

Development of Idling Stop System for PCX

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ABSTRACT

An idling-stop system that can be mounted on the 125-cm³ engine of the PCX scooter was developed in order to enhance the environmental performance of the PCX. The system was made to use an ACG starter, which does not have a reduction mechanism for use in starting, in order to realize quiet starts with an impression of high quality. Cranking this engine requires a large ACG starter, and mounting this starter within the space given for attaching the ACG in the 125-cm³ engine became an issue. This issue was addressed by reducing the engine cranking torque by means of a decompression device and by adopting a cranking method that makes use of inertial force. This approach realized an ACG starter of a size that allows mounting in the space for mounting the ACG in a 125-cm³ engine.

1. Introduction

Heightened concern for environmental issues in recent years has led to demand for reduction of CO₂ emissions, or in other words, further measures to enhance fuel economy, with the motorcycle field being no exception. One technology to address this issue is the idling-stop system utilizing an ACG starter, but practical application of such systems has stopped at the 50-cm³ engine. There is demand for application to vehicles of the 125-cm³ class, which make up a large proportion of unit sales worldwide. A system capable of application to 125-cm³ engines was therefore developed and mounted on the PCX, which is a model for global deployment, and this article describes the technical points involved.

2. Overview of the PCX Model

The PCX is a model that was developed to address diversifying customer needs through the key phrases “High-quality feel and advanced styling exceeding its class,” “Balance of high engine performance and environmental performance,” and “Comfort and good drivability demanded of a scooter.” The intention was to deploy this product globally as a next-generation 125-cm³ scooter raised one rank higher. Figure 1 shows the appearance of the PCX, and Table 1 lists its major specifications.

The engine is a newly developed 4-stroke, single-cylinder, liquid-cooled type with integrated radiator⁽¹⁾, made light and compact with 125-cm³ displacement



Fig. 1 Appearance of PCX

Table 1 Major specifications of PCX

Items	Specifications
Overall length (mm)	1915
Overall width (mm)	740
Overall height (mm)	1090
Wheelbase (mm)	1305
Vehicle mass (kg)	126 (Wet)
Engine type	Liquid-cooled, 4-stroke OHC, single cylinder
Engine displacement (cm ³)	124.9
Bore x Stroke (mm)	52.4 x 57.9
Compression ratio	11
Fuel supply system	PGM-FI
Maximum power (kW/rpm)	8.33/8000
Fuel economy (km/L)	45.9 *
Front tire size	90/90-14M/C 46P
Rear tire size	100/90-14M/C 57P

*In-house test value: EURO-3 control mode, with idling-stop system

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to produce a high-quality drive. It was designed with installation of the ACG starter in mind, so it does not have the starter motor, reduction gear, one-way clutch, driven gear, and other starter system parts found in conventional specifications. This enhances the scooter's quietness when starting while simplifying the construction. The weight is reduced by approximately 1.4 kg and the engine width is reduced by 15 mm relative to scooters with conventional starter systems. Figure 2 shows a comparison of starter system parts.

The adoption of a fuel injection system that provides optimal fuel supply for a variety of operating conditions achieved a balance of environmental performance and engine output with plenty of power to spare. It was also equipped with an idling-stop system (ACG-starter type) that automatically stops the engine at traffic signals, in congestion, and other temporary stops. This is a first in a 125-cm³ class scooter. This reduces the wasteful consumption of fuel and emission of exhaust gases during idling, realizing higher environmental performance.

