2. INTERIOR NOISE SOURCES

Measured one year after the revenue service the interior noise of the passenger car became explicitly at the train speed higher than 270 km/h inside the tunnel with slab track systems(Figure 1).

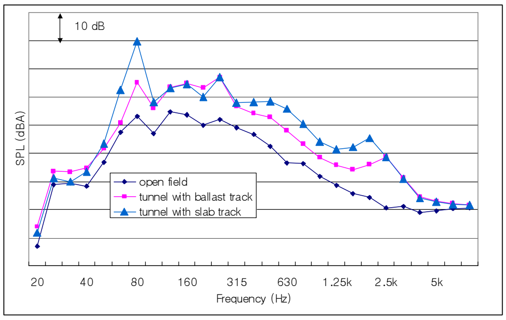


Figure 1. Interior noise in a passenger car of KTX measured at the speed of 300 km/h in 2005

As a view of mitigation targets following mechanisms can be referred as main affecting factors for this problem.

First the most directly affecting part can be the cat body, namely the vibration of the side wall, floor and the roof. Whatever the original noise or vibration source is, each of these structure can be accelerated at certain frequencies according to specific conditions, which match the correct mode for the vibration. In this case however we had to focus on the factor, which results in apparently higher noise level in the tunnel with slab track compared to that in the tunnel with ballasted track. It can be the different dynamic behaviour of the slab track structure or the faster air flow inside the tunnel with slab track system. The vibration characteristics of the car body showed related results with the interior noise.

Another possible affecting mechanism is the amplified noise effects between the passenger coaches, which has a cavity with a gap at the front. These cavities contain air damper system and the bogie system is located under the cavity(figure 2).

One or more of the acoustic modes of the innerspace of the cavity can match the frequency which is dominant for the interior noise of the coach and radiate [1]. But the different noise amplifying mechanism in this area between the two tunnels with different track structure has to be studied.

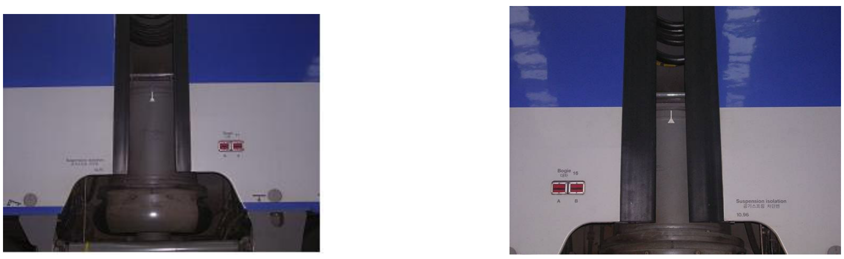
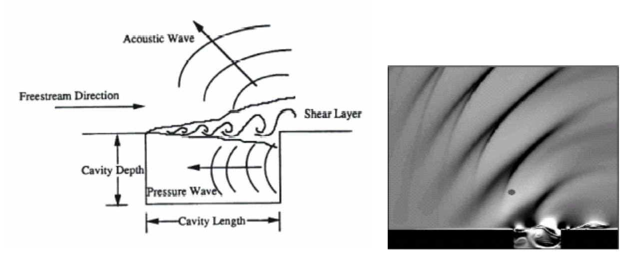


Figure 2. Cavity space between two coaches with different gap size

We observe this as a complex flow feedback and acoustic resonance problem which is shown in Figure 3. The sound pressure due to the pressure around the open gap of the cavity becomes lower with the reduced gap size and the more this reduction level difference becomes bigger the more the resonance frequency of the flow feedback inside the cavity resulted from this pressure becomes lower. In figure 3 the resonance frequency area is shown with the relation to flow speeds and gap sizes. This can be one of the explanation for the amplified noise level inside the cavity between the coaches in the tunnel, but which factor is responsible for the big difference of the noise level of two different type of the tunnel, that have not clearly defined yet. It can come from the different flow speed and different vibrating level of the car body or higher noise level inside the tunnel with slab track system due to the reflection at the concrete slab but the different track dynamic behaviour can be also affecting factor or all factors together simultaneously. The interior noise level of the passenger coach around the 80 Hz in 1/3 octave band analysis has reduced by reducing the gap size of the interspace coach cavity (figure 4).

