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Noise Prediction Based on Analysis of Noise Measured Near the Turnout System of Existing Railroad

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Abstract

At the crossings of turnout systems, noise is generated by the impact of train on the connection points. However, rapid movement changes between rail and wheels on connection point are inevitable on existing turnout section which may cause safety concern as well as noise problem caused by repeated impact load by passing train. And given the turnout is a complicated system which combines various functions such as rolling stock, trackbed, signaling, communication and electrical system, it's very difficult to expect to improve the overall performance of the turnout in such a way of optimizing only particular part of such integrated system. Since the turnout is the only movable section among the integrated parts and has complicated structure that inevitably brings about quick and sudden movement, safety has been still put on the top of the list. This study was aimed at comparing and analyzing the noise data obtained around the turnout of existing railway, by categorizing them into tilting train, high speed train and traditional train, and by distance, speed and type of turnout. And based on the data measured, the forecast of noise level when tilting train accelerates around a turnout was conducted in the study.

Keywords: *Turnout system, Noise, Tilting train, High speed*

I. Introduction

The Korean-style tilting train [1] was developed to enhance the speed of existing line and to make it possible to shorten travel time by accelerating the train at curve sections without deteriorating riding quality. However, the running speed has to be increased in turnout sections as well as curved sections [2], to accomplish speed improvement in existing lines. However, rapid movement changes between rail and wheels on connection point are inevitable on existing turnout section which may cause safety concern as well as noise problem caused by repeated impact load by passing train. And given the turnout is a complicated system which combines various functions such as rolling stock, trackbed, signaling, communication and electrical system, it's very difficult to expect to improve the overall performance of the turnout in such a way of optimizing only particular part of such integrated system.

Since the turnout [3] is the only movable section among the integrated parts and has complicated structure that inevitably brings about quick and sudden movement, safety has been still put on the top of the list.

This study was aimed at comparing and analyzing the noise data obtained around the turnout of existing railway, by categorizing them into tilting train, high speed train and traditional train, and by distance, speed and type of turnout. And based on the data measured, the forecast of noise level when tilting train accelerates around a turnout was con-

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ducted in the study.

II. Measurements on the sites

At the crossings of turnout systems, noise is generated by the impact of train on the connection points. In this study, the noise levels [4] of the tilting train under testing, Saemaeul, KTX, Mugunghwa, and freight trains, near the Point A in the Chungbuk Line where built-up crossing and manganese steel crossing type turnout system is installed and the Point B on the Honam Line where manganese steel crossing type turnouts system is installed, were measured for comparison and analysis.

2.1. Measurement Method of Noise near Turnout Crossing

As shown in the Fig. 1 below, the noise sensors were installed at 4 points from the crossing by 4 m, 8 m, 16 m, and 32 m. The noise sensors were 1/2-inch, free-field type microphones. Fig. 1 and Fig. 2 presents the connection scheme of the measuring instrumentation and general views of the sites, respectively. In the case, we measured a train velocity using a speed gun and we repeatedly measured a noise data of the train. Type of train is the same.

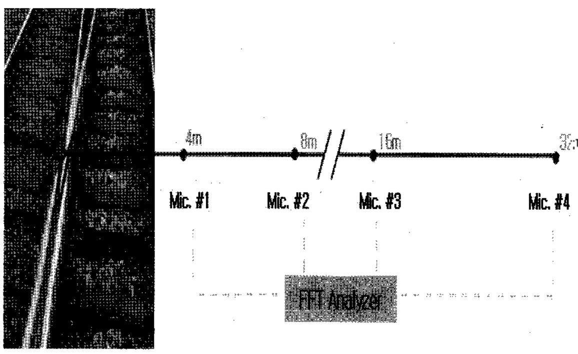

Fig. 1. Sensor positions.


Chungbuk Line (A) Honam Line (B)

Fig. 2. General view of the installation sites.

