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Flow Analysis on Formation of Back-pressure in Exhaust System Applying Electronic-variable Valve

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Abstract

In the present study, the Conducting copy device was made as considering the position of electronic-variable valves in the exhaust system. Using the device, which was made to be similar to an actual engine, basic testing was conducted. Based on these results, ANSYS analysis was performed. As for the analysis method, 5 angle variables for opening angle and 6 flow variables were used. As for analysis conditions, analysis was conducted based on the data from the basic testing. For increased precision of results, analysis was repeated 5 times. Results of analysis according to the opening angle of the valve showed that the maximum pressure range and maximum velocity around the valve increased with the angle. Also, analysis according to flow showed that maximum pressure range increased with flow, and formation of low pressure behind the valve due to development of flow was pronounced. Therefore, through the present study, it was concluded that the angle or exhaust flow of electronic-variable valves impact the formation of bask pressure in exhaust systems.

Keywords: Conducting Copy Device, Electronic-variable Valve, Exhaust System, Low Pressure Exhaust Gas Recirculation, Velocity Range

1. Introduction

Current motor vehicle technology development trends are dominated by efforts toward engine performance enhancements, downsizing for improved mileage at a given output, meeting environmental regulations, and the development of exhaust systems to reduce noise and improve performance [1–4].

With the current reinforcement of environmental regulations such as Tier 4 or EURO-VI, research into exhaust systems is required. Exhaust systems also need improved silence and enhanced engine power performance. As for relevant preceding researches, exhaust gas post cleaning technologies such as Diesel Oxidation Catalysts (DOC) to reduce hydrocarbon compounds and carbon monoxide, DPF to remove PM, and Urea-SCR, reducing NOx by spraying urea, are being developed. Also in progress are studies on valves or coolers for exhaust gas recirculation systems, along with studies to reduce exhaust system noise by attaching variable valves to the muffler [2–4]. Whereas many studies such as the above are in progress, studies to enhance the efficiency of LP EGR have not progressed much. This study attempts to maximize flow into the LP EGR using an electronic-variable valve [5,6]. It is difficult to analyze the impact of changes in the opening angle of electronic-variable valves within the exhaust system on flow. As maintaining uniform RPM and back pressure is difficult, this may result in data measurement errors [7].

Therefore, this study purposes to design and make a conducting copy device to examine the impact on back pressure characteristics of the internal components of exhaust systems. Using the analysis program ANSYS, the pressure range and velocity range within electronic-variable valves will be identified.

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2. Test and Analysis Method

2.1 Research Model

The position of the electronic-variable valve is as shown in Figure 1. Electronic-variable valves form back pressure by blocking the flow of the exhaust system. This back pressure increases the flow into the LP EGR.

2.2 Conducting Copy Device

Data was measured at 5 angles (0˚, 8˚, 18˚, 28˚, 38˚) and at 6 rates of flow. For increased precision of results, testing was repeated 5 times, and results were averaged.

As extraction of data for an electronic-variable valve located in an exhaust system is rather difficult, this study made a conducting copy device with an electronic-variable valve set up to measure back pressure according to opening angle, which is difficult to measure in actual exhaust systems.

The conducting copy device was made as shown in Figure 2, Table 1 shows the specifications for the components of the conducting copy device. In consideration of the position of the electronic-variable valve, the exhaust valves were arranged in line. The blow motor positioned on the left, and the DP flow meter and electronic-variable valve arranged in line. Flow was calculated by measuring the pressure differential at the DP flow meter using an indicator. Back pressure was measured before and after the electronic-variable valve.

