

Development of Positive Crankcase Ventilation System for Four-stroke Engine Used in Small Motorcycles

Ryuji MORIYAMA*

Yuki MURAOKA*

Kazuo FUJIHARA*

ABSTRACT

In a motorcycle engine blow-by gas is generally introduced into the intake system, including the air cleaner, to decrease blow-by emissions inside the crankcase. There was concern in the aforementioned system that some running conditions might shorten the oil change interval. Those phenomena were caused by mixing of water and gasoline in the blow-by gas into the engine oil. In order to control the phenomena, a new positive ventilation system of the crankcase was developed. In the new system fresh air is introduced into the crankcase by pressure fluctuations in the crankcase. The introduction of fresh air ventilates the crankcase. Comparing to the previous system, the developed Positive Crankcase Ventilation system has decreased the density of water and gasoline contained in the engine oil by 73% and 42% respectively.

1. Introduction

Most scooters with a displacement of 50 cm³ sold in Japan until 1999 were equipped with two-stroke engines. In 1999, Honda released the scooter equipped with a water-cooled four-stroke 50 cm³ displacement engine for the first time in Japan. The purpose was reducing emissions and improving fuel consumption. This scooter is used mainly as a means of daily transportation. Under some running conditions, water and gasoline components contained in the blow-by gas mix with the engine oil, which results in a shortened oil change interval⁽¹⁾.

The authors have developed a new positive crankcase ventilation system (PCV system) for the single-cylinder engines of small motorcycles in order to inhibit the mixing of these components and lengthen the time between oil changes. The system, unlike the conventional PCV system, has a one-way valve and a solenoid valve. This system was employed

in the Smart Dio Z4 scooter released in Japan in February 2004. Figure 1 shows an external view of this scooter.



Fig. 1 External view of Smart Dio Z4

* Asaka R&D Center

2. Engine Specifications

Table 1 shows the specifications of the four-stroke water-cooled engine mounted in the scooter released in February 2004. The radiator is located on the right side of the crankcase, and cooled by a fan attached to the crankshaft. The water pump is driven from the cam shaft via a magnet coupling, and the oil separator is located on the cylinder head. The fuel supply system uses the first fuel injection (FI) system in this category.

Table 1. Specifications of test engine

Engine type	4-stroke, 1 cylinder
Valve train	OHC 4-valve
Displacement (cm ³)	49.9
Bore × Stroke (mm)	38.0 × 44.0
Compression ratio	12
Cooling system	Liquid cooled
Lubricating system	Wet sump
Fuel supply system	Fuel injection
Power train	Belt converter

3. Mechanism of Water and Gasoline Components Mixing in the Engine Oil

When the engine temperature is low, the product of combustion, water and unburnt gasoline adhere to the cylinder walls in liquid form. This liquid enters the crankcase through the gaps between the cylinder, piston rings and piston. Also, the unburnt gasoline and water contained in the blow-by gas are cooled and condense inside the crankcase. In this manner, liquid gasoline and water blend into the engine oil. Figure 2 shows a model of this mechanism⁽²⁾.

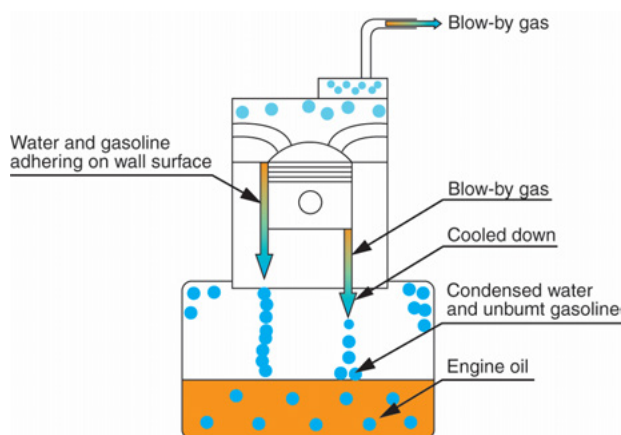


Fig.2 Generating mechanism of blending into oil

4. PCV System

4.1. System Outline

The PCV system introduces fresh air into the crankcase. Since the introduced fresh air dilutes the water and gasoline in the blow-by gas and the dew point is lowered, condensation becomes less likely. Furthermore, fresh air has an effect of vaporizing the liquid gasoline and water. The system, therefore, will be capable of discharging water and gasoline from the crankcase into the air intake system of the engine.

