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Pressure Characteristics on Korean High-Speed Railway Acoustic Screen Using 1/61 Scaled-Down Moving Model Rig

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Abstract

The experiments for aerodynamic characteristics of railway acoustic screen are performed using 1/61 scaled-down moving model rig facility which employs an axis symmetry and one wire guidance method. The launching mechanism is an air-gun type. The train model for the experiment is the high speed train (Korea Train Express: KTX) and the tested speed is about 300 km/h. The tested train length is 61 cm which is corresponding to two units of KTX train. The cross sectional area and weight of train model are 0.00264 m^2 and 287 g, respectively. The Reynolds number based on the model train length is 1.2×10^7. The strength of pressure wave is measured using piezo typed pressure sensor. The measured pick value of pressure was as high as 365 Pa in the shortest gap between the acoustic screen and model train. The measured pressure is well compared with the field test data of UIC 779-1[2] values. However, the experimental data were slightly lower than the UIC 779-1 values. The results show the model test can be used as a substitute for the field test.

Keywords : *High-speed train, Acoustic screen, Moving-model rig, Pressure characteristics*

1. Introduction

For the Korean high speed train - KTX, the acoustic screen is used to reduce the environmental noise and to isolate the dust particles caused by train passing in railway side. The slipstream and wind pressure by train push the acoustic screen back-and-forth, which generate the repeated load on the acoustic screen and then make some parts of acoustic screen loose. This becomes the serious issue of maintenance in railway facility manager. Not many documented reports for this problem are available. A series of field tests is necessary to investigate the load pressure on the acoustic screen in the railway side. However, the field test for high speed train running at speed of more than 300 km/h has to run a risk and sometimes is not allowed because of safety reason by railway manager. Moreover, it is difficult to measure the necessary data completely. Therefore, it is strongly recommended to develop the technique of getting necessary data using moving model rig and the theory of scaled-down model methods.

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2. Experimental condition

2.1 Background Theory

For this experiment, the Reynolds analogy should be satisfied as follows.

$$N_{Re})_P = N_{Re})_m \tag{1}$$

P stands for prototype and m stands for scaled-down model. Therefore,

$$\frac{\rho VD}{\mu})_P = \frac{\rho VD}{\mu})_m \tag{2}$$

And, ρ, μ in each side have the same value. Then,

$$\frac{V_P}{D_m} = \frac{V_m}{D_p} \tag{3}$$

To meet this condition, V_m has to be 61 times V_P with 1/61 scaled-down model. However, it is not possible to achieve this requirement in the normal atmosphere. But, if we consider the Re number of prototype (Total length of 20 units of KTX: D = 387 m);

$$Re_p = \frac{83.3m/s \times 387m}{1.5\times10^{-5}m^2/s} = 2.15\times10^9 \tag{4}$$

