

Development of Compact Lightweight Muffler Valve for 2005 Model Year LEGEND

Hidegori HAMASHIMA*
Satoshi WATANABE*

Masayuki UEGANE*
Hidekazu AKIYAMA*

ABSTRACT

For the 2005 model year LEGEND, a compact lightweight muffler valve with new construction was developed for the variable flow rate muffler.

A conventional muffler valve rotates about a shaft. A load is applied to the rotating shaft by a coil spring. For this reason many parts are required for the valve to open and close. The body of the muffler valve traditionally covers the entire valve operating range, resulting in the valve being large and heavy.

As a method of reducing the number of parts and the weight of the valve, this development employed the mechanism of the reed valve. A reed valve is used in 2-cycle motorcycle engines to control the intake air volume at the intake port. The addition of a support plate to the reed valve structure was investigated to suppress valve vibration and to apply a pre-load.

The number of parts in the newly developed muffler valve was reduced from 13 parts in the conventional valve to four parts. Both the weight and volume were reduced to about 1/10. This enabled the cost to be reduced to about 1/7 of a traditional exhaust valve.

1. Introduction

To achieve sound levels and engine power appropriate for the Honda LEGEND (Honda's flagship vehicle), a new variable flow rate muffler was adopted in the exhaust system.

In the variable flow rate muffler, a muffler valve was established to switch exhaust gas passage between the low engine speed and high engine speed ranges. In the low engine speed range, priority was given to silencing noise by increasing exhaust resistance. In the high engine speed range, it was possible to raise power by reducing exhaust resistance.

The flow of exhaust gas at low engine speeds with the variable flow rate muffler is shown in Fig. 1.

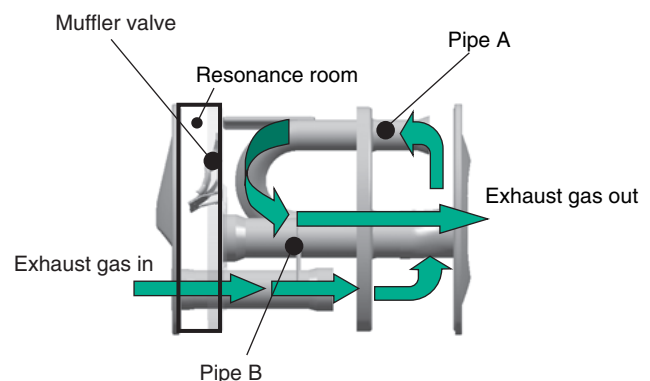


Fig. 1 Exhaust gas flow when muffler valve is closed

* Tochigi R&D Center

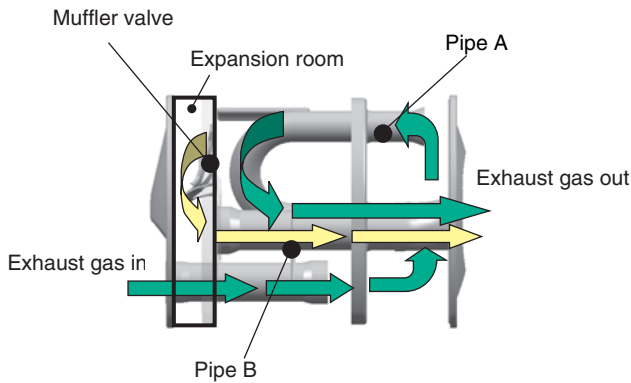


Fig. 2 Exhaust gas flow when muffler valve is opened

At low engine speeds the pressure inside the muffler is low, so the muffler valve is closed. When the valve is closed, exhaust gases are emitted without passing through pipe B. With the valve closed, the muffler valve room acts as a resonance room to silence noise.

The flow of exhaust gas at high engine speeds with the variable flow rate muffler is shown in Fig. 2.

At high engine speeds, the pressure inside the muffler rises. This causes the muffler valve to open. When the valve opens, exhaust gas passes through pipe B. The chamber that acted as the resonance room at low engine speeds now becomes part of the exhaust gas passage. This reduces exhaust resistance (backpressure).

The variable flow rate muffler uses a valve that switches the path of exhaust gas. The conventional muffler valve has traditionally been heavy and costly.

This paper reports on achievements in reducing weight and cost of mufflers by reducing the total part count of the exhaust valve assembly.

2. Development Goals

Figure 3 shows the operational states of a conventional muffler valve at high and low engine speeds.