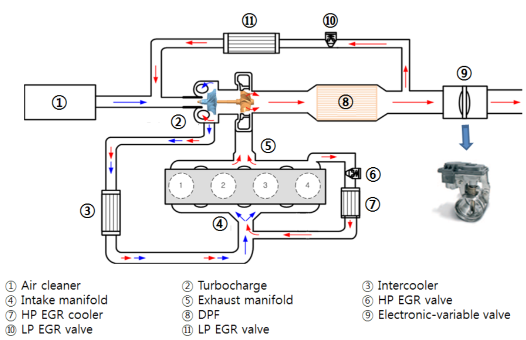

Figure 1. Exhaust system schematic.

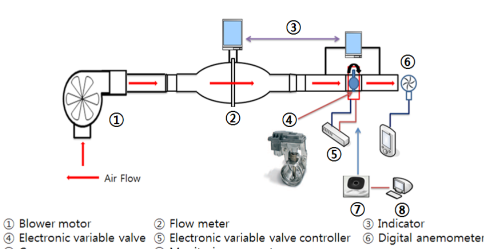

Figure 2. Schematic diagram of conducting copy device system.

2.3 Analysis Conditions and Method

In the present study, the CATIA V5 electronic-variable valve for motor vehicles was used to conduct 3D modeling at the same size as the actual model. Figure 3 is a photo of modeling according to the angle of the electronic-variable valve. For analysis conditions, valve opening angles of 0 ˚, 8˚, 18˚, 28˚, and 38˚ were used. As for input values, data measured from the conducting copy device was used. An output of 101.325 kPa, atmospheric pressure, was assumed. Assuming air at 25˚ with normal flow along the material within the boundaries, analysis was conducted with 1,396,466 particles and 261,783 contact points for the grid. For increased precision of results, analysis was repeated 5 times.

For analysis, the material used was SUS (Stainless Steel) 405. The material properties of the material are shown in Table 2.

Table 3 is analysis condition. To verify back pressure formation in the electronic-variable valve, analysis was

Table 1. Device component specification

Item	Specification
Blow motor	• Capacity : 10 m^3/min • Accuracy : ±3%
Flow meter	• DP(pressure)/Process connection: hose type • Accuracy : ±3%
Indicator	• Repeatability : 0.1% • Response time : 16 ms
Digital Anemometer	• Range : 0 ~ 45 m/s • Accuracy : ±3% ±0.1 dgts

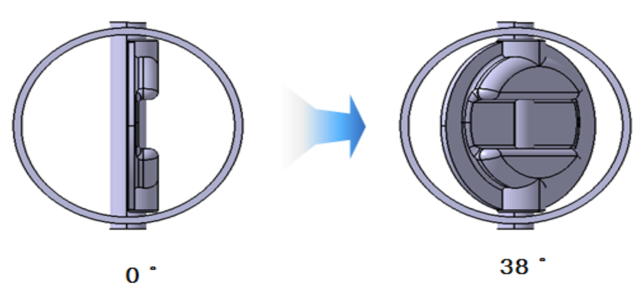

Figure 3. Electronic variable valve modeling of angle.

conducted at the same flow for each angle. The conditions for analysis were as shown in Table 3. Analysis for increasing flow at the same angle was conducted. The conditions for analysis were as shown in Table 4.

3. Results and Discussion

3.1 Results of Measurement from the Conducting Copy Device

Figure 4(a) is a graph of wind interval and velocity. It can be seen in this graph that with increasing wind interval, velocity at the exit increasing accordingly. It can also be seen that with increasing angle, exit velocity decreases. This is thought to be due to the reduction in pipe cross section resulting from the increased angle of the valve in the exhaust pipe. Figure 4(b) is graph of wind interval and differential pressure of valve as opening angle of electronic-variable valve. Differential pressure of valve is increased as increasing wind interval in this graph. As for the smaller differences between 0 ˚ and 8 ˚, and 28 ˚ and 38 ˚, it is thought that the two graphs approach each other due to the small change in valve area relative to exhaust pipe area.

