Development of 2018 PCX and PCX HYBRID

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ABSTRACT

In the fourth-generation model of the 2018 PCX, the basic structure of frame was reviewed to make it lighter and rigid. Weight reduction was also adapted to its wheels. These enhancements contributed to its increased dynamic performances. The engine performances were enhanced as well, and all these features made it possible to provide a high-quality riding with composure of rider's mind. In addition, we developed hybrid model PCX HYBRID that uses an ACG starter directly connected to a crankshaft as a drive assist system and realized pleasurable ride feeling with a more direct drive response.

1. Introduction

The market for small scooters has recently been expanding, mainly in Asia. The first-generation PCX, which was launched on the global market in 2009, was very successful in drastically transforming the 125 cc scooter concept through the following added values:

- Comfortable, relaxed riding position in the higher end models realized in the easy-to-handle 125 cc-size body
- High-quality feel provided by its styling package
- Comfortable, high-quality ride
- Reliable environmental performance.

The packaging design of the PCX has continued to provide all the above features. These features have led to the PCX series models being very well received by people around the globe, and it is seen as higher-class commuters in ASEAN and other countries in the region and seen as a distinguished higher grade product compared to other conventional scooters of the same class in both Japan and Europe. Since its introduction, the PCX has continuously evolved, also seeing the addition of 150 cc model, PCX150, in pursuit of an ideal packaging design for both 125 cc and 150 cc scooters.

The fourth-generation model introduced in this paper, the 2018 PCX, was developed as a full model change (Fig. 1). The main aim in developing this model was to make the PCX more attractive while at the same time retaining the core features of the previous PCX models that appeal to current consumers. When setting the design goal, we introduced five conceptual pillars: freshness, running performance, comfortability, ease of use, and economical efficiency, with the aim of making the new model better than the previous models in all these respects.

In addition, we newly developed the world's first hybrid system for use in a mass-produced motorcycle (according to a research study by Honda), and installed it in the PCX HYBRID (Fig. 2). This hybrid system is designed to assist the vehicle's acceleration through the utilization of a drive motor directly coupled to the crankshaft. This hybrid system enables the rider to experience a very different ride sensation from that offered by conventional models of the same class. Hence, the desire of the development team to offer users a model that is more "fun to ride" was realized.

This paper introduces the new technologies that were adopted in the 2018 PCX and PCX HYBRID models.

Fig. 1 The PCX (2018)

[1] Motorcycle R&D Center

[2] R&D Center X

Fig. 2 The PCX HYBRID (2018)

2. Development Concept

Before commencing development, we conducted a market survey to gather the opinions of current users in ASEAN countries. The survey results showed that users were fairly satisfied with the PCX model as a high-grade scooter. The survey also revealed that users had strong desire to show their wealth by purchasing a PCX.

So, we therefore decided to retain the core features of the current PCX that were the most appealing and to further enhance the attractiveness of the model. Accordingly, we decided to stay with the development concept of “personal comfort saloon,” which had been inherited from the first-generation PCX.

Then, the development theme of “premium daily use scooter to satisfy user’s sense of superiority around the world” was set together with three development objectives as follows:

- High-quality, comfortable ride enabled by enhanced maneuverability
- New expression of excellence
- More convenience and user friendliness

Furthermore, a new variant was added to employ an hybrid system in order to feature more innovation, quality, and the joy of riding.

3. Development of 2018 PCX

3.1. Reduced Weight and Enhanced Maneuverability

In order to get a better maneuverability, we implemented measures to reduce the weight and increase the rigidity of the body.

So, the body frame was changed from the previous underbone frame (Fig. 3) to a double cradle frame (Fig. 4). Also, the material of the front cover stay bolted to the frame was changed from metal to resin. As a result, the total combined mass of the frame and front cover stay was reduced by 2.4 kg compared to the previous model. As regards the rigidity of the frame, longitudinal stiffness was increased by 50.4% and torsional rigidity was increased by 2.9%, which contributed to enhanced operational performance of the suspension and vehicle stability.

