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A Study on Duct Integrated Resonator of Automobile Intake System

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Abstract

Automobile's intake system intakes air from outside and supplies it to the engine cylinder. However, due to various reasons throughout the intake system, they cause noises called intake noise. A resonator is mostly used to suppress this intake noise. However, due to its nature, a resonator requires big space in the limited engine room space, and it has limited usage. In this paper, we propose a duct integrated resonator to minimize the space requirement in the engine room, compare its performance with an existing Helmholtz resonator, and analyze the performance when two types of resonators are equipped at the same time. The duct integrated resonator mounted model showed a noise reduction effect by increasing transmission loss to around 2 dB when compared to the existing Helmholtz resonator, and obtained a space reduction effect inside the engine room.

Keywords: Intake system, Helmholtz resonator, Duct integrated resonator, Intake noise

INTRODUCTION

A system in an automobile that intakes external air and delivers it to the engine cylinder is called the Intake System. The intake system is composed of a snorkel that intakes air from outside, a duct that delivers, a resonator that suppresses resonance noise, an air cleaner that removes foreign material, a throttle valve that controls flow rate, and a manifold that distributes air to each cylinder. Dull and less than 600 Hz low range noise generated from this intake system is called intake noise. The main reasons for this noise are known as the pressure pulsation of air flow in the intake system and the resonance inside intake valve. Intake noise types consist of intake air discharge sound, surface radiation sound, pipe radiation sound. The proportion of this intake noise is around 30% of total automobile noise [1]. Although this noise is suppressed by mounting additional parts such as resonator or porous material parts, the improvement is limited due to space inside the engine room. Therefore, there are requirements for noise suppression measures that reduce space inside the engine room, keep existing shape to the maximum, but do not affect the output. PET duct, one of noise suppression means, has an excellent noise reducing effect for most frequency ranges. However, it has a low noise reduction effect at a low frequency range [2]. Therefore, a resonator is used to acquire a noise reduction effect at a low frequency range. Since a resonator basically has large volume, it disturbs efficient space design for the engine room which has limited space.

In this paper, we introduce a duct integrated resonator that minimized the space requirement, compare it with an existing Helmholtz resonator, compare the effect of transmission loss of simultaneous installation, and investigate the flow caused by the new resonator.

Helmholtz Resonator

The Helmholtz resonator is a device based on resonance principle. It is defined with the shape that has body, closed cavity, and neck that connects these items as shown in Figure 1. Technologies using resonance are used in various areas, and it is mounted to the intake system to absorb a specific frequency band in automobiles. The equation to calculate target frequency in a Helmholtz resonator is shown in Equation (1).

$$f = \frac{c_0}{2\pi}\sqrt{\frac{A_n}{l_n V_c}} \qquad (1)$$

Where, A_n is the neck cross section area, l_n is neck length, V_c is cavity volume and c_0 is sound speed.

Based on this equation, V_c shall be larger or the cross section of neck shall be wider if the low range frequency band is the target which is the intake noise range. Therefore, it is known from the equation and preceding studies that most resonators need to be big, and they are affected by the shape and volume of the neck [3, 4, 5, 6].

