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Flow Analysis of Air Intake Duct for Noise Reduction in Automobile

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Abstract

The air intake system of an automobile engine is divided into the dirty side from the passage where air intake begins through to the air cleaner and the clean side from the sir cleaner to the section just in front of the air intake manifold. In this study, the dirty side of the air intake system was selected for interpretation with the setting of the parameters such as the flux, pressure and temperature that corresponds to each of the numbers of the engine speed (RPM) as the terms of interpretation. Flux, pressure and noise within the air intake equipment were then obtained by using the said parameters in order to analyze and forecast the flow pattern and characteristics of the air intake system to be used as the basic data in an effort to reduce the flow noise. The air intake system was modeled by using CAITA while the analysis of the flow and noise was executed by using the ANSYS finite element interpretation program. The majority of the noise due to intake flow occurred at the inlet of the intake system and was confirmed to be approximately 78dB at 5,000rpm.

Keywords: Intake System, Dirty Side, Intake Noise, Flow Analysis, Resonator, Internal Flow

1 Introduction

All efforts are being devoted to creating even better automobiles that satisfy the demands of the consumers in the midst of the global automobile market, which is becoming increasingly more and severely competitive. Human-centered technologies for the designing and manufacturing of the automobile, particularly the technologies for the reduction of noise and vibration of automobile, are advancing rapidly through the development in overall aspects of the automobile industry throughout the world.

Automobile engine manufacturers are focusing their interests on the noises generated by the air intake system. The reduction in the noise of the air intake system plays very important role in the overall automobile noises, and the air intake noise is made mostly of the Airborne Noise generated by the engine. The range of audible frequency of an ordinary person is 20~20000Hz and the noise generated in the automobile belongs to low frequency range of 0~600Hz in general. Therefore, efforts are generally put in for the reduction of the air intake noises in the frequency range of 60~200Hz, which are perceived particularly well by the passengers of the automobile, in considerations for the audible frequency of human when developing and designing the automobile. Moreover, the desires of the consumers for outstanding quality of the sound are increasing and becoming a highly important element in the automobile market. Noise emitted from the entrance of air intake system is the result of the overlapping of the characteristics of the source of the noise and the resonance characteristics of the air intake system. Methods including the use of vibration-damping steel plate, application of control valve, and the use of even stronger brackets and cushions with further reduced hardness are employed for the purpose. In many cases, although the air cleaner (corresponding to simple expansion) substantially reduces the air intake noise, resonator, etc. is being installed in the air intake system in order to reduce the air intake noise to a greater extent.

In addition, due to the reasons of the improvement of fuel efficiency and regulations on exhaust gas, the automobile industry is able to reduce engine displacement by combining the turbo supercharger or direct fuel injection format of technologies in order to obtain high output and fuel efficiency at low engine displacement. The installation of engine components such as a turbo supercharger has reduced the existing available spaces, thereby resulting in an air intake system configuration and cross-sectional changes. Accordingly, research on the application of Polyethylene terephthalate (PET) to mass produced vehicles by transcending the existing practice of using the plastic as the raw ingredient are currently being carried out.

This Study is a basic research for the development of PET and will execute flow interpretation on the dirty side of the air intake system. Flux, pressure and temperature that correspond to each of the engine speed(RPM) were set as the parameters, and the ensuring flow velocity, pressure and noise within the air intake equipment were extracted. The outcome was then used to analyze and forecast the flow pattern and characteristics of the air intake system, and as the basic data for the reduction of flow noise. The air intake system was modeled by using CAITA and the ANSYS finite element interpretation program was used for the flow and noise analysis.

2 Analysis modeling and boundary conditions

Internal flow analysis of the air intake system was executed by using ANSYS FLUENT, which is a widely used flow stream analysis program. The reynolds numbers computed by using the hydraulic diameter and the air intake flux at the entrance of the air intake system are greater than 10^5. Therefore, in order to replicate the turbulent flow by presuming that the internal flow of the air intake system is an incompressible complete turbulent flow in normal, this Study executed numerical analysis by using the realizable K-ε turbulence model provided by FLUENT. In addition, continuity equation and momentum equation were used to compute the air velocity and pressure distribution. Fluid within the system was presumed to be air at room temperature that undergoes steady flow for the purpose of the ease of analysis. As illustrated in the figure 1, the air intake system is composed of an air intake pipe, a resonator and an air cleaner. In this study, flow analysis of only the dirty side will be executed.