● Mechanism of Cavity noise



● Rossister's semi-empirical formula

$$St = \frac{fL}{U_\infty} = \frac{m-\alpha}{\frac{1}{K}+M_\infty} \qquad f = \frac{U_\infty}{L}\frac{m-\alpha}{\frac{1}{K}+M_\infty}$$

$$\alpha = 0.25, \quad K = 0.57$$

		U(km/h)				
		50	100	150	200	300
L(m)	0.1	58	113	166	217	313
	0.2	29	57	83	109	156
	0.3	19	38	55	72	104
	0.4	15	28	42	54	78
	0.5	12	23	33	43	63

Figure 3. Flow feedback and pressure wave mechanism of cavity noise

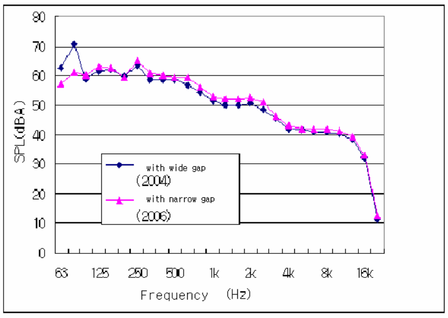


Figure 4. Measured interior noise level of passenger coach with different gap size of the cavity between two coaches

On the one hand direct mitigation methods can be implemented to the previous mentioned objects , such as car body or cavity form, but on the other hand we can consider mitigating the noise by solving the fundamental problem, which causing the structural vibration passing through structures of the vehicle and reach into the passenger rooms. These are for example the vibration of wheelsets or bogies due to the unround running behaviour of the wheel or roughness problem at the contact point of the wheel and rail and track dynamics[2]. To investigate the vibrating characteristics of the wheelset and bogie system at the high speed, the eigen modes of the KTX wheelsets under certain force condition is analysed (figure 7) and vibration levels of the wheelaxle and the bogie was measured at speed of 280km/h ~ 300 km/h (figure 5, figure 6). Both figure (figure 5 and 6) shows that the main interior noise components are focussed on 50 Hz ~ 300 Hz, at speed lower than circa 270 km/h it is more around 60 Hz ~ 100 Hz. In figure 7 we see that this interior noise level is related to the vibration behaviour of the bogie and wheelaxle, while at speed higher than 270 km/h the most pronounced vibration is found in the frequency range lower (at 50 Hz ~ 60 Hz) than the most noticeable frequency range

