

Presentation of “RTL250F” Four-stroke Engine Trials Motorcycle

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ABSTRACT

The RTL250F has a compact and lightweight 249 cm³, water-cooled, 4-stroke engine. As the world's first off-road vehicle with a batteryless electronically controlled fuel injection system (hereinafter referred to as batteryless PGM-FI system), the RTL250F has obtained the same or better racing performance than the RTL250R with a 2-stroke engine. Furthermore, the RTL250F motorcycle employs a kick-starter for engine ignition. The batteryless PGM-FI system utilizes a lower cost ECU (Engine Control Unit) integrated throttle body developed for small motorcycles. A control system was developed to obtain the drivability and usability required by a trials motorcycle. As a result, a commercially available trials motorcycle with a 4-stroke engine has been realized. This trials vehicle has shown competitive performance for the World Championship Trials.

1. Introduction

All manufacturers including Honda currently use two-stroke engines in trial competition motorcycles. The main reasons for this are that two-stroke engines feature superior throttle response from low engine speeds, and are lightweight and compact. However, due to a change in Federation Internationale de Motorcyclisme (FIM) regulations, the use of four-stroke engines from 2006 onward for all participating motorcycles has been mandated. Honda has taken the initiative and developed a four-stroke engine that provides superior competition ability, consisted with a high level of environmental suitability. The “RTL250F” trial motorcycle equipped with this engine was released in January 2005.

2. Development Concept

The performances demanded to trial motorcycles include (1) a lightweight, slim body with lower center of gravity, (2) an engine with sufficient low-speed torque and the ability to deliver bursts of power up to high engine speeds, and (3) a linear throttle response during rapid opening. Therefore, the following four important development goals were set as the development concepts for a four-stroke engine trial machine with superior environmental suitability and racing potential.

- (1) Equivalent or better handling, stability, and drivability than the two-stroke engine RTL250R.
- (2) A compact and lightweight four-stroke engine.

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- (3) No noticeable differences in engine characteristics when switching from the current two-stroke engine model.
- (4) Provide both environmental compliance and superior drivability.

3. Model Overview

Figure 1 shows an external view of the RTL250F, and Table 1 lists the major specifications along with those of the current two-stroke RTL250R. To provide the approximate equivalent racing potential as the two-stroke RTL250R, it was necessary to keep the same vehicle mass of 72 kg (dry vehicle mass). The RTL250F compensated for the increased engine mass, due to the change to a four-stroke engine, by reducing the vehicle body mass. These mass reductions were concentrated in the main frame, front and rear wheels, and brakes, etc (Fig. 2). In addition, the electrical parts were collected behind the engine in order to lower the center of gravity and concentrate the mass.



Fig. 1 External view of RTL250F

As shown in Fig. 3, in the batteryless PGM-FI system, the fuel injector is mounted directly onto the cylinder head to enhance throttle response, and the fuel pump is located inside the fuel tank to provide a stable supply of fuel even while undergoing intense vehicle body behavior, such as during trial competition (Fig. 4). The throttle body is based on an ECU integrated throttle body for small displacement motorcycles, but has been changed to an air screw type that enables the user to adjust the engine idle speed (Fig. 5). A batteryless system is used to reduce vehicle mass. Power is supplied only to the fuel pump and ECU during kick starting. In addition, a decompression cam is used and the kick ratio has been revised to enable smooth kick startability.

