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The Flow Analysis of Noise Reduction of Diffuser in Air Duct System

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Abstract
All of these businesses are conducting much research and development to satisfy consumers' NEEDS. Consumers' requirements can be largely divided into low noise, driving comfort, high performance, and lastly high fuel economy. Noise reduction, in particular, is essential for quality improvement of vehicles. To satisfy the consumers' NEEDS requiring quiet and good sounds to hear as well as to meet noise regulations being reinforced, the designers need to perform accurate evaluation of noise view points and design in the design and development processes. In the present article, methods and characteristics for intake noise reduction will be introduced, and compare air flow and flow noise in air cleaner diffuser according to entrance shape.

Keywords: Air Intake system, Intake noise, Diffuser, Air flow

INTRODUCTION
Automobile noise has been pointed out as an environmental or a social problem to be strictly managed on a national level. Particularly, the ratio accounted for by intake exhaust noise in the total noise is about 30%. Thus, finished car businesses and producers of intake/exhaust modules are making much effort to reduce the noise of 30 the intake noise is produced during a combustion process due to pressure pulsation of air current and resonance phenomenon of internal sounds. Particularly, upon burst of power, explosion sound and opening/closing shock sound of valve become very loud as the compressed gas pressure of the piston is increased by 2~3 times. In addition, resonance with resonance frequency of intake pipe or indoor acoustic field may also occur, causing intake noise upon acceleration. Figure1 showed noise production path in intake/exhaust system. Figure2 showed the intake noise during the process when air came in to the cylinder and explode. Several method are used for reducing the noise which has various causes. However, those methods cause increasing negative pressure and have an effect on the performance.
In the present article, methods and characteristics for intake noise reduction will be introduced, and compare airflow and flow noise in air cleaner diffuser according to entrance shape.

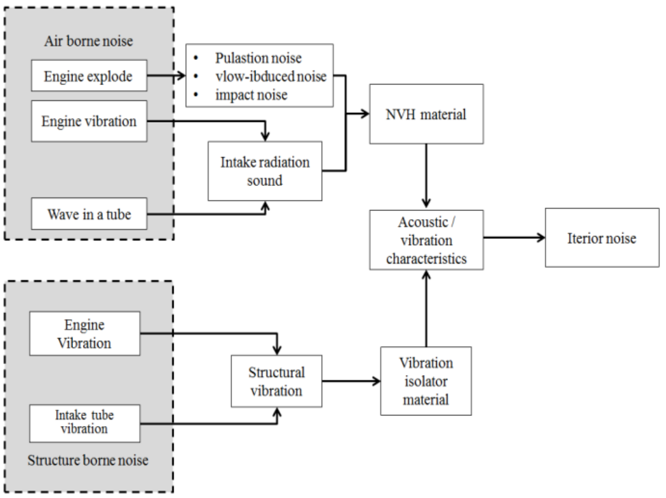

Figure 1: Noise production path in intake/exhaust system

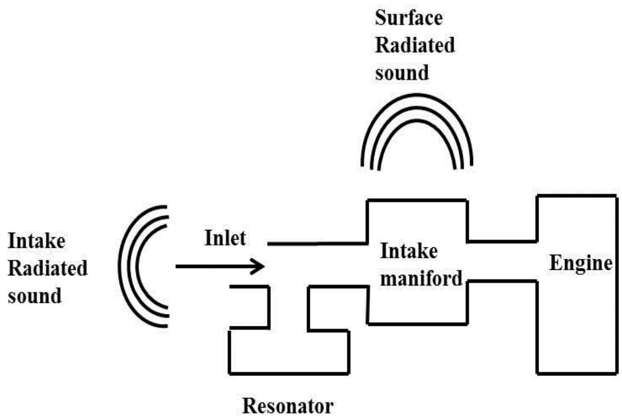

Figure 2: Intake system noise modeling

REDUCTION METHODS FOR INTAKE NOISE
Use of sound-absorbing material for noise reduction
1) Porous type sound-absorbing material
It is a sound-absorbing material made of fibers or chemical products. When only porous-type sound-absorbing materials are used, the effects are greater in the high sound range than in the low sound range, and the sound absorption rates are increased with the material density for the porous-type sound-absorbing[1].