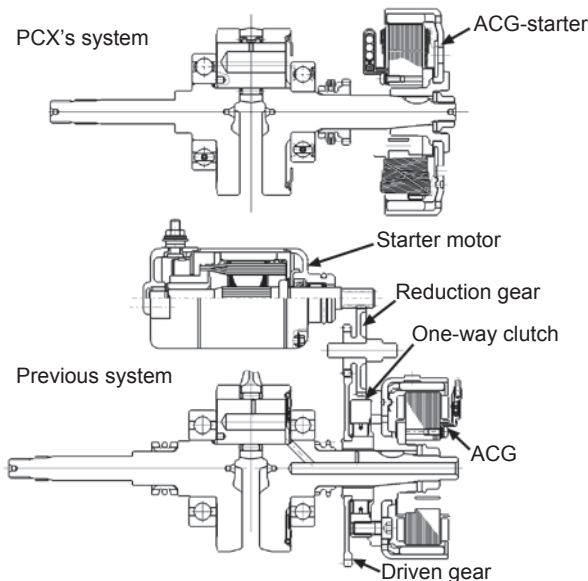


Fig. 2 Comparison of starter system parts

3. Overview of System

Figure 3 shows an overview of the idling-stop system for the PCX. This system is made up of the ACG starter that combines the AC generator and starter motor functions, a decompression device to reduce cranking torque when restarting the engine, an electronic control unit (ECU) that controls ignition, fuel injection, and idling-stop as well as electric power generation and motor drive control, and various sensors and indicators.

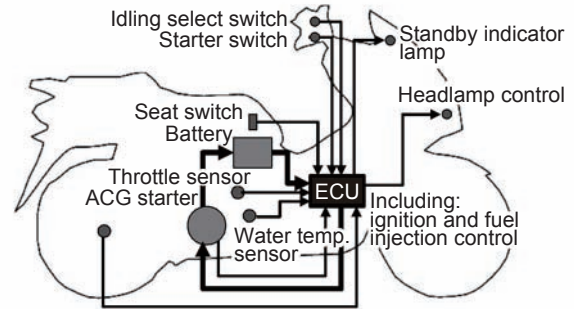


Fig. 3 Configuration of idling-stop system for PCX

4. Idling-stop System Operation

The method used to first start up is to press the starter button in the same way as when starting an ordinary scooter. Under these conditions, the engine will idle even when the scooter is stopped, and this state will continue until the scooter shifts to the idling-stop execution mode, which will be described next.

After the engine has started and the scooter is detected to be running at 10 km/h or faster and the water temperature is 60°C or higher, the system shifts to the mode that executes idling-stop. From that point, the engine will stop automatically and enter the idling-stop state when the system detects that the throttle is fully closed, the driver is seated, and the scooter is continuously stopped for three seconds or more. When the system detects that the driver is seated and the throttle is opened, the engine is restarted by the ACG starter and the scooter will be able to start moving⁽²⁾.

5. Features of the Idling-stop System for the PCX

5.1. ACG Starter

5.1.1. Structure and performance

As shown in Fig. 4, the starter device has the newly developed ACG starter located on the engine crankshaft

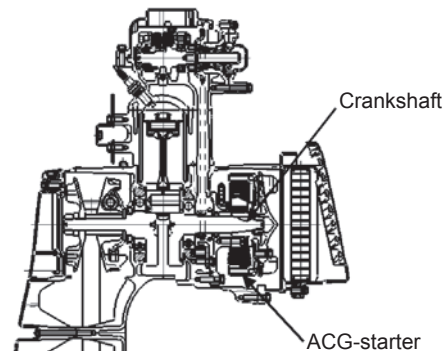


Fig. 4 Layout and configuration of ACG-starter and transmission

so that it drives the crankshaft directly. This ACG starter is an outer-rotor type, three-phase DC brushless motor. The flywheel is of the surface permanent magnet (SPM) type that is easy to manufacture. Figure 5 shows the configuration of the ACG starter.

Conventional ACG starters used dedicated sensor magnets. These were eliminated by inserting an angle sensor between the stator coil poles, as shown in Fig. 6, to detect the crankshaft phase from the position of the magnet for power generation. The effect on the angle sensor's crank angle detection accuracy from the magnetic field generated when power to the motor was on was at the level shown in Fig. 7, which does not affect the motor torque characteristic.

The ACG starter was also made more compact in size for this system by a starting system that makes use of inertial force. When cranking, therefore, it is important to raise the engine cranking speed higher just before the compression start. Figure 8 shows the engine cranking speed just before the compression start that this system is capable of. When the engine starts, as shown in Fig. 9, the system turns the crankshaft back from its current position to