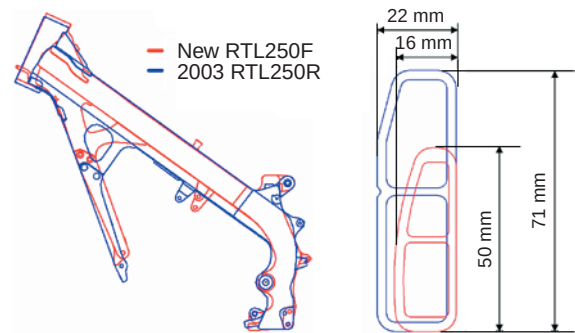


Fig. 2 Comparison of frame body

Table 1 Major specifications of RTL250R and RTL250F

RTL250R		
Items		Specifications
Overall length	(mm)	2020
Overall width	(mm)	830
Overall height	(mm)	1130
Wheelbase	(mm)	1330
Ground clearance	(mm)	340
Seat height	(mm)	650
Caster angle	(deg)	23° 20'
Trail length	(mm)	65
Vehicle dry mass	(kg)	72
Engine type		Liquid cooled 2-stroke single cylinder
Valve train		Crank case reed valve
Engine displacement	(cm³)	249
Bore × Stroke	(mm)	72.2 × 61
Max. power	(kW/r/min)	12.9/5000
Max. torque	(Nm/r/min)	26.5/4000
Fuel supply system		Delorto PHBL26BS
Ignition system		Digital CDI
Transmission		5 speed constant mesh
Clutch type		Wet multi-plate type (hydraulic)
Fuel capacity	(Liter)	2
Frame type		Aluminum twin-tube
Brake system	Front	Single 180 mm disc with twin-piston caliper
	Rear	Single 100 mm disc
Tire size	Front	2.75 × 21
	Rear	4.00 × 18
Suspension	Front	Telescopic
	Rear	Pro-link

RTL250F		
Items		Specifications
Overall length	(mm)	2010
Overall width	(mm)	830
Overall height	(mm)	1130
Wheelbase	(mm)	1320
Ground clearance	(mm)	335
Seat height	(mm)	650
Caster angle	(deg)	23°
Trail length	(mm)	63
Vehicle dry mass	(kg)	72
Engine type		Liquid cooled 4-stroke OHC single cylinder
Valve train		SOHC 4 valves
Engine displacement	(cm³)	249.1
Bore × Stroke	(mm)	76.5 × 54.2
Max. power	(kW/r/min)	14/7000
Max. torque	(Nm/r/min)	21.8/5500
Fuel supply system		PGM-FI
Ignition system		Full transistor
Transmission		5 speed constant mesh
Clutch type		Wet multi-plate type (hydraulic)
Fuel capacity	(Liter)	1.9
Frame type		Aluminum twin-tube
Brake system	Front	Single 180 mm disc with twin-piston caliper
	Rear	Single 100 mm disc
Tire size	Front	2.75 × 21
	Rear	4.00 × 18
Suspension	Front	Telescopic
	Rear	Pro-link

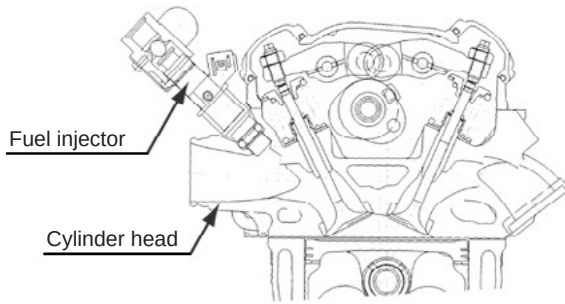


Fig. 3 Layout of fuel injector

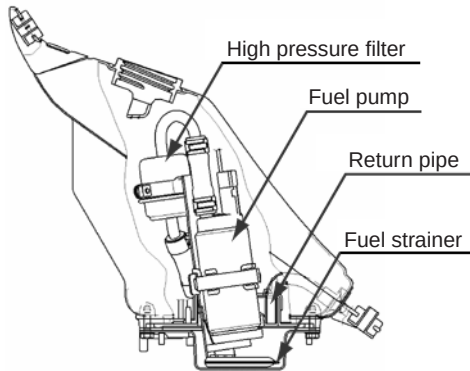


Fig. 4 Fuel tank assembly

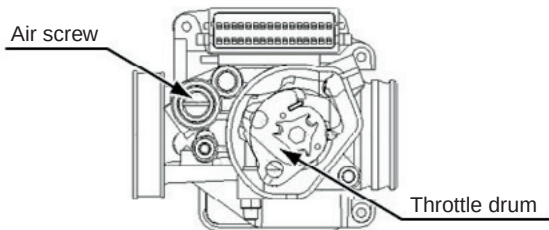
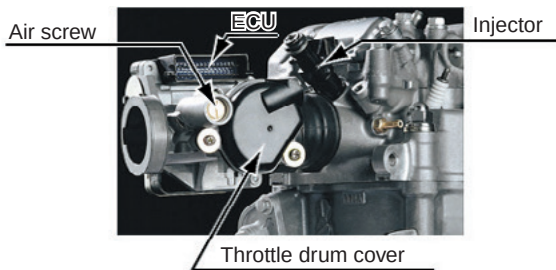


Fig. 5 Throttle body assembly

4. Engine

The engine layout is based on the commercial motocrosser, CRF250R, but significant modifications have been made to the crank case and other locations in order to satisfy the performance requirements of trial motorcycles such as a lower center of gravity and more compact size. Figure 6 shows a comparison of the overall engine size.