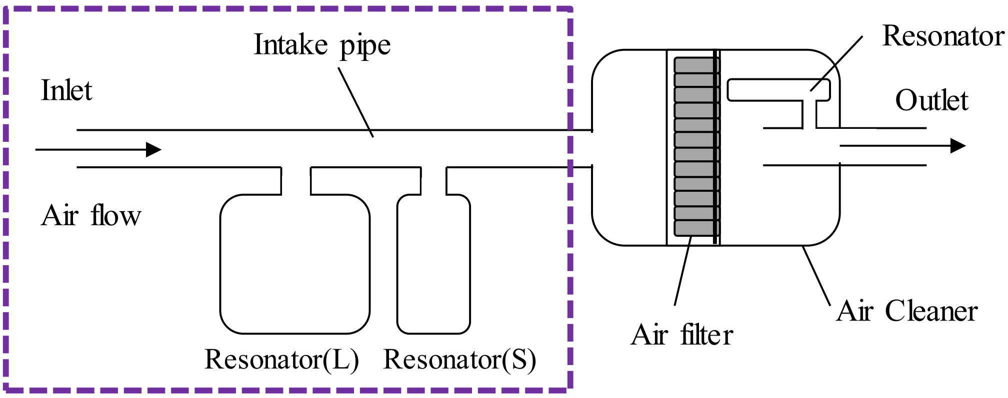

Fig 1. Schematic diagram of air intake system

Figure 2 illustrates the air intake system model and mesh model used at the time of flow interpretation. The pressure condition was set at atmospheric pressure in order to allow influx of air into the air intake system from the atmosphere. The hemisphere was modeled at the air flow inlet in order to realize the intake of air from the atmosphere. Moreover, air intake flux and the velocity boundary conditions that correspond to such flux at the air intake system outlet were applied as the interpretation conditions in order to allow the air to forcibly enter the inner aspects of the air intake system by the piston action of the engine. The boundary conditions of the inlet, outlet and air properties in accordance with the engine rev. count are given in the table 1. The finite elements are composed of approximately 1.5 million meshes, and an inflation mesh was used to mimic the boundary layer at the internal walls of the air intake system.

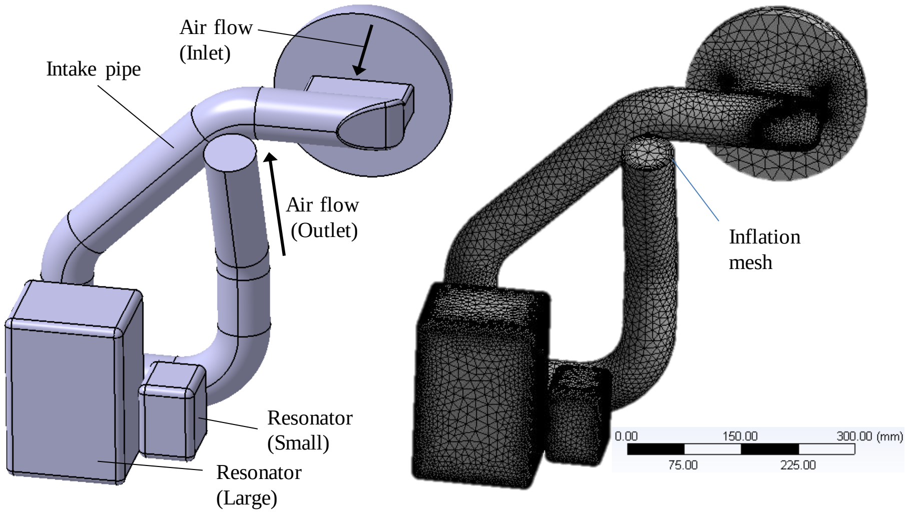

Fig 2. Air intake system model and meshes

Table 1. Simulation boundary condition

Condition	Value
Inlet	Pressure = Atmospheric pressure
Outlet	Case1 (1,000rpm) = 42 kg/h Case2 (2,000rpm) = 87 kg/h Case3 (3,000rpm) = 140 kg/h Case4 (4,000rpm) = 207 kg/h Case5 (5,000rpm) = 264 kg/h
Air properties	Density = 1.225 kg/m^3 Viscosity = 1.515x10^{-5} kg/m·s