The front and rear tires and wheels were also renewed (Fig. 5). The wheels were newly designed not only for wider tires but with the aim of also reducing the weight. For

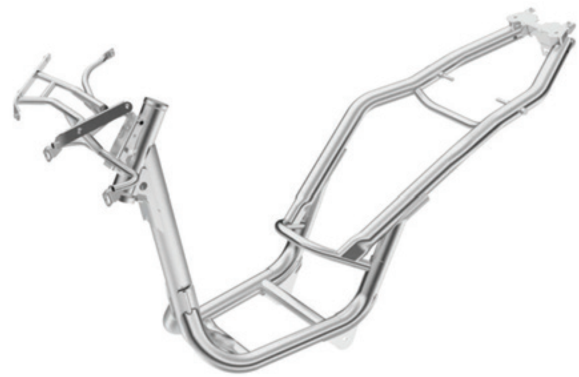

Fig. 3 Frame of previous model

Fig. 4 Frame of developed model

Rear Front

Fig. 5 Wide tire and newly designed wheel this purpose, the wall thickness of the rim was effectively reduced by decreasing the circumferential stress, which was achieved by increasing the number of spokes from the previous 5 to 8. In addition, the front wheel hub was partly hollowed and the wall thickness of the rear wheel hub was reduced. As a result, we achieved weight savings of about 7% (-0.2 kg) for the front wheels and about 11% (-0.5 kg) for the rear wheels compared with the previous model.

Accordingly, through the above changes, smoother maneuverability was realized to give a seamless, comfortable vehicle response to the rider's actions.

3.2. Enhanced Performance of Gasoline Engine

From the engine development point of view, the objective of a "high-quality, comfortable ride" could be attained through higher engine power and such engine characteristics that could make the rider feel relaxed and comfortable while out on a ride. As increasing the engine speed to shift the belt-driven transmission increases vibration and thus reduces comfort, we focused on generating sufficient power at lower engine speed while making the engine more powerful in the higher engine speed range for smooth and seamless acceleration.

Since one of the development goals in this model was to meet Euro 4 equivalent emission regulation, we redesigned the layout of the exhaust system to accommodate a larger size catalyst unit. Then, we increased the power in the higher engine speed range by increasing the bore size (only for the 125 cc model) and by straightening the exhaust pipe structure in the muffler. Furthermore, we increased the capacity of the air cleaner case by 1 liter and optimized the flow and pressure balance in the intake line which consists of the air intake duct and connecting tube through computational fluid dynamics (CFD) analysis, as shown in Fig. 6. In this way we were able to achieve a quicker engine response to the throttle control while maintaining the same engine power as that of the previous model in the low and medium engine speed ranges.

In addition, we adjusted the fuel injection setting, with the aim of realizing a smooth, comfortable response to the rider's input. Through these, the engine power was increased in the higher engine speed range to enable smooth and continuous acceleration while maintaining the same gear-shifting engine speed and acceleration at the lower engine speed range as the previous model, as shown in Figs. 7 and 8, to successfully achieve the desired high-quality, comfortable ride.

Accordingly, as a result of the above changes coupled with the enhanced maneuverability, the new model realizes an enjoyable and energetic ride in a wide range of applications from daily commuting to weekend touring.