Figure 7 shows the output characteristics of the RTL250R (two-stroke) and RTL250F (four-stroke). The maximum output was controlled to 14 kW. The torque characteristics were flattened and priority was given to enhancing torque at low engine speeds. In addition, by increasing output in the range of partial throttle opening

at low engine speeds, the equivalent or better torque feeling in the range of wide throttle openings was achieved. Although, the torque in this range is actually inferior to that of two-stroke engines.

4.1. Fuel Supply System

When a carburetor is used for the fuel supply, the intake duct area of the air cleaner must be reduced to enhance response during rapid throttle opening, but this factor lowers the output at high engine speeds. The employment of the batteryless PGM-FI system in the developed engine enabled simultaneous achievement of good throttle response and output at high engine speeds without reducing the intake duct area.

4.2. Exhaust System

The three-chamber silencer used in a conventional four-stroke engine trial motorcycle was changed to a straight type silencer. This reduced the reflected exhaust gas inside the silencer and made it possible to obtain flat output characteristics at entire engine speed range. In addition, the silencer material was also changed to aluminum to reduce mass.

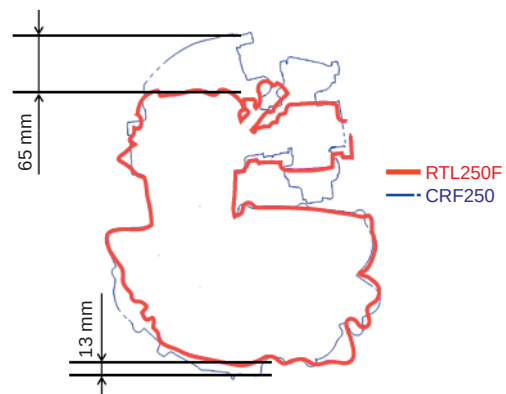


Fig. 6 Comparison of engine size

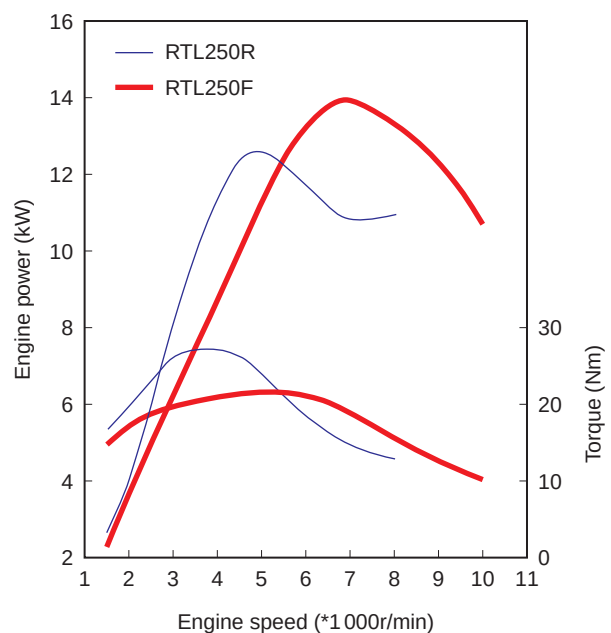


Fig. 7 Engine performance curve

4.3. Flywheel

A large diameter flywheel was used to enhance running using inertia mass (a running method in which high engine speed is maintained in the no-load state with the throttle wide open and rapid clutch connection performed in order to accelerate quickly from a standstill). The large diameter flywheel also increased anti engine stall performance and torque feeling at low engine speeds (Fig. 8).