2) Plate vibration-type sound-absorbing material
Vibration occurs as the sound collides with the material (thin MDF or plywood). Here, the sound energy is converted to vibration energy and thermal energy to cause sound absorption, and the sound absorption in the low sound range is better, the larger the material weight and the larger the background air layer.

3) Perforated board-type and slit-type composite sound-absorbing structure

For the perforated board-type sound absorption structure, boards such as plywood or metal plates are employed. In general, it has mountain-shaped sound absorption characteristics around a particular frequency as the center. The perforated board-type sound absorption structure has a disadvantage of being expensive although the allowed aperture ratios are large. Thus, efficiencies of general sound-absorbing/insulating materials are difficult to expect, although sound absorption coefficient in a high sound range is good. Particularly in the 2 cases of porous sound-absorbing material or plate-shaped sound-absorbing material, noise reduction in a high range is difficult to achieve. Therefore, a composite sound-absorbing structure having even sound-absorption coefficients for the frequency is necessary where plate vibration of surface material and porous sound absorption of intermediate material, perforated board wooden bowl sound-absorbing structure with resonance sound absorption, and wooden slit are employed together. [2-3].

Use of resonator for noise reduction

In the case of resonator for intake system, helmholtz resonator, hole resonator, 1/4 wavelength pipe, etc. are used. Helmholtz resonator among these is an acoustic apparatus consisting of a large-volume cavity and a narrow connecting pipe with characteristics where the intake noise with a strong pure tone component is very effective for reduction. It can suppress noise only at a particular frequency in an acoustically very narrow region. The noise reduction effect is very large for sharp noises with a very small frequency width. Most passenger cars have mounting of 1~2 Helmholtz resonators and 1/4 resonance pipe supplementing them. Using resonator for noise reduction, should extend length and cavity of volume. However, those methods increase resistance. It should be balanced. Figure3 descried Helmholtz resonator.

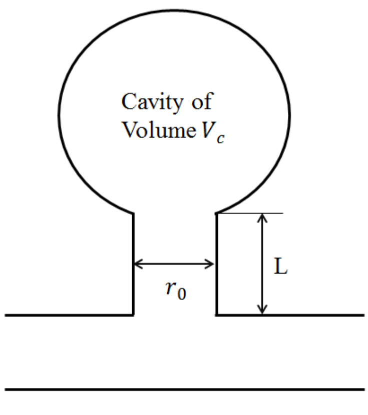

Figure 3: Helmholtz resonator

In the case of small cars, use of Hole resonator and 1/4 wavelength pipe as a means for major noise control in general intake system is very limited due to the structure of engine room. Hence, porous resonators are developed recently to substitute for Helmholtz resonators and sound-absorbing ducts in small cars[4-9].

Active noise control for noise reduction

It is a method for noise control by using secondary source. Although the resonator has many constraints as it should be installed in a limited space, the installation space is relatively comparatively small and capable of controlling noises with multitudes of resonance frequency in the active noise control. The booming noise, caused by the coupled effect from the structures and sound medium, is typically a low frequency noise. It is believed that using active noise controllers is more effective in controlling such low frequency noise than using sound absorption materials. Basic concept of active noise control is shown in Figure 4. Figure 5 is a outlining the active noise controlling system[10].

