Development of Expansion of Flow Rate for Solenoid Type EGR Valve

1. Introduction

The exhaust gas recirculation (EGR) valve is used in the exhaust gas recirculation system and adjusts the amount of exhaust gas of gasoline and diesel vehicles to be returned to the air intake (Fig. 1). In recent years, emission regulations for vehicles are becoming stricter. It is expected that fuel efficiency will be improved by reducing NOx and pumping loss by increasing the flow rate of the EGR valve.

Looking at trends in other companies, the motor type of valve is common because the EGR drive system is suitable for large flow rates. On the other hand, the operational response performance of the motor type is inferior to the solenoid type. We have worked on expanding the flow based on a high response solenoid.

In this report, we introduce examples of achievements of 2.5 times larger flow rates than the existing small type valve while maintaining the same size (Fig. 2). By making it equal in size, we were able to reduce costs with the use of existing parts and reduction in investment. With this approach, we tried to improve the attractiveness of the product to customers.

2. Characteristics of Solenoid Type EGR Valve

The solenoid type EGR valve consists of a high response solenoid and a low leak poppet valve. Its characteristics are as follows.

- When a voltage is applied, a current flows through the coil. Thrust is generated and the valve is opened by moving the iron core.
- The lift amount can be adjusted linearly. The exhaust gas flow rate is controlled by changing the lift amount.
• The maximum flow rate of the EGR valve is reached at a lift of 5 mm.

3. Efforts in Development

3.1. High Flow Rate

As an indispensable element increasing the flow rate, the opening area of the valve must be expanded. However, this becomes a factor in increasing the load of differential pressure applied to the valve portion. As a result, it would become difficult for the EGR valve to open. Normally, the solenoid thrust is set to be large and the size expansion is carried out accordingly, but it turned out that size expansion was larger than expected in the initial design. In particular, it was impossible to maintain the size of both the height and radial directions of the solenoid. As a countermeasure for this, we focused on improving the efficiency of the magnetic circuit.

The key point of high efficiency is coil setting and optimization of magnetic circuit. What was difficult with the optimization of coils and magnetic circuit was the occurrence of a phenomenon where the thrust did not rise even if the number of turns of the coil was increased by changing the setting balance of the base and the fact that the movable iron core could not be linearly lifted. These were solved by repeating magnetic analysis. On that basis, the transfer of the magnetic flux between the movable iron core and the fixed iron core was improved. The result was a highly efficient circuit in which a high magnetic flux density was obtained. Results of numerical analysis were as follows: The magnetic flux density of the movable iron core of the base production unit was about 1.0 T, and that of the newly developed unit was about 2.0 T (Fig. 3).

As a result of this investigation, we were able to expand the opening area of the valve, which is an indispensable element for creating a large flow rate, and thus a large flow rate was achieved.

3.2. Cost Reduction by Increasing the Number of Common Parts

In the production EGR valve, the number of parts of the solenoid area was 70%. Therefore, maintaining the size of the solenoid and increasing the number of common parts was effective for cost reduction due to increased production. The basic structure of the production EGR valve was the exhaust gas passage in the first stage, the solenoid in the second stage and the sensor in the third stage (Fig. 1). Equalizing the size of the solenoid would...
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The more common motor actuated type could be realized.

Mass production of this product, which contributes to cleaner exhaust gas and improved fuel economy performance in the finished vehicle, commenced in February 2018.

### Table 1 Ratio of shared parts

<table>
<thead>
<tr>
<th>Component parts</th>
<th>Ratio of parts count</th>
<th>Ratio of shared parts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial design</td>
</tr>
<tr>
<td>Sensor</td>
<td>11 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Solenoid</td>
<td>67 %</td>
<td>28 %</td>
</tr>
<tr>
<td>Exhaust Gas Flow Passage</td>
<td>22 %</td>
<td>17 %</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>22 %</td>
<td><strong>52 %</strong></td>
</tr>
</tbody>
</table>

Improvement

make it possible to use the first and third fastening parts and the sensor itself, thus increasing the number of common parts.

Focusing on production equipment, it is possible to limit the investment of the automatic assembly line by maintaining the solenoid size. For example, as the size increases, problems occur such as components not being able to be passed through the parts supply line or not being able to be set onto assembly jigs. Measures for such problems cause additional costs and can be avoided by maintaining the size.

As a result of efforts to maintain solenoid size during this development, the parts sharing ratio has improved from 22% (initial specification) to 52% (final specification), and increase in production efficiency obtained with the use of shared parts (Table 1). In the assembly line, it was possible to use existing line for 95% of the processes, with a dedicated line for the remaining 5%, thus achieving a reduction in investment.

### 4. Summary

A competitive EGR valve was achieved by increasing the flow rate while keeping the size equivalent to the previous model. Furthermore, with the use of a solenoid to actuate the valve, a higher responsiveness than what would be expected from the more common motor actuated type could be realized.

I would like to thank everyone who cooperated with this development. In this development, there were many difficulties, but we received much advice and cooperation. As a result, we were able to accomplish all tasks and realize commercialization of the new product.

I would like to aim for further development of new products that can contribute to the future by making use of this experience. (ITO)

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