

# Development of a 4-stroke Engine for Small Motorcycles with Low Fuel Consumption and Low Emissions for Thailand

Yoshinobu SAWAMURA\*

Norio SAITO\*

Bunichiro SAKAMOTO\*

Hideo KOBAYASHI\*

Yoshihisa HIROSE\*

---

## ABSTRACT

Concerns about environmental protection and energy savings continue to grow, including in Thailand where the market is requiring improvements in fuel consumption and emissions for motorcycles. Therefore, we developed a 125 cm<sup>3</sup> 4-stroke engine with revolutionized fuel consumption and emissions for the Thailand market. To enhance the fuel consumption, the friction of contact surfaces of the rocker-arm and piston and the mechanical input of the generator were reduced. Also, the combustion efficiency was enhanced by changing the ignition timing according to the throttle opening. To reduce the emissions, a secondary air pulse induction system, which introduces fresh air into an exhaust port, was employed. As a result, the fuel consumption was enhanced 30% in ECE40 mode compared to the 108 cm<sup>3</sup> engine of the previous model. The emissions were reduced 55% in CO and 60% in HC + NOx against the value of Thailand's 4th emission regulation.

---

## 1. Introduction

The small motorcycle market in Thailand has shifted toward motorcycles with 4-stroke engines since the second half of the 1990s, as shown in Fig. 1. In order to deal with Thailand's market conditions, such as a depressed economy and the 4th emission regulation, Honda is actively introducing motorcycles with 4-stroke engines that are both economical and offer superior environmental performance.

A 125 cm<sup>3</sup> 4-stroke engine for small motorcycles, which makes full use of the advantages of 4-stroke engines with the goal of further improving fuel consumption and reducing emissions, has been developed for the Thailand market. This paper describes the fuel consumption improvement and emissions reduction technologies applied to this engine.

## 2. Development Goals

The development goals were set as follows from the viewpoint of energy savings and environmental protection.

- (1) Energy savings: Improve fuel consumption in ECE-40 mode by 30% compared to the previous model
- (2) Environmental protection: Half or less of the Thailand 4th emission regulation values (4th emission regulation values = CO: 4.5 g/km, HC + NOx: 3.0 g/km)

## 3. Engine Overview and Major Specifications

Figure 2 shows a structural drawing of the developed engine, and Table 1 lists the main specifications.