Table 2. Material specification of electronic-variable valve

Item	Specification
Density(kg/m^3)	7800
Poisson's Ratio	0.3
Young's Modulus(Pa)	2E+11
Tensile Yield Strength(Pa)	2.76E+08
Tensile Ultimate Strength(Pa)	4.69E+08

Table 3. Analysis conditions of Input pressure of angle parameter

Angle	0˚	8˚	18˚	28˚	38˚
Pressure (kPa)	0.195	0.218	0.385	0.5	0.54

Table 4. Analysis conditions of Input pressure of flow parameter

Speed interval	1	2	3	4	5	6
Pressure (kPa)	0.238	0.432	0.5	0.537	0.57	0.59

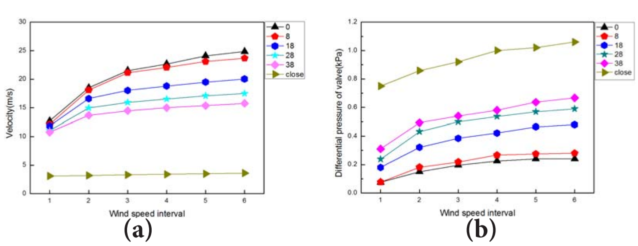

Figure 4. Result of exhaust conducting copy device experiment, **a** Wind interval – Velocity graph and **b** Wind interval – Valve graph of DP

3.2 Analysis Results

3.2.1 Analysis by Angle at the Same Flow

Figure 5 shows the results of analysis for velocity around the valve at each angle. Analysis of each case showed that when the angle is small, the impact of flow is very small. Maximum velocity occurred at the gap between the pipe and the electronic-variable valve. It was seen that the flow around the valve decreased approximately 60%, as the opening angle increased. It was seen that the maximum flow increased about 2.5 times as the opening angle increased. This reason considered to indicate as increasing dimensions which was contacted between flow and valve passing in pipe as angles up from flap in electronic-variable valve.

Figure 6 shows the results from analysis of the pressure range around the valve at each angle. The pressure differential before and after the valve increased with the open angle. Maximum pressure occurred at the front end of the electronic-variable valve, and it was seen that the maximum pressure increased. It was seen that at a small

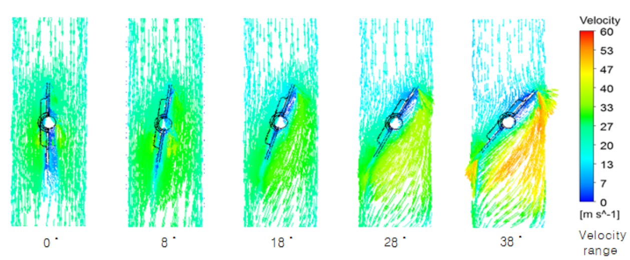

Figure 5. Surrounding velocity distribution by angle change.

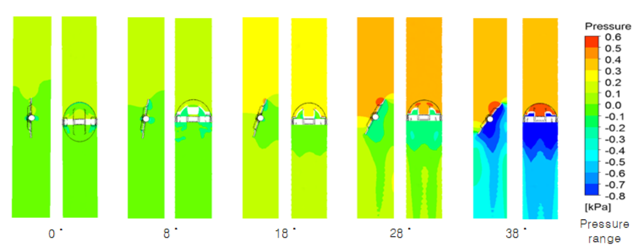

Figure 6. Surrounding pressure distribution by angle change.

angle, as there is almost no impact from the valve, there is almost no difference in the pressure range. It is judged that the valve blocking and decreasing flow within the pipe caused this phenomenon.

3.2.2 Analysis by Flow at the Same Angle

Figure 7 shows the results of analysis for velocity around the valve at each flow rate. Velocity ranged from 0 m/s to 50 m/s, and maximum velocity increased about 1.4 times with increasing flow. Maximum flow occurred at the gap between the electronic-variable valve and the pipe. It was seen that as open angle increased, the flow around the valve decreased, and maximum flow increased. It is thought that this phenomenon is caused by the increased flow due to increased wind interval.

