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Air Flow Analysis of Snorkel in Vehicle Intake System

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Abstract

Air intake systems perform the role of supplying clean air to the engine, but cause intake noise, which accounts for a substantial portion of vehicle noise. Studies have been carried out by numerous research institutes to reduce the intake noise of air intake systems, but due to the increasing need to reduce its costs, it has become more difficult than ever to satisfy noise level targets using less sound absorption/insulation materials.

The purpose of the present study is to analyze air flow and noise from an intake snorkel under vehicle operation conditions, and to adjust height/width ratios to propose an optimized intake snorkel appropriate to the experimental model. Assuming fixed engine revolutions at 5,000RPM and a flow rate fixed at 264kg/h, the speed of the air taken in by the vehicle grille was varied among cases. With flow rate and rpm fixed, turbulence and noise in the turbulence tended to increase with the flow speed of the air entering the grille. A model with a width to height ratio of 1:1.6 was found to be optimal.

Keywords: Air intake system, Intake noise, Snorkel, Air flow

INTRODUCTION

A broad range of research has been carried out to reduce intake noise, which accounts for a substantial portion of engine noise. Until now, studies on noise reduction methods have used resonators or multiparous sound insulation/absorption materials, or reduced noise using active noise control methods. However, such noise reduction methods result in reduced engine output, hinder air flow, and cause intake noise. Most of the intake noise from a vehicle is accounted for by airborne noise, which is caused by the engine. Here, noise radiates from the engine to the snorkel, against the flow of air from the snorkel toward the engine. The intake noise caused by air intake systems is shown in Fig. 1. As shown in the figure, surface radiated sound and intake radiated sound radiate in the direction opposite air flow[1-3].

In the present study, fluid flow within the snorkel was modeled assuming the vehicle is running. Using a general finite element analysis program, the impact of changes in air intake speed caused by variations in vehicle speed was determined.

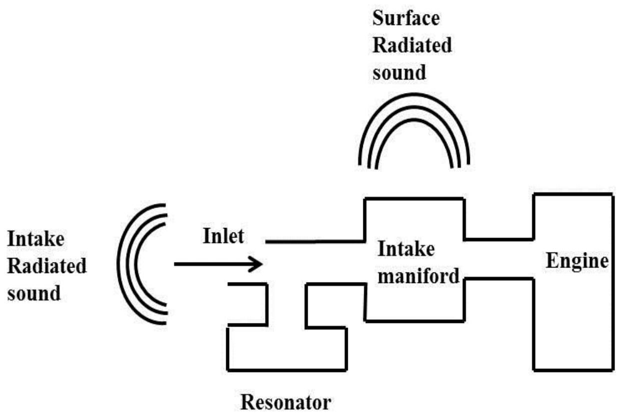

Figure 1: Paths of noise generation in an intake system

INTAKE SNORKEL

Intake system components include an air intake snorkel, air ducts, air cleaner, surge tank, intake manifold and various resonators. Figure 2 is a simple representation of snorkel components. The air snorkel, a part of the intake system, is a part used to uptake clean outside air required for engine combustion.

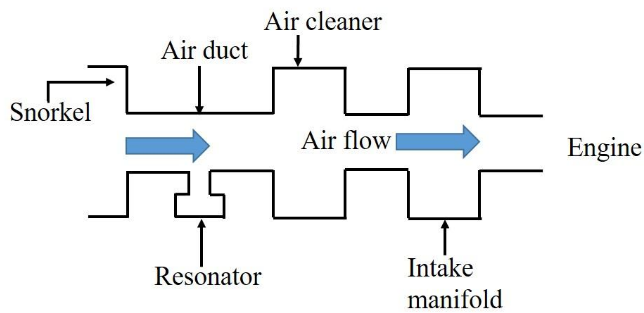

Figure 2: Simple structural diagram of an intake system

Here, the air snorkel is located in front or on the side of the engine room, depending on the vehicle. When located in front of the engine room, the air intake efficiency is good, and the simple structure allows for ease of servicing. However, intake noise enters the cabin. When located on the side of the engine room, the longer length of the intake system results in lowered air intake efficiency. Also, engine output and intake noise respond sensitively to the length and cross section of the intake port [4].

Air flow and flow noise analysis of air intake system snorkel, and snorkel optimization

Analysis Modeling

To analyze flow characteristics depending on changes in air intake speed, assuming the vehicle is running, the snorkel of the air intake system and their air taken in were modeled as shown in Fig. 3. Here, the direction of air flow is indicated by the arrows in Fig. 3. Then, to reduce snorkel noise and improve air flow, flow analysis was carried out for model optimization, adjusting the width to height ratio of the snorkel opening while maintaining the same cross section. The model used for this analysis is shown in Fig. 4. As indicated by the arrows, the air enters Inlet 2, and exits from Outlet 3.