Figure 3 shows an outline of the Honda PCV system used in automobiles⁽³⁾. This fresh air flow is generated by the negative pressure of the inlet manifold. A PCV valve is provided to control the flow in order to stabilize the idling performance at a small throttle angle. At a wide throttle angle there is much blow-by gas and the inlet pipe has a low negative pressure, so the blow-by gas also flows backwards from the fresh air line. Therefore, oil separators are needed in the locations where the fresh-air line and the PCV valve are attached. However, this conventional system cannot be used in small motorcycles for the following reasons.

- (1) Since the amount of air intake at idling is extremely small, it is impossible to control such an amount of air intake with the PCV valve and to achieve adequate idling performance.
- (2) Since most motorcycles have one cylinder and one throttle body, negative pressure in the inlet pipe is relatively low compared with automobiles so that a sufficient amount of fresh air will not flow.
- (3) Gas-liquid separator systems must be installed for both the case and head for the system. It is difficult to locate these components on compact engines for small motorcycles.

Therefore, the authors devised a method not to return the blow-by gas to the inlet pipe.

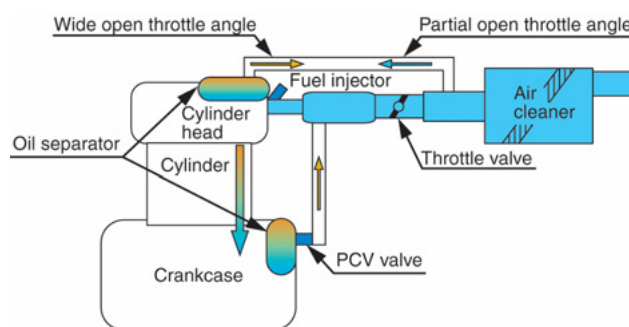


Fig. 3 PCV system for automobiles

4.2. PCV System with Two One-way Valves (Specification 1)

The blow-by gas in a motorcycle is normally returned to an air cleaner to prevent air pollution by the blow-by gas. In case of a scooter, an oil separator is located on the cylinder head due to layout restrictions, and the blow-by gas is returned from the oil separator outlet to the clean side of the air cleaner (Fig. 4). In addition to this system, a reciprocating type pump was formed utilizing the pressure fluctuation inside the crankcase by using two reed-valve type one-way valves (Fig. 5). One reed-valve type one-way valve was installed in the conventional tube that leads the blow-by gas to the air cleaner. This one-way valve is oriented to flow from

the cylinder to the air cleaner. The other one-way valve was installed in a new tube leading from the air cleaner to the crankcase. This one-way valve is oriented to flow from the air cleaner to the crankcase.

Installing this system produced the flow rate characteristics shown in Fig. 6. The return gas flow rate was higher at low vehicle speeds, and in particular the fresh air flow rate was about six times the blow-by gas flow rate at a vehicle speed of 5 km/h.