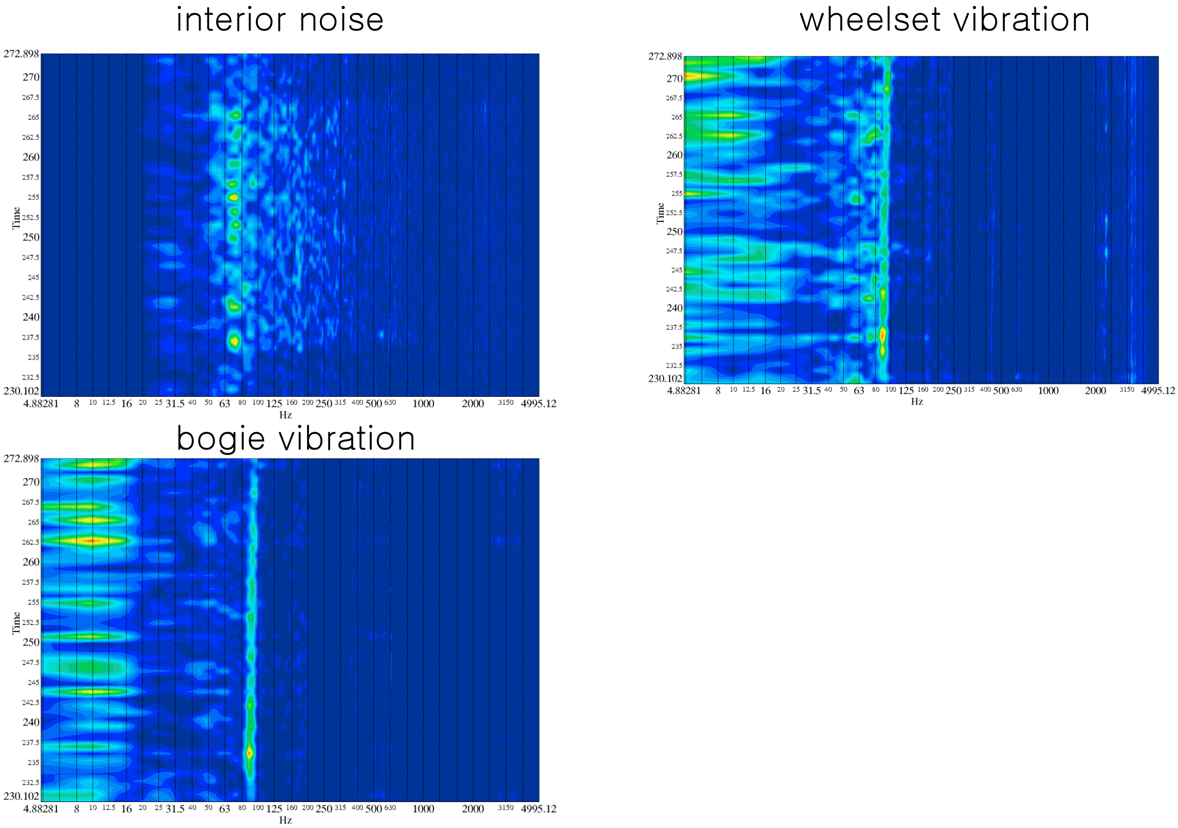


Figure 5. Measured interior noise and vibration level of wheelaxle and bogie at passing a tunnel with ballasted track system at speed of 211 km/h