III. Analysis on the Noise Measurements near the Turnouts

In this section, a comparison is made to the noise level measurements obtained during the passage of various types of vehicles at the new manganese turnout system, and this allows the performance of the new system to be tested. The measurement data was obtained from the Point A in the Chungbuk Line and the Points B and C in the Honam Line, where the noise levels were measured when tilting trains pass manganese steel crossings.

3.1. Analysis on the Characteristics by Train Type

Fig. 3 shows the analysis results of the noise by train types, measured at the manganese steel crossing at Point B. The speed of the tilting train at the highest noise of 95.3 dB (A) was 112 Km/h, and other trains including Saemaeul and Mugunghwa Trains had stopped at the Point B, and passed the measurement point while speeding-up. Therefore, when compared at

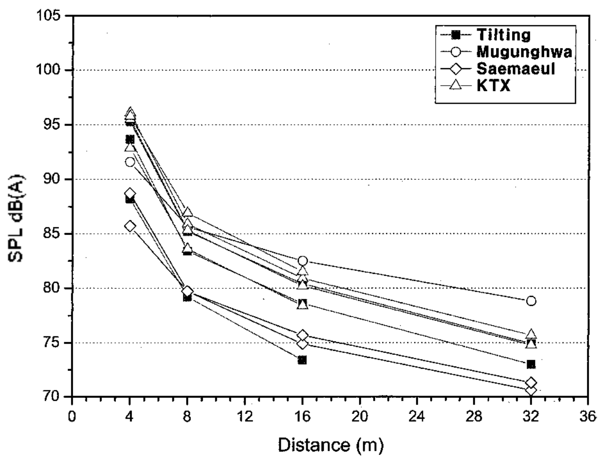

Fig. 3. Comparison of the noise levels by train type in the Honam Line (manganese steel crossing).

similar speed levels, the noise levels at 4 m distance of the Saemaeul, tilting, and Mugunghwa trains were 85.7~88.7 dB (A) (approx. 45 Km/h), 88.2 dB (A) (approx. 53 Km/h), and 86.1~91.6 (approx. 43 Km/h), respectively. Though the noise levels are similar, the speed of the tilting train was faster than other train types by about 10 km/h, showing relatively better noise performance.

The noise levels of the KTX whose service speed is 130~140 Km/h were measured at the speeds similar to that of the tilting train whose service speed is 53~120 Km/h. At 4 m distance from the crossing, the KTX and the tilting train showed similar noise levels of 92.9 dB (A) (132 km/h) and 93.7 dB (A) (120 km/h), respectively. These two train types showed similar noise levels at 8 m, 16 m, and 32 m points too.

3.2. Analysis on the Characteristics of Crossings by Train Speed

According to the analysis results of the changes in the noise levels by speed of tilting train, the noise levels differed significantly by track and trackbed conditions on the same manganese steel crossings. The noise level on the Honam Line whose ground and rail conditions were lower than those of the Chungbuk Line at the same of even higher speeds. It has been reported that, the noise level of the trains equipped with disc brakes on favorable track conditions is lower than unfavorable tracks by 8~10 dB, or 20 dB at maximum on exceptionally poor tracks.

3.3. Analysis on the Noise Levels at Crossings by Distance

Fig. 5 presents the 57 noise measurements on the Point C, Honam Line, regardless of the train type and running speed. Different from the measurements at the Chungbuk Line and the Point B of the Honam Line, the measurements at the Point C show linear diminution across the entire distance, while those in previous tests showed sharp decline between the 4 m and 8 m distances and smoother decline from 8 m to 16 m and 32 m distances.

