

Development of Small Fuel Pump Module for Motorcycles

Masaki UENO*

Minoru UEDA*

Takashi UDONO*

Shunji AKAMATSU*

Mineo TORIKAI**

Mitsuru FUKUDA**

ABSTRACT

A small, low-cost fuel pump module has been developed for use in motorcycles with smaller engines. Removing the diaphragm from the pressure regulator has simplified the structure and has reduced the volume ratio to approximately 40% that of the former model. The pump motor has been designed specifically for use in low-displacement engines. Optimizing the winding specifications and reducing the size of components enabled the total length to be reduced by 11 mm. Reducing the size of the pressure regulator and the pump motor also reduced the mounting diameter of the fuel pump module, enabling the axial face seal, previously used for the mounting area, to be replaced by a radial seal. A retainer slide has been used instead of bolts to fix the pump in place, enhancing workability and reducing the number of parts. Together, these changes have reduced the cost of the unit by approximately 30% and the mounting area by approximately 40%.

1. Introduction

Honda has set itself a severe numerical target in its commitment to reduce CO₂ emissions from its products and production processes worldwide by 10% or more against 2000 figures by 2010. The proposal and introduction of new regulation values around the world are also stimulating efforts to increase fuel economy in and reduce exhaust emissions from motorcycles. Table 1 shows a map of exhaust gas regulations currently being applied or under consideration.

The use of fuel injection (FI) is an effective means of responding to environmental needs without sacrificing the functions and performance levels of motorcycles, and Honda intends to use FI in most of its market models by 2010.

However, FI involves more parts than a carburetor system, and its cost is therefore higher. In particular, the fact that there is no space margin in smaller motorcycles as there is in larger motorcycles, in addition to the low cost of the smaller motorcycles themselves, demands the development of small, low-cost FI systems.

The project discussed in this paper reexamined the

specifications and production plans of every functional component of the small motorcycle FI system used in the 2005 Wave 125i motorcycle in an attempt to further reduce the size and cost of the system. In particular, it was important to reduce the size of the small fuel pump modules employed in the smaller fuel tanks used in motorcycles in developing nations. This paper describes the technologies employed to reduce the size of the fuel pump module used in the 2008 Wave 110, which will be marketed in Thailand.

2. Fuel Pump Module for Small Motorcycle: Issues and Approaches

2.1. Issues

Figure 1 shows the standard fuel tank layout used in the commuter motorcycles that represent the majority of motorcycles throughout the world. A fuel tank fitted with a fuel pump module is positioned under the seat between the luggage box and the rear fender. In this layout, there are height restrictions and limitations on the positioning of the fuel pump. The fuel pump module should also be fitted in a limited space to avoid the fuel filler opening,

* Motorcycle R&D Center

** Keihin Corporation

Table 1 Trends of exhaust gas emissions regulations for motorcycles

		EURO-2						EURO-3 or equivalent				
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
EU					EURO-2			EURO-3				
Japan								2nd (< 50 cc)				
								2nd (< 125 cc)				
Thailand		4th			5th (< 110 cc)			6th				
China					EURO-2				EURO-3			
Indonesia						EURO-2						
Vietnam								EURO-2				
Brazil						EURO-2			EURO-3			
India		4th				5th			6th			
USA	EPA							2007YM		ARB Tier-2		
								OFF/ATV 2006YM		ON & OFF		
								ARB Tier-1 2006YM				
	ARB				Tier-1 2004YM				Tier-2 2008YM			

located near the center of the upper part of the fuel tank. In addition, the height of the upper section of the pump is determined by its position in relation to the seat. The height of the pump is lower than the height of the tank by an amount equivalent to the height of the joints of fuel line and couplers of electric equipment, and any increase in the mounting area of the pump would result in a reduction in the size of the tank.

Conventional fuel pump modules are in need of a large space for mounting and use a large number of parts. Reducing the mounting space and cost of the units is therefore a major issue in terms of increasing the range of models in which they can be used.