In order to switch the exhaust gas passage with a conventional muffler valve, a shaft is established at the edge of a plate (referred to as the valve, hereafter). The valve rotates around this shaft.

When the engine is at low speeds, a load in the opposite direction to the exhaust gas flow (referred to as the pre-load hereafter) is applied on the shaft via a coil spring. The exhaust gas passage is closed in valve A position. At high engine speeds, a pressure exceeding the pre-load is applied. This pressure causes the valve to rotate about its shaft, and opens to valve B position. Exhaust gas flows inside the muffler valve body, reducing exhaust gas resistance.

A stopper function is added to the muffler valve so that valve opening is restricted during high engine speeds. This means that when it comes into contact with pipe A, the valve will not open any further (Fig. 4).

Conventional muffler valve component parts are shown in Fig. 5.

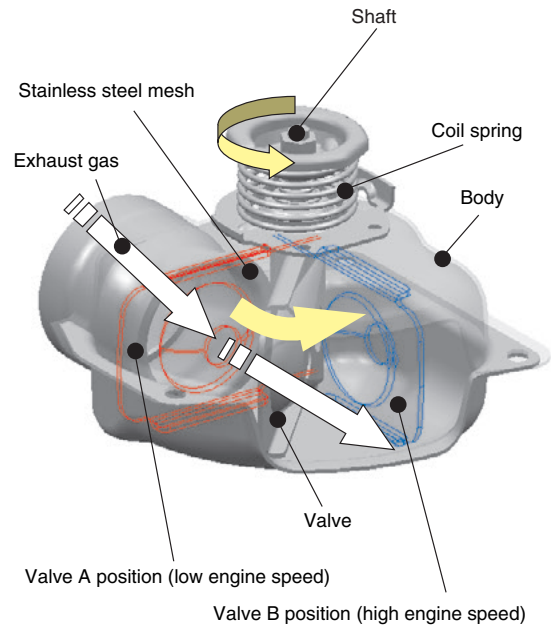


Fig. 3 Operation principle of conventional muffler valve

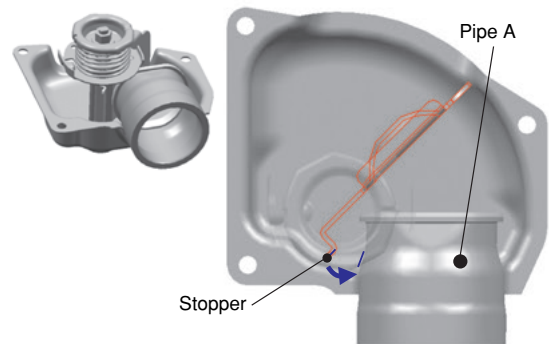


Fig. 4 Structure of stopper

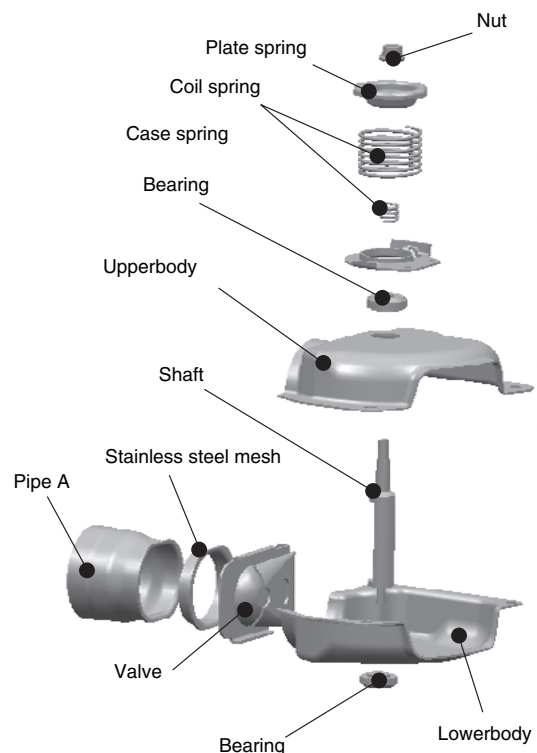


Fig. 5 Structure of conventional muffler valve

A rotational shaft is at the edge of the valve, and bearings are fitted on both ends of the rotational shaft. For installation purposes, plates are placed at both ends of the coil spring.

The shaft, bearings and the coil spring holding plates are fitted to the upper body and lower body. The upper and lower bodies cover the valve operating range. When the valve is open the upper and lower bodies form the exhaust gas passage way.

A conventional muffler valve has a more complex structure. The following three structural issues can be assumed with the use of a conventional muffler valve.

