

Development of NSF250R Commercial Road Racer with 4-stroke Engine

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ABSTRACT

A Moto3 category that uses 4-stroke 250 cm³ engines has been established for Grand Prix motorcycle racing from 2012. Due to this new category, Honda has developed the NSF250R, which is equipped with a newly developed 4-stroke single-cylinder 249 cm³ engine. The new engine features an intake-from-front, exhaust-to-rear layout to increase charging efficiency, and a 15° rearward tilted cylinder to concentrate mass. A thinner lightweight piston and nut-less connecting rod are used to reduce weight, an offset cylinder and a closed crankcase with scavenging pump are used to reduce friction, and a midship muffler is used to concentrate mass. These and other measures realize engine performance and maneuverability suitable for a commercial racing machine in the Moto3 category, which is the gateway to road racing.

1. Introduction

Honda produced and sold 2-stroke 125 cm³ racing machines for entry-level road racing starting from the MT125R in 1976 to the RS125R, which ended production with the 2009 year model. These machines broadened the base of motorcycle sports both in Japan and overseas, and raised many racing riders.

On the other hand, the need for environmental measures for general commercial vehicles is increasing on a global level, and motorcycle racing machines are also changing to 4-stroke engines. In 2002, the premier class of Grand Prix motorcycle racing changed from GP500 (500 cm³ 2-strokes) to MotoGP (currently 1000 cm³ 4-strokes), and the GP250 category (250 cm³ 2-strokes) changed to Moto2 (600 cm³ 4-strokes) from 2010. In addition, a new Moto3 category that uses 4-stroke 250 cm³ engines has been created to replace the GP125 category (125 cm³ 2-strokes) from 2012. In conjunction with this change, the NSF250R has been newly developed as a machine for entry-level riders.

The NSF250R carries on the aim of broadening the base of motorcycle sports fostered by the RS125R, and was developed as a high-performance, compact, lightweight racing machine that feels familiar to RS125R users and can be used to learn the riding basics required to step up from the entry-level class to the premier class.

2. Development Goals

Two-stroke GP125 class races currently held around the world are the gateway to road racing, and support a wide range of road racing, from young riders to veterans, and from local races to the Grand Prix Championships. The characteristic of GP125 class machines is a vehicle size class that enables easy machine control even by younger entry-level riders. In addition, these machines feature good engine and body responsiveness with a direct feeling, and have a wide range of setting functions to display the maximum machine performance. The basic concept of the NSF250R inherits these elements, and the development goals were to realize high maneuverability as a racing machine with the easy handling of a 4-stroke engine; that is to say, “lightweight, compact, high output, and high efficiency.”

3. Overview of Model

Figure 1 shows an external view of the NSF250R, and Table 1 lists the basic specifications. To pursue speed as a racing machine and as a result of aiming for “lightweight, compact, high output, and high efficiency,” it was determined that a specially designed engine and a compact body equivalent to the RS125R should be selected.

A DOHC single-cylinder engine equipped with an

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Table 1 Major specifications

Model name		NSF250R
Dimensions (L x W x H) (m)		1.809 x 0.560 x 1.037
Wheelbase (m)		1.219
Ground clearance (m)		0.107
Seat height (m)		0.729
Caster angle (deg)		22° 36'
Curb mass (kg)		84
Tire size	Front	90/580R17
	Rear	120/600R17
Brake type	Front	Hydraulic disk ϕ 296
	Rear	Hydraulic disk ϕ 186
Suspension type	Front	Inverted telescopic
	Rear	Pro-link suspension system
Frame type		Aluminum twin tube



Fig. 1 NSF250R external view

intake-from-front, exhaust-to-rear layout, an integrated crankshaft, and a closed crank chamber with scavenging pump was newly developed to realize these goals. In addition, the motorcycle mass was concentrated by adopting a midship muffler, placing the throttle body inside the air box, and other measures.

4. Power Unit (Engine)

4.1. Engine Major Specifications and Development Targets

Figure 2 shows an external view of the NSF250R engine, and Table 2 compares the major specifications with those of the RS125R.

The motorcycle development goals were to realize the

high maneuverability of the lightweight, compact RS125R with the easy handling of a 4-stroke engine, so the engine development targets were set as follows.