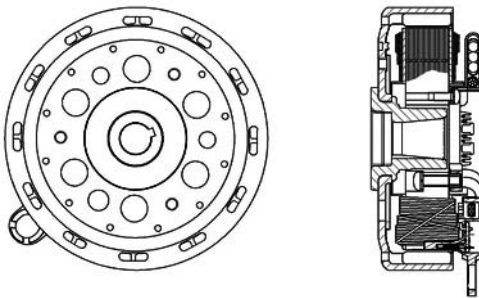


Fig. 5 Design of ACG-starter

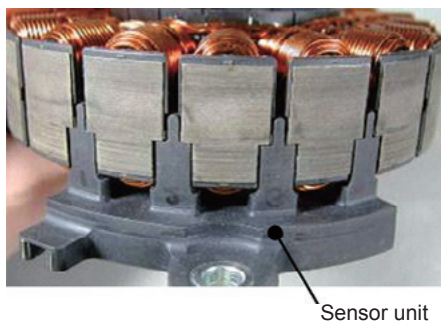


Fig. 6 Layout of angle sensor

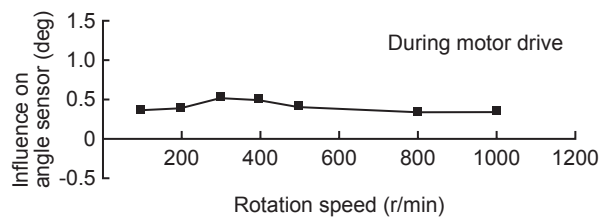


Fig. 7 Influence on angle sensor (at motor drive)

immediately after compression top dead center one stroke before, and then starts the crankshaft moving in the normal manner (swingback movement). This can provide an adequate cranking angle up to just before the compression start, and can make maximum use of the inertial force.

The above measures enabled the ACG starter to be made in a size that would fit in the space allotted for mounting the ACG. Figure 10 shows the motor torque characteristics of this ACG starter.

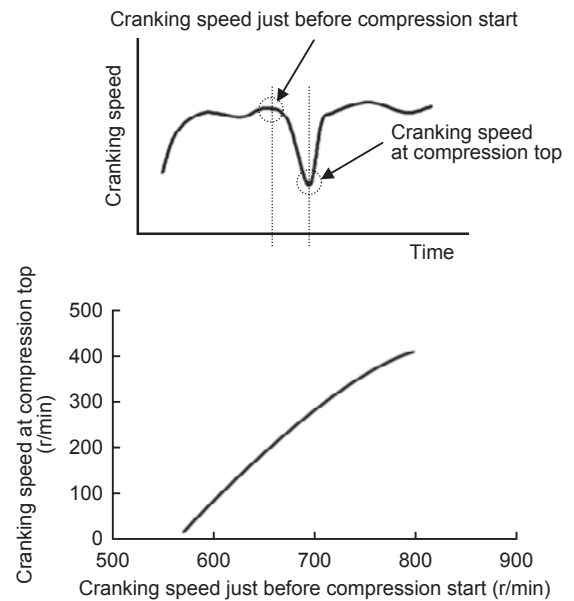


Fig. 8 Relation of cranking speed just before compression start and the compression top

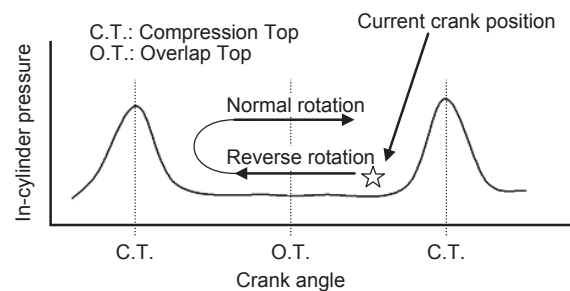


Fig. 9 Explanation of swing-back movement

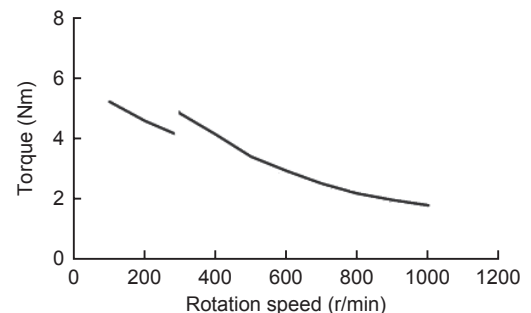


Fig. 10 Motor characteristics of ACG-starter

5.1.2. Electric generation control

In this system, the power generated by the ACG is controlled by advancing or retarding the electricity phase of the three-phase bridge for driving the ACG starter, as shown in Fig. 11. Figure 12 shows the relationship between the electricity phase and the power generated by this ACG starter. Adoption of this method enabled a reduction of electrical friction loss relative to the ordinary short-circuit type of regulator as shown in Fig. 13. Figure 14 shows the difference in electrical friction loss between the electricity phase angle control method and short circuit method.