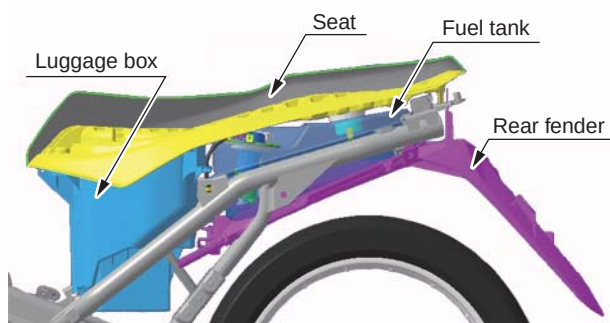


Fig. 1 Fuel tank layout

2.2. Approach of Issues

In this development, efforts to miniaturize the size and lower the costs of the pump focused on the following two points:

- (1) Development of a small fuel pump module
- (2) Simplification of the mounting structure for the fuel pump module

3. Major Technologies

3.1. Small Fuel Pump Module

Figure 2 shows a comparison of the inner configurations of the fuel pump module for the 2008 Wave 110 and the former model, the 2005 Wave 125i. The fuel pump module is composed of a pump motor, a pressure regulator (hereafter referred to as "P/REG"), a plastic case, a fuel filter, and a fuel level sensor. The module was miniaturized by downsizing each component and designing an optimum layout, employing the four technologies and techniques listed below. The use of this strategy resulted in the reduction of the diameter of the module insert hole in the fuel tank from $\phi 65$ to $\phi 49$ (Fig. 2).

- (1) Diaphragm-less P/REG
- (2) Reduction of pump motor size
- (3) In-line layout of P/REG and pump motor
- (4) L-shape layout of fuel level sensor

3.1.1. Diaphragm-less P/REG

Figure 3 shows the configuration of the former and

the developed P/REGs. In the former P/REG, a diaphragm receives a pressure (function of pressure-receiving). Motion of the diaphragm in response to the pressure changes the gap between a ball valve and a seat, which adjusts the return flow rate and maintains constant pressure. In the developed P/REG, the pressure-receiving

function was added to the ball valve that regulates the return flow rate, enabling the diaphragm to be removed, thus reducing the number of parts and the size of the unit.

The major performance criteria for the P/REG are as follows:

- (1) Stabilization of fuel-feed pressure to flow rate
- (2) Low fuel-feed pressure pulsation
- (3) Ability to hold residual pressure

The diaphragm-less P/REG should achieve these performance criteria. Regarding item (1), the former P/REG had a stable Q-P (fuel flow rate – feed pressure) characteristic up to a high flow rate, but the Q-P characteristic was expected to decline in the developed module because the pressure-receiving function is accomplished with the ball valve only. Regarding item (2), since the pressure-receiving and pressure-regulating functions were unified in the ball valve, it was thought that fluttering of the ball valve caused by the fuel flow might generate a large pressure pulsation. Item (3) is a necessary function to facilitate restarting, avoiding a decline in pressure in the fuel line while the pump is stopped. In the new model, however, since the smaller area of the ball valve receives the pressure formerly received by the diaphragm, the spring load is also set lower. The contact pressure on the valve seat is therefore lowered, and the ability to hold residual pressure tends to decline.

In order to address these issues, the P/REG function was limited to the flow rate range in small motorcycles of 150 cm³ displacement or below, to achieve a stable characteristic. The developed P/REG configuration employs a valve guide to exert a uniform spring load using a spring with a larger coil diameter. This helps prevent a slant of the spring and equalizes the valve seat contact pressure, thus increasing the ability to hold residual pressure. Figure 4 shows the residual pressure characteristic of the former and the new configurations. Although the residual pressure with the diaphragm-less configuration is lower than with the former pump, it is not an issue in terms of actual use.

In addition, the design of a concave area in the valve guide that houses the ball valve has reduced the fluttering