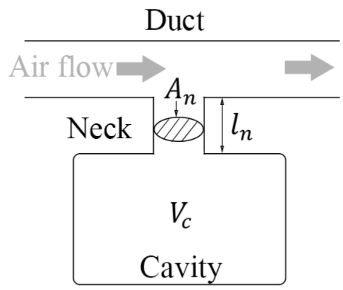

Figure 1 : Simple structural diagram about the Helmholtz resonator

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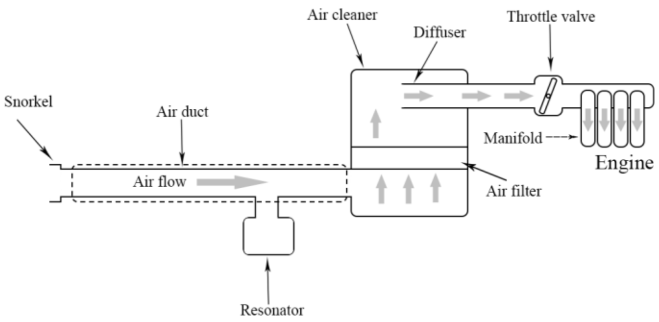
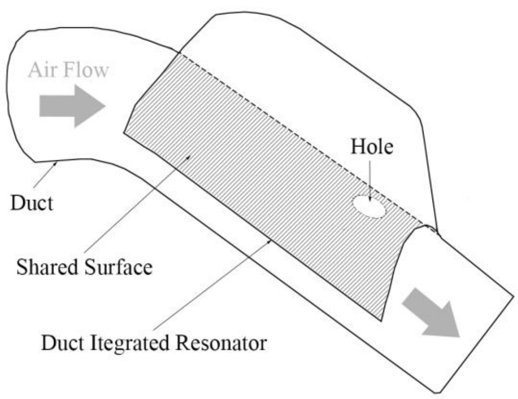
Duct Integrated Resonator

Due to its existing shape of neck and cavity, it was hard to mount the Helmholtz resonator in addition to an already designed engine room or the shape of the resonator was smaller than the original plan due to the lack of space in the engine room. The duct integrated resonator is designed to minimize this space requirement. The biggest feature of the duct integrated resonator is that it shares one side of the duct and resonator to reduce the space required in the engine room. In addition, the resonator's neck is made to have a cylinder type hole that is shared by the duct and resonator.

Figure 2 (a) shows the overall system of the intake system, and (b) shows the shape of the duct integrated resonator that can be mounted to the duct which is displayed in the dashed line in (a).



(a) Simple diagram of intake system



(b) Simple diagram of duct integrated resonator

Figure 2: Simple diagram of intake system and resonator

ANALYSIS MODELING

A total of 3 types of analysis models are constructed to evaluate the noise absorption ability of a normal Helmholtz resonator and duct integrated resonator – a single Helmholtz resonator model, single duct integrated resonator model, and simultaneous mounting model of the 2 resonator types. Table 1 shows the comparison between each mounting case. The same ducts are used for each base duct for equal comparison between each resonator, and the half sphere is created at the intake area to assume atmospheric pressure. Figure 3 shows the mesh generative model for case 3 which is mounted with both resonators.

Table 1: Type of installing resonator

Model	**Type of installing resonator**
Case 1	Helmholtz resonator
Case 2	Duct integrated resonator
Case 3	Helmholtz + Duct integrated resonator

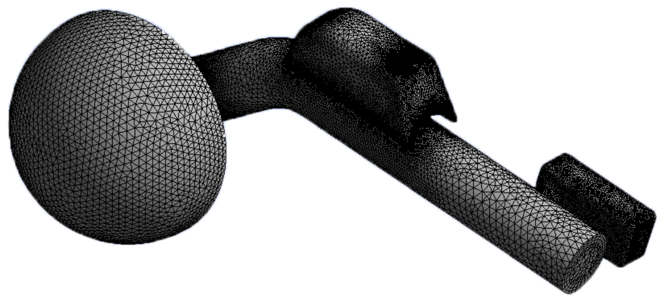


Figure 3: Meshed model of case 3

Comparison and analysis for noise characteristics of each resonator

Boundary Conditions

To evaluate noise absorption ability, which is an acoustic analysis, analysis is performed with the values shown in Table 2. A half sphere is set to outlet, and the cross section cut at the opposite end is set to inlet from Figure 3. Noise direction goes from engine side (inlet) to outlet. Acoustic velocity is set to normal direction to the inlet cross section. Air temperature is assumed as 20℃, and detail parameters are as follows:

Table 2: Boundary condition for acoustic analysis

Condition	**Value**
Mass density	1.2047 kg/m^3
Sound speed	343.24 m/s
Dynamic viscosity	1.821 x 10^{-5} Pa·s
Bulk viscosity	0.718 x 10^{-5} Pa·s
Thermal conductivity	0.0256 W/m·s
Specific heat c_p	1.006 J/kg·K
Specific heat c_v	0.718 J/kg·K