Fig. 6 compares the noise levels of various types of trains passing the Point C of the Honam Line at similar speeds. At 4 m, the 3 train types excluding the tilting train showed similar noise levels, and the KTX showed higher attenuation according to distance than Mugunghwa and Saemaeul trains. The reason was thought to be because, for the diesel or diesel-electric motive power of the Saemaeul and Mugunghwa, excluding the KTX, the major noise source is the impact at turnout in near range, however, the noise of the motive power itself becomes dominant as the distance increases. The tilting train also showed a similar pattern with that of the KTX. The significantly-lower noise level may be due to the

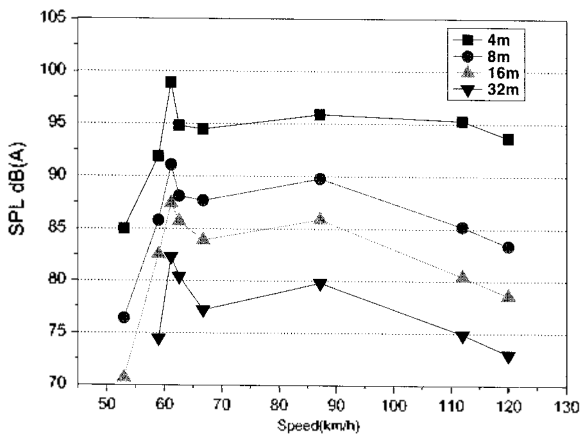

Fig. 4. Comparison of the noise levels by speed of tilting trains (manganese steel crossing).

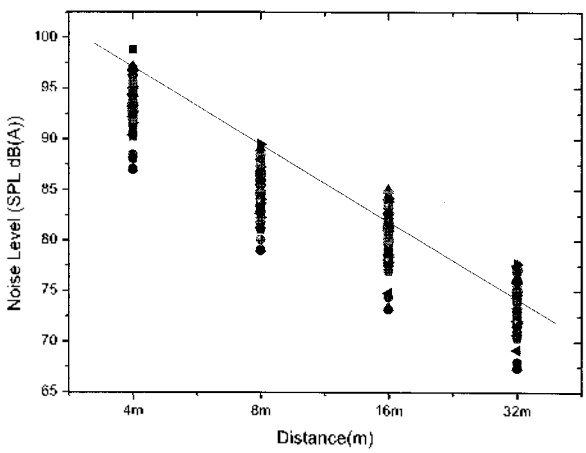

Fig. 5. Noise characteristics by distance and train type.

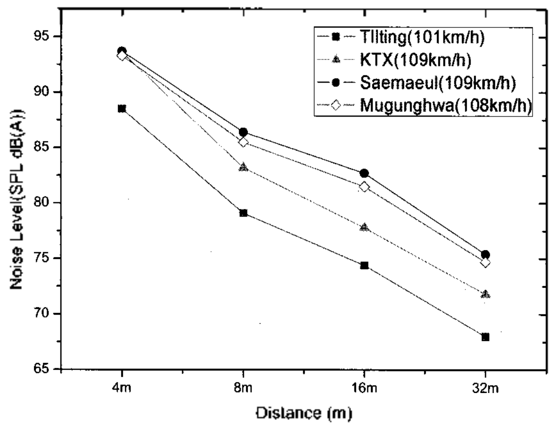

Fig. 6. Noise characteristics by train type and distance at similar speed.

lower passing speed than other train types by 7~8 km/h, however, considering the noise of the tilting train at 120 km/h is about 94 dB (A) which is the noise of other type of trains at 110 km/h, as shown in the Fig. 6, it can be judged that the noise level of tilting trains is lower than other types of trains by 3 dB (A) or more.

IV. Comparison Analysis between Noise Measurements and Predicted Values

On the basis of the measurement [5] of the noise level of the tilting trains on the Chungbuk Line Point A and Honam Line, the noise levels near manganese steel crossings are derived by simulation and compared with the prediction values calculated by linear curve fitting to evaluate the feasibility of the two methods.

4.1. Linear Curve Fitting Analysis of Noise

With the measurement data at the Points B and C of the Honam Line, installed with manganese steel crossings, a prediction formula for the noise levels at the same distance was derived by linear curve fitting method. Fig. 7 shows the results of the noise level, at 4m distance by speed, predicted by linear curve fitting. It can be seen that, for tilting trains, the noise level rises according to the increase in the

Table 1. Noise prediction formula by distance.