---

\* Asaka R&D Center

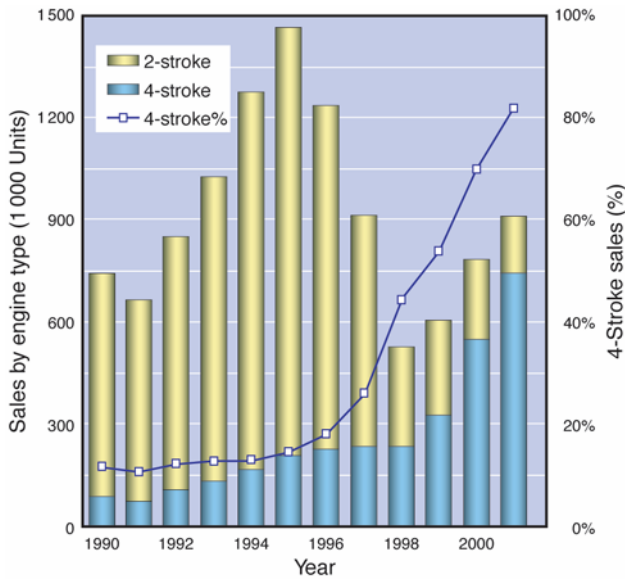


Fig. 1 Motorcyle market demand in Thailand, share by engine types

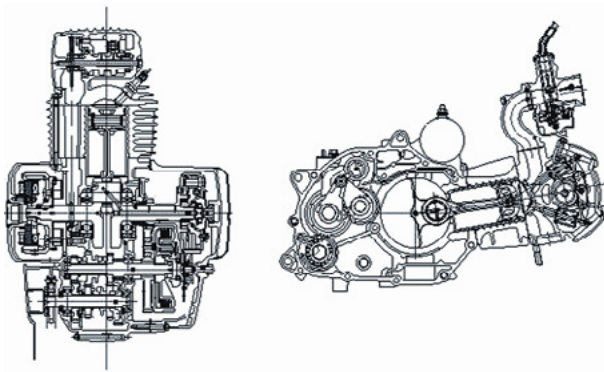


Fig. 2 Sectional drawing of developed engine

The developed engine is an OHC 2-valves, air-cooled, single-cylinder, 4-stroke engine. The displacement was increased to 125 cm<sup>3</sup> from the 108 cm<sup>3</sup> of the previous model. The included valve angle was changed from 66° to 49°. The intake valve diameter has been changed from 23 mm to 24 mm, and the exhaust valve diameter from 20 mm to 21 mm. In addition, the compression ratio was changed from 9.0 to 9.3.

#### 4. Fuel Consumption Improvement Technologies and Effects

The technologies employed to improve fuel consumption and their effects are described below.

##### 4.1. Employment of a Roller Bearing Type Rocker-arm

A roller bearing type rocker-arm was employed to reduce the sliding friction of the cam and the rocker-arm. However, simply adding a roller bearing to the same layout as the previous model would increase the inertia equivalent mass of the valvetrain system. Increasing the inertia equivalent mass of the valvetrain system would impair durability due to bounce at high engine speeds, and increasing the valve spring load to suppress bounce would increase the friction. Therefore, the included valve angle was changed from the 66° for the previous model to 49°, and the rocker-arm size was reduced. In addition, the weight was reduced by offsetting the valves and using a straight rocker-arm shape as shown in Fig. 4. As a result, the rocker-arm weight was kept the same as the previous model even with the addition of a roller bearing.

Offsetting the valves also made it possible to increase the valve diameters, thus securing sufficient air-fuel mixture volumetric flow without increasing the valve lift.

These developments reduced the friction due to valve drive at an engine speed of 4,000 rpm by approximately 13% as shown in Fig. 5.

Table 1 Major specifications of engines

| Items                      | Developed engine          | Previous engine           |
|----------------------------|---------------------------|---------------------------|
| Engine type                | 4-stroke, single-cylinder | 4-stroke, single-cylinder |
| Bore × Stroke (mm)         | 52.4 × 57.9               | 50 × 55.5                 |
| Displacement               | 125                       | 108                       |
| Compression ratio          | 9.3                       | 9                         |
| Valve train                | SOHC 2-valves             | SOHC 2-valves             |
| Valve diameter (mm)        | IN 24, EX 21              | IN 23, EX 20              |
| Included valve angle (deg) | 49                        | 66                        |
| Clutch type                | Automatic centrifugal     | Automatic centrifugal     |
| Transmission               | 4 speed constant mesh     | 4 speed constant mesh     |