- (1) Thorough concentration of engine mass including the intake and exhaust systems to realize a motorcycle frontal projected area roughly equivalent to that of the RS125R, even though using a 4-stroke engine with twice the displacement.
- (2) Setting the power-to-weight ratio equal to that of the RS125R, and achieving maximum power of 34 kW or more.
- (3) Adoption of a battery-less electronic controlled fuel injection system (hereafter, PGM-FI system) to enhance drivability and help ensure advantages in terms of circuit time, acceleration performance, and maximum speed.
- (4) Adoption of a cam-type auto decompression system that enables push start without the use of a self-starter, kick-starter or other starting device, in order to secure the same push startability as the 2-stroke RS125R while reducing weight and simplifying the mechanism.
- (5) Each part has a limited guarantee with the aim of maintaining high competitiveness as a dedicated racing engine. However, all parts require durability of 2000 km or more, and durability of 4000 km should be guaranteed for major parts, assuming periodic maintenance.

4.2. Basic Layout

The engine is based on the CRF250R commercial motocrosser, which is also a competition machine. However, all parts were reviewed including major changes to the valve train, crankcase and other areas in order to realize a dedicated road racing design that secures the qualities required of road racers while also providing advantages for future potential upgrades.



Fig. 2 Engine external view

Table 2 Comparison of engine major specifications

	NSF250R	RS125R
Engine type	Liquid cooled 4-stroke DOHC 4-valve single cylinder	Liquid cooled 2-stroke single cylinder
Displacement (cm ³)	249.4	124.8
Bore x stroke (mm)	78 x 52.2	54 x 54.5
Compression ratio	12.3	7.98
Maximum power (kW/rpm)	35.5 / 13000	32.6 / 12250
Maximum torque (Nm/rpm)	28.0 / 11000	25.9 / 11500
Fuel supply system	Battery-less PGM-FI, GQD1A ϕ 50	Carburetor, PJ38
Starting type / starting assist system	Push start / auto-decompression system	Push start / none
Ignition system	Full-transistor	Digital C.D.I.

Figure 3 shows an overview of the engine layout. The basic engine layout aims to realize the development concept of “lightweight, compact, high output, and high efficiency.” First, an intake-from-front, exhaust-to-rear layout was selected and a ram-air intake system was equipped as standard to increase the charging efficiency. The cylinder which has a relatively shallow water jacket was tilted rearward by 15° to secure the space required for intake-from-front and to concentrate mass.

In addition, a DOHC-type valve train was adopted as suitable for a small displacement road racer that is frequently used in the high-engine-speed range, and titanium materials were used in both the intake and exhaust valves for the first time in a Honda mass-production vehicle.

The shaft layout places the balancer shaft above the crankshaft in order to shorten the engine longitudinal length and concentrate mass.

Furthermore, a semi-dry sump system was adopted that uses the space comprising the bottom of the left side cover

and the right and left crankcase as an oil tank inside the case, and a scavenging pump was added inside the closed crank chamber to reduce friction by reducing pumping loss.

4.3. Output Characteristics

Figure 4 compares the output characteristics of the RS125R (2-stroke) and the NSF250R (4-stroke). The port shapes, valve timings, and intake and exhaust systems were optimized and friction loss was reduced to obtain the easy-to-handle output characteristics of a 4-stroke engine with flat torque characteristics, enabling simultaneous achievement of the target maximum power. This resulted in performance enhancement of approximately 9% in terms of maximum power and approximately 8% in terms of maximum torque.