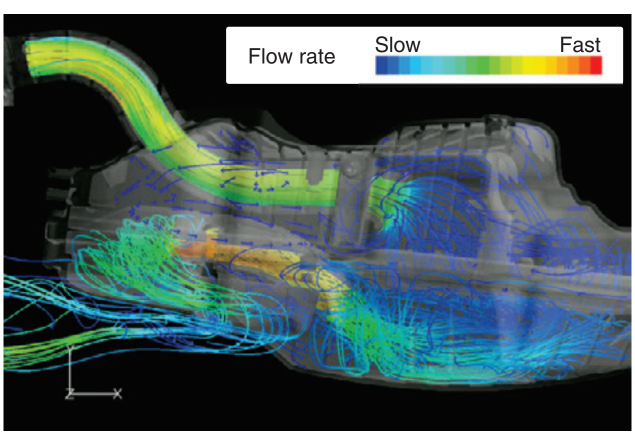

Fig. 6 Example of CFD analysis in air cleaner case

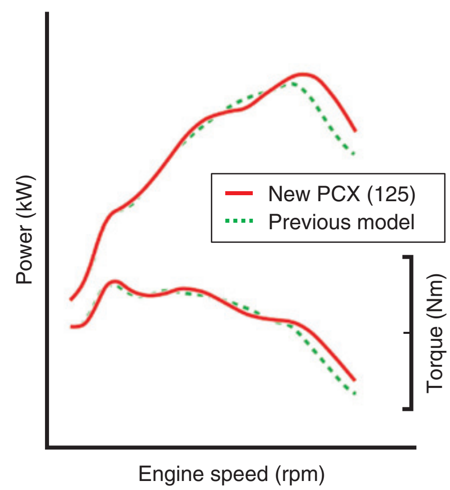

Fig. 7 Engine performance (PCX)

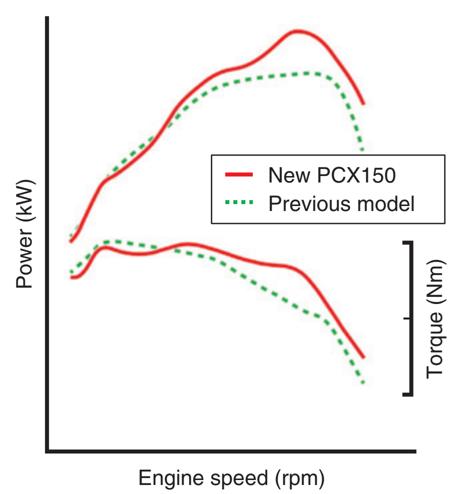

Fig. 8 Engine performance (PCX150)

4. Development of PCX HYBRID

4.1. Aim of Hybrid System

In a scooter of this displacement class, there is a slight time lag due to the characteristics of the belt converter, from the opening of the throttle to the response of the vehicle body. Therefore, a response like a manual transmission motorcycle could not be realized. This is one of the reasons why motorbike enthusiasts are not willing to use scooters. So, in developing the new model, we tried to find a solution to enhance this response to realize a more enjoyable ride.

One way to realize the desired quick response is to develop a hybrid system consisting of a gasoline engine and an electric motor, which reacts directly to the input, and hence provide a direct enjoyable ride sensation.

Note that the performance data on the PCX HYBRID presented here are those for the 125 cc engine installed hybrid model marketed in Japan. Also note that the performance data that are used for comparison are those for the 125 cc gasoline engine model, the 2018 PCX.

4.2. Outline of Hybrid System

4.2.1. Compact system layout

When designing the hybrid system, we placed the highest priority on not impairing the maneuverability expected of a motorcycle. As a hybrid vehicle needs to have a drive battery and a complicated control system, the total mass as well as the size of the vehicle body tends to increase, which then possibly lowering maneuverability. Therefore, we aimed to build a compact system that could be accommodated in the body size of the PCX gasoline engine model, to allow easy handling in town and to maintain a comfortable, high-quality ride without losing inherent mobility.

To make the system simpler so that it could be used in the same body as that for the gasoline engine model, we decided to employ a parallel drive system that utilizes the ACG starter[(1)] for drive assist. The ACG starter of the gasoline engine model, which is used to start the engine and to generate electric power, is directly coupled to the crankshaft, as shown in Fig. 9. By developing a special hybrid drive motor that uses electromagnetic steel sheets as the stator's core material, core loss was reduced and a compact unit was realized without changing the basic structure of the engine including the starter system.

