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Study on the Noise Reduction in the Resonator Connection of Automotive Air Cleaner

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Abstract

In an automobile, the intake system refers to the entire process from sucking in outside air to purifying it and supplying it to each cylinder of the engine. Thus, the performance of the intake system is directly related to the performance of the engine. However, within the intake system, variety of flow changes occur in the air cleaner and flow noise due to such occurrence of flow changes. In this research, air cleaner is modeled, the flow changes inside of it are analyzed, and the flow noise that had been generated has been confirmed. The transmission loss of the air cleaner has also been checked. The flow noise was mainly generated at the edge part of the diffuser and the connecting part of the resonator. Additionally, it was shown, in comparison to the existing shape, that 13% of the noise had been reduced by changing the shape of the connecting part and that the frequency band can be changed without affecting the transmission loss value.

Keywords: Intake system, Air cleaner, Resonator, Flow noise, Transmission loss

INTRODUCTION

An overall system for supplying air into the engine cylinder of an automobile is called the intake system. The intake system consists of a snorkel, a duct, an air cleaner, and a resonator. The outside air is sucked into the snorkel and is supplied into the air cleaner through the duct, where impurities are filtered by the filter of the air cleaner then sucked through the diffuser. Next, air is supplied to each cylinder through the throttle valve and the manifold.

The noise generated during this process is called the intake noise, and mainly the dull low noise of below 600 Hz is dominant. The main cause of this is due to pressure pulsation and resonance phenomenon of the airflow, where the types include intake discharge sound, surface radiation sound, and pipe radiation sound, which accounts for 30% of the total noise of the vehicle. However, such intake noise is often constrained in suppression, so it is common to obtain an improvement effect by installing other additional parts such as a resonator [1, 2]. However, these additional parts have a pressure drop effect and produce flow noise at the edge of the mounted area.

In this research, we modeled the air cleaner for automobiles, examined the flow and flow noise of the existing air cleaner, and examined the reduction effect by changing the resonator connection part. Then, we are trying to figure out if there are any changes in transmission loss due to the resonator of the existing air cleaner's altered parts.

INTAKE AIR CLEANER ANALYSIS

Air cleaners installed in automobiles filter impurities in the air from the intake system. The air entering through the snorkel enters the bottom of the air cleaner as shown in Figure 1. Next, the impurities are filtered by the filter then moved to the upper end of the air cleaner, sucked into the diffuser, and flowed toward the engine. The air cleaner is more complicated in shape than the other intake system parts, so various flow changes occur, which results in a large amount of flow noise [3, 4]. Therefore, only a slight change in shape can change the flow and affect engine performance as well [5, 6, 7].

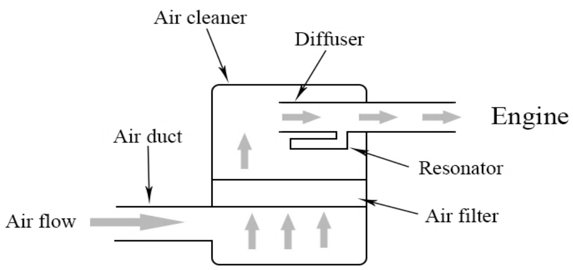
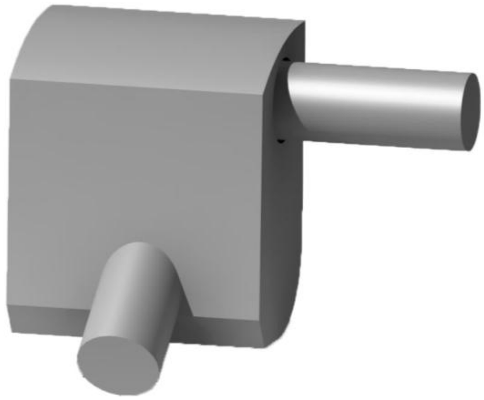


Figure 1: Simple structural diagram of an air cleaner

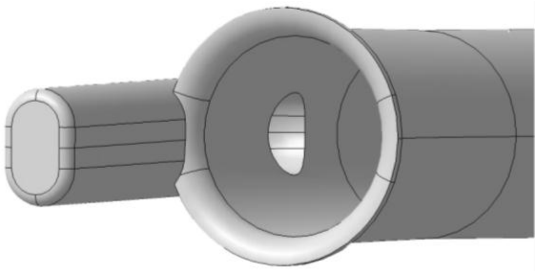
FLOW AND FLOW NOISE ANAYLSIS OF AIR CLEANER

Analysis Modeling

In order to confirm the flow change and noise generation within the air cleaner, the internal fluid volume shape of the air clear was modeled, as shown in Figure 2 (a). Also for the convenience of analysis, unnecessary parts were not formed and the resonator and diffuser were modeled as shown in Figure 2 (b), and the connecting part of the resonator was designed to have no fillet.