Friction loss was reduced by approximately 21% at the

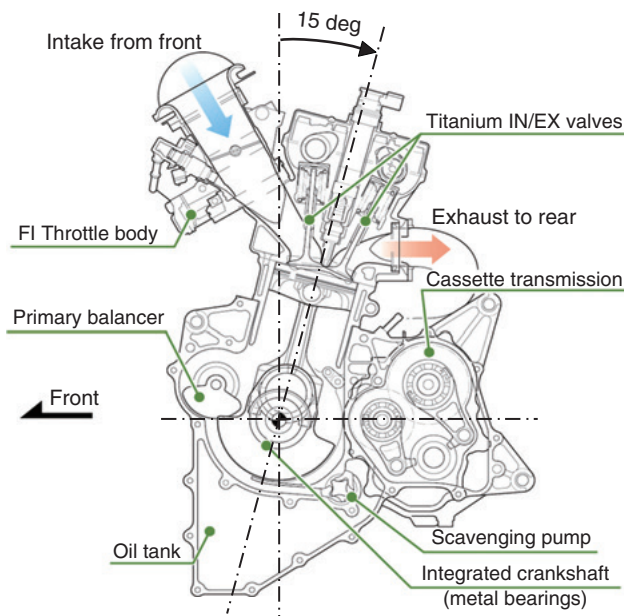


Fig. 3 Engine layout

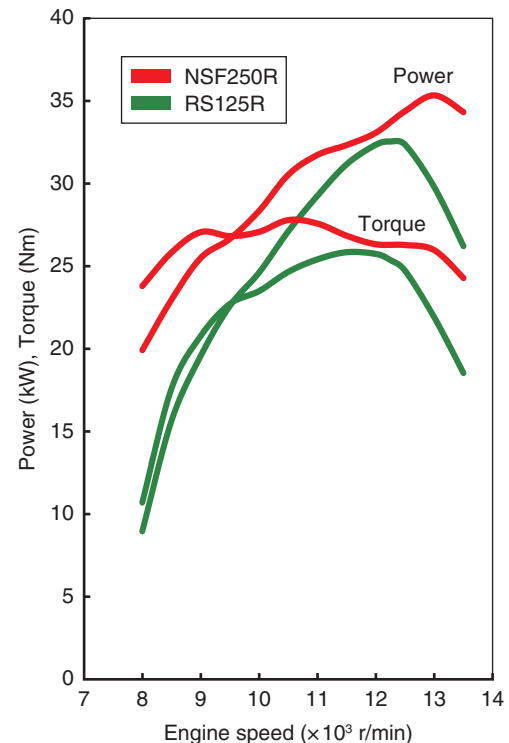


Fig. 4 Comparison of output characteristics

maximum output engine speed of 13000 r/min compared to the CRF250R (2009 year model), which has the same bore-stroke. Figure 5 compares the friction loss under the same oil temperature conditions, as measured by the motoring method.

The main technologies introduced to the engine to realize these results are described below.

4.4. Thinner Lightweight Forged Piston

Figure 6 shows the structure around the piston. A thin, lightweight piston with a bore diameter of 78 mm and a total height of 31.5 mm is used. The piston is hot-forged using A2618 materials with good high-temperature strength, and the piston head that forms the combustion chamber is finished by full machining. In addition, T6 treatment is performed as the piston heat treatment to increase strength for racing.