Figure 10 shows the layout of the hybrid system components. The power drive unit (PDU) to control the motor assist function is integrated with the engine control unit (ECU) by reducing the size of the ECU components, increasing the thermal efficiency of the power supply, and optimizing the layout within the original size of the ECU enclosure.

The down regulator is used to supply power to the lamps, lead-acid battery, and other general electrical components. The junction unit is used to connect an external 12 V DC power supply to start the engine in the case of an emergency. These two units and the lithium-ion battery pack (described in Clause 4.2.4. below) were placed adjacent to each other in order to reduce the length of the connecting cables.

Accordingly, the hybrid system components were installed in a compact manner without affecting the appearance of the original gasoline engine model.

4.2.2. Overview of system operation

Figure 11 shows how the hybrid system works. The motor assist function is activated when the engine is restarted after an idling stop state or when the rate of throttle control applied by the rider exceeds a threshold level. The PDU calculates an optimum assist torque from the throttle position, engine speed, and remaining capacity

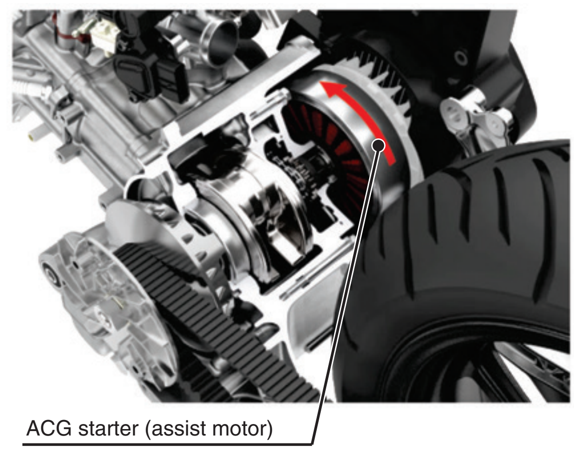

Fig. 9 ACG starter (assist motor)

Fig. 10 Layout of hybrid system parts

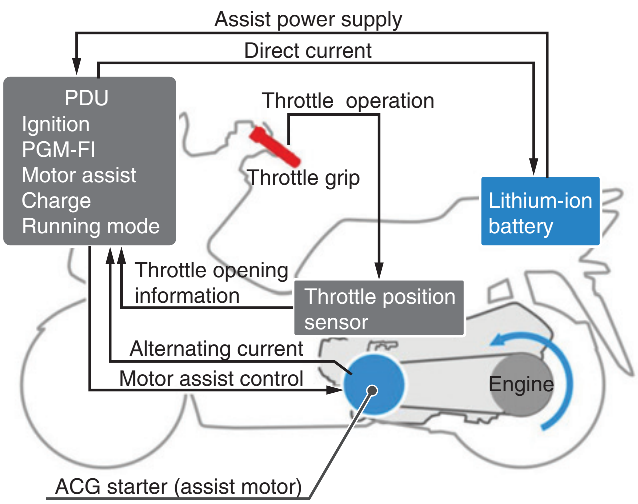

Fig. 11 Overview of hybrid system

and temperature of the lithium-ion battery to generate assist torque control commands.

Note that whenever the motor assist function is not in operation, the ACG starter is used for power generation to charge the lithium-ion battery.

4.2.3. Setting of assist duration

As the assist duration has an impact on the battery size, it was necessary to determine the minimum acceptable duration from the viewpoint of usability. For this purpose, we surveyed the use situation of Thai users, which are often accelerating rapidly, in order to measure the time from opening the throttle to starting to close it to maintain vehicle speed. The frequency results for the throttle-opening time for two different driving conditions are shown in Figs. 12 and 13. We can see from Fig. 12 that about 90% of the measurements fell into the duration of 3 seconds or less in urban areas of Thailand. Similarly, about 80% fell into the 3-second duration in the suburbs of Thailand, as shown in Fig. 13. From these results, it was determined that setting the assist duration to 3 seconds would be able to cover most of the acceleration cases.