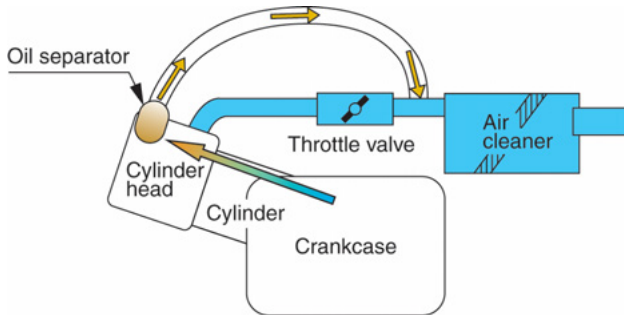


Fig. 4 Conventional blow-by return system

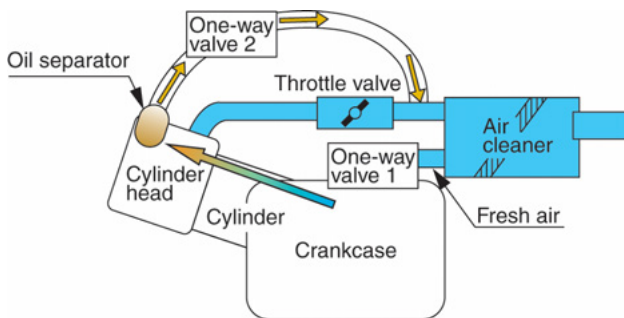


Fig. 5 Spec. 1: PCV system with two one-way valves

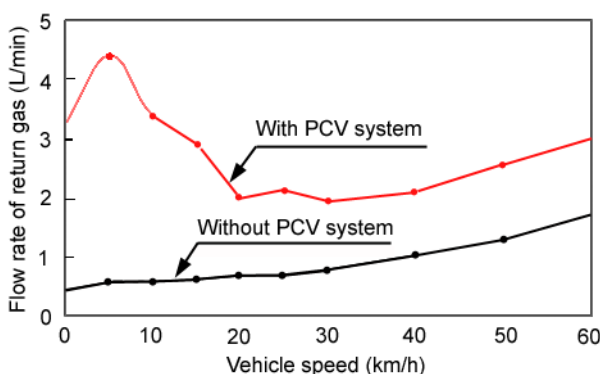


Fig. 6 Return gas characteristics in Spec. 1

- Fresh air:
Air taken into the crankcase from the air cleaner by the PCV system
- Return gas:
Gas returned from the crankcase to the air cleaner
- Flow rate of return gas:
Fresh air flow rate + Engine blow-by gas flow rate

4.3. PCV System with a Single One-way Valve (Specification 2)

With Specification 1 there was a concern that the pressure inside the crankcase might rise to abnormal levels if the one-way valve oriented towards the air cleaner becomes blocked due to oil degradation or water freezing. Therefore, the one-way valve 1 flowing toward the air cleaner as shown in Fig. 5 was removed. There was a concern that removing this one-way valve would cause the flow rate to drop, but roughly the same flow rate was ensured by reviewing the characteristics of the piping and the one-way valve (Fig. 7). Figure 8 shows the pressure in each part.

When the piston moves from the bottom dead center to the top dead center, the pressure inside the crankcase becomes lower than the pressure inside the air cleaner (A in Fig. 8). This pressure difference causes the one-way valve to open and lead fresh air to the crankcase. At the same time, the pressure inside the oil separator on the cylinder head also becomes lower than the pressure inside the air cleaner, which produces a flow from the air cleaner to the oil separator (B in Fig. 8). Then, when the piston moves from the top dead center to the bottom dead center, the pressure inside the crankcase becomes higher than the pressure inside the air cleaner (C in Fig. 8). This pressure difference causes the one-way valve to close and sends the return gas which consists of blended blow-by gas and fresh air through the oil separator to the connecting tube. In this manner, fresh air is led into the crankcase by operating the one-way valve using the pressure fluctuation inside the crankcase.