Results

As shown in Figure 4, transmission loss is obtained through acoustic analysis. As a result of analysis from a wide range from 0 ~ 1000 Hz, the ranges that are not affected by the resonator are almost similar for all cases. Accordingly, for a detailed analysis on the affected range, analysis results performed by 0.5 Hz step for 200~450 Hz range are shown in Figure 4. Figure5 (a) and (b) show the resonance effect at each frequency. Figure (a) shows that the resonator absorbs sound at 350 Hz band, and (b) shows that it absorbs sound at 353 Hz band. It was found that the target frequency of Case 1 is 280 Hz, and its sound absorption effect is 68 dB. Also, target frequency of Case 2 is 350 Hz, and sound absorption effect is 66 dB. In Case 3, it is found that it almost has a similar sound absorption ability and target frequency as Case 1 at 280 Hz band. In case of 350 Hz band, target frequency is increased around 3 Hz than that of Case 2, and its sound absorption effect is 70 dB which is 4 dB higher. This is because the Helmholtz resonator absorbs part of the resonance noise in 350 Hz band as shown in Figure 5 (c) when both resonators are mounted simultaneously. Therefore, even though the duct integrated resonator can have a bit of a different target frequency band than an existing Helmholtz resonator, it can bring slight performance improvement when both resonators are mounted simultaneously. Also, it is proved that the hole in the duct has a sufficient effect to replace the role of the neck.

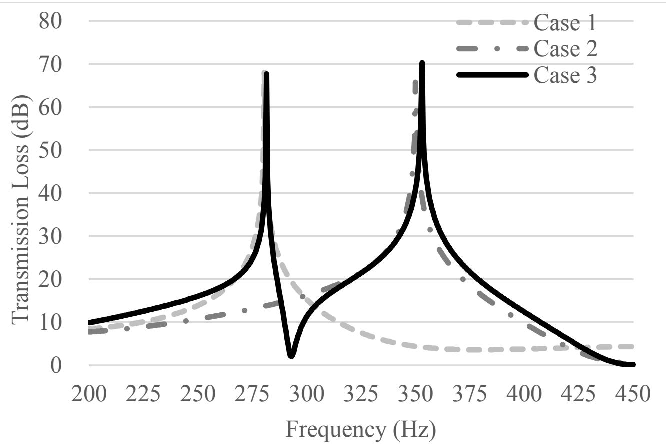
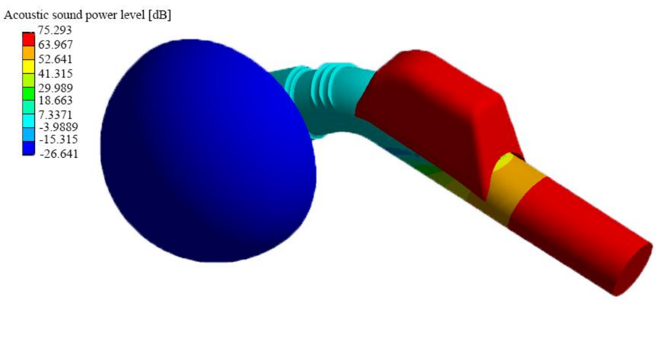
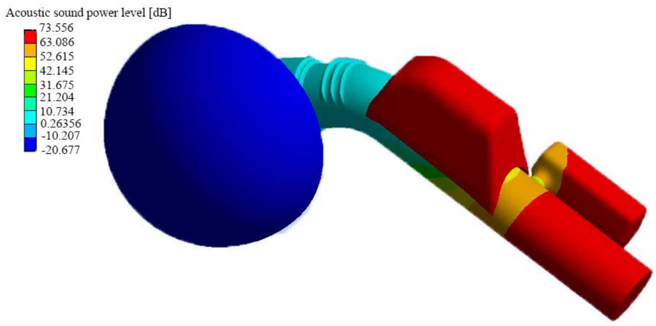


Figure 4: Result of transmission loss in 200~450Hz



(a) Result of acoustic power level at 350Hz



(b) Result of acoustic sound power level at 353Hz

Figure 5: Result of acoustic analysis

Flow analysis due to duct integrated resonator

Boundary condition

Analysis is performed using the values in Table 3 to check the flow rate of the newly designed duct integrated resonator. Engine RPM is assumed as 5000 rpm, and used actual measured value. Inlet and outlet are set as the same as the acoustic model. Here, inlet and outlet are in opposite directions because it intakes external air from the engine side, instead of natural air inflow.