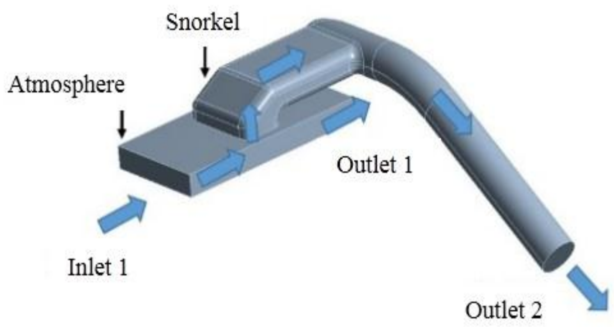

Figure 3: Intake snorkel model analysis

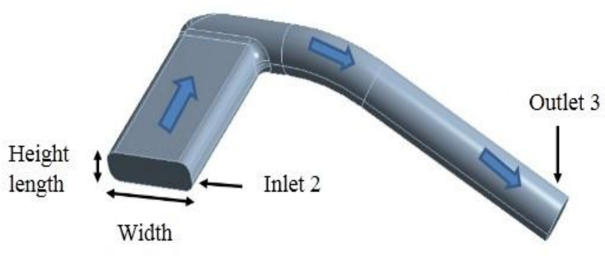

Figure 4: Analysis model for air intake snorkel optimization

Boundary condition

Assuming incompressible perfect turbulent flow within the air intake snorkel, analysis was carried out using the K-ε model, which is most commonly used to recreate turbulent flow.

Data on the boundary conditions for air properties at the inlet and outlet are shown in Table 1. To compare the air flow within the snorkel depending on the speed of air taken in through the engine grille, the flow rates were set as shown in Table 1.

The cross section of the snorkel to be optimized was fixed at 7500mm2, with the width-to-height ratios and inlet/outlet boundary conditions shown in Table 2. Flow rate and air characteristics were set as shown in Table 1.

Table 1: Simulation boundary condition in intake snorkel

Condition	Value
Mass flow rate	264 kg/h (at 5,000 rpm)
Inlet	Inlet 1 : Atmosphere Case 1 : 2m/s (Velocity magnitude) Case 2 : 4m/s (Velocity magnitude) Case 3 : 6m/s (Velocity magnitude)
Outlet	Outlet1 : 0 Pa (gauge pressure) Outlet2 : -2,115 Pa (gauge pressure)
Air properties	Density = 1.225 kg/m^3 Viscosity = 1.7894x10^{-5}kg/m·s

Table 2: Boundary condition in intake snorkel for optimization

Condition	Value
Inlet	Inlet 2 : Atmosphere
Outlet	Outlet 3 : -2,115 Pa (gauge pressure)
Width to height ratio	Case 5 = 1:1.6 (A=7500mm^2) Case 6 = 1:2 (A=7500mm^2) Case 7 = 1:3 (A=7500mm^2) Case 8 = 1:4 (A=7500mm^2) Where A is cross section of snorkel

Analysis results

Analysis of flow within snorkel when vehicle is running

Assuming the vehicle was running, engine revolutions were fixed at 5000 rpm, and intake the flow rate was varied to analyze flow. Fig. 5 shows the streamline for flow within the air intake snorkel in each case.

It can be seen that, while only small vortices are created when the flow rate of air taken in at the grille is 2m/s or 4m/s, substantial vortices are created when the flow rate is 6m/s or 8m/s.

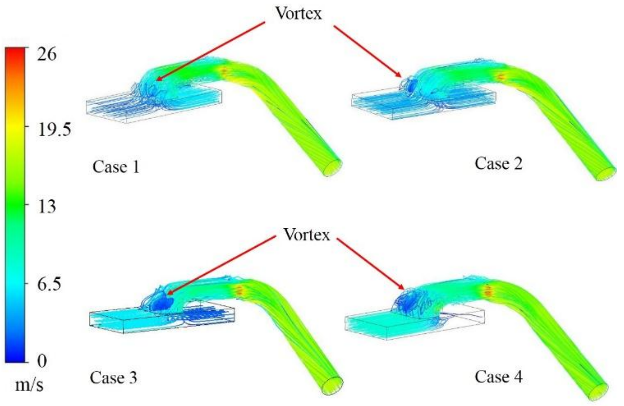

Figure 5: Air flow streamline

It can also be seen that when intake flow rate is low, air is taken in in the direction of the snorkel not only at Inlet 1 but also at Outlet 1. As the flow rate increased, however, the volume of air taken in at Outlet 1 gradually decreased. The flow rate of air taken in by the snorkel must remain constant, and it is judged that the low flow rate is made up for by taking air in through Outlet 1 when the speed of air taken in through the grille is low.