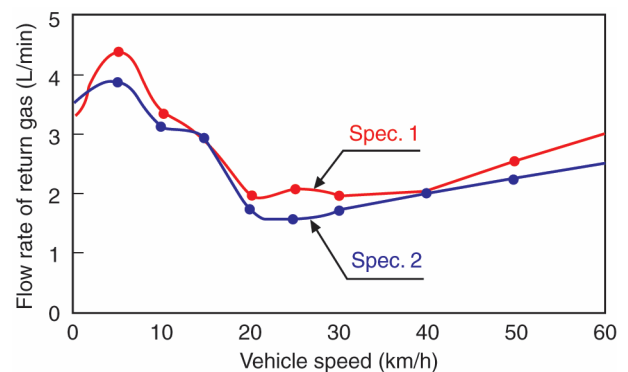


Fig. 7 Flow rate of return gas in Spec. 2

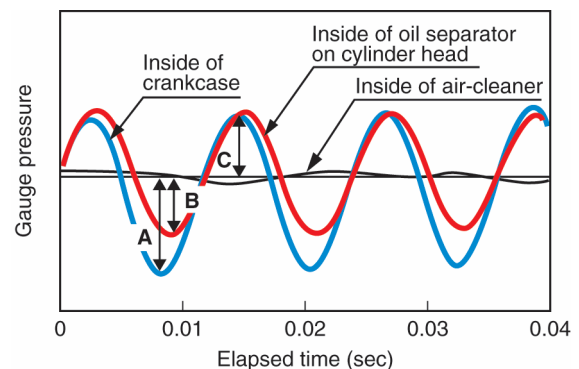


Fig. 8 Pressure fluctuation at 20km/h of vehicle speed

4.4. Specification with a Single One-way Valve and a Solenoid Valve (Specification 3)

The fresh air must be controlled to improve separation of the oil in the return gas in the high engine revolution range, and to enhance the idling performance in the low revolution, low load range in the vicinity of idling. Therefore, a solenoid valve was added to Specification 2 as Specification 3. This solenoid valve is map controlled by the ECU. The basic control consists of turning the PCV system off when the engine is idling, and turning it on when running starts (Fig. 9). The PCV system is also turned off at the high revolution side to improve the oil separation performance.

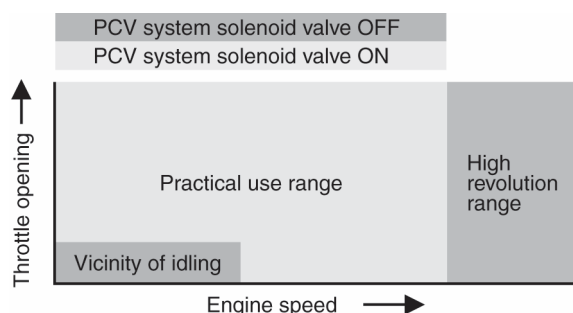


Fig. 9 Solenoid valve control map

5. PCV System Specifications for the Smart Dio Z4

Figure 10 shows the PCV system based on Specification 3 which was employed in the Smart Dio Z4. The PCV system reed valve type one-way valve is located on top of the crankcase, and the solenoid valve is located between the reed valve and the air cleaner. The return gas flow rate was set to the flow rate characteristics shown in Fig. 11 based on the oil separation performance and the reduction effects of water and gasoline in the engine oil. The maximum fresh air flow was approximately 6.5 times that of the blow-by gas. The flow rate characteristics were controlled by the plate thickness and lift amount of the reed valve. The flow rate of the return gas from the engine to the air cleaner was greatly increased by the PCV system in this manner, so it was necessary to enhance the gas-liquid separation capability of the oil separator. This was done by providing a labyrinth structure under the cylinder head cover. It was also confirmed that fresh air flows from the air cleaner at the reed valve location on the fresh air line side, so an oil separator is not needed in this location.

The concentration of CO in the exhaust gas while cruising was measured at the flow rate characteristics shown in Fig. 11. The results showed that the concentration of CO in the exhaust gas was slightly higher for the specification with the PCV system than without the PCV system due to the effects of the HC in the return gas (Fig. 12). The CO value in the mass emissions in ECE40 mode was also about 6% higher. However, this increase can be eliminated by setting the system in consideration of this increase.