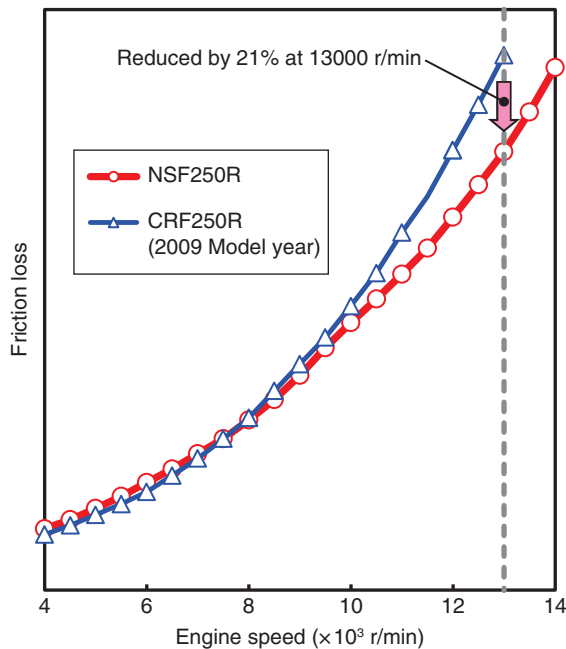


Fig. 5 Comparison of friction loss

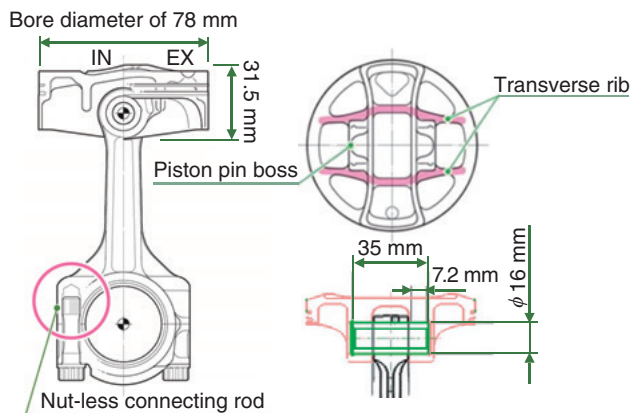


Fig. 6 Structure of piston and connecting rod

The shape was investigated and verified by CAE analysis. Based on these results, two transverse ribs connecting the pin bosses were added to the piston rear surface, and the transverse rib height decreases towards the piston peripheral wall. This enabled simultaneously increasing rigidity and reducing mass.

The top ring groove and the piston pin clip groove are plated with a nickel-phosphorous (Ni-P) alloy to increase wear resistance. This enables maintaining high performance while enhancing durability.

The piston pin is short with an overall length of 35 mm relative to an outer diameter of $\phi 16$ mm, and the contact surface width between the pin boss and the piston pin is narrow at 7.2 mm per side, which is disadvantageous in terms of resistance to surface contact pressure. Therefore, wear resistance is increased and friction is reduced by applying a diamond-like carbon (DLC) coating as surface treatment. In addition, heat-resistant case hardening steel with an increased molybdenum blending ratio is used as the piston pin material.

The specifications use only the two piston rings of the top ring and the oil ring. The top ring surface treatment consists of a nitriding base with ion plating on the sliding surface around the circumference to increase wear resistance and reduce friction.

These reductions in size and weight around the piston reduced the reciprocating motion mass by approximately 4% compared to the CRF250R (2009 year model).

4.5. Forged Integrated Crankshaft and Nut-less Connecting Rod

Figure 7 shows a sectional view of the area around the crankshaft.

The forged crankshaft has an integrated structure and uses originally developed high-strength nitriding steel⁽¹⁾, with low-temperature carbonitriding (LCN) applied as surface treatment, and high frequency induction hardening applied to the timing sprocket and oil pump drive sprocket

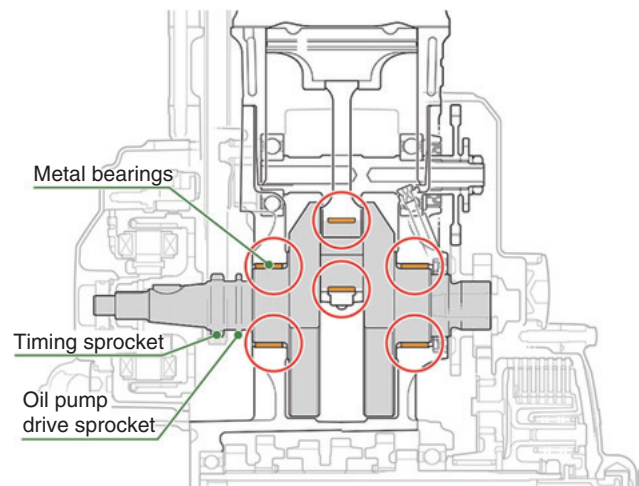


Fig. 7 Sectional view of crankshaft unit

areas. With these techniques, it was made possible to realize the high rigidity and high accuracy required for a high-speed, high-power racing engine while also increasing the strength of the sprocket area.

The connecting rod uses a lightweight nut-less system (Fig. 6). The simple structure is fastened by screwing a bolt into a hole cut directly into the rod side, which reduces the mass compared to the conventional type.

Metal bearings are used for the connecting rod big end bearings and crankshaft journal bearings to support higher power and reduced friction as well as to reduce the engine mass and size.

4.6. Cylinder Head, Cylinder and Valve Train System

Figure 8 shows a sectional view of the intake and exhaust port shapes and an overview of the offset cylinder and the valve train system.

The intake-from-front, exhaust-to-rear layout makes it easier to straighten the ports. In particular, the position of the injector mounted on the throttle body built into the air cleaner box is shifted forward (toward the front of the motorcycle). This enables the inlet port to rise more directly upward, which realizes a high-efficiency downdraft-type straight port.