4.4. Clutch

A large capacity (diameter 140 mm) hydraulically actuated, release bearing, right-side directly actuated type clutch was used. This allows the rider to realize a lever load that can be operated by a single finger, and maintain connecting performance that responds linearly to rider operation and is stable even with the clutch half-engaged at high engine speeds. In addition, the slave piston was incorporated into the clutch cover to achieve a more compact size (Fig. 9).

4.5. Lubrication System

Regarding engine lubrication, the CRF250R's closed type crankcase was modified, mainly by changing the area around the intake port (Fig. 10). Like the CRF250R, the AC generator chamber is used as the oil tank, but the RTL250F has a structure with additional separators and ribs and a modified oil port that supplies the oil around the strainer during driving, using the oil adhered to the external side of the rotating large diameter flywheel. This made it possible to reduce the amount of oil from 830 cm³ to 600 cm³ and increased ground clearance by 13 mm. With this reduction in

oil the piston rings were changed from two rings to three, with the aim of reducing oil consumption. In addition, the modification to three rings also contributed to an enhanced torque feeling at low engine speeds.

Regarding lubrication of the transmission, the oil recovery ability using the clutch outer was increased by changing the shapes of the oil return guide ribs and transmission cover. This made it possible to reduce the amount of transmission oil from 770 cm³ (CRF250R 2004 model year) to 570 cm³ while maintaining seizure resistance of the transmission (Fig. 11).

4.6. Three-point Support Crankshaft Structure

A needle roller bearing was used on the left side of the three-point support crankshaft. The rotational deflection inhibiting effects of this roller bearing reduced vibration and increased durability (Fig. 12).

4.7. Valve Train

In order to reduce the engine height, the uncam system (a single cam shaft system that drives the intake valve with a valve lifter, and the exhaust valve with a rocker arm) used by the CRF250R was changed to a SOHC system in which both the intake and exhaust valves are actuated by a rocker arm (Fig. 13). This made it possible to reduce the cylinder head height by 65 mm. In addition, the spark plug inclination was kept below 28° by greatly offsetting the camshaft, thus allowing a central arrangement (Fig. 14).

The conventional two-valve system is adequate for engines that emphasize torque at low engine speeds, but the engine must also be rotated smoothly at high engine speeds, so a four valve system