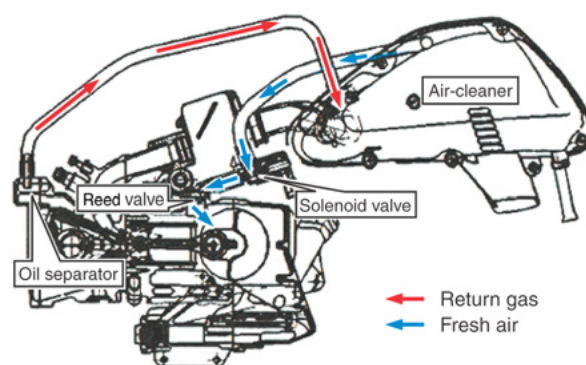


Fig. 10 PCV system for Smart Dio Z4

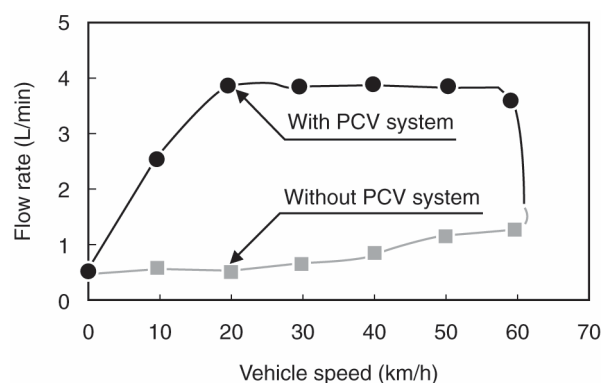


Fig. 11 Flow rate of return gas of Smart Dio Z4

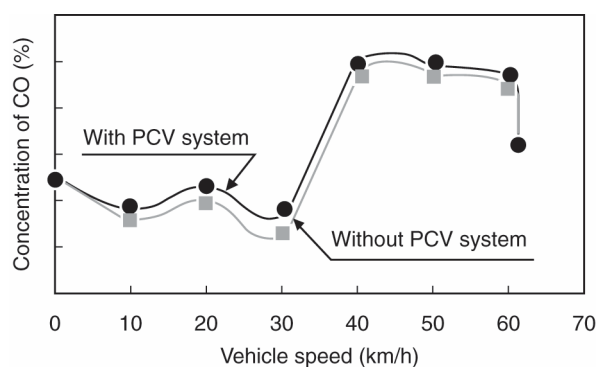


Fig. 12 Concentration of CO in exhaust gas

5.1. Confirmation of Water Content and Gasoline Content Reduction Effects by Vehicle Tests

5.1.1. Test conditions

The test mode was low-speed short-distance running. The running distance was 2 km per cycle, and 40 cycles were performed.

5.1.2. Climatic conditions

The environmental conditions were a temperature of 0 to 7 °C and relative humidity of 43 to 88%. (Fig. 13)

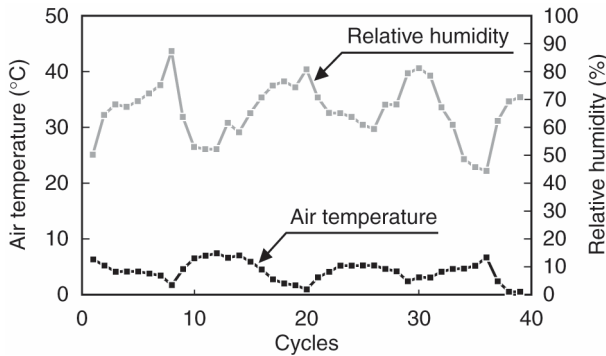


Fig. 13 Climatic conditions for running test

5.2. Test Results

The effects of the PCV system were evaluated by simultaneously running the vehicles equipped with and without the PCV system. The results showed that the gasoline concentration was reduced by 42% and the water concentration by 73% compared to the vehicle without the PCV system (Fig. 14).