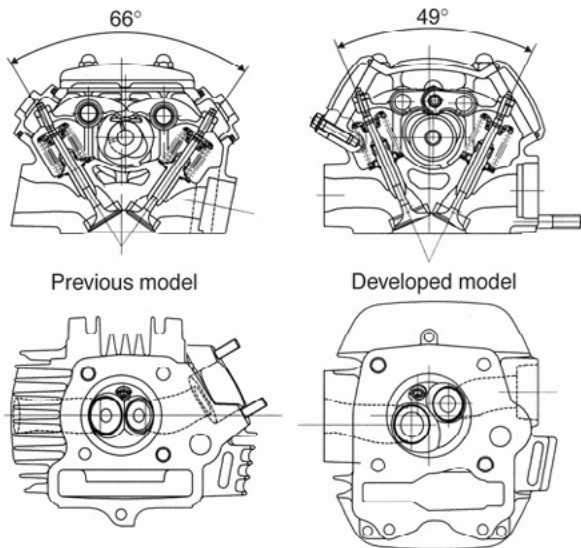


Fig. 3 Comparison of valve systems

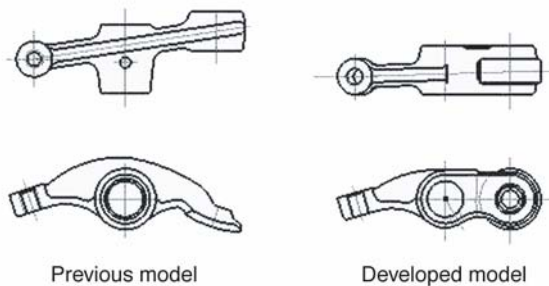


Fig. 4 Comparison of rocker-arms

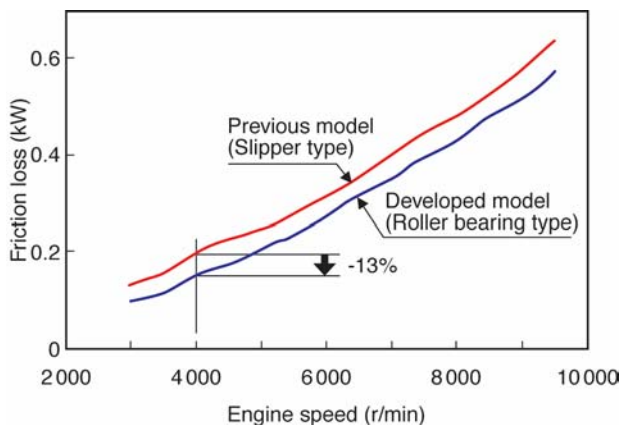


Fig. 5 Result of friction reduction by roller bearing type rocker-arm

#### 4.2. Reduction of Piston Sliding Friction

A molybdenum disulfide resin coating<sup>(1)</sup> was applied to the piston skirt as shown in Fig. 6 to reduce the piston sliding friction. In addition, striation machining was performed to create oil collection grooves in order to improve lubrication performance. Furthermore, the piston ring plate thickness of the TOP, 2ND and OIL rings was reduced from 1.0 mm, 1.0 mm and 2.0 mm of the previous model to 0.8 mm, 0.8 mm and 1.5 mm, respectively. This reduced the piston ring tension by 22% compared to the previous model.

As a result of these developments, the total piston height was reduced by 8 mm compared to 125 cm<sup>3</sup> class engines of existing models, thus reducing the piston system weight by 28%. The employment of these friction reduction technologies reduced friction at an engine speed of 4,000 rpm by 5% as shown in Fig. 7.

#### 4.3. Reduction of Friction by Lowering the Normal Cruising Engine Speed

In order to reduce the friction, which increases together with the engine speed, a high gear ratio was set to increase the displacement and achieve a low-speed, high torque type engine. This made it possible to set a low normal cruising engine speed. As shown in Fig. 8, the engine output was increased by approximately 20% compared to the previous model, and the engine speed at the same cruising speed was also reduced by approximately 20% compared to the previous model.

As a result, lowering the engine speed reduced the engine friction produced at the same cruising speed by approximately 23% compared to the previous model.