- Because the structure rotates around a shaft, the necessity for valves, shafts, and bearings is inevitable. This increases the number of parts.
- Because a coil spring is used, spring bearings are necessary. This also increases the number of parts.
- Because the entire valve operation range is covered by the muffler valve body, the unit becomes large and heavy.

The goal of this development project was to reduce the number of component parts. This is accomplished by creating a structure in which the valve itself opens and closes without any rotational shaft or coil spring. Additionally, the body does not cover the valve operation range. This makes the unit smaller.

3. Technologies Adopted

In order to address the issues raised in the previous section, a reed valve was chosen. Reed valves are used in 2-cycle motorcycle engines to control intake air volume at the intake port. This makes it possible to reduce the number of component parts.

Figure 6 shows the operation principles for this newly developed muffler valve.

In this structure a thin plate flexes open and closed. This controls the exhaust gas passage.

A conventional valve structure has a plate of 1.5 mm thickness that opens and closes on a rotational shaft. This has been replaced by a thin 0.2 mm thick plate. The function of the rotational shaft and the valve is integrated into the thin plate.

Two issues arise when the valve is to be replaced by a thin plate. The first issue is valve resonance. The other issue is that the pre-load typically applied by the conventional coil spring, cannot be applied.

To address these two issues, another thin plate acting as a spring (referred to as the support plate hereafter) has been placed in contact with the valve.

At low engine speeds the support plate is in support plate C position. A pre-load is applied to the valve at valve D position. This load closes the valve, and consequently the exhaust gas passage.

When the engine speed is high, pressure exceeding the pre-load is applied to the valve. This causes the valve unit to flex open to valve F position. The support plate slides on top of the valve to position E while flexing. With the valve in this position, the exhaust gas flows outside the muffler valve body.

Figure 7 shows the muffler valve structure.