Distance \ Train	Tilting Train
4 m	Y (dB)=78.70+0.110 V
8 m	Y (dB)=72.21+0.081 V
16 m	Y (dB)=65.31+0.099 V
32 m	Y (dB)=61.59+0.074 V

※ Y=noise level [dB (A)], V=train speed (km/h).

speed. In the Table 1, the constants by distance are 78.70 dB (A) at 4 m, 72.21 dB (A) at 8 m, 65.31 dB(A) at 16 m, and 61.59 dB (A) at 32 m. The differences of the constants are 6.49 dB (A) between 4~8 m, 6.9 dB (A) between 8~16 m, and 3.72 dB (A) at 16~32 m, showing constant reduction between 4~16 m but drops by about 40% after 16 m which means that the reduction per distance becomes less after 16m distance. The speed variable at 4 m was 0.110, which reduced to 0.081 (73% of 0.110) at 8 m, increased to 0.099 (122% of 0.081) at 16 m, and then reduced to 0.074 (75% of 0.099) at 32 m. This shows that the noise level by distance increases at relatively higher rate in the 4~8 m and 16~32 m ranges, but lower rate in the intermediate range. Though many factors are related with this phenomenon, it was thought that the near range of 4~8 m is at the boundary between the near and far sound fields and the difference by distance according to the change of sound field is greater. The ranges farther than 8 m are located in the same sound field, thus, show no difference by sound field, but it was thought that the sound absorption by the ground and atmosphere becomes more significant as the distance becomes farther.

4.2. Noise Level Prediction

The noise level of tilting train at high speed was predicted with the noise according to speed by linear curve fitting technique. As shown in the Table 2, the differences in the noise levels by speed in each distance range are 10~13 dB (A) in 4~8 m, 3~5 dB (A) in 8~16 m, and 7~9 dB (A) in 16 m~32 m, showing the largest difference in the 4~8 m range,

Table 2. Noise prediction by distance (Mn c Unit: dB (A)).

Speed / Train type		140 km/h	160 km/h	180 km/h	200 km/h
Tilting Train	4 m	94	96	99	101
	8 m	84	85	87	88
	16 m	79	81	83	85
	32 m	72	73	75	76

which then sharply reduced in the 8~16 m range, and the reduction rate became smaller in the range farther than 16 m, as same as in the linear curve fitting analysis. The noise level increased by about 1~2 dB(A) as the speed increased by 20 km/h, at a constant trend.

4.3. Verification of Noise Prediction

The Fig. 4 and Table 3 present the noise analysis modelling and the prediction results, and the comparison and deviation between the measurements and prediction results, respectively. In the Fig. 7, the ground around the track was modelled to be flat and the noise source was defined as a rolling stock noise source passing the crossing at 120 km/h of speed. The noise receiving points were defined up to the 40 m vertical to the noise source at 1.5 m above the ground at the defined distance.

as shown below, the deviation by distance is good within the range of ±1 dB(A) except at 32 m distance. The 3.5 dB (A) of deviation at 32 m distance is thought to be caused by the difference between the calculating method of the prediction software program and the actual measurement results. However, considering the 4 dB (A) of error range of common noise prediction software applications, this error is not excessive.

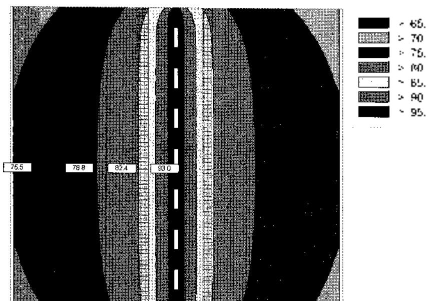

Fig. 7. Results of the noise prediction of tilting train by frequency band (B, passing speed 120 km/h).

Table 3. Comparison between the noise prediction and measurement by distance Unit: dB (A).