Inflation is created considering the friction at the wall when generating mesh. Same model as Figure 3 is used for detailed flow analysis model.

Table 3: Boundary condition for fluids analysis

Condition	Value
Mass flow rate	264 kg/h
Inlet pressure	-2115 Pa
Outlet Pressure	Atmosphere pressure
Air Density	1.225 kg/m^3
Air Viscosity	1.7894x10^{-5} kg/m·s

Results

Analysis is carried out to check the flow change due to additional mounting of the duct integrated resonator. Cross section is prepared to observe at the hole center of resonator, and velocity vector is obtained as shown in Figure 6. Almost the same results are obtained as the other Helmholtz resonator. A slight difference is observed, which is a small amount of air flow along the wall surface after air intake. It is estimated due to the result of inclined design of the duct integrated resonator from the upper neck side. In conclusion, Case 2 shows an almost similar flow as Case 1. There was some difference in flow noise between Case 1 (54 dB) and Case 2 (64 dB). However, flow noise is not significantly affected by the resonator in both cases because the highest noise of 74 dB is generated at the curved pipe inside duct.

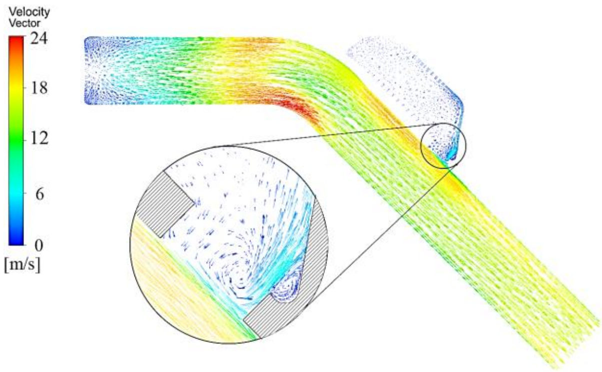


Figure 6: Result of velocity vector in cross section of resonator

CONCULUSION

The duct integrated resonator proposed in this paper can enhance space utilization of the limited engine room space, and acquired the following conclusions:

1) When it is mounted with a Helmholtz resonator simultaneously, it shows 2 dB of transmission loss performance improvement compared to the Helmholtz resonator only mounted case.
2) It is confirmed that the hole at the duct can play the role of the neck for the Helmholtz resonator, and the duct integrated resonator can be adopted as an efficient space design method for limited engine room space.
3) The duct integrated resonator and the Helmholtz resonator showed an almost similar flow. So, it is confirmed that the new resonator does not interfere the flow of the intake system like the existing Helmholtz resonator.

ACKOWLEDGMENTS

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REFERENCE

[1] J.S. Sa, H.G. Kim and C.H Yang, “Understanding Car Vibration Noise”, Cheong-Mun-Gak, 2016:302-311,

[2] C.M. Lee, S.S. Han, B.I. Jung and J.M. Lim, “Development of a Low Noise Intake System Using a Non-Helmholtz Type Resonator”, Korea Society for Noise and Vibration Engineering,2000:1643-1647

[3] H.Y. Song and D.H. Lee, “A Study on the Absorption Performance of a Helmholtz Resonator”, Transactions of the Korea Society for Noise and Vibration Engineering, 2008;18(1):71-79

[4] S.K. Tang, “On the Helmholtz Resonator with Tapered Necks”, Journal of Sound and Vibration, 2005;279: 1085-1096

[5] J.S. Lee, J.H. Kim, S.D. Lee and J.S. Kim, “Experimental Study on the Influence of Helmholtz Resonator for the Intake System of Spark Ignition Engines”, The Korean Society of Automotive Engineers,1994;212-219

[6] J.E. Kim, “Helmholtz Resonator”, Journal of KSNVE, 2015;25(6):24-28