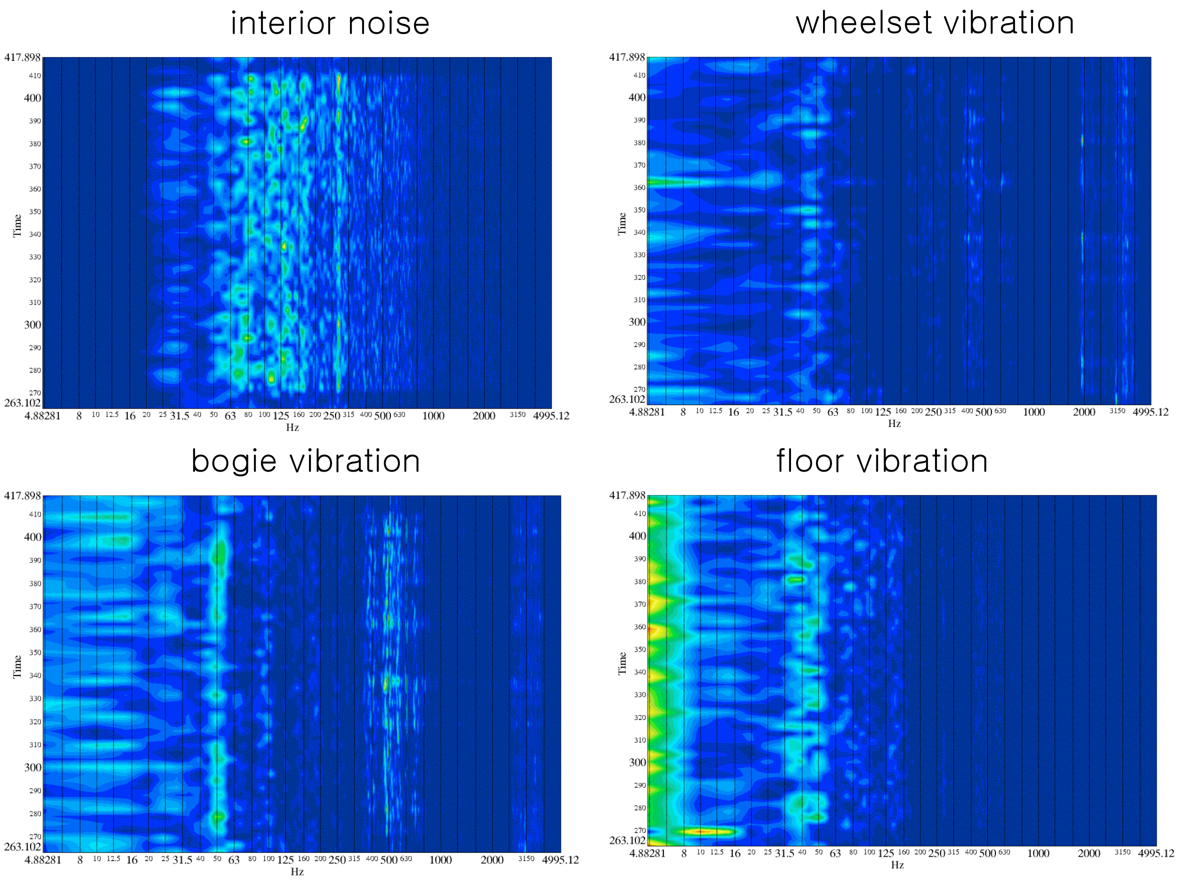


Figure 6. Measured interior noise and vibration level of wheelaxle and bogie at passing a tunnel with slab track system at speed of 270 km/h

for interior noise (63 Hz ~ 160 Hz), which was to see independent of the track system of the tunnels. The main frequencies pronounced in the interior noise at passing the tunnels could be found in the
calculated modes of the wheelsets of KTX train shown in Figure 7.

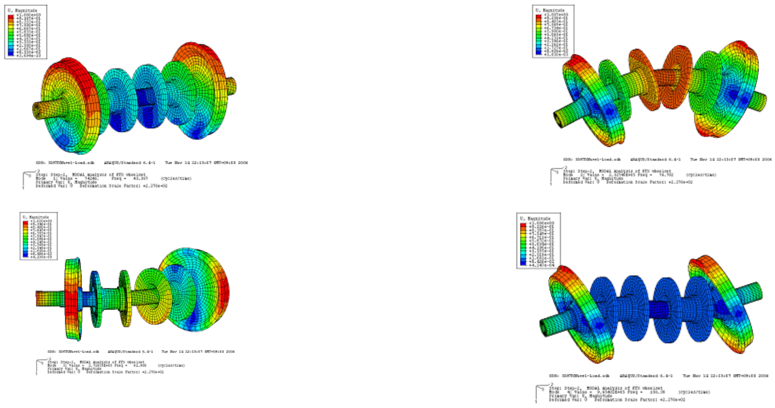


Figure 7. Modes of the wheelset; (first 43.4 Hz, second :76.8 Hz, third : 83 Hz, fourth :156.4 Hz)

3. PASS-BY NOISE SOURCES

In this part pass-by noise sources of the KTX trains at the speed of 280 km/h ~ 300 km/h are investigated by means of microphone array system comprised with 48 microphones (figure 8).