Classification	Distance				Speed (km/h)
	4 m	8 m	16 m	32 m	
Measurements	93.7	83.4	78.6	72.0	120
Prediction	93.0	82.4	78.8	75.5	
Deviation	0.7	1.0	-0.2	-3.5	

4.4. Results of Noise Prediction at High Speed

As presented in the Table 4, the predicted noise levels by speed were similar within the error range of 2.2 dB (A), except at 32 m distance, supporting the appropriateness of the values predicted by linear curve fitting method with measurement values. However, for the 3~4 dB (A) of error of the values 16 m or farther, further studies would be necessary in order for the application of more precise calculation factor for both calculation and simulation values. The railway noise prediction method presented in this paper is valid within the range of 16 m from the track.

The noise level by speed predicted with the linear

Table 4. Comparison of the measured/predicted noise level by distance Unit: dB (A).

Speed (km/h)	Classification	Distance			
		4 m	8 m	16 m	32 m
140	LCF	94.0	84.0	79.0	72.0
	Simulation	93.0	82.4	78.8	75.5
	Deviation	1.0	1.6	0.2	-3.5
160	LCF	96.0	85.0	81.0	73.0
	Simulation	95.6	85.0	81.4	77.1
	Deviation	0.4	0.0	-0.4	-4.1
180	LCF	99.0	87.0	83.0	75.0
	Simulation	98.2	87.6	84.0	78.4
	Deviation	0.8	-0.6	-1.0	-3.4
200	LCF	101.0	88.0	85.0	76.0
	Simulation	100.8	90.2	86.6	79.7
	Deviation	0.2	-2.2	-1.6	-3.7

*LCF: Linear Curve Fitting.

curve [6] fitting method and the predicted simulation values by speed, and their deviations are summarized below.

V. Conclusions

In this study, the noise generated at the turnouts in existing lines were measured, compared and analyzed by being classified into tilting, high speed, and common speed trains, and distance, speed, and crossings. The noise levels expected to be generated at the turnout systems when the tilting trains have been speeded-up in the future are predicted and evaluated with the measured data. The conclusions are summarized below;

(1) Comparing the noise levels at similar speeds, at 4 m distance, the noise levels of the Saemaeul, tilting, and Mugunghwa trains were 85.7~ 88.7 dB (A) (approx. 45 Km/h), 88.2 dB (A) (approx. 53 Km/h), and 86.1~91.6 (approx. 43 Km/h), respectively. Considering higher speed of the tilting train than others by about 10 km/h, the tilting train is evaluated to have better noise performance than other types of trains.

(2) According to the analysis on the changes in noise by the running speed of the tilting train, at the same manganese steel crossing and similar passing speed, the Honam Line whose ground and track conditions are better than the Chungbuk Line showed generated noise level, showing that the differences in the ground or track can cause significant difference in noise level even at the same crossing type. On the Honam Line whose ground and track conditions are better than the Chungbuk Line, the train speed at the turnout system is the major factor for noise generation. On the other hand, on the Chungbuk Line, the sub-conditions including the subgrade and rail are the major influencing factors on noise.

(3) The noise level by speed was calculated by linear curve fitting technique. The differences in the noise levels by speed in each distance range are 10~13 dB (A) in 4~8 m, 3~5 dB (A) in 8~ 16 m, and 7~9 dB (A) in 16 m~32 m, showing the largest difference in the 4~8 m range, which then sharply reduced in the 8~16 m range, and the reduction rate became smaller in the range farther than 16 m, as same as in the linear curve fitting analysis. The noise level increased by about 1~2 dB(A) as the speed increased by 20 km/h, at a constant trend.

(4) The predicted noise levels by speed were similar within the error range of 2.2 dB(A), except at 32 m distance, supporting the appropriateness of the values predicted by linear curve fitting method with measurement values. However, for the 3~ 4 dB(A) of error of the values 16 m or farther, further studies would be necessary in order for the application of more precise calculation factor for both calculation and simulation values. The railway noise prediction method presented in this paper is valid within the range of 16 m from the track.

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[Profile]

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