The cylinder is made from a lightweight aluminum alloy with nickel silicon carbide (Ni-SiC) surface treatment applied to the bore surface. In addition, the cylinder axis is offset by 2 mm to the inlet side, which reduces the thrust load between the piston and the cylinder, reducing friction loss.

In contrast to the piston bore diameter of 78 mm, four valves consisting of two IN valves with a diameter of 32.5 mm and two EX valves with a diameter of 26 mm are set for the valve train, and lightweight titanium valves are used for all valves. The IN valves use a Ti-6Al-4V based titanium alloy that uses off-grade sponge titanium with a large iron component⁽²⁾. The EX valves use a

heat-resistant titanium alloy that is a modification of Ti-6Al-2Sn-4Zr-2Mo, and marks the first titanium EX valves in a Honda mass-production vehicle.

In addition, a compact combustion chamber with the ideal shape was realized by setting a narrow angle of 21.5° between the valves and using a flat shape for the combustion chamber surfaces of both valves.

The cam chain uses a BorgWarner 96 type chain to simultaneously increase strength and reduce friction, and to secure the required crank timing sprocket strength. The specifications also support future potential upgrades such as even higher rotation speeds and enhanced performance.

The cam chain tensioner uses a double tensioner system that provides an auto tensioner lifter in the cylinder area and a manual tensioner in the head area. This realizes stable cam chain driving under the operating conditions of road racers that are frequently used at high engine speeds, and is also an effective means of suppressing irregular vibration of cam chain behavior due to sudden crankshaft rotation speed fluctuation produced by gear shifting and other conditions during actual operation.

4.7. Dual-Channel Lubrication System and Closed Crank Chamber with Scavenging Pump

Figure 9 shows an overview of the dual-channel lubrication system.

A dual-channel type lubrication system is used that places an oil seal on the right side of the crankshaft and balancer shaft, and divides the lubrication methods for the crankshaft and piston side (internal-combustion engine side) and for the transmission and clutch side (drive system side) into two separate channels. The internal-combustion engine side adopts a force feed-type lubrication system using a trochoid-type feed pump, and the drive system side adopts the same oil bath-type lubrication system as that used in 2-stroke engines.

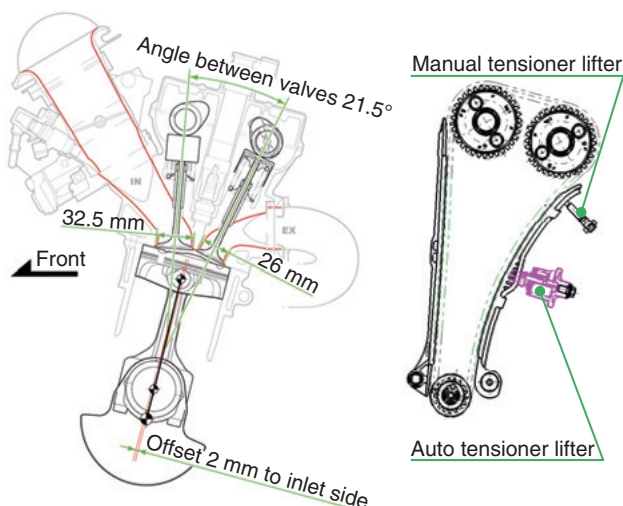


Fig. 8 Engine sectional view and valve train system

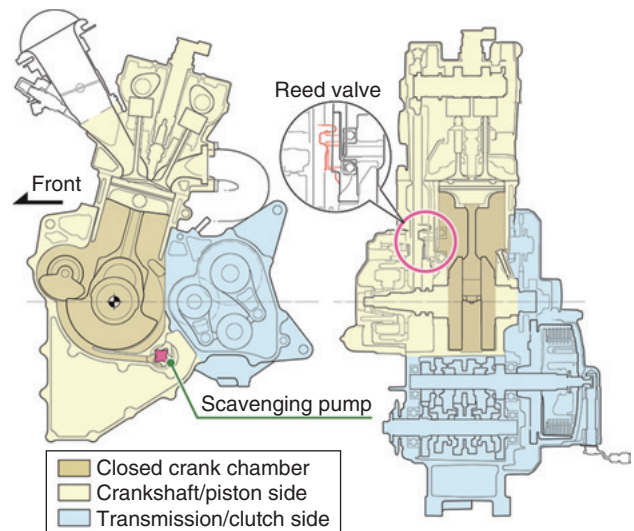


Fig. 9 Dual-channel lubrication system

The merits of a dual-channel lubrication system are that the drive system side oil does not directly receive the combustion heat from the internal-combustion engine, which suppresses the rise in oil temperature, and the size can be reduced due to the smaller clutch capacity. This enables use of the same clutch capacity, transmission and other specifications as those of the RS125R.