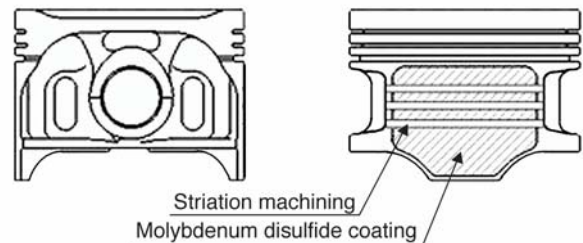


Fig. 6 Sectional drawing of developed piston

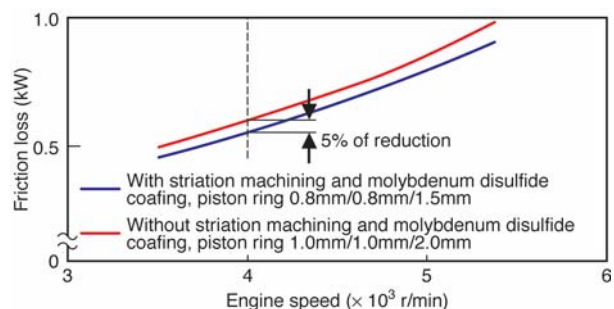


Fig. 7 Result of friction reduction by developed piston

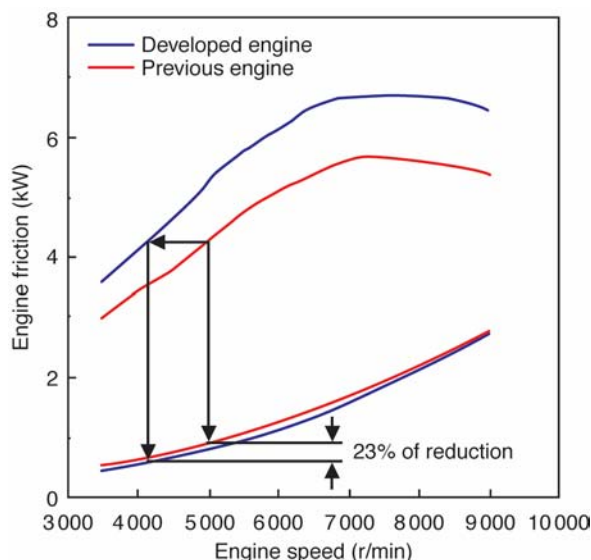


Fig. 8 Engine output and friction

#### 4.4. Reduction of Mechanical Input to the Generator

Reducing the engine speed also made it necessary to increase the charging output of the generator at low speeds.

However, simply increasing the generation capacity caused the mechanical input to the generator to rise due to the increased magnetic force. As a result, the mechanical input at an engine speed of 4,000 rpm increased by 20% compared to the previous model.

Therefore, the control system was changed as shown in Fig. 9 to reduce the generator friction. This system de-energizes voltage in excess of the prescribed voltage for the lighting side that was formerly short-circuited and became heat loss with conventional generation voltage control.

This made it possible to reduce the mechanical input to the generator even when increasing the charging output as shown in Fig. 10. As a result, the mechanical input value at an engine speed of 4,000 rpm could be reduced by 67% compared to the previous model.

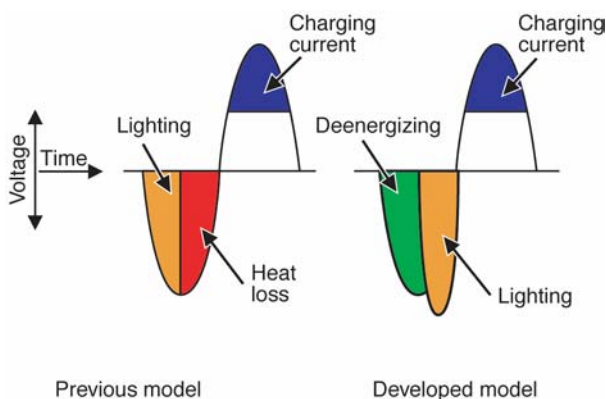


Fig. 9 Comparison of charging characteristics

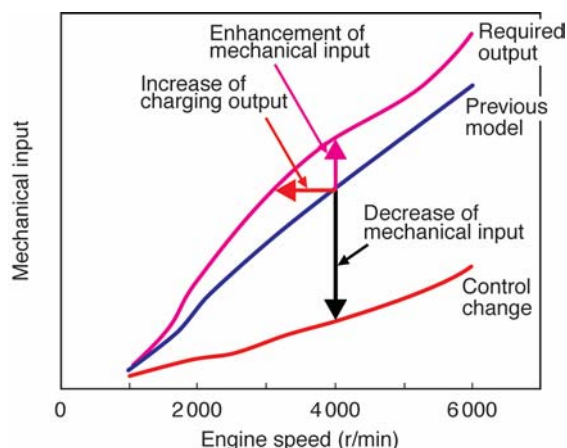


Fig. 10 Reduction of mechanical input

#### 4.5. Improvement of Combustion Efficiency by Optimizing the Ignition Timing

Simply advancing the ignition timing and increasing the compression ratio to improve combustion efficiency produces the knocking<sup>(2)</sup>, which is undesirable. Therefore, control must be performed to change the ignition timing as required according to the throttle opening and the engine speed. To achieve this, a throttle opening detection switch was provided to the side of the carburetor throttle valve to detect the throttle opening. This switch is used to switch the ignition timing at a throttle opening of around 40%. Controlling the ignition timing as shown in Fig. 12 made it possible to avoid knocking which occurs easily at a throttle opening of 40% or more, and allowed the compression ratio to be increased from the 9.0 of the previous model to 9.3. As a result, BSFC at an engine speed of 4,000 rpm increased by 17%. Figure 13 shows a comparison of BSFC when the ignition timing is changed.