3 Analysis results

Figure 3 illustrates the flow patterns within the dirty side (air intake pipe, resonator). Although small rotational flow was generated in the intermediate pipe situated between the resonator and the air intake pipe, the majority of air displayed the tendency of passing through the resonator. Same tendencies were observed in all the case conditions.

Figure 4 illustrates the pressure in accordance with the changes in the flux, which is greatest at the intake inlet. Pressure difference was generated within the pipe due to the curvatures of the air intake pipe. Although there was a difference in the pressure in accordance with the flux for each of the cases, they all displayed the same tendency. In addition, it was possible to confirm that the internal pressure of the resonator decreased as the flux of the air taken in increased.

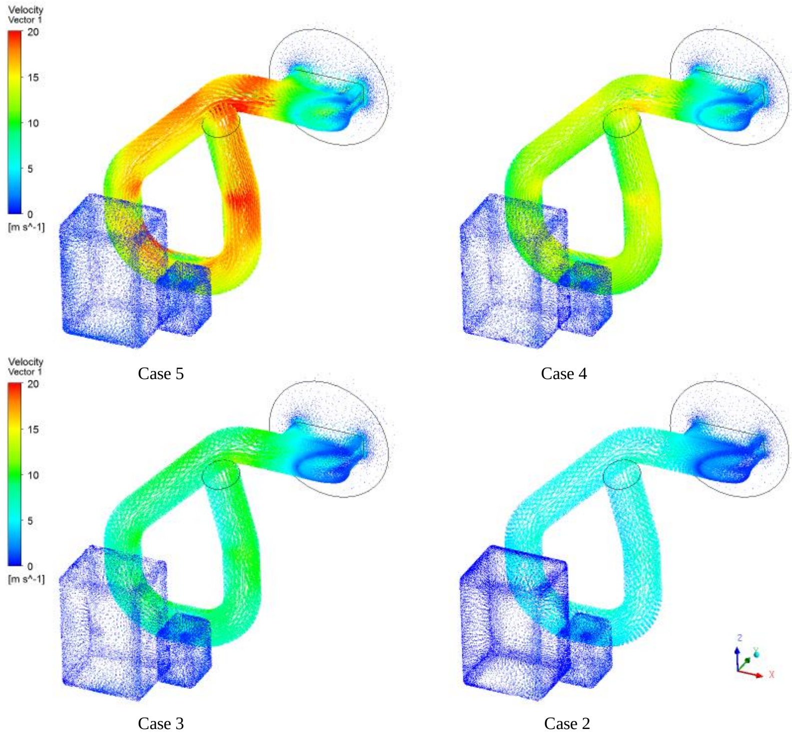

Fig 3. Velocity flow of intake system

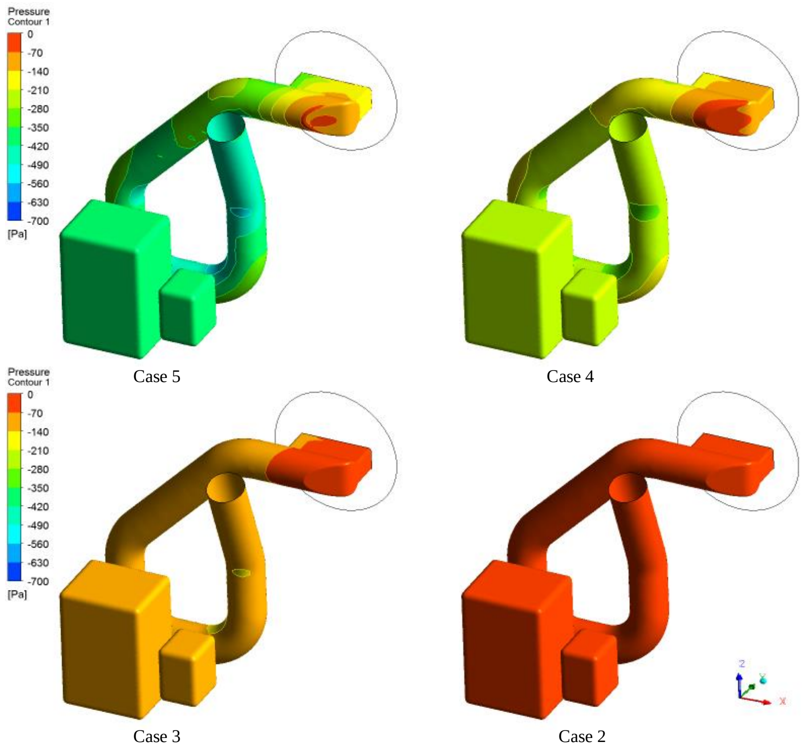

Fig 4. Pressure of intake system

Diagram 5 illustrates the results of flow noise at 5000rpm. The majority of noise occurred in the air intake pipe and, in particular, the maximum noise at the intake inlet was approximately 78dB. It is deemed that noise is generated as the air collides with the walls of the air intake pipe as the direction of the flow