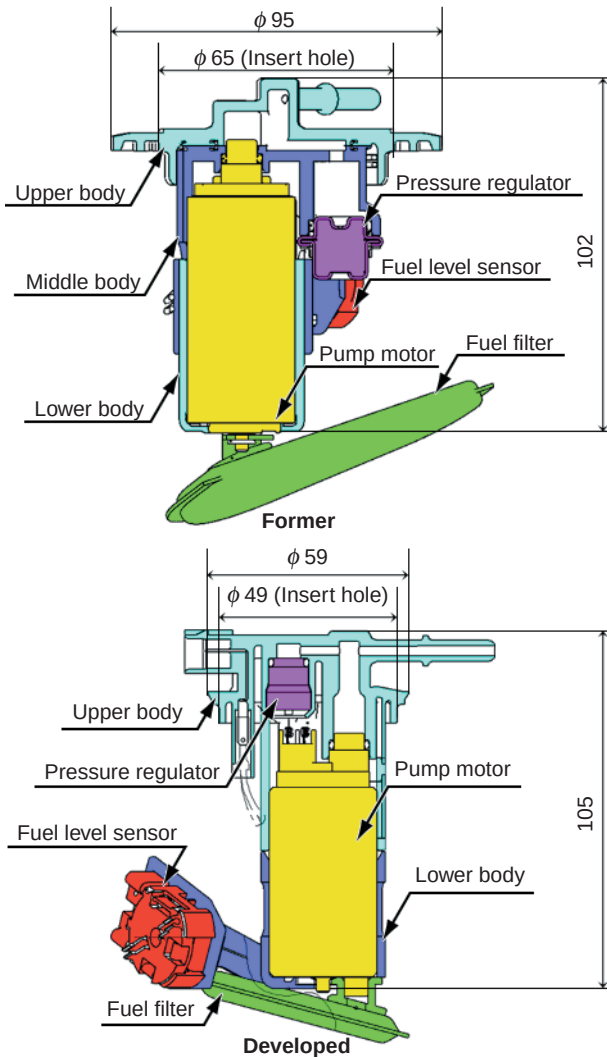


Fig. 2 Comparison of inner structure of fuel pump modules

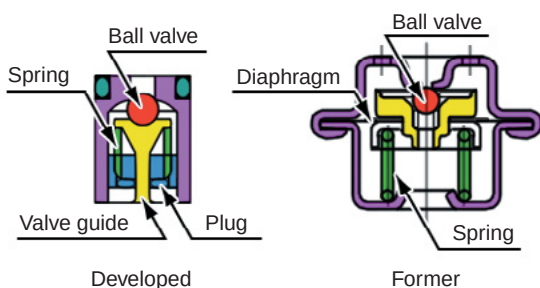


Fig. 3 Structure of former and developed pressure regulators

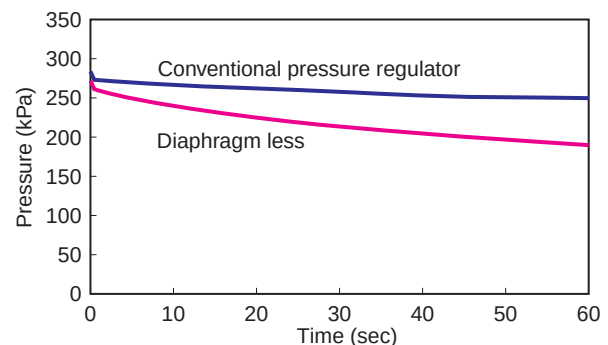


Fig. 4 Residual pressure characteristic

of the valve, enabling the stabilization of fuel-feed pressure.

As shown in Fig. 5, even without the diaphragm, these modifications achieved a Q-P characteristic equivalent to that of the former pump within the flow-rate range of small motorcycles.

3.1.2. Miniaturization of pump motor

Components of the pump motor were miniaturized for use in small motorcycles less than or equal to 150 cm³ displacement. In the pump section, the rotor and the flow paths employed the same shapes as before, but the thickness of the pump casing and the dimensions of the bearings were modified to achieve miniaturization. In the motor section, reducing the core laminate thickness, the total length of the magnet, and the coil winding space enabled the armature to be made smaller. In addition, optimization of the coil winding specifications allowed the achievement of a torque constant equivalent to that achieved by the former specifications, resulting in an equivalent motor characteristic. A check valve holds residual pressure in the fuel line when the pump motor is stopped, enabling the engine to restart easily. This check valve was also reduced in size without impairing its functioning. With these modifications, the total length of the pump motor was reduced by 11 mm against the former model, while an equivalent level of performance and functions was maintained.

3.1.3. In-line layout of P/REG and pump motor

In order to reduce the mounting space of the pump module, it is necessary to lay out the components in as small an area as possible in terms of each cross section when the pump is inserted. In the previous model, the P/REG and the pump motor were fitted parallel to the pump axis due to height restrictions. Miniaturizing the components as described above allowed the P/REG to be mounted on the top plate. This in turn enabled in-line layout of the P/REG and the pump motor without an increase in height, and allowed the diameter of the insert hole in the fuel tank for the pump module to be reduced.