#### 4.6. Fuel Consumption Improvement Results

Reducing friction in each part and increasing the combustion efficiency improved fuel consumption by 30% compared to the previous model. Figure 14 shows the measurement results for fuel consumption in ECE-40 mode.

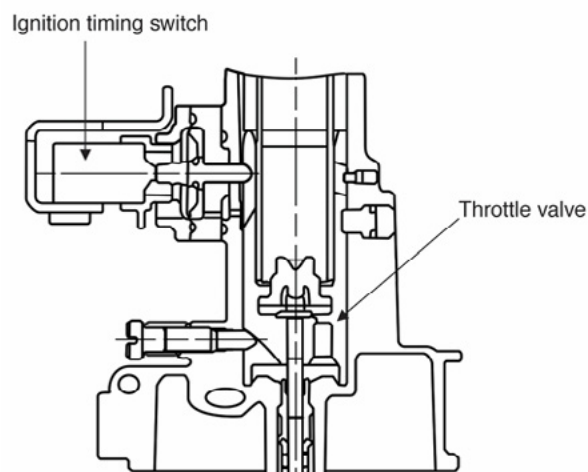


Fig. 11 Sectional drawing of developed carburetor

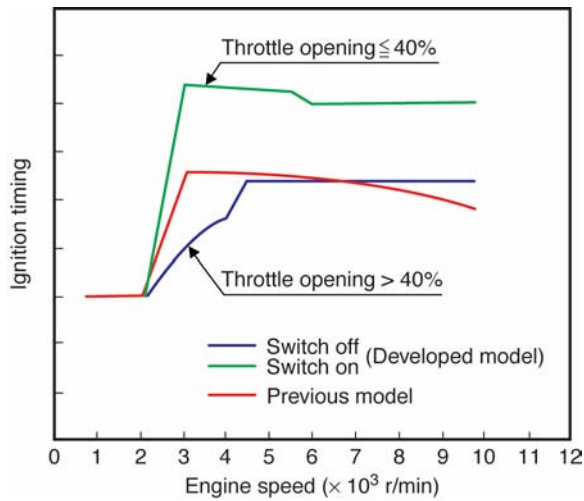


Fig. 12 Characteristic of ignition timing

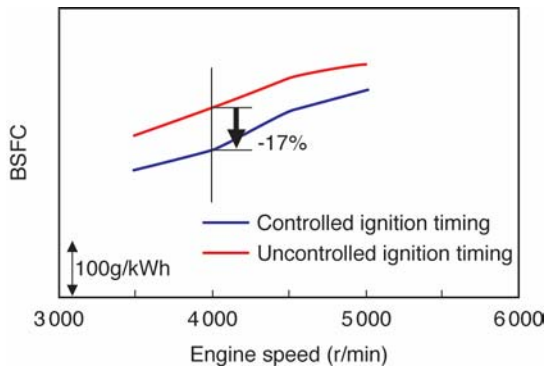


Fig. 13 Result of BSFC reduction by controlling ignition timing

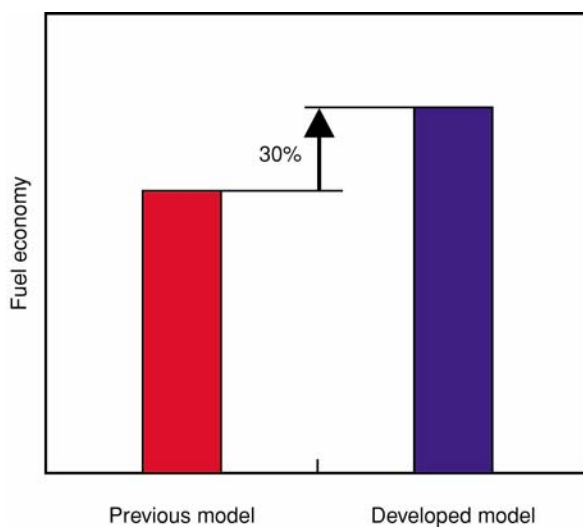


Fig. 14 Result of fuel consumption in ECE-40 mode

## 5. Reduction of Emissions

A secondary air pulse induction system<sup>(3)</sup> was added to the exhaust port to combust the unburned gas discharged from the combustion chamber to the exhaust port. Figure 15 shows the structural drawing. This system leads fresh air to the exhaust port with an air suction valve (ASV) utilizing the negative pressure generated at the exhaust port.