(a) Analysis model of internal flow of air cleaner



(b) Diffuser and resonator model

Figure 2: Modeled air cleaner

Analysis Mesh

As shown in Table 1 and Figure 3, the upper and lower sections were considered to have complex flow, so a mesh was formed using a tetrahedral and hexahedra to predict the directional flow of the filter. Also, inflation was applied considering the flow of the wall, which is composed of three layers. The total number of mesh was about 1.34 million.

Table 1: Boundary condition in air cleaner

Part	Method
Upper	Tetrahedra
Lower	Tetrahedra
Filter	Hexahedra

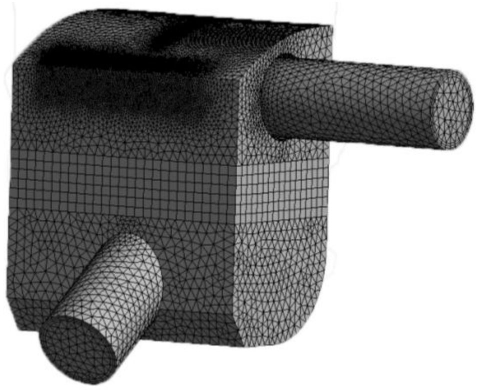


Figure 3: Mesh creation of air cleaner

Cell Zone Definition

Since the expression and performance of the filter of the air cleaner is difficult, the porous media setting was used from the analysis program in order to perform the effect of the filter. The detailed input bale of the porous media for the filter part is shown in Table 2.

Table 2: Cell zone condition in air filter

Condition	Value
Filter Porosity	0.85
Viscous Resistance	2487 1/m^2
Inertial Resistance	18.19 1/m

Solver Set Up

Since the k-ε model can predict the boundary layer under strong turbulent gradient or separation in comparison to other turbulence models, it was used for this analysis. Also, a more stable realizable model was used instead of the standard model. Additionally, since the air cleaner flow is an incompressible flow, the simple algorithm was used and for the pressure calculation method, PESTO! Technique, suitable for sudden pressure change, was used considering the porous media setting.

Table 3: Solver set up

Condition	Value
Solution Method	Steady state
Solution Algorithm	Simple
Turbulence Model	k-ε model
Interpolation Methods for Pressure	PESTO!

Boundary Condition

The characteristics of the air in the inlet and the input values are used as experimental results. The engine speed used in this analysis is set to 3500 rpm, which is the range of the engine rpm that is changed to the commercial rpm band.

The detailed values relative to the air characteristics and flow rates are shown in Table 4.

Table 4: Boundary condition in air cleaner

Condition	Value
Mass flow rate	171 kg/h
Inlet pressure	Atmosphere pressure
Outlet Pressure	-1322 Pa
Air Density	1.225 kg/m^3
Air Viscosity	1.7894x10^{-5} kg/m·s

Harmonic Response Set up

For the analysis of transmission loss of the air cleaner, Acoustic model values for air characteristics and speed were set as shown in Table 5.

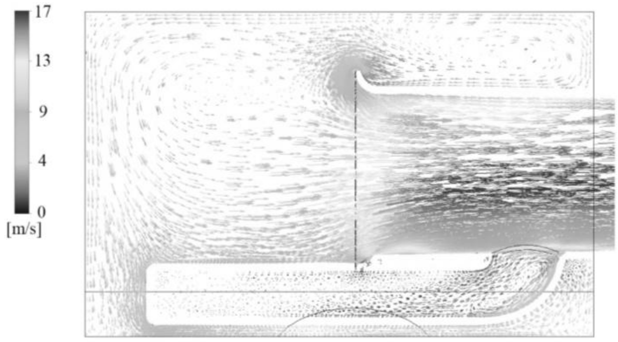
Table 5: Parameters of harmonic response