5.2. Decompression Device

5.2.1. Structure and configuration

This system makes use of a decompression device to reduce cranking torque. At the cranking speed obtained with the ACG starter, the rocker arm is temporarily pushed up

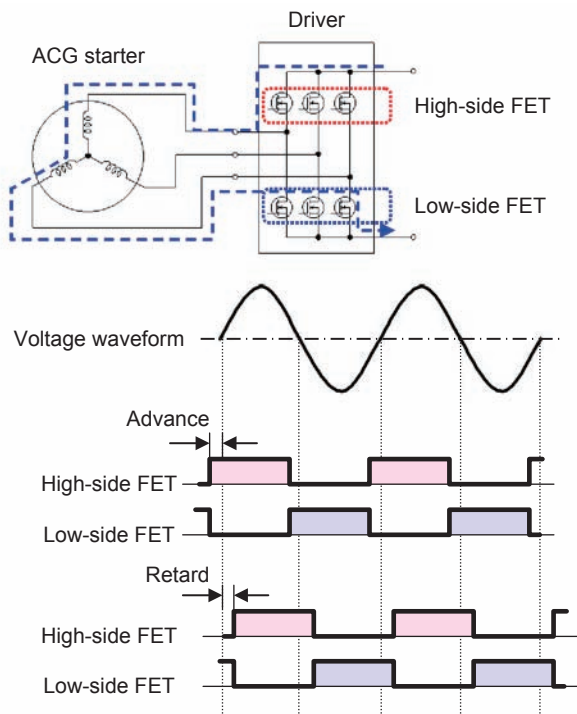


Fig. 11 Output electric current control by phase control

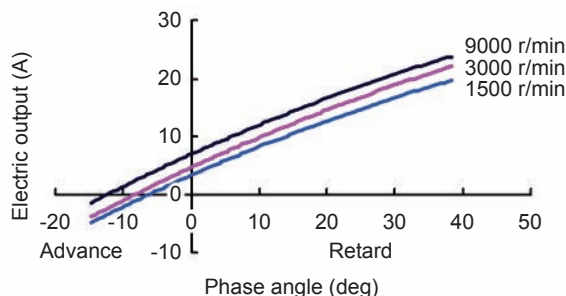


Fig. 12 Relation of phase angle and output current

by the decompression cam during the engine compression stroke. This lifts the exhaust valve and reduces the pressure in the cylinder, allowing reduction of the cranking torque when the engine restarts.

On the other hand, centrifugal force on the decompression arm when the speed rises above idling will cause the decompression cam to turn, deactuating the decompression function. Figure 15 explains the operation of the decompression device. When the decompression device is actuated during idling, noise may be generated due to the repeated operation of the decompression arm and the engine might stop due to reduced compression. Therefore, the decompression release rotation speed was set at 1100 r/min, allowing some extra margin from the lower idling limit. Furthermore, it is necessary to set the upper limit on ACG starter speed at or below the decompression release rotation speed in order to avoid cranking faults due to deactuation of decompression. In order to satisfy these conditions, the decompression release rotation speed was set at 850-1100 r/min and the upper limit on ACG starter speed was set at 850 r/min (Fig. 16).

Moreover, in order to assure the necessary combustion force to start the engine, it is necessary to assure a minimum level of compression. Given the results of the limit test on startability, the compression lower limit was set at 720 kPa.