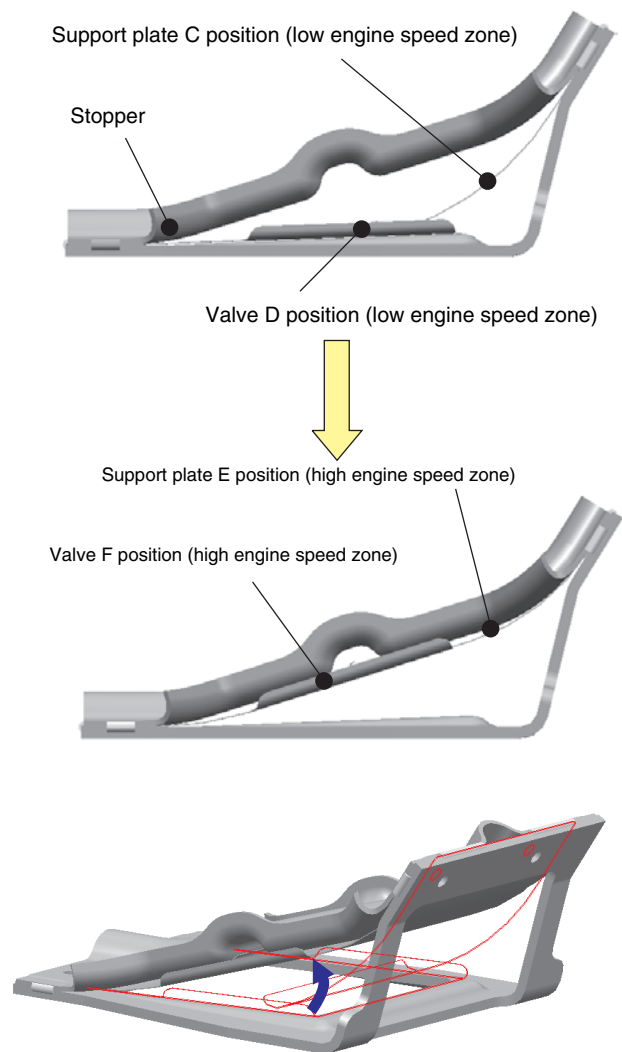


Fig. 6 Operation principle of developed muffler valve

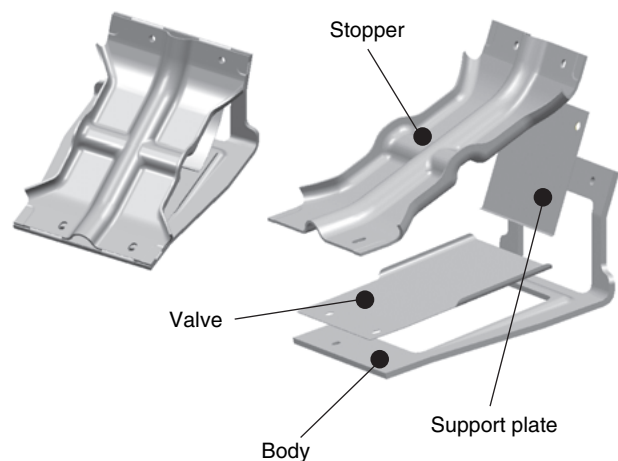


Fig. 7 Structure of developed muffler valve

A stopper has been added so that stress on the fixed ends does not exceed the material fatigue limit when the valve and support plate are fully open. The stopper limits the valve and support plate operation. At the same time, the stopper holds one side of the valve and the support plate.

Inconel material was used for the valve plate and the support plate. This was done so that both parts would have the same level of heat and corrosion resistance as that of the conventional coil spring.

Figure 8 shows a functional part comparison of the conventional muffler valve and the newly developed one.

Compared to the conventional muffler valve, the pre-load function was reduced from three parts to one. The rotational shaft function was reduced from six parts to one. The stopper function was reduced from two parts to one, and the exhaust gas passage was modified from two parts to one. The number of parts was reduced for each function.

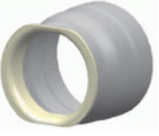
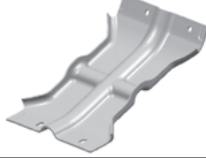
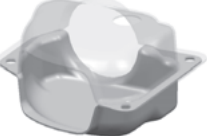
Function	Conventional muffler valve	Developed muffler valve
Preset load		
Shaft		
Stopper		
Exhaust gas passage		

Fig. 8 Parts list for each function



Fig. 9 Size comparison of conventional and developed muffler valve

Table 1 Specification comparison of conventional and developed muffler valves

	Conventional muffler valve	Developed muffler valve
Wt (kg)	1.34	0.12
Number of parts	13	4
Volume (mm ³)	1.12×10^6	0.08×10^6

A size comparison between the conventional and newly developed muffler valves is shown in Fig. 9.

Table 1 shows a comparison of the main specifications for the conventional and developed muffler valves.

The new structure has the following advantages over the conventional structure.

- The number of parts has been reduced from thirteen to four.
- Weight and volume has been reduced to approximately one tenth that of conventional unit.
- Due to the reduction in part number and size, cost has also been reduced to approximately one-seventh of the conventional unit.

4. Effects on the Vehicle

The benefits of the variable flow rate muffler were verified on an actual vehicle with the valve forced open and forced closed. The exhaust noise results are shown in Fig. 10, and backpressure results are shown in Fig. 11.

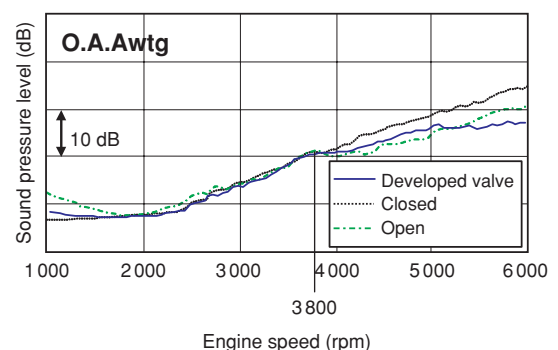
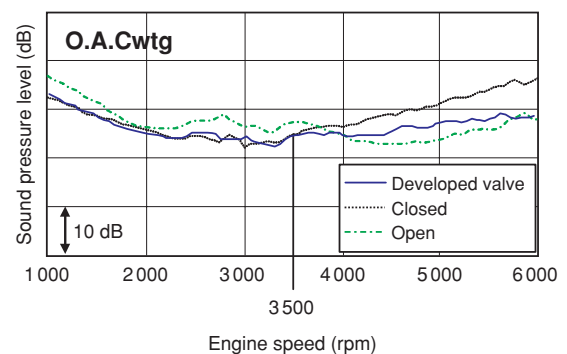