On the other hand, we also expected that terminating the assist operation immediately after the assist time of 3 seconds would result in a significant drop in the driving force and have a negative effect on the rider's experience. To address this issue, we decided to add a 1-second interval to gradually reduce the amount of assisting power and thereby set the maximum total assist duration to 4 seconds. In addition, we also gradually increased the power generation load after the end of the assist to help prevent any uncomfortable ride sensation.

4.2.4. Lithium-ion battery

Among the hybrid system components, the motor drive battery is the largest. Hence, there is a conflict between the compactness requirement so as not to impair the mobility of the motorcycle and the minimum size required to deliver enough assist power.

So, first we needed to select a small, lightweight battery that could be mounted on the vehicle and that met both the assist power and assist time requirements. For this purpose, we selected a cylindrical, 18 mm diameter high power lithium-ion battery cell.

As the cell voltage was 3.6 V, we connected 14 cells in series to obtain a voltage that was high enough to assist the drive up to the high engine speed range. Then, to satisfy the required engine starting output even under cold weather conditions and the low state of charge (SOC), we paralleled two series strings of 14 cells to obtain the rated voltage of 50.4 V and rated capacity of 3.8 Ah (192 Wh).

The battery pack was integrated with the battery management unit, which monitors the battery temperature and SOC to control the charge/discharge operation, in an IPX5 protection rated (IEC 60529) waterproof housing.

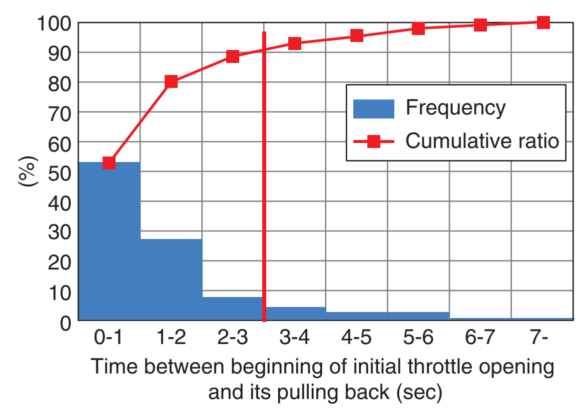

Fig.12 Measurement results for throttle-opening time (urban area driving in Thailand)

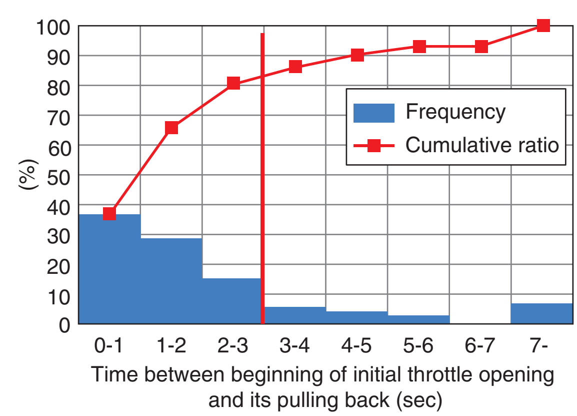

Fig. 13 Measurement results for throttle-opening time (suburban area driving in Thailand)

Figure 14 shows the resulting vehicle-mounted compact battery pack. The lithium-ion battery pack measures length 205 mm x width 134 mm x height 90 mm and weighs 2.6 kg.

4.2.5. Performance enhancement by motor assist

The motor delivers the power of 1.4 kW and the torque of 4.3 Nm at 3,000 rpm. The addition of motor assist power to the 125 cc gasoline engine increased the torque by about 33% at 4,000 rpm and about 22% at 5,000 rpm, as shown in Fig. 15 for wide open throttle (WOT); hence a very torqueful assist was realized.