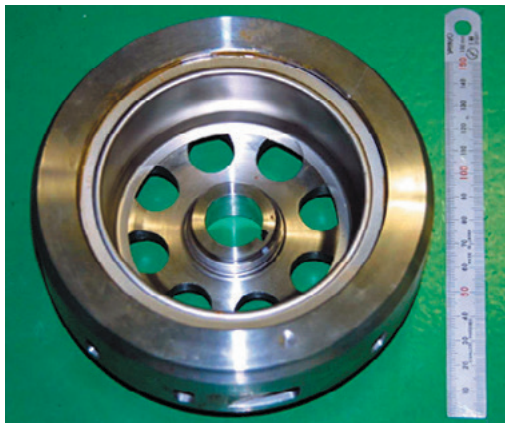


Fig. 8 AC generator flywheel

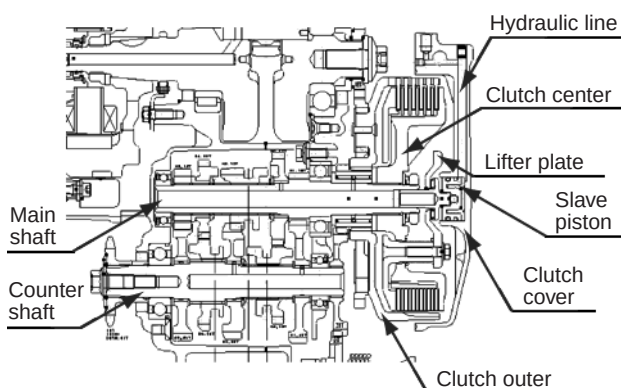


Fig. 9 Clutch system

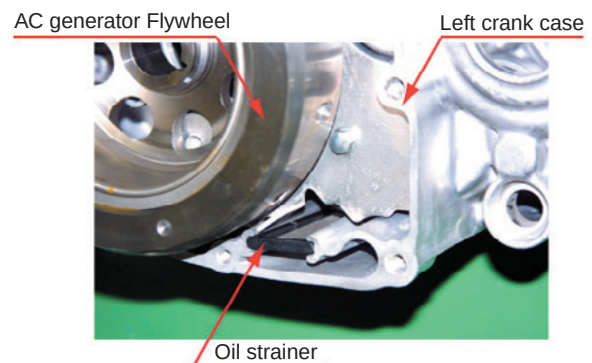


Fig. 10 Engine oil lubrication system

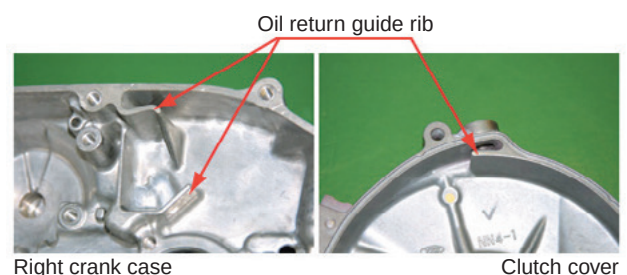


Fig. 11 Transmission oil return system

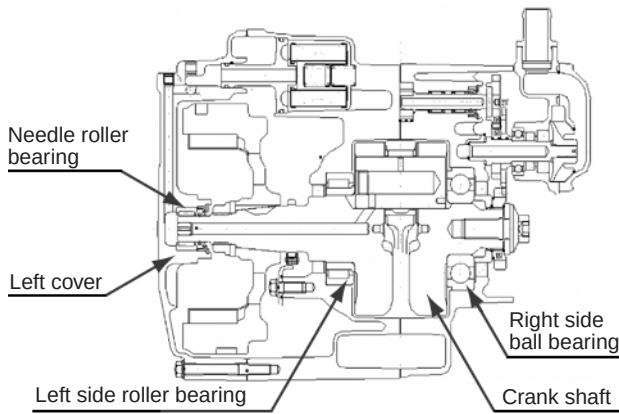


Fig. 12 Crankshaft

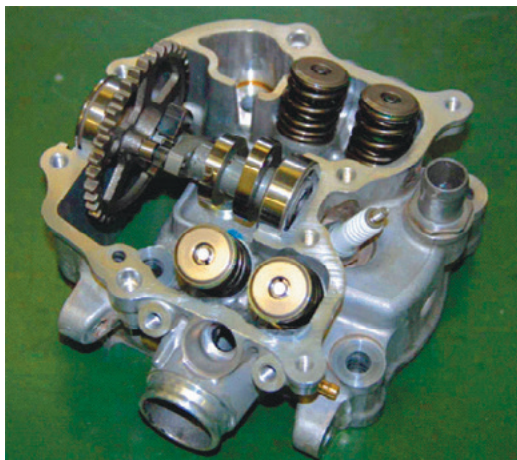


Fig. 13 Cylinder head with valve system

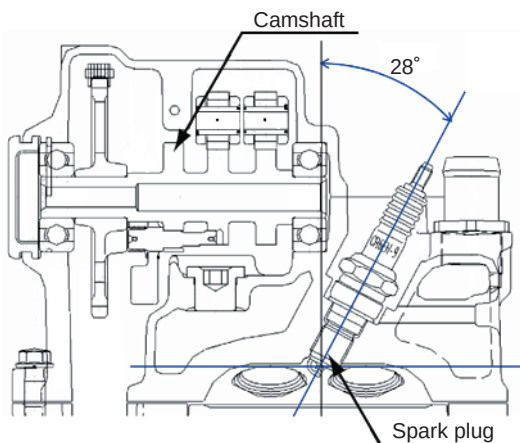


Fig. 14 Arrangement of camshaft and spark plug

was used. SCM carburizing and quenching was performed on the camshaft to reduce the mass without loss of fatigue strength.

5. Batteryless PGM-FI System

Figure 15 shows an overview of the batteryless PGM-FI system. Gasoline fed by pressure from the fuel pump passes through a high

pressure filter inside the tank and is then sent via a high pressure fuel pipe to the injector. The high pressure gasoline is adjusted to 294 kPa by a pressure regulator, and then returned to the tank by a fuel return pipe.