Fig. 10 Exhaust noise comparison by difference valve condition

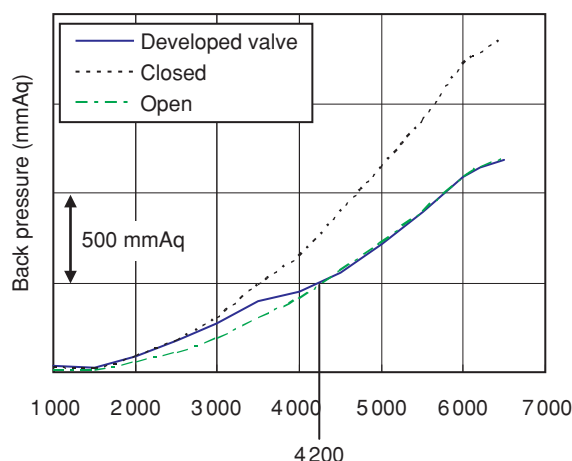


Fig. 11 Back pressure comparison by difference valve condition

Backpressure expresses exhaust gas resistance in terms of pressure inside the pipe.

Figure 10 shows the exhaust noise C weighted value dB-C measurement results from 1000 to 3500 rpm. Compared to the valve in a forcibly closed state, this newly developed variable flow rate muffler has the same noise silencing performance. It is clear that exhaust pulse noise level is equivalent. The exhaust noise A weighted value dB-A is also shown. In the 3800 rpm range and higher, the flow noise is clearly reduced by opening the muffler valve when compared to the state when the valve is forcibly closed.

In general, exhaust noise at 4000 rpm and higher is dominated by flow noise emitted from the tailpipe. If flow speed is increased then flow noise also increases. At engine speeds of 4000 rpm and higher if the exhaust gas flow path increases then flow noise is reduced.

Backpressure measurement results are shown in Fig. 11. The valve begins to open at engine speeds of 3000 rpm and higher. This causes a reduction in backpressure of the newly developed variable flow rate muffler. The same muffler with the valve forced closed is shown for comparison. At engine speeds of 4200 rpm and higher, the backpressure performance is equivalent to when the valve is forcibly open.

It becomes clear that by adopting the variable flow rate muffler, it is possible to maintain a low exhaust pulse noise level. At the same time flow noise and backpressure at high engine speeds are reduced.

5. Conclusion

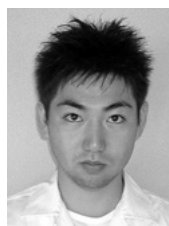
1. Adopting the newly developed muffler valve in the variable flow rate muffler for the 2005 model year LEGEND has many benefits. Both exhaust sound level and engine power appropriate for Honda's flagship vehicle has been achieved. This has been accomplished with low weight and low cost.
2. The variable flow rate muffler developed in this project has the same level of noise silencing performance between 1000 and 3000 rpm with the muffler valve closed, compared to when the valve is forcibly closed. At speeds of 3800 rpm and higher, by opening the muffler valve, it is possible to reduce flow noise. At 4200 rpm and higher, the newly developed muffler has the same backpressure performance, compared to when the valve is forcibly open.

3. In comparison with the conventional unit, the newly developed muffler valve has nine fewer parts, reduced from thirteen to four total. Weight and volume are approximately one-tenth of the conventional. Cost has also been reduced to approximately one-seventh, thanks to the reduction in the number of parts and the reduction in size.

6. References

- (1) Murakami, M., et al.: Hydraulic Losses in Pipes And Ducts, The Japan Society of Mechanical Engineers, p. 3-126 (1998)
- (2) Fukuda, M., Okuda, J.: The Solution To Noise And Silencing Design, KYOURITSU SHUPPAN CO., LTD., p. 160-225 (1982)
- (3) Spring Technology Research Association. : Spring, Maruzen Co., Ltd., p. 13-387 (1982)
- (4) Koibuchi, K., Kokubo, K.: Strength of materials and Strength design know-how for Products development, THE NIKKAN KOGYO SHINBUN, LTD., p. 160-225 (2002)
- (5) Koizumi, T., Hara, T., Kasano, H., Minakuchi, Y.: Foundation Strength Of Materials, Yokendo Co., LTD., p. 55-98 (1996)
- (6) JSAE. : Handbook Of Society Of Automotive Engineers Of Japan (Book Of design), p. 33-183 (1991)
- (7) Miyagawa, O., Sakaki, T.: Metal Technology Generality, Asakurashoten Co., Ltd., p. 132-193 (1996)
- (8) Mochizuki, O., Maruta, Y.: Introduction to Fluid Noise Engineering, Asakurashoten Co., Ltd., p. 60-138 (1991)

■ Authors ■



Hidenori HAMASHIMA



Masayuki UEGANE



Satoshi WATANABE



Hidekazu AKIYAMA