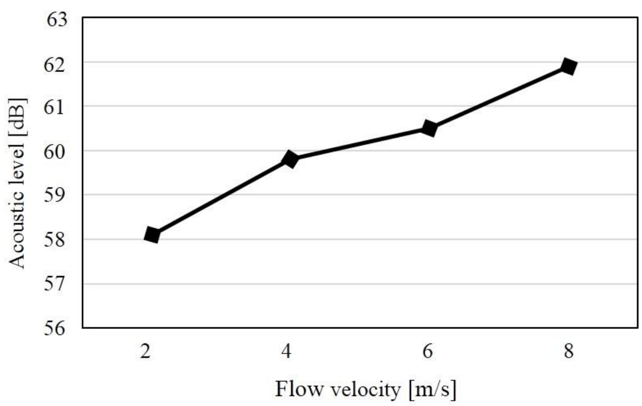

Figure 6: Air flow noise according to flow velocity

In Fig. 6, it can be seen that air flow noise also increases. That is, it was confirmed that vortices and air flow noise increase together with the speed of air entering the intake. Vortices hinder normal flow, and more specific future studies are required to resolve this problem.

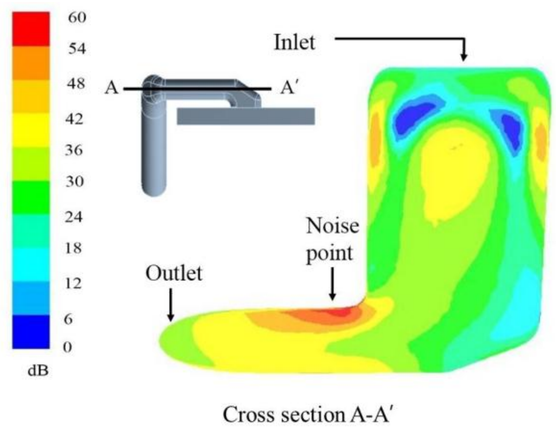

Figure 7: Air flow noise within the snorkel

Fig. 7 is a cross section showing flow noise inside the pipe at 5,000 rpm and 8m/s inlet flow rate. Noise of up to 60dB occurred at the snorkel and the curved section of the pipe. Here, the sudden change in air flow caused by the snorkel and the bend in the pipe cause noise to be generated.

Analysis of optimized models with adjusted snorkel width-to-height ratios

The air flow noise and flow rates depending on snorkel width-to-height ratios are shown in Table 3. It can be seen that Case 6 has the lowest noise levels.

Table 3 : Flow noise and flow rate by optimization case

Model	Flow noise (Max)	Flow rate (Max)
Case5 (1:1)	60.5 dB	26.3 m/s
Case6 (1:1.6)	54.9 dB	26.0 m/s
Case7 (1:3)	62.7 dB	26.9 m/s
Case8 (1:4)	75.3 dB	26.0 m/s

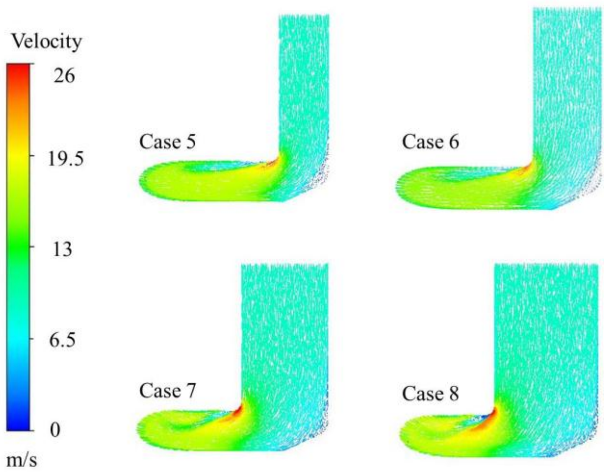

Figure8: Flow rate vectors by case

Fig. 8 shows the flow rate vectors for each case. It can be seen that when the width-to-height ratio is 1:1.6 (Case 6), the height of the air intake pipe and the snorkel are the same. Here, the flow is smoother than in other cases, as the resulting shape is neither an expansion chamber nor a reducer.

CONCULUSION

In the present study, the snorkel of air intake systems was discussed. Through finite element analysis, air currents and air flow noise inside the intake snorkel were analyzed and optimized, and the following conclusions were reached.

1) It was found through finite element analysis that more vortices were generated within the snorkel as intake flow rate increased. Future research on this matter is necessary.
2) The highest levels of air flow noise occurred at the bent sections within the snorkel, with a minimum level of 54.98dB and a maximum level of 68.57dB.
3) By fixing the cross sectional area of the snorkel inlet and adjusting the width-to-height ratio, an optimized model with a width-to-height ratio of 1:1.6 was found to have low air flow noise and smooth air flow.

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