The ECU of the batteryless PGM-FI system calculates the fuel injection quantity and timing based on the engine speed, throttle opening, negative pressure in the intake pipe, intake air temperature, atmospheric pressure calculated from the negative pressure in the intake pipe, water temperature, and crank angle information. The ECU then determines the targeted air fuel ratio in accordance with the load.

The ignition timing is controlled to the optimum timing based on a three-dimensional map determined by the throttle opening and engine speed.

Drivability requirements for trials competitions include the response during rapid throttle opening from low engine speeds and the torque feeling at low engine speeds. When expert riders drive through rock sections such as shown in Fig. 16, they control the machine by opening and closing the throttle and subtle clutch operations. At such times it is extremely important that the throttle response be exactly as the rider wishes. Figure 17 shows the throttle speed ($\Delta\theta$ th: delta throttle) data per unit time during trial competition, together with $\Delta\theta$ th data for the first lap from the start of Moto GP Japan GP (Motegi) 2004 for reference. This shows that trial competition differs from road races in that high throttle speeds are often used from low engine speeds. In order to meet these requirements, the RTL250F is the first mass production motorcycle to use fuel injection control after double calculating at engine speeds of 5 000 rpm or less. An overview of this control is described below.

As mentioned above, the greatest drivability requirement issue is the ability to follow rapid throttle opening operations from extremely low engine speeds near idling. Conventionally, the fuel injection quantity was calculated one time for a crank rotation angle of 720° through the intake, compression, expansion, and exhaust process. However, this produced a long fuel injection quantity calculation interval. The issue of insufficient response, due to delayed calculations with respect to rapid throttle operations, such as during trial competition, was present. Therefore, calculation of the fuel injection quantity was increased to two times, with recalculation (the second calculation) performed just before the intake timing. The fuel injection timing was then modified based on these recalculation results. This allowed optimal adjustment of the fuel injection quantity in response to rapid throttle operations, which in turn made it possible to supply the targeted air fuel ratio. In addition, double calculation was performed only at engine speeds of 5 000 rpm or less. The calculation of the fuel injection quantity was performed only once at high engine speeds, which have shorter calculation intervals. This system can be controlled by even a low cost ECU with slow processing speed (Fig. 18).

Figure 19 shows the in-cylinder pressure during rapid throttle opening. The pressure for the two-stroke engine (RTL250R) rises significantly from the start of throttle opening, so riders experience good throttle response. As mentioned above, in order to allow a smooth switchover from two-stroke engine motorcycles, the development concept for the RTL250F focused on achieving a response during rapid throttle opening equivalent to that of a two-stroke engine. As a result, adoption of the new control system described above obtained the same pressure rise as a two-stroke engine, thus realizing a good throttle response.

Stabilization of the air fuel ratio can be given as a major reason for using the batteryless PGM-FI system. In preliminary tests performed with carburetor specifications, the air fuel ratio fluctuated

widely in accordance with the large changes in vehicle body behavior of typical trial driving. This caused the engine to stall during rapid throttle opening from idling, or when braking (when running downhill, etc.). In addition, throttle response delay occurred

due to the delay of the negative pressure in the intake pipe during rapid throttle opening. However, adopting the PGM-FI system and modifying the fuel pump arrangement completely eliminated these phenomena.

