A Study on Enhancement of existing Noise Barriers in Railways

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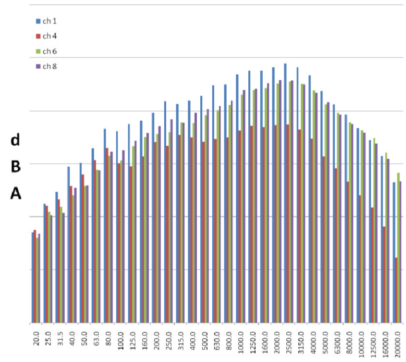
Introduction

The research project "Noise and vibration reduction technology development for speed increase in railways" is initiated concerning the technical limits of existing noise barriers against the high speed trains with the speed of 300km/h, and higher, and the tightened environmental noise limit for the night time in 2010. There exist multiple noise sources with different incident angles to the noise barrier when the high speed train passes by. The most critical restriction of the shielding performance of the conventional noise barriers are related to the high positioned noise source of the high speed train, such as the pantograph noise and the aerodynamic noise from the upper part of the train. Furthermore, for many high-rise receivers is the noise barrier more or less ineffective. Another technical challenge is the enhancement of the insertion loss of the barriers against the relatively low frequencies, which remain energy considerably behind the noise barrier due to the diffraction at the upper edge of the barrier. As one of the possible measures, a model for an acoustically soft upper edge is considered by means of passive and active control of the sound pressure. Based on the civil appeal site investigations, the technical compensation has been focused on the frequency area in 120Hz~400Hz and in 1kHz~4kHz at the same time, as possible and on the noise incidence from the upper part of the train. Another important aim is to increase the height of the shadow area or to adjust the sound field control to the target receiver area, which needs an improvement of the shielding performance urgently. Theoretical models are considered for the prediction and prototypes are in building on the basis of the prediction studies. In this paper some analytical results are presented and discussed.

Noise characteristics of the railway sites with noise barriers

As the measurement sites, locations with noise barriers are chosen, where civil appeals have been recorded recently. Abbildung 1 shows the spectral characteristics of the noise measured from the pass-by of the high speed train and the freight train at different heights. Noise frequency area in 125Hz~400Hz is for each types of trains the weak point in the schielding performance of the existing nosie barrier. On the other hand, the noise barrier in the high speed line needs to be improved in the insertion loss for the frequency are in 1kHz~4kHz. Through another previous study on the noise source locations, it could be identified that noise in this frequency area is radiated from the wheel/rail height but furthermore from the upper part of the train at the speed of 300km/h.



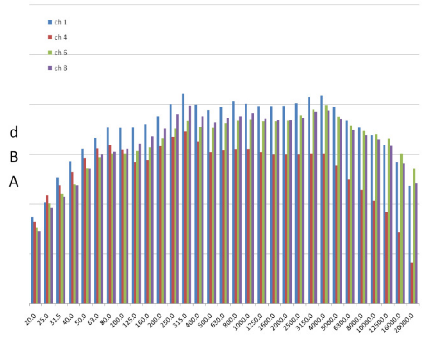


Abbildung 1: Noise spectrum of a high speed line measured at the distace of 16m(top) and of a freight train line measured at the distace of 55m (bottom) with noise barriers.

Theoretical investigation

As a model is considered a cylindrical body with the radius of $r=b$ attached to a rigid half plane[1][2]. The influence on the surrounding sound field of the acoustical properties of the cylindrical upper edge can be examined by means of its surface impedance Z;

$$Z = -\frac{p(b)}{v_r(b)}, \qquad (1)$$

where $p(b)$ is the sound pressure on the surface of the cylinder and $v_r(b)$ is the outward radial component of the velocity on the surface. The sound field at an arbitrary field point (r,φ) can be expressed as a sum of components of the noise barrier and it's upper edge.

$$p_{screen} = p_Q(0)\sum_{n=0}^{\infty}\frac{2e^{j\frac{n\pi}{4}}}{\varepsilon_n}J_{\frac{n}{2}}(k_0 r)\cos(\frac{n}{2}\varphi)\cos(\frac{n}{2}\varphi_0) \qquad (2)$$

is the sound pressure due to the screen alone and

$$p_{edge} = -p_Q(0)\sum_{n=0}^{\infty}\frac{2}{\varepsilon_n}e^{j\frac{n\pi}{4}}Q_{\frac{n}{2}}(k_0 b)H_{\frac{n}{2}}^{(2)}(k_0 r)\cos(\frac{n\varphi}{2})\cos(\frac{n\varphi_0}{2}) \qquad (3)$$

is the sound pressure due to the cylindrical upper edge with a certain acoustical impedance Z without the screen[2]. k is the wave number, $H^{(2)}_{n/2}$ is the Hankel function, $p_Q(0)$ means the sound pressure of the source in free field at the center point of the cylinder $r=0$. φ_0 is the incidence angle to the barrier. $Q_{n/2}(kb)$ means the effect of the upper edge on the reflection factor and includes the characteristics of the acoustical impedance. For our study, first optimal value of Z is investigated considering the special condition, such as the target noise source height, the incidence angle, the frequency and the receiver position. An acoustically soft surface ($Z \rightarrow 0$) for an upper edge of the noise barrier can be realized with various resonators [3] but their additional improving effect is restricted to a certain frequency band related to the resonance frequency. We choose the target frequency area as 1kHz~4kHz, in that the passive soft edge will give the additional enhancement of the insertion loss of the noise barrier. As an additional measure for the soft edge realization with the purpose of improvement in the frequency area 125Hz~400Hz, active sound field control is considered. By means of secondary soures the sound pressure at the optimal area along the surface of the cylindrical edge is minimzed :