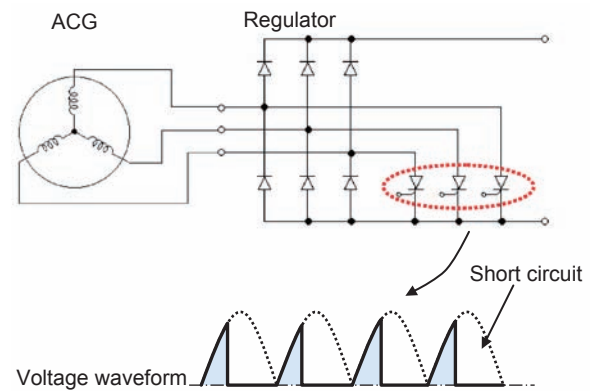


Fig. 13 Short circuit type regulator

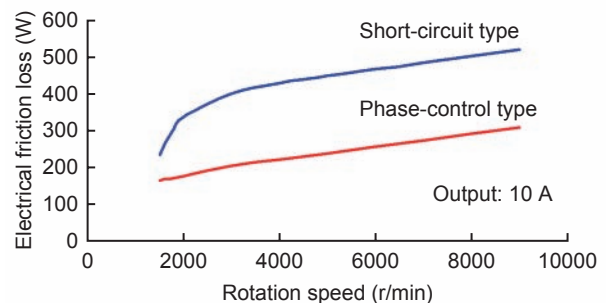


Fig. 14 Difference of electrical friction loss during electric generation by difference of control method

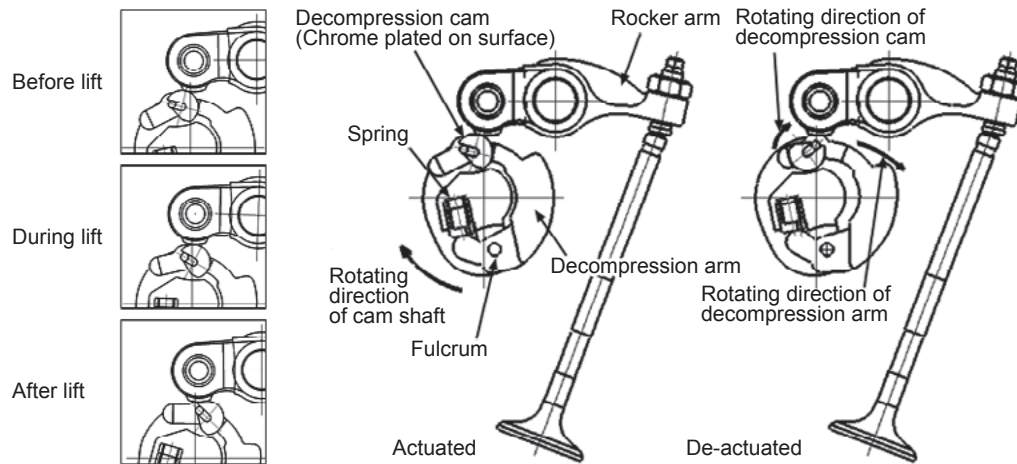


Fig. 15 Actuation of decompression device

5.2.2. Decompression device issues and responses

Previous engines in the same category had the decompression cam part and the weight part in a single integrated structure. The angle of rotation of the decompression arm was large, so that when the decompression arm hit the stopper it would generate an impact sound. In the case of the idling-stop system, the frequency of operation increased, raising concerns about the effect on product appeal. Therefore, the decompression cam part and the decompression arm part were made separate parts employing a linking structure that reduced the angle of rotation of the decompression arm and reduced the impact noise. Figure 17 shows a comparison of the specifications of the newly developed decompression device and the previous decompression device. The new development contributes to realization of the PCX aim for “High-quality feel exceeding its class.” This new device also allowed reduction of the space situated so as to avoid interference by the decompression arm with other parts, thus contributing to making the cylinder head part more compact.

The decompression cam in previous engines not

equipped with idling-stop system was made from carburized SCM420H steel. However, taking into consideration the frequency of starting involved on the assumption that idling-stop system is installed, there is concern that the decompression cam may undergo unusual wear. Therefore, the decompression cam surface was chromium plated to enhance its wear resistance. This reduced the wear on the decompression cam to a level that would not become an issue.

The fulcrum point for the decompression arm was placed ahead of the weight part relative to the direction of rotation so that the inertial force generated when reverse rotation switches to forward rotation during swingback operation would not deactivate decompression.

5.2.3. Effects of decompression

The installation of a decompression device, as shown in Fig. 18, enabled reduction of the compression torque (peak value) from 18 Nm to 12 Nm. This enabled cranking the 125-cm³ engine while holding the ACG starter size down to a minimum, contributing to making the engine more compact.