On the other hand, the Re number of scaled-down model

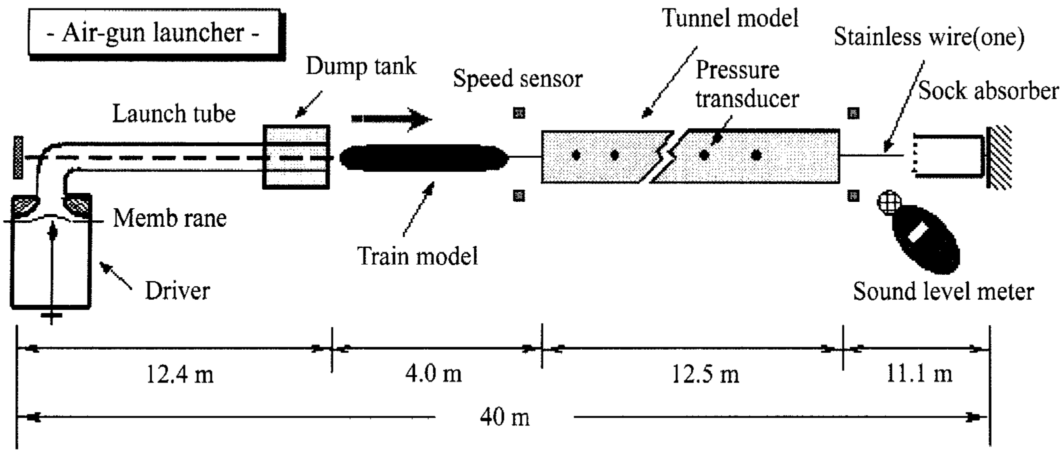

Fig. 1 Schematic Diagram for Moving Model Rig

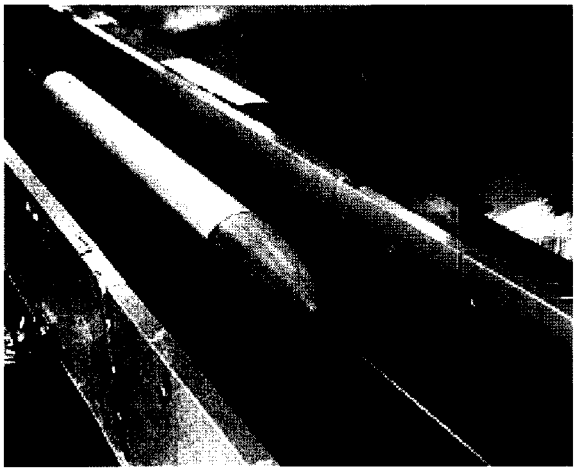

Fig. 2 The High-speed Train Model and Acoustic Screen

(D = 0.6 m for about two units of scaled-down model);

$$Re_m = \frac{83.3m/s \times 0.6m}{1.5 \times 10^{-5} m^2/s} = 2.15 \times 10^9 \quad (5)$$

The Re number for prototype is 180 times higher than the scaled-down model. However, if the Re number is more than 10^6, it is well known that the boundary layer flow is completely developed to be turbulent one and the drag coefficient is not much changed according to fluid mechanics theory - Fox and McDonald [1]. Therefore, it is appropriate decision that the Reynolds analogy can be achieved with Re_m in this experiments.

2.2 The description of experiment

In this research, moving model rig facilities are developed as shown in Fig. 1 to perform the scaled-down model test. The employed method is an axis symmetry and one wire guidance for this moving model rig. The scale is 1 to 61. The launching mechanism is an air-gun type. The maximum speed can be reached as high as 520 km/h with this facility. The total length of test rig is about 40 m. For train model, the recently introduced Korean high speed train KTX which has a streamlined nose is used as model. To do that, a 1/61-scale-down train model was built with the nose part of KTX train transformed into an axis-symmetric shape as shown in Fig. 2, Table 1 & 2. The material for the train is aluminum for car body and polycarbonate for train nose which can reduce the total weight. The total weight (car body+nose) is about 287 g. The train model is supposed to run along the strained wire.

Table 1. The Geometric Detail of High-speed Train Model

	Weight (g)				Length(cm)
High Speed Train Model	Nose	Body	Rear	Total	Total
	88.5	163.0	35	286.5	61.0

Table 2. The 1/61 Scaled-down Mock up for Train

	Radius of train (m)		Cross sectional area(m^2)	
High Speed Train Model	1:61 (model)	1:1 (KTX)	1:61 (model)	1:1 (KTX)
	0.029	1.769	0.00264	9.831

Fig. 3 The Arrangement of Acoustic Screen Model

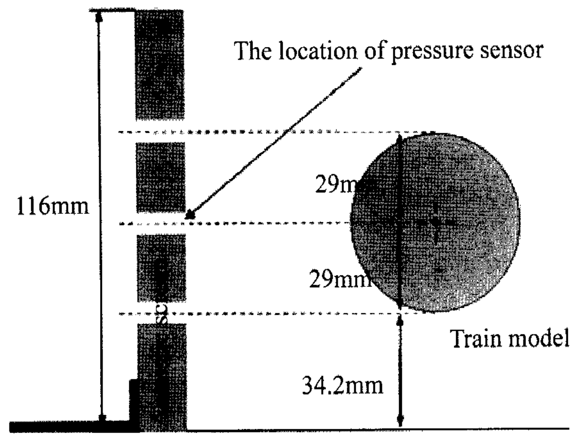

Fig. 4 The Location of Pressure Sensor and Acoustic Screen Model

The total length of acoustic screen is 5.64 m which is enough length for checking the slipstream effect caused by high-speed train model. The acoustic screen is installed at both sides of train model to simulate the reality of field as shown in Fig. 2 & Fig. 3. The gap between the train model and acoustic screen is possible to be adjusted by sliding mechanism to see the effect of various gap distances. The connecting parts of each panel for acoustic screen are tightly sealed to protect the leakage of air. The thickness and height of acoustic screen is 1.2 cm and 11.6 cm, respectively, which was adjusted to model train.