$$\sum_{m=1}^{M} \left|p(b,\varphi_m)\right|^2 = Min. \tag{4}$$

with

$$p(r,\varphi) = p_{screen}(r,\varphi) + p_{edge}(r,\varphi) + \sum_{j=1}^{J} p_{act_j}(r,\varphi)\cdot\alpha_j \tag{5}$$

$$p_{act} = \sum_{n=0}^{\infty} S_{n/2} \frac{H_{n/2}^{(2)}(k_0 r)}{H_{n/2}^{(2)'}(k_0 b)} \cos(\frac{n}{2}\varphi) \tag{6}$$

$S_{n/2}$ include the velocity, angle to the barrier and the size of the secondary source, α_j is the complex control factors of each secondary sources. In Abbildung 2 is shown the additional improvement due to the acoustically soft edge to the sound field with barrier only. B is the diffraction angle and the upper edge is realized by the combination of the surface impedance of Z/ρc=0.01 and an active sound field control. Compared to the improvement due to the edge with Z=∞ and an active control (Abbildung 3), dominant effect in 1kHz~4kHz is achieved while the enhancement in the low frequency target area is up to 6dB. Since we have specific target receiver area for the improvement, Abbildung 4 shows the reduced sound field in the target area, the red quadrangle, for 400Hz and for 4000Hz as an example.

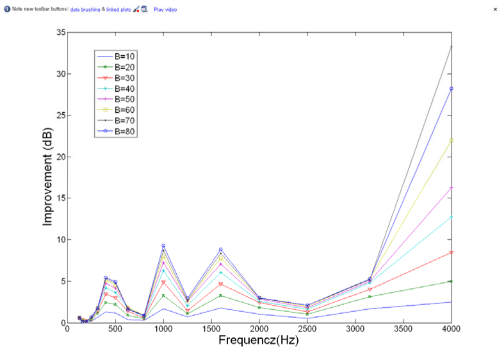


Abbildung 2: Improvement due to a cylindrical upper edge of = Z/ρc=0.01 and active control (secondary source at 45°to the barrier, minimizing at 293° to the barrier), sound incidence φ_0 =90°

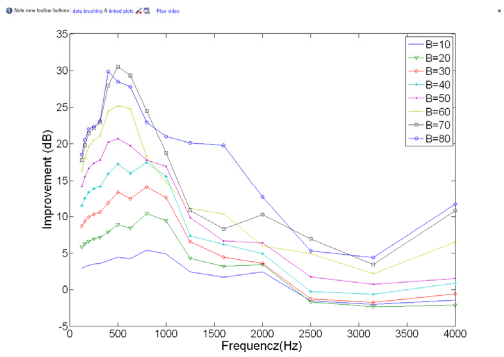


Abbildung 3: Improvement due to a cylindrical upper edge of = Z/ρc = ∞ and active control (secondary source at 45°to the barrier, minimizing at 293° to the barrier), sound incidence φ_0 =90°

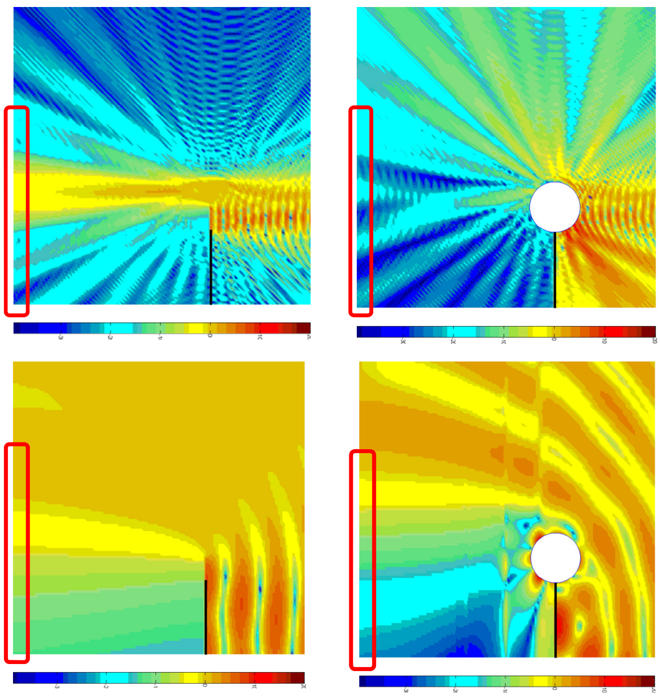


Abbildung 4: Sound pressure comparenis ; Z/ρc=0.01 with active control, 400Hz(top), 4000Hz(bottom) related to the sound field with barrier only.

Literatur

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