Figure 8 shows the results of analysis for pressure around the valve at each flow rate. As for pressure characteristics, it was seen that maximum pressure and differential pressure before and after the valve increased about 1.75 times with increasing flow. Also, due to the development of the flow, a clear area of low pressure was seen behind the valve. This is thought to be the result of the increased pressure differential before and after the valve due to the increased flow colliding with the valve owing to increased flow.

Figure 9 shows the results of analysis of the pressure applied on the valve at each flow rate. As flow increased,

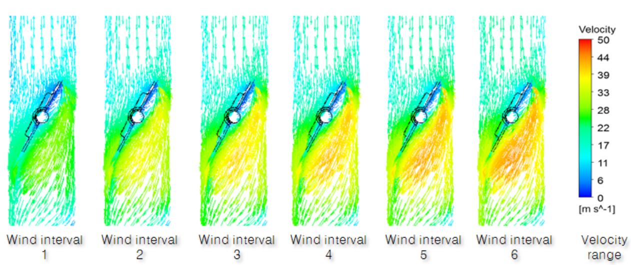

Figure 7. Surrounding velocity distribution by flow change.

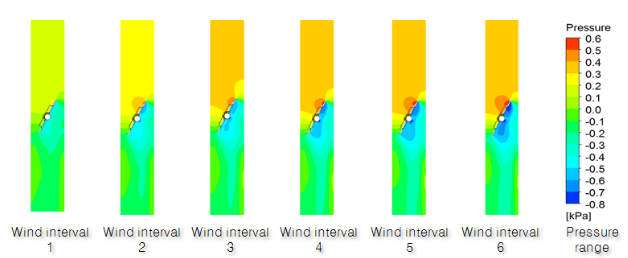

Figure 8. Surrounding pressure distribution by flow change.

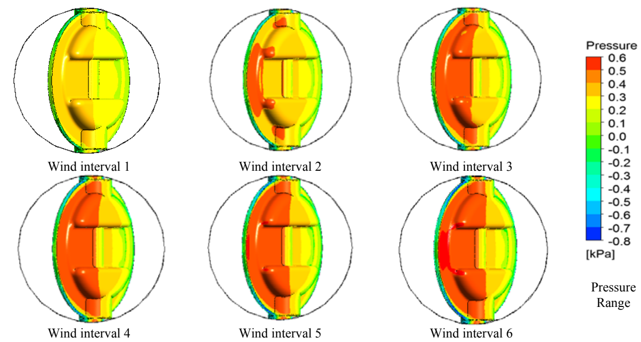

Figure 9. Pressure distribution of Electronic-Variable Valve by flow change.

the maximum pressure on the valve gradually increased. With the valve operating from left to right, results showed that pressure began to be applied from the left side. This is thought to be the result of increased flow colliding with the valve as valve flow increases.

4. Conclusion

In this study, experiments proceeded as designing and making of conducting copied device in order to complement such as challenging things to study within muffler from electronic-variable valve. It also, using that data, from the results of flow analysis through ANSYS program, conclusion could be obtained like following below.

- It was observed that as the open angle of the valve increased, the maximum velocity around the electronic-variable valve increased 2.5 times. It was seen that in the exhaust pipe past the electronic-variable valve, average velocity decreased to approximately 60%.
- When the open angle was 38˚, the pressure differential was approximately 3 times that when the angle was 0˚. It was seen that the maximum pressure range also increased.
- It was observed that the maximum velocity around the valve increased by 1.4 times as the flow rate of the valve increased. It was seen that flow became clear as flow rate increased, and that the strength of turbulent flow increased.
- It was seen that, with increasing flow rate, maximum pressure and the pressure differential before and after the valve increased by approximately 1.75 times. With increased flow rate, it was seen that due to the development of flow, low pressure was formed behind the valve.

- It was seen that with increased flow rate, the pressure acting on the left side of the valve gradually increased.

5. Acknowledgment

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