Figure 16 shows the engine speed versus time when the vehicle is accelerated from a stopped state with WOT for both the gasoline engine model and the hybrid model. We can see from the graph that the centrifugal clutch is engaged at the time of the fourth combustion in the case of the gasoline engine model, whereas it is engaged at the third combustion in the hybrid model. In other words, the time from the start to clutch engagement is successfully reduced by about 20 % due to the quick response provided by the motor assist. These enhancements provide a feeling of direct acceleration, and the quick standstill acceleration in town and the reliable traction characteristics during cornering make for a more exciting and pleasurable ride.

Also, as shown in Fig. 17, the hybrid model can run

Fig. 14 Appearance of lithium-ion battery pack

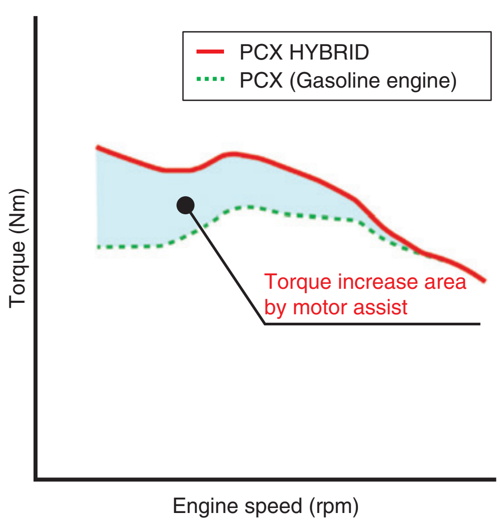

Fig. 15 Increase in torque by motor assist at wide open throttle (WOT)

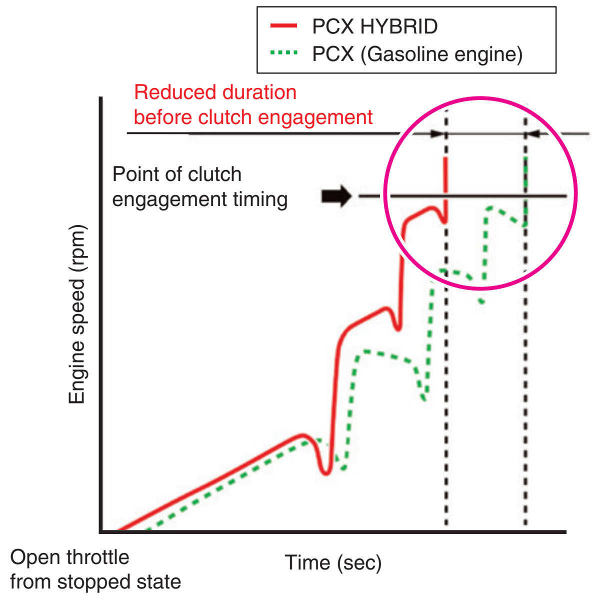

Fig. 16 Comparison of duration before clutch engagement

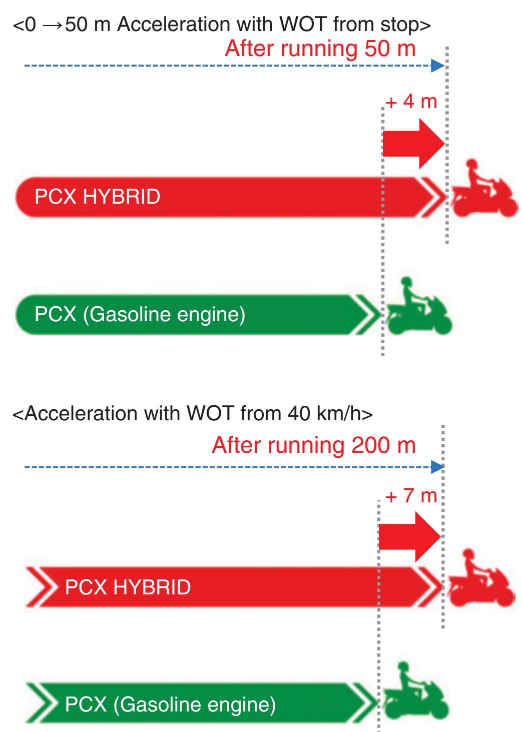

Fig. 17 Comparison of power performance

about two vehicle lengths (4 m) ahead of the gasoline engine model at a distance of 50 m from a standstill start with WOT. Similarly, in the case of WOT acceleration from 40 km/h, the difference was about 3.6 vehicle lengths (7 m) at 200 m after starting the acceleration. From the above results, we understand that the motor assist function has also enhanced the power performance.

