Visualization of cavity flow for various guide grill shapes on a sound absorbing board

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Abstract In this study, the cavity flows for various guide grill shapes on a sound absorbing board have been numerically investigated, which is installed on the wall of subway tunnel to block noises transmitting into the interior of the subway. To see the effects of the cavity hall of the guide grill on the bulk intake flow into a resonator of a sound absorbing board, the cavity length, angle and depth were changed. The amount of the intake flow through the cavity hall is evaluated from the velocity profile at the cavity top and bottom. The results show that the absolute velocity of intake flow at both the cavity top and bottom is reduced as the length and angle of the cavity become smaller. However, the effect of depth is negligible at the condition that the intake flow is a minimum.

.**Keywords:** Guide grill, Cavity flow, Sound absorbing board, Resonator

1. Introduction

When a subway vehicle moving through a tunnel, squeal noises may happen due to the friction between wheel and railroad [1]. The squeal noise with high frequency cause passengers uncomfortable so that it is required to block the noise transmitting into the interior of the subway. Meanwhile, by the subway passing the tunnel, many flow problems are accompanied such as strong winds, pressure wave and impulse wave at the exit of tunnel [2].

There have been efforts to prevent the noise from transmitting into the subway room by installing soundproof wall, soundproof tunnel on sound transmission path [3]. Recently, it was reported that the soundproof wall attached onto tunnel wall could be more efficient if a sound interference device was adopted [4]. One of the interference device is a sound absorbing board with a guide grill. The guide grill has a structure of a plate with many slits. The primary role of the guide grill is to pass only acoustic noise into ta resonator of a sound absorbing board without bulk intake flow through the slits. However, the strong wind and pressure inside the tunnel cause cavity flows by the existence of slits, which might be another source of acoustic noise. Thus, it is important to design the slits or cavity halls of guide grill by considering the flow and pressure fields on the tunnel wall. There was several studies on the generation of acoustic noise by the flow passing the cavity. Howe [5] and Alvarez et al. [6] investigated the characteristic of acoustic fields generated near the leading and trailing edges of cavity without a resonator, respectively.

In this study, the cavity flows on the slit of the guide grill including the resonator are numerically investigated. Various shapes of guide grill are considered to see the effects of the geometry of guide grill on the bulk intake flow which is transmitted into the resonator of a sound absorbing board. The geometrical parameters are cavity length, depth and angle. From the numerical simulations, the optimum shape of cavity hall of the guide grill is discussed to minimize the intake flow.

2. Method of numerical simulations

The schematic of computational domain for the cavity flow is shown in Fig. 1. On the wall of subway tunnel, a guide grill is installed with a cavity hall for noise absorption. Just below the narrow cavity hall, there is a resonator for a sound absorbing board. The dimension of tunnel is 30 x 6 mm^2 and the resonator is 3 x 10 mm^2. The shape of the guide grill has a parallelogram cavity hall. In this study, the effect of the geometry of the cavity hall is investigated and the parameters for the cavity hall of the guide grill are shown in Table 1.

For the numerical simulations, the flow is assumed to be unsteady incompressible turbulent flow. As a turbulence model, k-ε model is used. As boundary conditions, the inlet velocity is given by 27 m/s(=100 km/h), and at the outlet, pressure is set to be an atmospheric pressure. The computational grid has about 400,000 meshes and the wall unit y+ of the first mesh point for the turbulence model is almost 2.