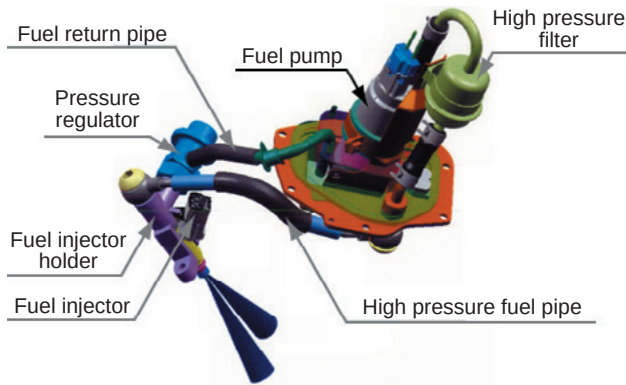


Fig. 15 Fuel line system



Fig. 16 Rock section

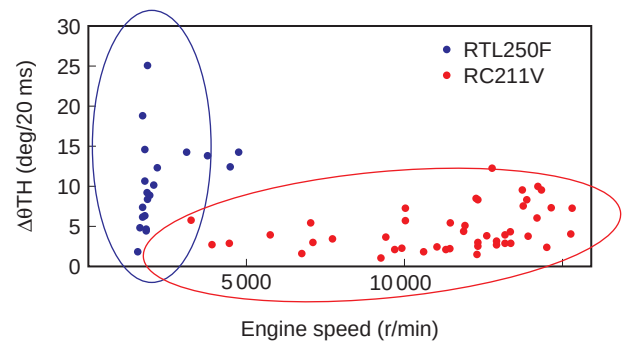


Fig. 17 Comparison data of throttle speed

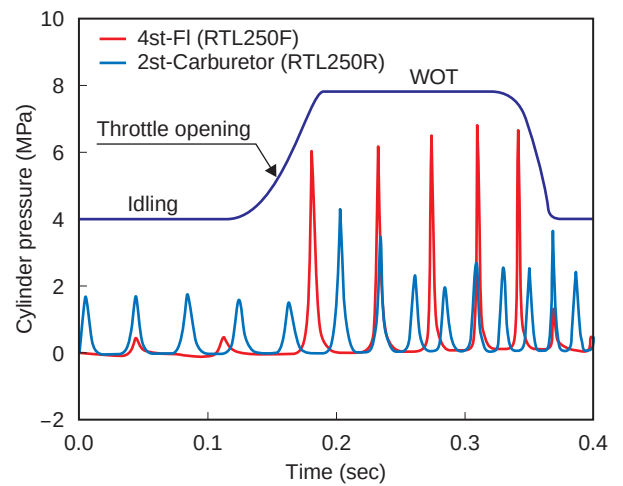


Fig. 19 Comparison of cylinder pressure at rapid throttle opening

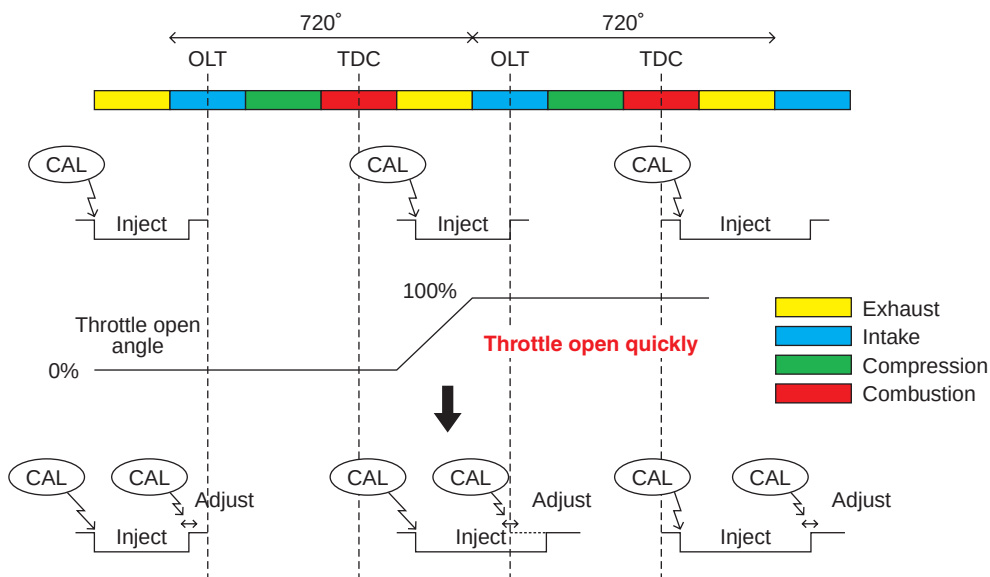


Fig. 18 Injection timing chart

6. Electrical System

The electrical system uses a batteryless system to reduce vehicle mass. In order for this batteryless system to allow kick starting, the AC generator is a three-phase star connection type that generates an output current of 7.5 A at a rotational speed of 1 000 rpm, and has characteristics that provide the necessary amount of electric power at low rotations during kick starting. Figure 20 shows the output characteristics of the AC generator. The current and voltage of the electrical power generated by the AC generator are regulated to 14.4 VDC by a three-phase full-wave commutator type regulator rectifier, smoothed by a 10 000 μ F capacitor, and then supplied to each electrical load. The regulator and capacitor are located together with the bank angle sensor and fan motor relay on the electrical equipment stay in order to reduce the voltage drop and simplify wiring. These parts are fixed on the crankcase which also helps to concentrate the mass. Figure 21 shows an external view of the electrical equipment stay and the electrical equipment located on it. When kick starting electric power is supplied only to the fuel