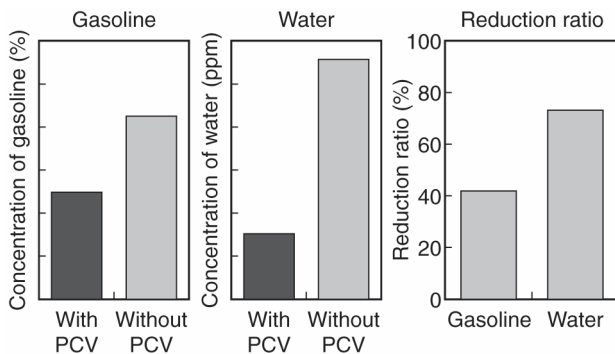


Fig. 14 Test results of running test

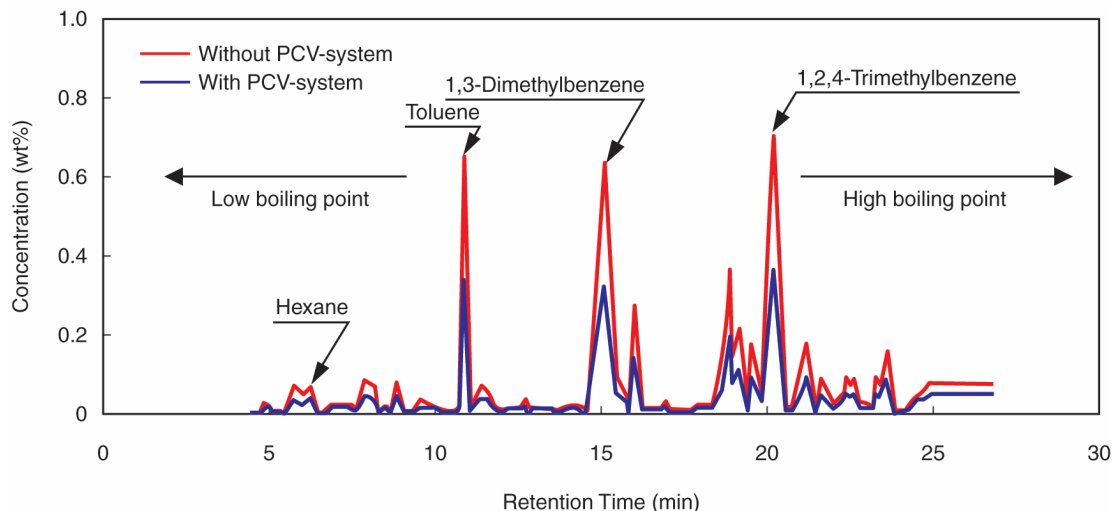


Fig. 15 Gasoline components in engine oil of running test

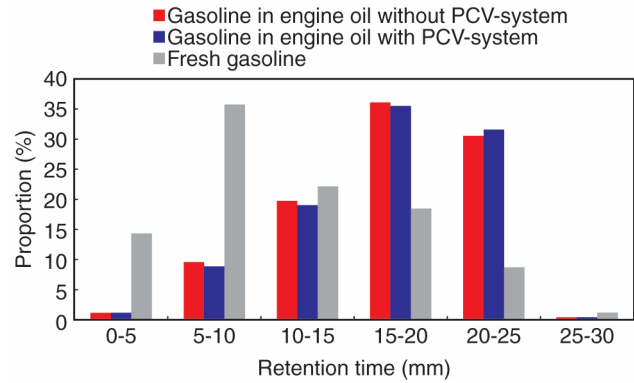


Fig. 16 Proportion of gasoline component after running test

The gasoline components contained in the engine oil after 40 cycles of these vehicle running tests were analyzed using gas chromatography. Figure 15 shows the results. The gasoline components in the oil for the vehicle with the PCV system were less than those for the vehicle without the PCV system. This included all components from low boiling point with a small retention time (RT) to high boiling point components with a large RT. This is due to the effects of the PCV system. Figure 16 compares the proportions of these gasoline components, and shows that the proportions are roughly the same both with and without the PCV system. In addition, the gasoline in the engine oil has less low boiling point components and more high boiling point components than fresh gasoline. This reason is thought to be that the low boiling components vaporize and burn easily inside the combustion chamber, and that even if these components enter the crankcase, most are returned to the air cleaner as blow-by gas.

6. Conclusion

- (1) Water and gasoline accumulate in the engine oil as a result of repeated short-distance running at low temperatures. This gasoline in the engine oil has less low boiling point components and more high boiling point components than fresh gasoline.
- (2) Using the newly developed PCV system in a compact four-stroke water-cooled engine with a displacement of 50 cm³ reduced the concentration of water by 73% and gasoline by 42% in the engine oil, respectively.

Acknowledgement

The authors wish to express their deep thanks to all related parties at Idemitsu Kosan Co., Ltd. for their cooperation in promoting this research and development.

References

- (1) Ishikawa, M.: The Crankcase Emission Control System of Automotive Engine, ENGINE TECHNOLOGY, Vol. 3, No. 6 (in Japanese)
- (2) Murakami, H., Aihara, H.: Analysis of Mechanism Intermixing Combustion Products in Engine Oil, Transactions of The Japan Society of Mechanical Engineers (Edition B), Vol. 55, No. 519 (1989)
- (3) Schwartz, S.E., Smolenski, D.J.: Development of an Automatic Engine Oil-Change Indicator System, SAE Paper 870403 (1987)

■ Authors ■



Ryuji MORIYAMA



Yuki MURAOKA



Kazuo FUJIHARA