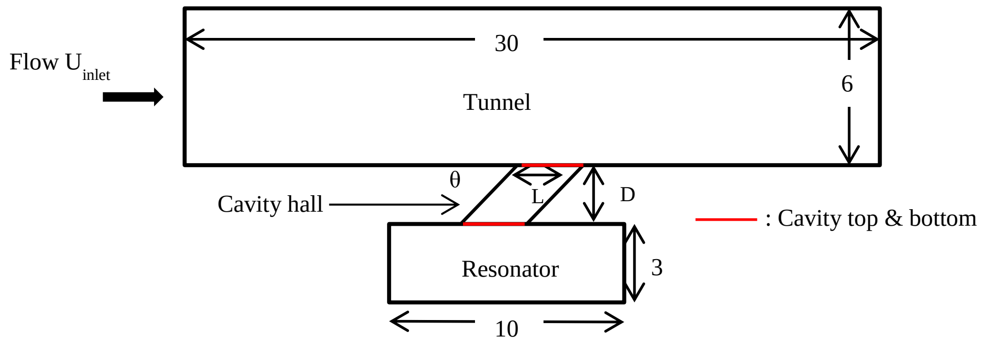


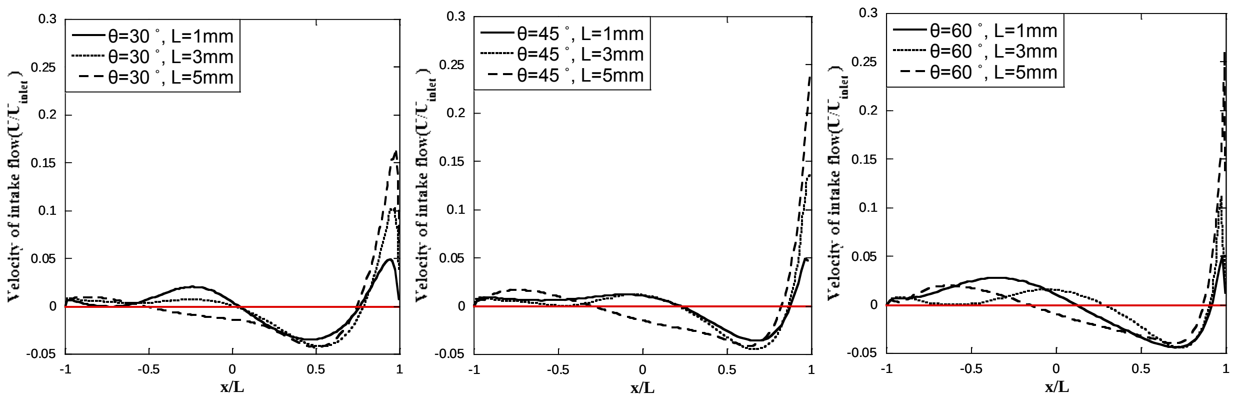
Fig. 1 Schematic of the computational domain

Table 1 Geometric parameters of the guide grill shape

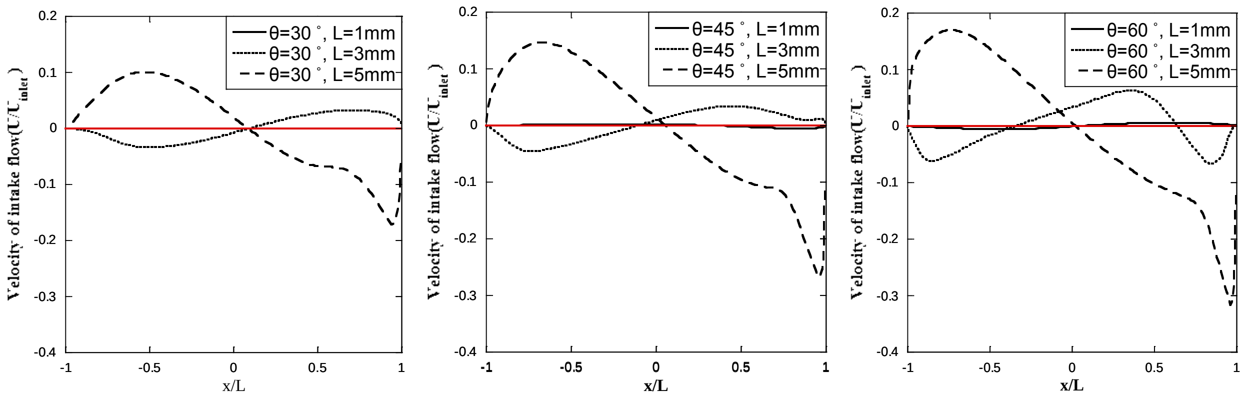
Cavity angle (θ)	30˚, 45˚, 60˚
Cavity length (*L*)	1, 3, 5 mm
Depth (*D*)	1, 3, 5 mm