Condition	Value
Mass Density	1.2041x10^{-9} kg/m^3
Sound Speed	343.24 m/s
Bulk Viscosity	1.096x10^{-5} Pa·s
Thermal Conductivity	2.57x10^{-2} W/m·C
Specific Heat C_p	1.005 J/kg·C
Specific Heat C_v	0.718 J/kg·C
Reference Pressure	2x10^{-5} Pa
Reference Static Pressure	101,325 Pa
Amplitude of Normal Velocity	200 m/s

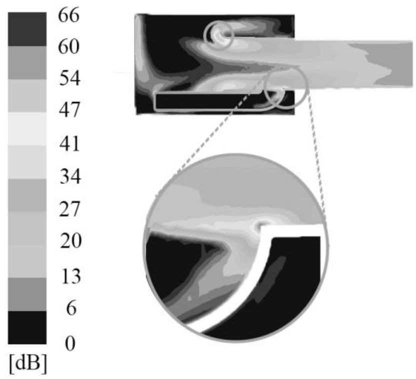
Analysis Result of Flow and Flow Noise

The pressure drop of the existing air cleaner was 141.26 Pa. As a result of analyzing the cross-sectional flow of the diffuser of the air cleaner, a small amount of air enters and exits the resonator as shown in Figure 4 (a). However, it was confirmed that the flow of air flowing through the diffuser was fast and was not affected by the air that came out again from the resonator.

The result of viewing from the flow noise confirmed that a large amount of flow noise occurred at the connecting part of the resonator and the edge part of the diffuser as shown in Figure 4 (b). It was confirmed that a rather high noise of 66 dB occurs due to the non-smooth shape especially at the connecting part.



(a) Vector flow in air cleaner XY plane



(b) Flow noise in air cleaner XY plane

Figure 4: Analysis result of normal air cleaner

Analysis Result of Transmission Loss

We confirmed that the target frequency of 500 Hz is the target frequency by checking the transmission loss target frequency by the existing air cleaner resonator, as shown in Figure 5.

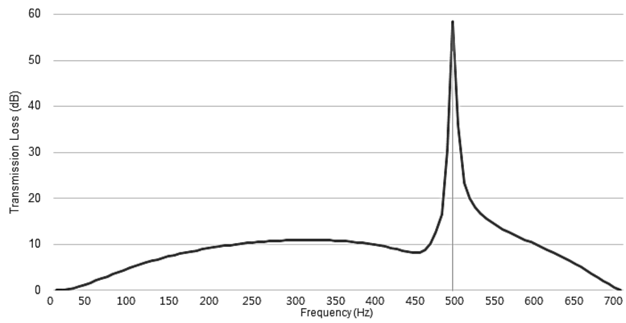


Figure 5: Transmission loss of normal air cleaner

REDUCTION EFFECT ANAYLSIS BY IMPROVING THE CONNECTING PART OF THE RESONATOR

Analysis Modeling

It was confirmed that the flow noise was generated in the connecting part of the resonator within the air cleaner. The case values are set as shown in Table 6 while changing the radius value of the connecting part. Case 1 was set as an existing air cleaner, and the remaining cases were set by raising the radius value. When the radius value was greater than 3.5mm, the curved shaped was not formed smoothly since it was larger than the thickness, and the maximum value was set to 3.5mm in order to maintain the existing shape as much as possible. The altered shape was the same as Case 6 in Figure 5, and the shape of the remaining cases, except case 1, is changed as in Case 6. The circle in Figure 5 shows the position of the altered shapes.

Table 6: Radius value of each air cleaner case

Case	Radius Value
Case 1(Normal)	R=0
Case 2	R=1.5mm
Case 3	R=2.0mm
Case 4	R=2.5mm
Case 5	R=3.0mm
Case 6	R=3.5mm

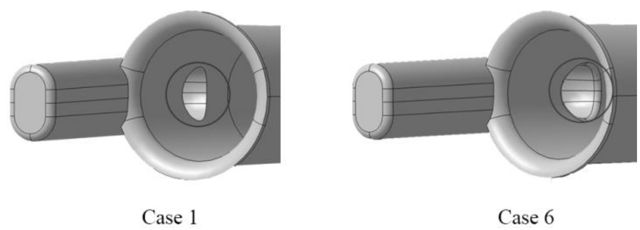


Figure 5: Differences in shape of the resonator mount

Analysis Result of Flow Noise

The change in flow around the resonator due to the altered shape was almost the same as that of the existing air cleaner. This is considered to be negligible since the flow rate in the diffuser is faster than the flow rate of the connecting part of the resonator. However, there were many differences in flow noise; it is considered that the natural flow in the curved surface part affected the noise. As a result, the flow noise can be reduced by up to 13% at the radius of 3.5mm. The flow noise of each case is shown in Figure 6. Also, each pressure drop was the same or only slightly different from the existing air cleaner, as shown in Table 7.