4.2.6. Reduction of idling stop waiting time

In previous PCX model, the idling stop function operates 3 seconds after the vehicle stops. This duration was intended to reduce repetitive start/stop operations on congested roads as the restarting time lag would be annoying for the rider if the engine stopped too frequently. As the PCX HYBRID can achieve quicker clutch engagement by using the assist motor, it should be able to help eliminate or reduce this annoyance for the rider. So, we studied the possibility of reducing the idling stop waiting time. By finding a setting that struck a balance between the rider's annoyance with the time lag and the sense of security in the restart, we were able to reduce the waiting time by 2.5 seconds compared to the previous model, as shown in Fig. 18. In other words, we were able to stop the engine for only 0.5 seconds after the vehicle was stopped; this greatly contributes to reducing emissions and to enhancing engine quietness in town.

4.2.7. Run mode switching to use different assist characteristics

During the process of developing the detailed specifications, we created a prototype model that could legally run on public roads and tested it to check the suitability of the PCX HYBRID design on public roads. As a result, we found that the required assist force is different between the cases when the vehicle is on a congested road and when it is on a winding road even if the throttle position is the same.

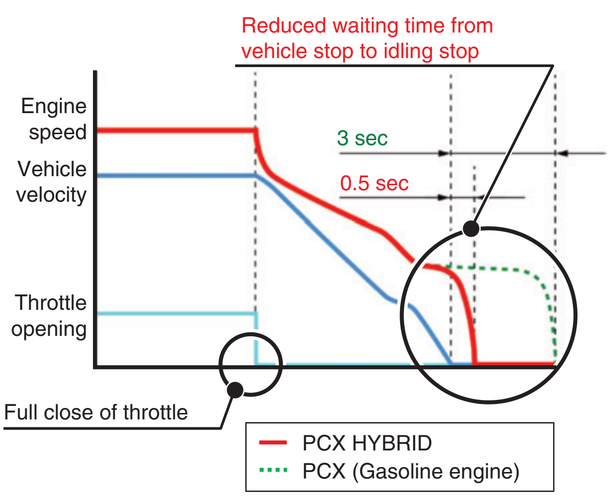

Fig. 18 Reduced waiting time for idling stop system operation

So, we added a function to enable the rider to switch the run mode to select motor assist characteristics according to the context or the rider's preference.

When the main switch is turned on, it enters D mode, where a relaxed, comfortable ride and moderate motor assist are provided at the same time. On the other hand, S mode enables a sporty run by enhancing the assist power to provide more fun when riding the vehicle. To be more specific, while the assist power is the same in both modes when the throttle is wide open, the assist power at a low to medium throttle position is different according to the mode and throttle position, as in the example shown in Fig. 19. The mode select switch is on the left handlebar (Fig. 20) so as to enable selection even during a ride, according to whether there is traffic congestion or a winding road.