An additional merit is that mixing of wear debris produced by sliding of the transmission gears and other parts into the internal-combustion engine side oil is suppressed, enabling use of a smaller oil filter. Furthermore, molybdenum and other additives can be used on only the internal-combustion engine side, enabling reduced friction loss without lowering clutch performance.

Regarding the crankcase, the area housing the crankshaft, balancer shaft, connecting rod and piston unit has a closed structure. Pumping loss and friction are reduced by using a scavenging pump located on the same axis as the oil feed pump to forcibly discharge the oil inside this closed crank chamber and generate a negative pressure.

In addition, a reed valve was added to the upper left of the closed crank chamber (the balancer bearing housing area). When push-starting the engine, the rotational speed is low so the scavenging pump is unable to operate effectively, and a positive pressure is generated inside the closed crank chamber. In these cases, the reed valve opens to help prevent a rise in the pumping pressure, providing the stable crankshaft rotation speed required for starting.

4.8. Auto Decompression System

An auto decompression system is mounted to help start the engine by push-start. This system uses a lightweight, simple cam-type decompression system with a centrifugal weight as shown in Fig. 10. By reducing the compression pressure inside the cylinder during engine start and securing sufficient crankshaft rotation speed even during push start, the required power generation level can be obtained from the ACG. This enables ECU start-up even with a battery-less system.

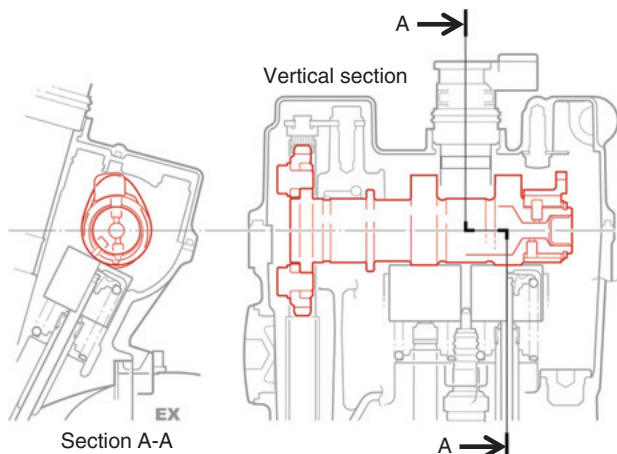


Fig. 10 Auto decompression system

The two important points for the decompression system settings are optimization of the valve open timings and lift amounts, and setting the proper decompression OFF engine speed in combination with the centrifugal weight and set spring settings. In addition, push-startability equivalent to that of the 2-stroke RS125R is provided by optimizing the fuel injection settings.

4.9. Cassette-Type Transmission

An easily replaceable cassette-type transmission is used to enable the optimal gear selection in accordance with the characteristics of each circuit (Fig. 11).

This cassette-type transmission enables maintenance and gear ratio changes in a short time without the need to remove and remount the engine or disassemble the crankcase. In addition, the RS125R transmission can also be used in consideration of convenience for RS125R users.

4.10. Fuel Supply System and Induction System

Figure 12 shows an overview of the throttle body, and Fig. 13 shows an overview of the induction system.

The throttle body uses an intake air control valve (IACV), and the amount of intake air in the throttle closed state is controlled by regulating the throttle opening with the PGM-FI system. This reduces the strong engine braking in a 4-stroke single-cylinder engine, enabling the deceleration



Fig. 11 Cassette type transmission

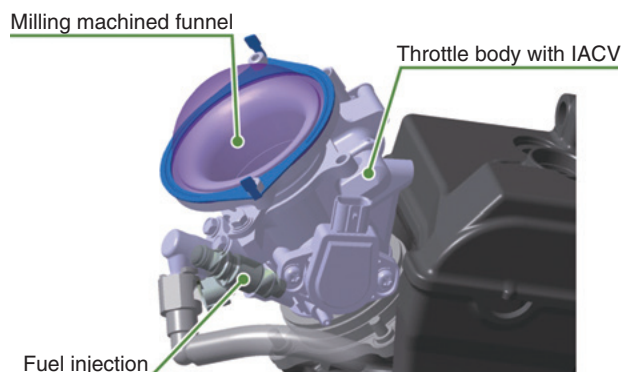


Fig. 12 Throttle body external view

feeling to be set in accordance with the rider's preferences.