Table 7: Pressure drop of each case

Case	Pressure drop
Case 1(Normal)	141.2 Pa
Case 2	141.3 Pa
Case 3	141.0 Pa
Case 4	140.9 Pa
Case 5	140.7 Pa
Case 6	140.5 Pa

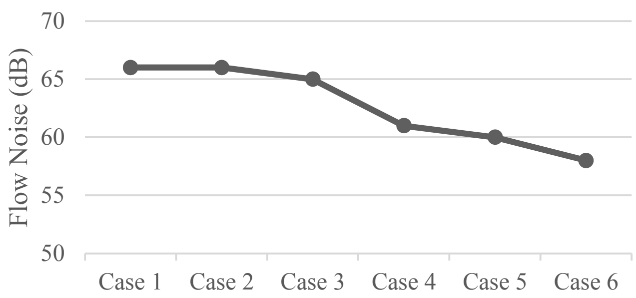


Figure 6: Flow noise of each case

Analysis Result of Transmission Loss

It was confirmed that the resonator target frequency of the exisiting air cleaner was 500 Hz previously, and the analysis frequency range was set to 450 to 550 Hz in order to check whether the resonator caused by the changed shape affected the resonator. The transmission loss value of each case is shown in Figure 7. There was no significant difference in the transmission loss due to the change of shape within 2 dB, but it was confirmed that the target frequency band had gradually increased as the edge radius value increased for each case. This was because the volume of the resonator neck part changed due to the curved surface part and the target frequency band was changed.

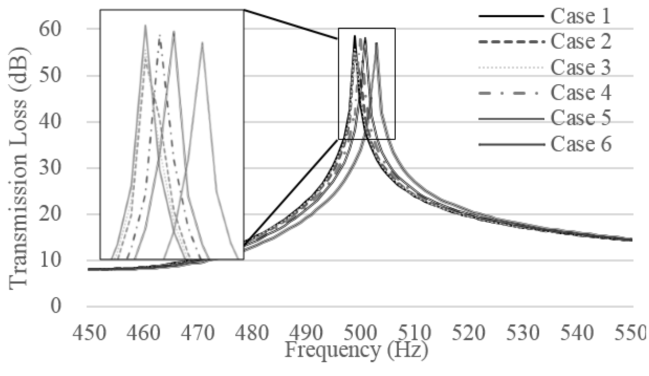


Figure 7: Transmission loss of each case

CONCLUSION

In this research, the flow, noise and transmission loss of air cleaners for automobiles were analyzed and the following results were obtained:

1) The flow analysis of the air cleaner showed almost no flow change due to the resonator, but it was confirmed that a large amount of flow noise was generated at 66 dB.
2) The flow noise can be reduced by up to 13% by improving the connecting part of the resonator of the air cleaner to a curved surface.
3) Through the analysis of transmission loss, it was confirmed that the target frequency value can be changed due to the changed shape, and it was confirmed that the transmission loss value may also be slightly reduced.

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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] David A. Crolla, "Automotive Engineering: Powertrain, Chassis System and Vehicle body", Butterworth-Heinemann is an imprint of Elsevier, 2009;762-773

[3] K.L Srinivasulu, D. Srikanth, K. Rafi and B. Ramanjaneeyulu, "Optimization of Air Filter in an Automobile Diesel Engine by CFD Analysis", IOSR Journal of Mechanical and Civil Engineering, 2016;13(2):78-89

[4] A.S. Phulpagar and N.S Gohel, "CFD Analysis of Air Intake System", International Journal on Theoretical and Applied Research in Mechanical Engineering, 2015;4(2):45-48

[5] W.S. Choi, "Study about Nvh Optimization of Air Intake System", The Korean Society of Automotive Engineers, 2008;145~149

[6] J.W. Ryu and Y.H. Noh, "An Optimized Design of Intake System Verification with CAE Simulation and Performance Test", The Korean Society of Automotive Engineers, 2016; 13(2):866-871.

[7] M.S. Lyu, "A Study on the Performance Improvement in the Intake System of a Large-sized Commercial Bus", The Korean Society of Automotive Engineers, 2005;13(2):16-21