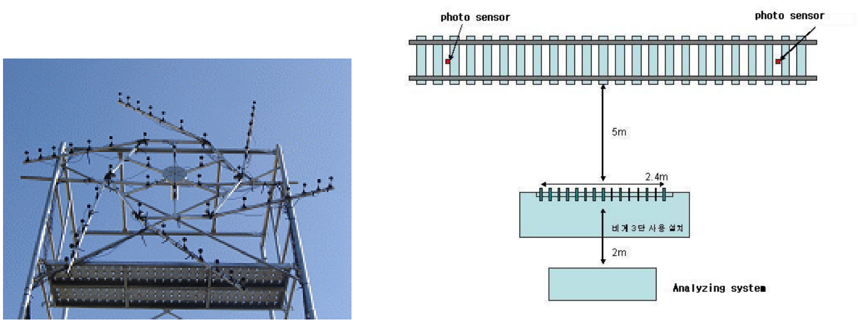
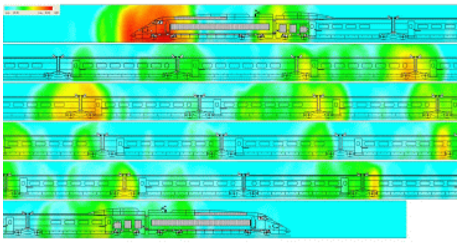
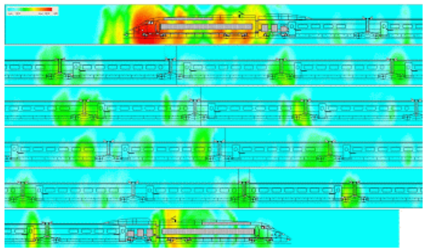


Figure 8. Microphone array system

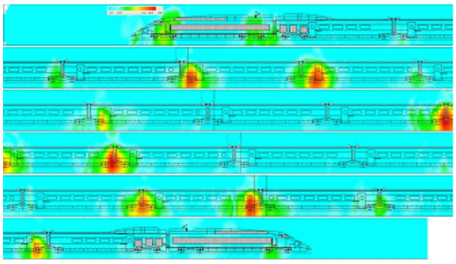
In figure 9 some parts of the tests are shown. The 70 Hz ~ 90 Hz noise components are mostly located between cars, which are the area with intercoach spaces and lower part of the cars, namely the bogie part and rolling sections. Most high levels are shown in the area of the power cars. This is clearly to see in the frequency range 120 Hz ~ 130 Hz, here belongs also the noise radiated from the pantograph areas of the front power car. The most highly radiated noise from the wheel and track areas is in the range of 240 Hz ~ 260 Hz, between 1 kHz ~ 2.5 kHz the aerodynamic noise part around the power cars is shown near the bogie and pantograph areas. In the frequency of 2.5 kHz ~ 4.5 kHz the highly radiated noise from the wheel modes at rolling and the aerodynamic noise around the boundary layer from unsteady flows at high speed are shown.



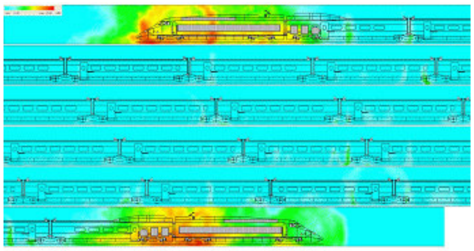
(a) 70 Hz ~90 Hz



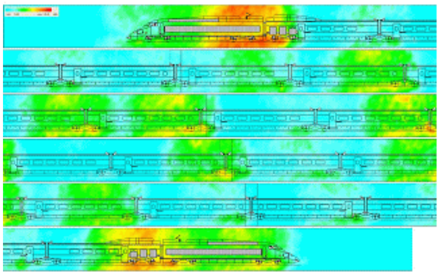
(b) 120 Hz ~ 130 Hz



(c) 240 Hz ~260 Hz



(d) 1 kHz ~ 2.5 kHz



(e) 2.5 kHz ~ 4.5 kHz

Figure 9 Pass-by noise sources at speed of 280 km/h ~ 300 km/h

4. Concluding remarks

In this paper the noise source identification process and the results are shown and discussed. Several affecting parameters which are related to the low frequency noise (60 Hz ~300 Hz) problem for the interior noise are investigated. The fundamental region can be found in the rolling and vibration parts of the bogie and wheels systems but whether these are directly matched to the interior noise problems or not, depend on the train speed and on other conditions. We examine the aerodynamic mechanism influencing the tonal noise amplification inside the passenger coaches. The noise map produced by the microphone array system show the noise sources 70 Hz ~ 300 Hz mostly between the coaches, especially at the under part of the Vehicles.

REFERENCES

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[2] R.Schirmacher, G.Hoelzl, M.Redmann, J.Scheuren, “Active noise and vibration control for a high speed rail car: a case study”, Active 97