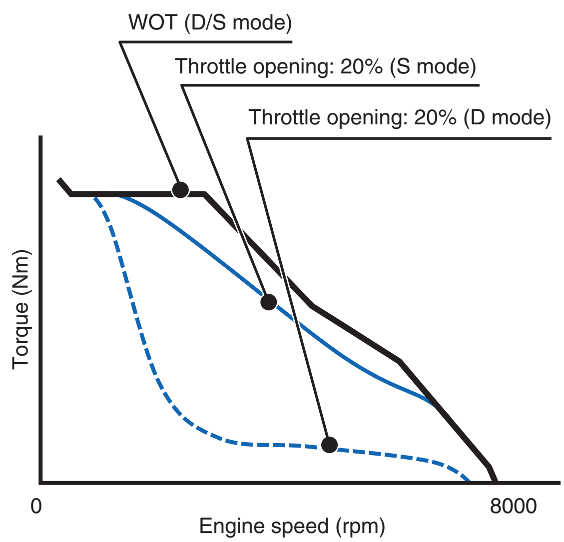

Fig. 19 Example of torque difference due to difference in assist mode

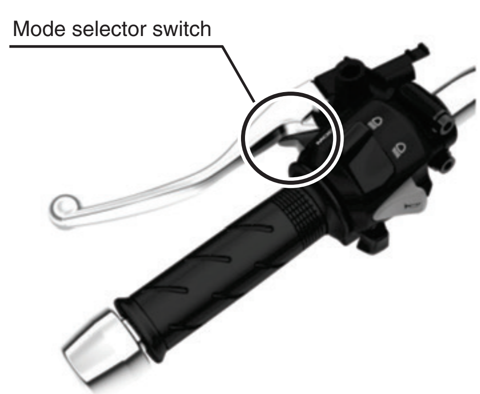

Fig. 20 Mode selector switch

4.2.8. Speedometer display for hybrid model

A special display panel was designed in order to show various types of information of hybrid system in an easily understandable way. In addition to the same display content of the gasoline engine model, such as speedometer, clock, and average gas mileage, the following indications were added specifically for the hybrid model:

- Run mode indicator (D/S/Idling modes)
- Indicator of motor assist level for engine
- Lithium-ion battery charge level indicator
- Residual capacity of lithium-ion battery
- Lithium-ion battery indicator

Figure 21 shows the center display. The assist level indicator and charge level indicator are five-segment and two-segment bar-graph displays, as shown in Figs. 22 and 23, respectively.

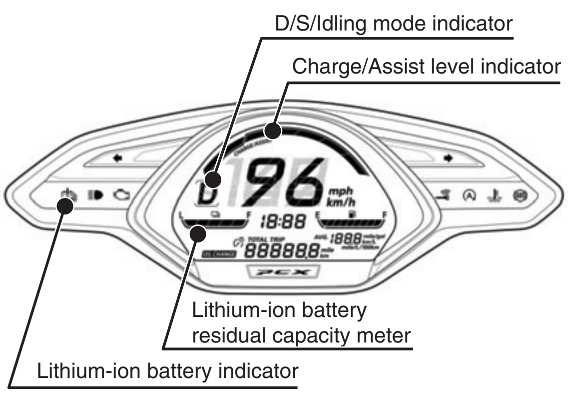

Fig. 21 Speedometer for PCX HYBRID

Fig. 22 Assist level indicator (at maximum level)

Fig. 23 Charge level indicator (at maximum level)

5. Summary

The fourth-generation model, the 2018 PCX, was developed as a full model change with a newly designed frame body and wheels and enhanced intake and exhaust systems. The new Euro 4 emission standard was satisfied, and the functions and performance greatly exceeded those of the previous model to enable a more enjoyable and energetic ride in a wide range of settings from commuting to weekend touring.

The PCX HYBRID model was designed to use the packaging of the PCX to the maximum extent possible while adding the minimum required hybrid system of a dedicated motor and optimized assist time. The quick standstill acceleration in town and reliable traction characteristics during cornering of this world-first mass production hybrid motorcycle model realized a more exciting and pleasurable ride.

We expect that this hybrid system will be well accepted by customers and that it will be further developed as one of the most attractive forms of technology applicable to motorcycles.

Reference

(1) Yanagisawa, T., Yamanishi, T., Utsugi, K., Nagatsuyu, T.: Development of Idling Stop System for PCX, Honda R&D Technical Review, Vol. 22, No. 2, p. 80-86

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