The air funnel is a short type with an overall length of 26 mm to optimize the output characteristics and response, and is made of machine-processed aluminum for increased accuracy.

The throttle body unit is housed inside the air cleaner box like a MotoGP machine, and the layout places the air cleaner box between the cylinder and the radiator. This makes the most of the limited motorcycle body space while concentrating mass, enabling realization of a large-capacity 5L air box.

Regarding the induction system, a ram-air intake system not mounted in the RS125R is equipped as standard, and the air passing below the bottom bridge passes through an air duct with a large opening and is led straight to the air box. This active use of ram-air intake increases the power.

4.11. Exhaust System

The exhaust pipe uses stainless steel with good heat resistance. A diffuser shape with pipe diameter that expands gradually as it approaches the muffler for good exhaust efficiency was adopted and the output characteristics were optimized with the aim of simultaneously achieving both the flat torque characteristics of a 4-stroke engine and the target maximum power (34 kW or more).

In addition, the exhaust system layout uses a "midship

muffler layout" in which the exhaust pipe leads from the back of the rearward tilted cylinder in a large reverse "S" shape to the muffler located under the engine. Placing the muffler, which is a heavy object, close to the center of gravity of the motorcycle body concentrates the mass and realizes handling that does not convey the effects of the increase in mass due to the change to a 4-stroke engine. Furthermore, placing the muffler, which has a large volume, inside the cowl also helps to reduce air resistance.

Figure 14 shows an overview of the exhaust system layout.

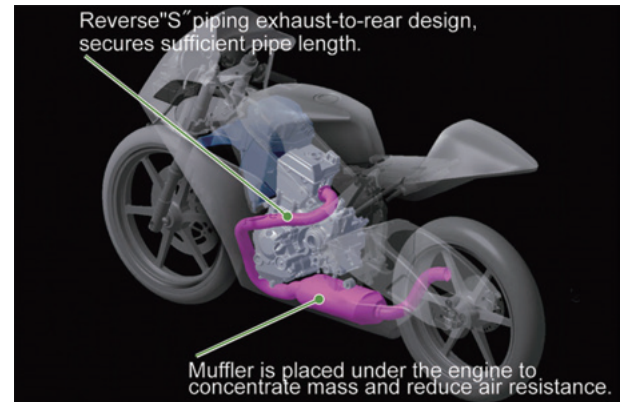


Fig. 14 Exhaust system layout

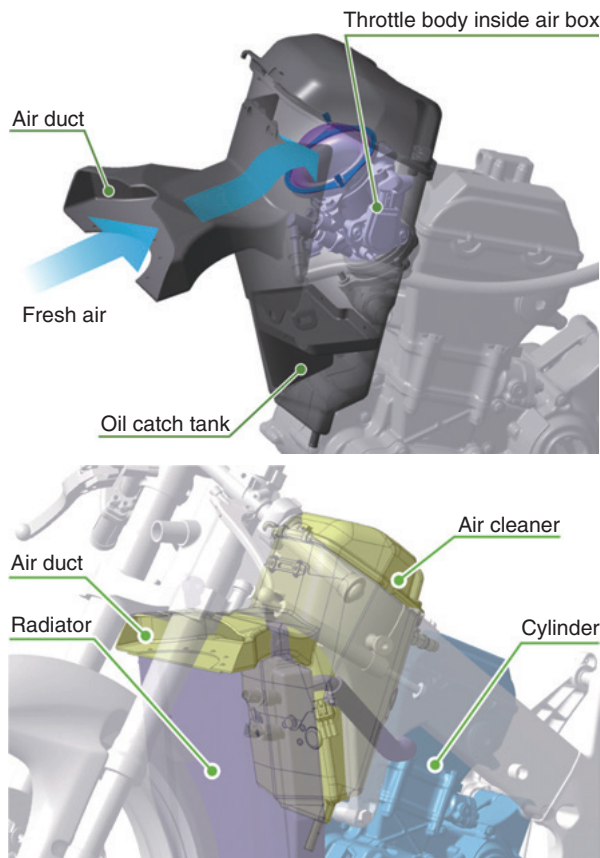


Fig. 13 Induction system

5. Motorcycle Body Layout

The following technical means were adopted to realize a package that carries on the compact body of the RS125R with a 4-stroke 250 cm³ engine.