3. Results and discussion

When a wind flows on the cavity in the subway tunnel, an intake or outtake flow occurs through the cavity hall by a separated vortex at the leading edge of the cavity. It is important to minimize the intake/outtake flow in the design of the guide grill. Fig. 2 shows the absolute velocity of intake flow at the cavity top (a) and bottom (b). The simulation was carried out for a variety of cavity angle and length at a given depth of D = 1 mm. The velocity and coordinate are non-dimensionalized by the inlet velocity U_{inlet} of the channel and cavity length L, respectively. As shown in Fig. 2, the velocity of intake flow at both the cavity top and bottom becomes faster as the length and angle of the cavity become bigger. The intake flow is closely related with the vortex generated at the leading edge of the cavity. The larger length of the cavity induces the larger vortex, which results in the increased intake flow. The cavity angle also affect the size of vortex. Since the cavity hall is formed opposite to the direction of the vortex, the smaller angle prevents the vortex more effectively from coming into the cavity hall. Thus, the intake velocity is slowest at length of L = 1 mm and angle of θ = 30˚.



(a)



(b)

Fig. 2 Absolute velocity of the intake flow at the cavity top (a) and bottom (b) for various cavity lengths and angles

Fig. 3 shows the absolute velocity of the intake flow at the cavity bottom for various depths of cavity. The cavity angle and length are fixed to θ = 30˚, L = 1mm, respectively, since the intake flow is minimum at those conditions. In this figure, the positions of negative and positive values in the intake flow velocity is different when the depth is 1 mm, compared with the depth is 3 or 5 mm. It is because when the depth is short (D = 1 mm), the distance between vortex and cavity bottom is so close that the vortex has an effect on the velocity distribution at the cavity bottom. However, in all cases, the velocity of intake flow is very slow. the maximum velocity is about 10^{-5}, 10^{-7}, 10^{-8} m/s at the depth of 1, 3, 5 mm, respectively. Thus, the depth is not important factor in the design of the guide grill.

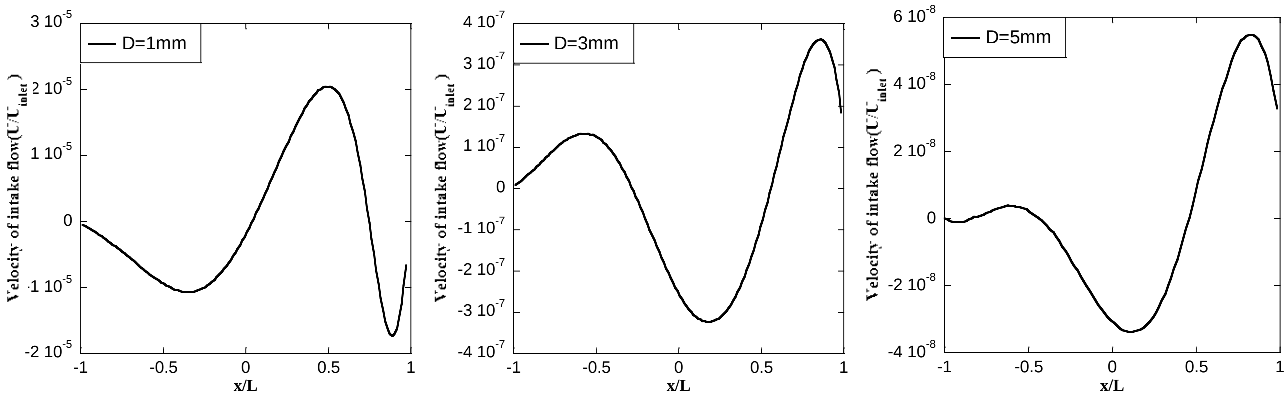


Fig. 3 Absolute velocity of the intake flow at the cavity bottom for various depths of cavity; (angle = 30˚, length = 1mm)

4. Conclusions

In this study, the cavity flows for various shapes of guide grill including a resonator were numerically investigated. The geometrical parameters for the guide grill were cavity length, depth and angle. The absolute velocity of intake flow at both the cavity top and bottom is reduced as the length and angle of the cavity become smaller. Thus, the guide grill needs to be designed for the cavity length less than 1 mm and the cavity angle less than 30˚, where the intake flow is minimum and which is sufficient to prevent the bulk flow from being transmitted into the resonator. On the other hand, the depth is not important factor at the cavity shape of minimum intake flow when designing the guide grill.

5. Acknowledgements

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6. References

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