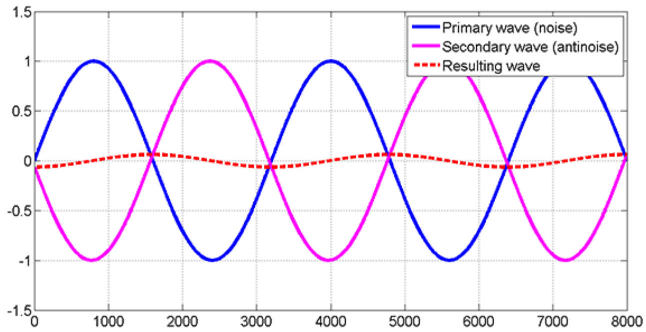

Figure 4: Concept of active noise control

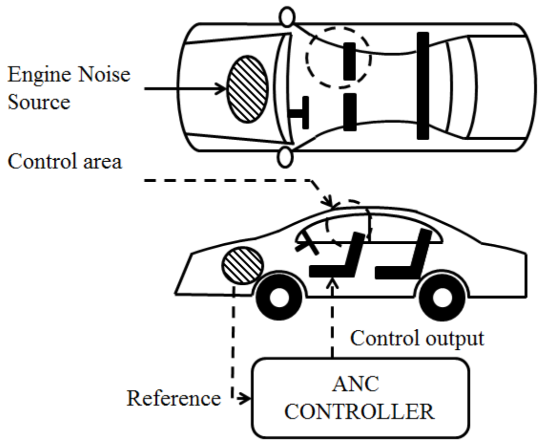

Figure 5: Outline of active noise control system

DIFFUSER ANALYSIS AND BOUNDARY CONDISIONS

Boundary conditions

The diffuser modeling designed for check airflow and airflow noise according to radius of diffuser of curve (entrance type). Figure 6 descried entrance type of the diffuser. Where ‘r’ is radius of diffuser hole of curve and ‘D’ is diameter of the diffuser. Airflow will follow to arrow in figure 5. The boundary conditions of the RPM, pressure, end of diffuser hole radius, and air properties in accordance with the r/D are given in the table 1. Where r is radius of curve in diffuser and D is diameter of intake pipe.

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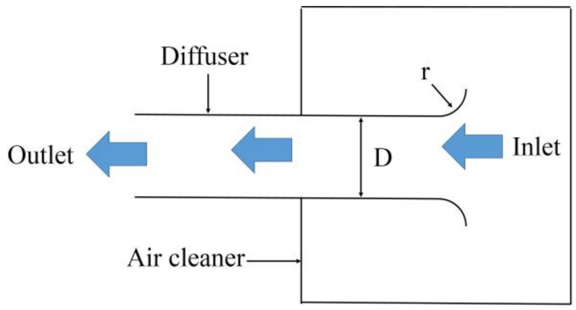

Figure 6: The model of air cleaner part with diffuser

Table 1: Simulation boundary condition

Condition	Value
Mass flow rate	140.6 kg/h (at 3,000 rpm)
Pressure	Inlet: -95 Pa (gauge pressure) Outlet: -1,095 Pa (gauge pressure)
End of Diffuser hole radius	Case1 r/D =0.2 Case2 r/D =0.1 Case3 r/D =0 (without radius)
Air properties	Density = 1.225 kg/m^3 Viscosity = 1.7894x10^{-5}kg/m·s