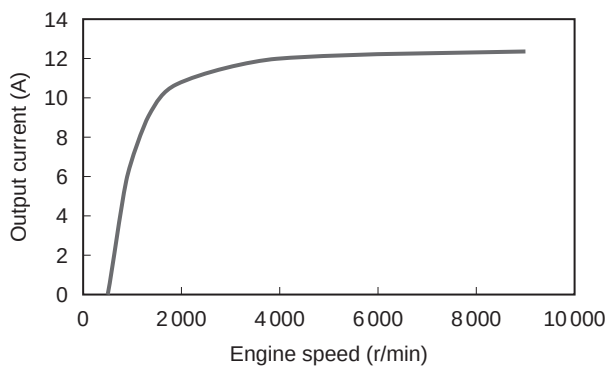


Fig. 20 Output characteristic of AC generator

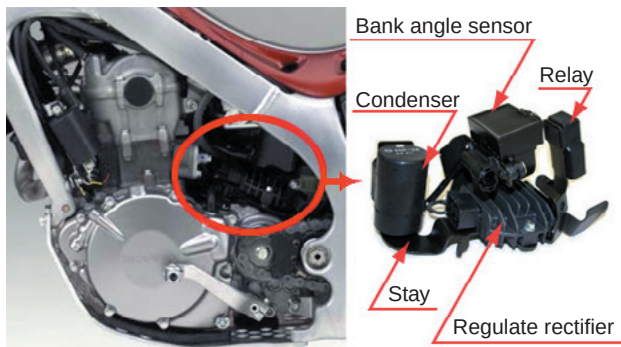


Fig. 21 External view of electrical equipments

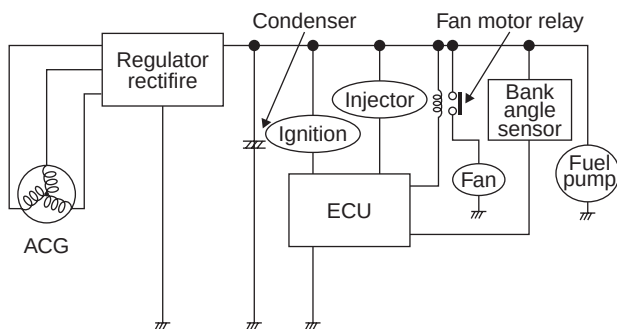


Fig. 22 Electrical system

pump, fuel injector, ignition coil and control ECU, but not to the cooling fan motor. This makes it possible to supply sufficient fuel from the first rotation of the crankshaft. The voltage drop and vehicle mass were reduced by eliminating the drive relay and connecting the fuel pump directly to the power supply.

When the motorcycle falls down the engine is stopped by stopping the ignition coil and the injector, approximately seven seconds after the stacking signal is input to ECU from the bank angle sensor. The system is batteryless so when the engine stops the AC generator does not generate power and the fuel pump stops automatically. Figure 22 shows an overview of the electrical system.

7. Conclusion

The RTL250F was developed with a wide target market from beginning riders to World Championship Trial (WCT) users. A commercial prototype motorcycle participated in the WTC Motegi Round held in Japan in 2004, and achieved the favorable results of 9th place on both days of the two-day competition. This 250 cm³ four-stroke commercial prototype motorcycle was able to achieve sufficient results amidst upper ranks dominated by the two-stroke works motorcycles of various manufacturers, thus the high potential of the new engine was verified.

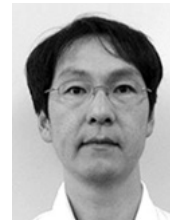
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