In the former pump, a middle body was welded to the

top plate to build a path from the P/REG to the pump outlet. In the new pump, the pump outlet and the P/REG have been set on the outlet joint axis, simplifying the path structure and enabling the middle body to be removed (Fig. 2).

3.1.4. L-shaped configuration of fuel level sensor

Formerly the fuel level sensor was placed next to the pump, but it was necessary to separate it from the pump in the developed model due to the reduced diameter of the module insert hole. The fuel level sensor was set in an L-shape in the same direction as the fuel filter to accommodate height restrictions and for ease of insertion. This enabled the insert hole to be reduced to $\phi 49$, and the mounting space to be reduced.

3.2. Simplification of Pump Module Mounting Structure

The following two methods were used to modify the pump module mounting in order to reduce size and the number of components in conjunction with the smaller diameter of the pump insert hole:

- (1) Radial seal structure with O ring
- (2) Snap-fit retainer

3.2.1. Radial seal structure with O ring

As Fig. 6 shows, the former module used a rubber seal with a double lip, fitted in the planar direction, to seal the mount section. This increased the diameter of the pump module, and made a large flat section necessary for mounting.

In the new module, an O ring radial seal has been used for the pump mounting. The use of a radial seal on a module of the size of the former model would have increased the insertion load and affected workability, but the reduction in the diameter of the insert hole has enabled the load to be controlled to a level that maintains workability. Machining of the base plate helps achieve sufficient accuracy in the seal face on the tank side. The seal on the radial plane does not need a pressure load, and the seal performance is maintained as long as the load is not so large as to separate the O ring from the seal face, creating a highly reliable configuration.

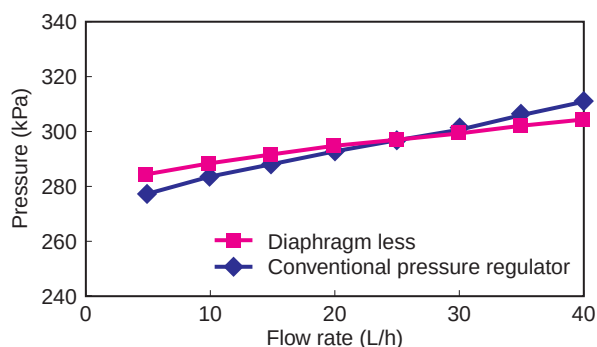


Fig. 5 Comparison of Q-P characteristics

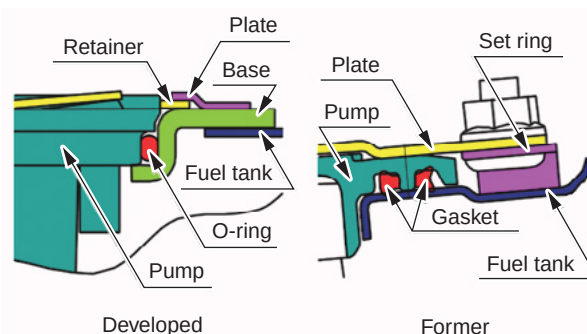


Fig. 6 Comparison of seal structure

The seal on the radial plane, in combination with the modification of the positioning of the parts, made possible an approximately 40% reduction in the diameter of the flange of the fuel pump module. In addition, the reduced use of high-cost rubber in the seal and the reduction of the size of the upper body have lowered materials costs.

3.2.2. Snap-fit retainer

Bolts were used to fasten the former module in place. In the new model, a sliding retainer holds the upper section of the module in place (Fig. 7).

In the former configuration, a ring plate used to fasten the fuel pump module was welded to the tank. Height accuracy was challenging to achieve, necessitating adjustment following spot welding, which increased costs. The use of five bolts also affected workability.

In the new configuration, the base plate that forms the pump mount is welded to the tank. Nickel plating is used to help prevent rust. A holding plate that forms a slit for the insertion of the retainer is welded to the base plate. When the retainer is pressed into the slit following insertion of the pump module, it fits onto protrusions on the slope formed on the upper section of the flange part,