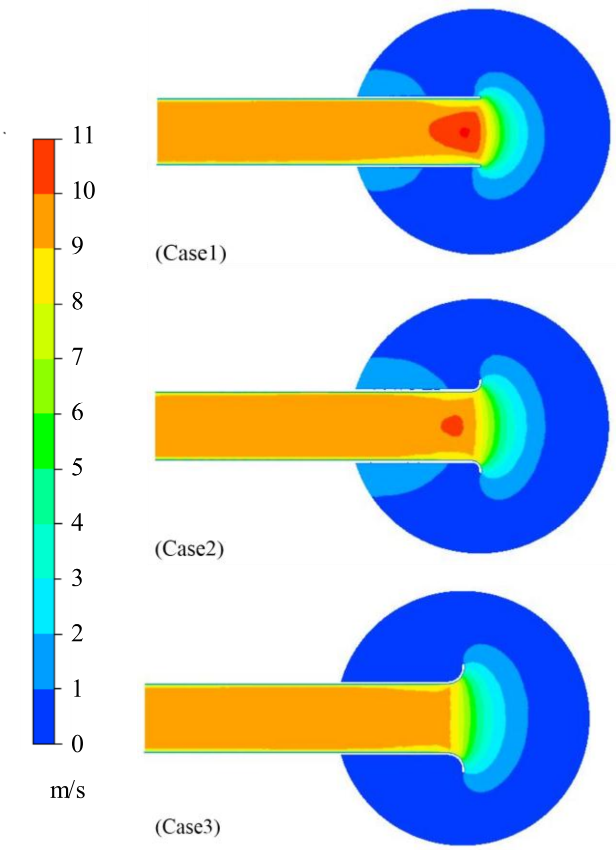

Figure 7: Velocity contour of each shape of entrance

Analysis results

Figure 7 analyzes the flow of each diffuser in air cleaner according to entrance type of diffusers. It shows the velocity of the airflow in the diffuser. The flow showed identical tendencies in all engine rpm (3000rpm). It was confirmed that the flow was fastest in the middle of the pipe at 11m/s (case 3). Flow was slowest in the middle of the pipe at 10m/s(case1). The fastest speed of airflow is concentrate in case1. The case2 and case3 are diffused the fastest speed of airflow. The flow moved in a widening gyre, creating a vortex. It barely changed in the straight sections.

Figure8 shows the flow noise at 3,000rpm according to entrance shape. There was a noise is 72dB(case1), 62dB(case2) and 50dB(case3) according to the cases. The noise reduced according to entrance shape.

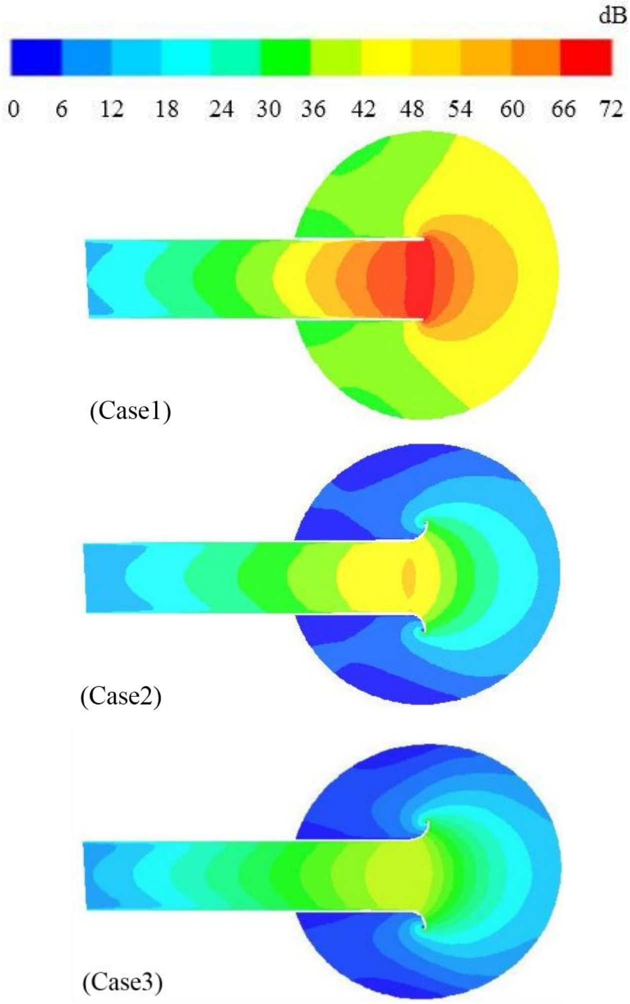

Figure 8: Flow noise in diffuser according to entrance shape

CONCLUSION

In the present study, reduction methods for intake noise in automobile engines were discussed, and the following conclusions have been obtained by analysis of air flow and flow noise inside the diffuser pipe in air cleaner clean side through finite element analysis

1) Since there are mutual advantages and disadvantages, the intake noise reduction for automobile engines should be achieved by composite methods.

2) A decrease in flow rates for the diffuser pipe with increase in entrance curve's radius of the diffuser was affirmed.
3) Through finite element analysis, a part with relatively high noise has been reduced inside the diffuser, when entrance curve's radius of the diffuser is increased.

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