The piezo-resistive pressure transducer (ENDEVCO 8510B-1 & 8510B-2) is implanted into the surface of

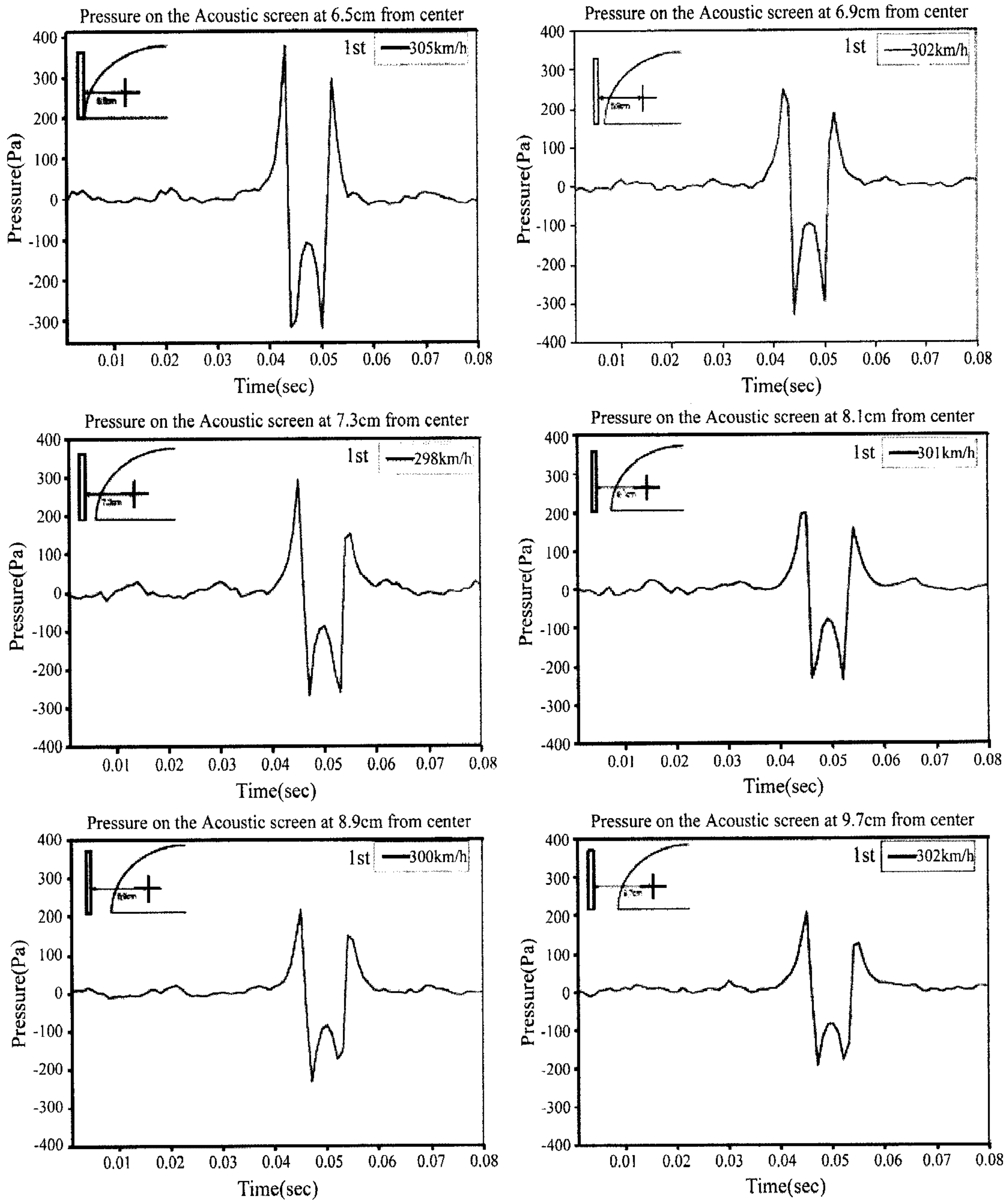

Fig. 5 The Pressure Variation According to the Gap

Table 3. The Gap Between the Train and Acoustic Screen

The gap between the train model and acoustic screen	The gap between the train and acoustic screen in reality
6.5 cm	4.0 m
6.9 cm	4.2 m
7.3 cm	4.5 m
8.1 cm	4.9 m
8.9 cm	5.4 m
9.7 cm	5.9 m