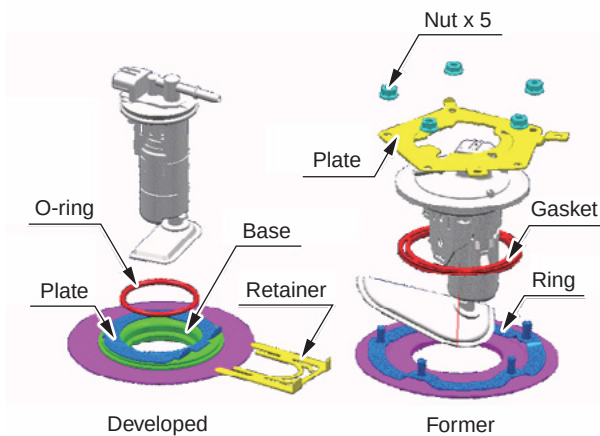


Fig. 7 Comparison of pump mounting

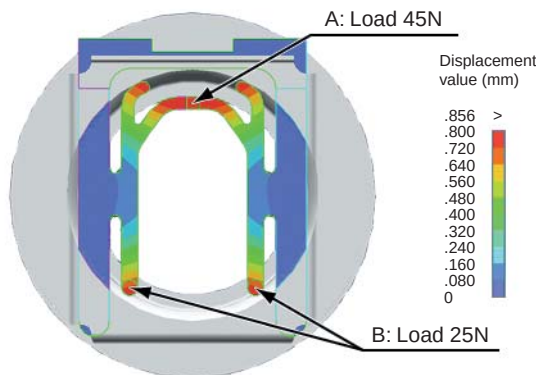


Fig. 8 Generated load at deformation of retainer

and a retaining load is generated in the direction of the pump axis. Figure 8 shows the results of a CAE analysis of the deformation of the retainer when the load needed to hold the pump in place is applied onto the protrusions on the slope section. These results were used to set the protrusion height and the retainer shape to obtain the necessary load.

The retainer has the locking shape shown in Fig. 9. During insertion the retainer is pushed by the sloping section. Following insertion, the locking section is immediately released from the holding plate and pops up, catching on the holding plate and keeping the retainer from moving. A screw is then used to accurately position the retainer. The use of this method rather than the former clamp screw method has reduced the workload involved in fitting the module by approximately 80% and the necessary mounting area by approximately 40%.

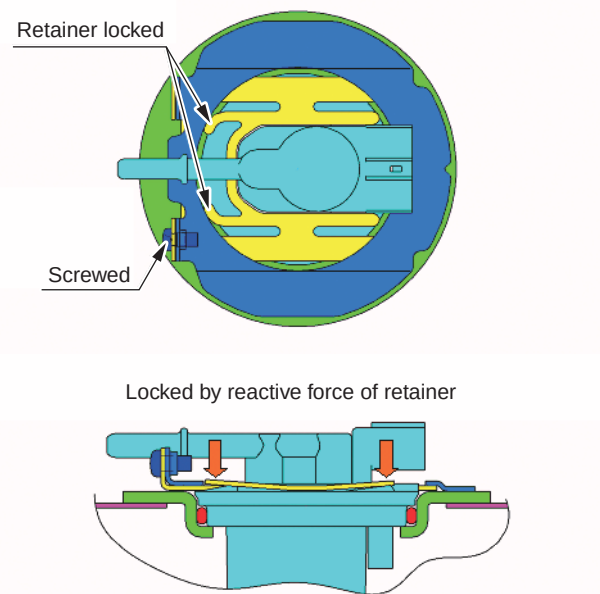


Fig. 9 Configuration of locking retainer

4. Conclusion

A small, low-cost fuel pump module for small motorcycles has been developed and employed in the 2008 Wave 110 motorcycle to be marketed in Thailand.

- (1) The removal of the diaphragm from the pressure regulator has reduced the size and simplified the structure of the component, while the use of a valve guide has been effective in achieving a performance level equivalent to the previous model in the range of fuel flow rates used in small motorcycles.
- (2) The pump motor has been designed for use in the range of flow rates used in small motorcycles of 150 cm³ displacement or below, and the coil winding

specifications have been modified, resulting in a reduction of 11 mm in the total length of the motor.

- (3) Reducing the diameter of the insert hole has enabled the use of an O ring radial seal, and a snap-fit retainer has also been employed, resulting in increased workability and a smaller mounting space.

Use of these strategies has reduced the mounting area of the module by approximately 40% and its cost by approximately 30%, enabling the developed module to be used in a wide range of small motorcycles.

■ Author ■



Masaki UENO



Minoru UEDA



Takashi UDONO



Shunji AKAMATSU



Mineo TORIKAI



Mitsuru FUKUDA