changes rapidly as well as due to an increase in the flow velocity as the flow area decreased. Moreover, it was confirmed that there is no generation of noise in the resonator since there isn't any flow into the resonator.

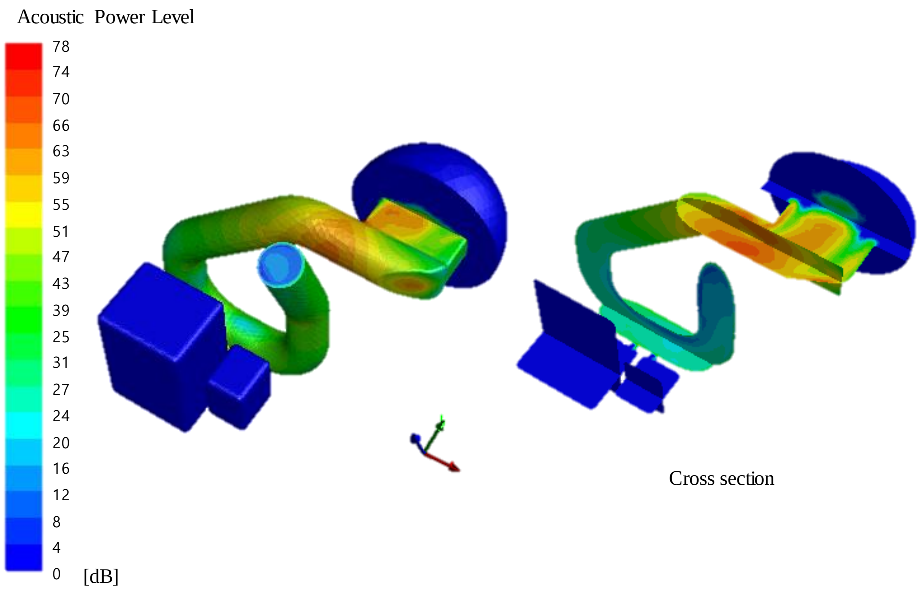

Fig 5. Acoustic power level at 5000rpm

4 Conclusion

In this study, simulation of the air intake system was executed along with the analysis of the flow analysis. Flow pattern and characteristics of the air intake system were forecasted through the finite element analysis technique, and used as the basic data for the reduction of flow noise.

The majority of noise due to the flow of air intake occurred at the inlet and was confirmed to be approximately 78dB at 5,000rpm. It is deemed that even greater noise will be generated if the noises generated inside the engine cylinder and flow noises are added. Since the air intake noise in automobiles propagates in the opposite direction of the flow of the air intake, which has low temperature and low flow velocity, predictable modeling would be possible if the forecast and improvement in the early stage of the problems that would be incurred in the future by using the data obtained from the analysis of such air intake model onto the designing of the air intake system.

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