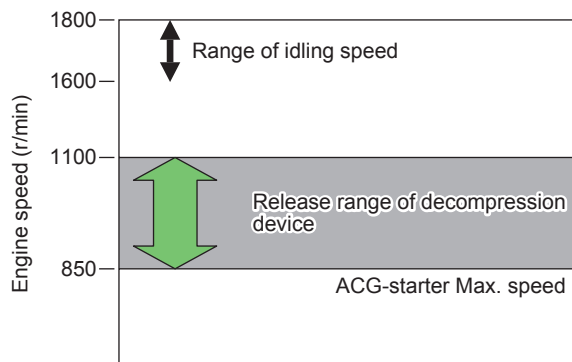


Fig. 16 Release rotation speed range of decompression device

5.3. Control of Engine Stopping and Restarting

Stopping the engine when idling-stop occurs is done by stopping the injection of fuel in order to reduce the outflow of non-burned gasoline. When the engine is automatically stopped by the idling-stop system, the swingback movement is performed immediately after the engine stops so that cranking can take place promptly in the normal direction the next time the engine is started.

On the other hand, it may become necessary to restart the engine immediately after it has been automatically stopped and while it is still turning under its momentum. In such cases, it may be that the engine can be started more smoothly if the swingback movement is not performed. It is necessary, therefore, to judge whether or not to implement

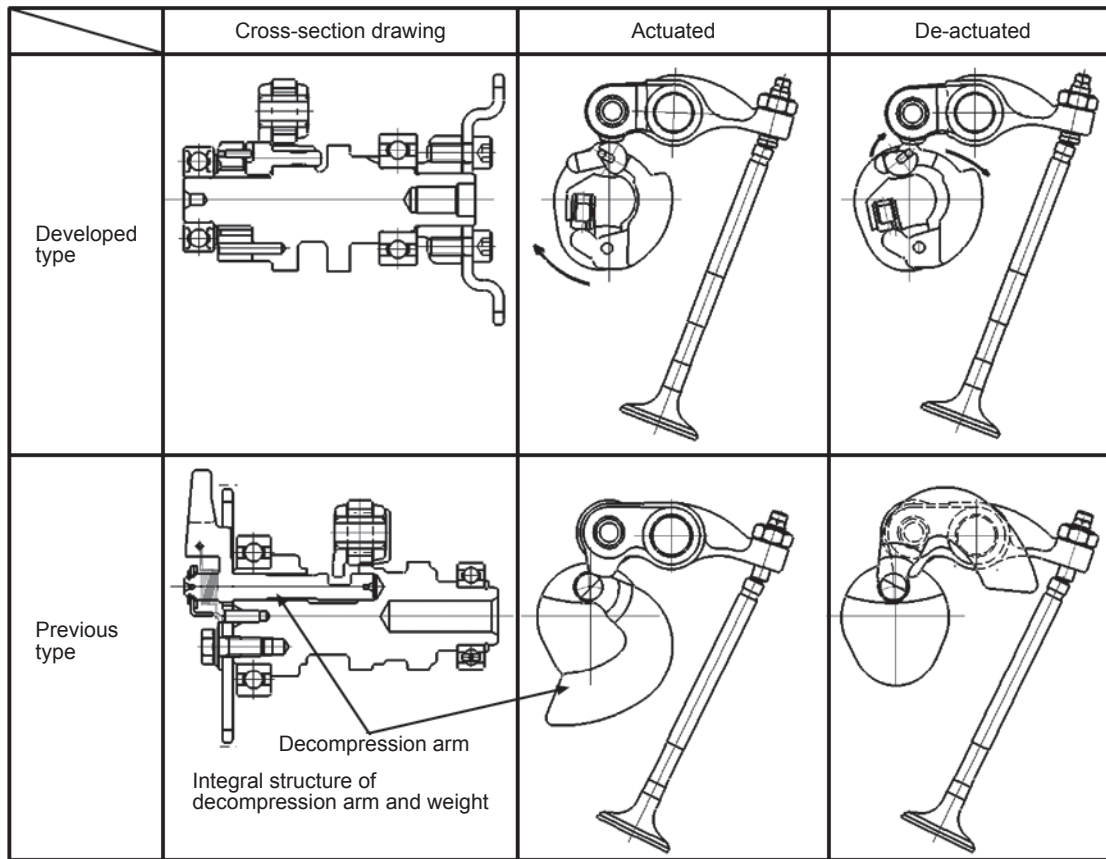


Fig. 17 Comparison between developed and previous decompression devices

the swingback movement. This is decided by the crankshaft position and speed. Figure 19 shows the swingback decision table.