The employment of a secondary air pulse induction system reduced CO by 55% and HC + NO<sub>x</sub> by 60% from the Thailand 4th emission regulation values as shown in Fig. 16.

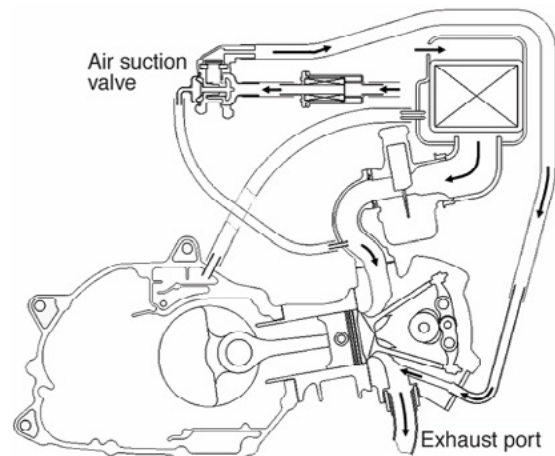


Fig. 15 Diagram of secondary-air pulse induction system

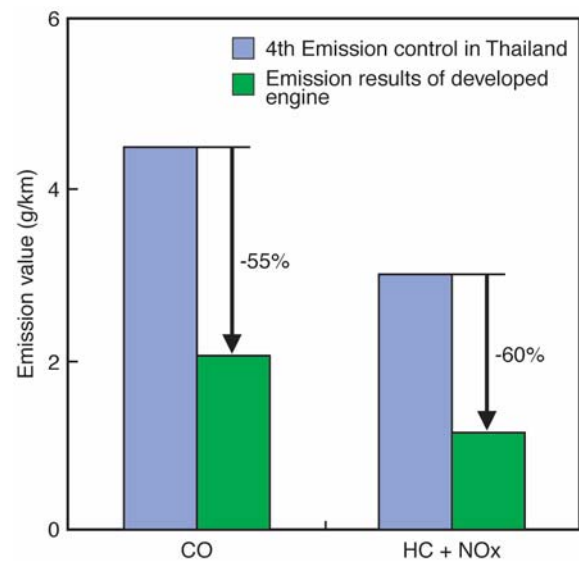


Fig. 16 Results of emission

## 6. Summary

The newly developed engine introduced technologies to reduce engine friction, improve combustion efficiency and reduce emissions. The following was achieved.

- (1) Friction at an engine speed of 4,000 rpm was reduced by 23% compared to the previous model.
- (2) Fuel consumption in ECE-40 mode was improved by 30% compared to the previous model.
- (3) CO emissions were reduced by 55% and HC + NO<sub>x</sub> emissions were reduced by 60% from the Thailand 4th emission regulation values.

## References

- (1) Editorial Committee for Automobile Piston: Surface Treatment of Automobile Piston, Sankaido, Tokyo, p. 167-173 (1997) (in Japanese)
- (2) Nakajima, Y., Muranaka, S.: Chapter 2 Enhancement of Fuel Consumption, Revision: Automobile Gasoline Engine, Sankaido, Tokyo, p. 29-31 (2001) (in Japanese)
- (3) Nakajima, Y., Muranaka, S.: Chapter 4 Cleaning of Exhaust Gas, Revision: Automobile Gasoline Engine, Sankaido, Tokyo, p. 109-110 (2001) (in Japanese)

## ■ Authors ■



Yoshinobu SAWAMURA



Norio SAITO



Bunichiro SAKAMOTO



Hideo KOBAYASHI



Yoshihisa HIROSE