Table 4. Comparison between present experimental data and UIC 779-1 values [2]

Distance from track center (1/61 scale)	Distance in UIC 779-1 (reality)	Present Averaged Experimental Data (Pa)	UIC 779-1 Value(Pa)
6.5 cm	4 m	365	430
6.9 cm	4.2 m	273	400
7.3 cm	4.5 m	254	360
8.1 cm	4.9 m	230	320
8.9 cm	5.4 m	214	270
9.7 cm	5.9 m	185	240

acoustic screen which is aligned with the center of train model as shown in Fig. 4. The pressure data were acquired by LabView and NI data acquisition system.

3. Results and Discussion

The speed of train model was 300 km/h. The tested gaps between the train model and acoustic screen were 6.5, 6.9, 7.3, 8.1, 8.9, 9.7 cm which correspond to 4, 4.2, 4.5, 4.9, 5.4, 5.9 m respectively in reality.

The measurements at each gap were performed 5 times. Fig. 5 show the pressure variation caused by the slipstream of train model which was taken at the first try. The pattern of pressure show the positive pick value (push) when the nose of train passes by and, the negative pick value (pull) when the tail of train passes by. Surprisingly, this pressure behavior is the same as the reality. The averaged experimental data were compared with the UIC 779-1 data in Table 4. As it can be seen, the measured values were lower than the one in UIC 779-1 by 50–130 Pa. It is guessed that this error is caused by the gap distance between the train model and the bottom surface. In experiment, this gap is 34.2 mm as shown in Fig. 4 which can be converted to 2 m in reality. However, this gap distance in real high speed train is far less than 1 m.

Therefore, the vortex pattern generated behind the tail of train model will be quite different with reality which is well predicted by Jang [3, 4, 5] in which a pair of vortex behind moving vehicle is predicted and the generated vortices are strongly affected by the rear part of moving vehicle and the gap between the body and surface. Therefore, if tail vortex pattern is deformed due to the different gap between the train and surface, the aerodynamic behavior between the train and screen will be different and the pressure field affected on the screen surface will be also different. One of the other reasons for the low pressure field on the screen surface of model could be the different shape of cross section of train between model and reality. In experiment, the cross section of model train is a circle but, in reality, that is a rectangular.

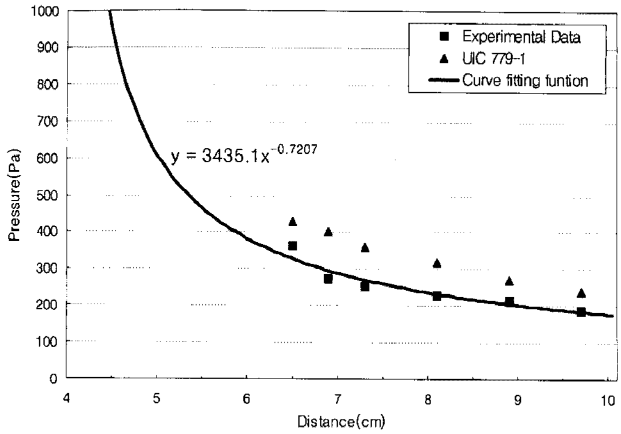

Fig. 6 Comparison between experimental data and UIC 779-1 values [2]

Fig. 6 show the comparison between averaged experimental data and UIC 779-1 values and curve fitting function for experimental data. As it can be seen in this figure, the closer to acoustic screen the higher pressure field is generated which is the same tendency as the UIC 779-1 values (a triangular symbol in Fig. 6). It means that the experiment is quite successfully done. However, the absolute values of the experimental data are lower than UIC 779-1' one as indicated previously. Curve fitting method is employed to get the relation within the measured data. The numerical formula obtained by curve fitting is

$$Y = 3435.1X^{-0.7207} \tag{6}$$

4. Conclusion

The aerodynamic characteristics on railway acoustic screen were analyzed using 1/61 scaled-down mock-up experiment. The train model was the high speed train (KTX) and the tested speed was about 300 km/h. The strength of pressure wave was measured using piezo typed pressure sensor. The measured pressure was well compared with UIC 779-1[2] values. It was revealed that the closer to acoustic screen the higher pressure field was generated which is the same tendency as the UIC 779-1 values. However, the absolute values of the experimental data were slightly lower than UIC 779-1.

Reference

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