Electric power consumption during idling-stop is reduced by dimming the headlamp and stopping the fuel pump. Therefore, a fuel pump with the increasing characteristic of the fuel pressure required for restarting was used. Figure 20 shows the increasing characteristic of the fuel pressure in the fuel pump.

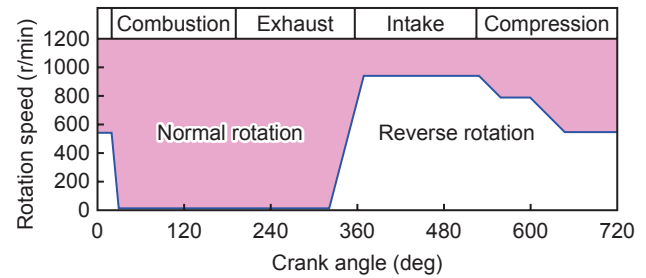


Fig. 19 Transition of swing-back operation during idling-stop

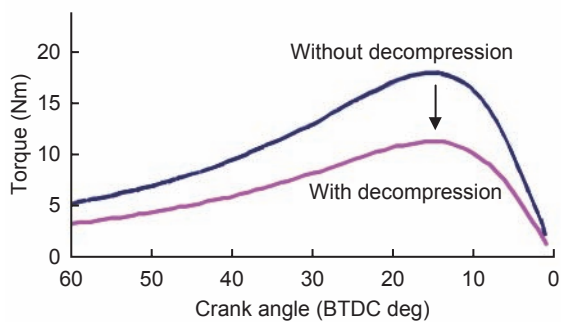


Fig. 18 Effect of reduction of demand torque by decompression device

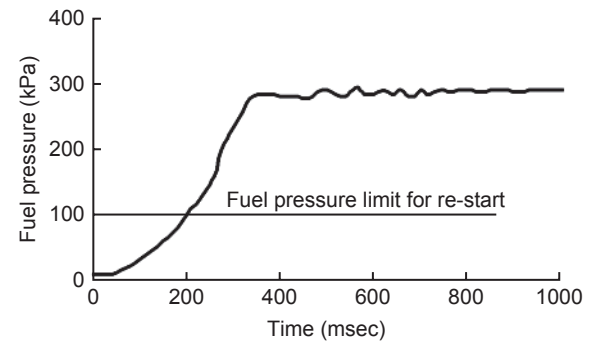


Fig. 20 Increasing characteristic of the fuel pressure in pump

6. Effects Obtained by Idling-stop

Making use of idling-stop yielded a 7.5% increase in fuel economy and a 7.0% reduction in CO₂ emissions (Table 2). The EURO3 control mode was used as the measurement mode (Fig. 21).

Table 2 Effects of Idling-stop

	Fuel economy (km/L)	CO ₂ (g/km)
Without idling-stop system	42.7	53.0
With idling-stop system	45.9	49.3
Effect	7.5%	- 7.0%

In-house test value: EURO-3 control mode

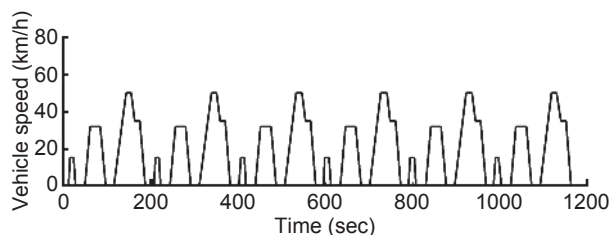


Fig. 21 Measurement mode of EURO 3 control

7. Conclusion

An idling-stop system that can be mounted on a 125-cm³ scooter was developed. The ACG starter drives the crankshaft by a direct link to realize quiet starts and enhance the impression of PCX quality.

The following are the technical points involved.

- An ACG starter capable of starting a 125-cm³ engine with low electrical friction loss was developed.
- A decompression device was adopted in order to reduce cranking torque.
- A cranking system that makes use of inertial force was adopted in order to keep the size of the ACG starter down to a minimum. The effects of this system were a 7.5% increase in fuel economy and a 7.0% decrease in CO₂ emissions (in EURO3 control mode).

8. References

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