- (1) Rearward tilted cylinder engine with intake-from-front and exhaust-to-rear
- (2) Throttle body inside the air box
- (3) Reverse "S" piping exhaust pipe
- (4) Midship muffler

This motorcycle packaging helped to reduce both weight and size. Figure 15 shows the major dimensions and riding position.

In terms of dimensions, the wheelbase is the same as that of the RS125R, but the crankshaft center in the engine-mounted condition was set 27.4 mm to the front and 51.5 mm below that of the RS125R. As a result, the front shared load ratio was able to increase 0.7 percentage points while keeping the same center of gravity height as that of the RS125R. In addition, the motorcycle mass increased by approximately 9.2 kg, but increasing the degree of mass concentration achieved a yaw moment of inertia equivalent to that of the RS125R. Optimizing the mass distribution and center of gravity height in this manner enabled simultaneous achievement of a high degree of controllability and stability, which realized the cornering performance demanded by the lightweight class.

Figure 16 compares the yaw rate at cornering when the RS125R and NSF250R are driven by the same driver over the same circuit. This shows that the yaw rate at cornering is the same in the high-speed range, and is enhanced by approximately 5% in the low-speed range.

The frame body is based on the RS125R, and the optimal rigidity balance required for the NSF250R was achieved by changing the front engine hanger shape and the main pipe sectional shape to increase torsional rigidity while maintaining lateral rigidity compared to the RS125R (Fig. 17).

The newly designed swing arm was optimized by a similar rigidity balance technique as that used for the frame body with the aim of increasing stability and the sense of integration with the frame. In addition, the center of gravity of the standalone swing arm was shifted toward the front to concentrate mass. Furthermore, both the swing arm and the frame body have skeletal shapes that enable them to twist flexibly.

These measures increase stability when braking and provide a degree of cornering freedom and nimbleness equal to or greater than that of the RS125R. This realizes handling that does not convey the increase in mass due to the change to a 4-stroke engine, even when approaching corners.

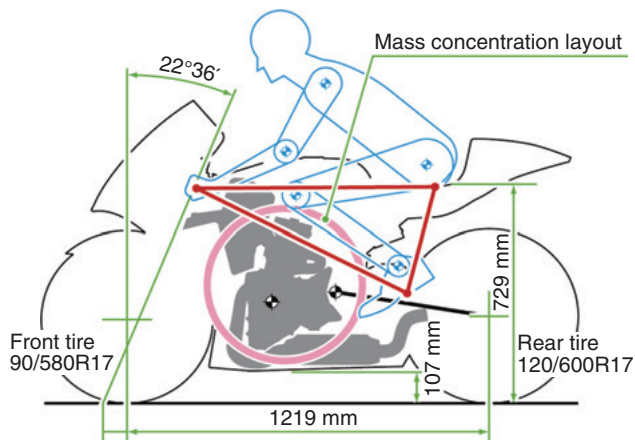


Fig. 15 Major dimensions and riding position

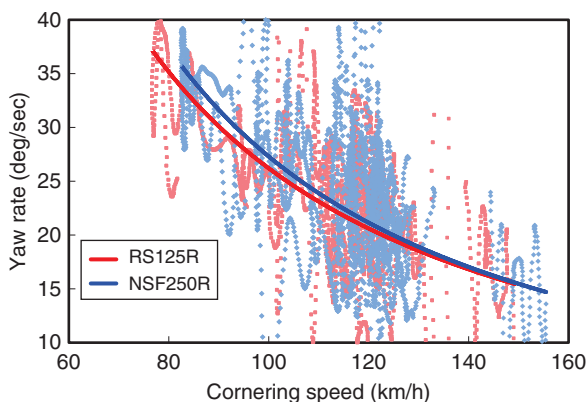


Fig. 16 Comparison of yaw rate at cornering

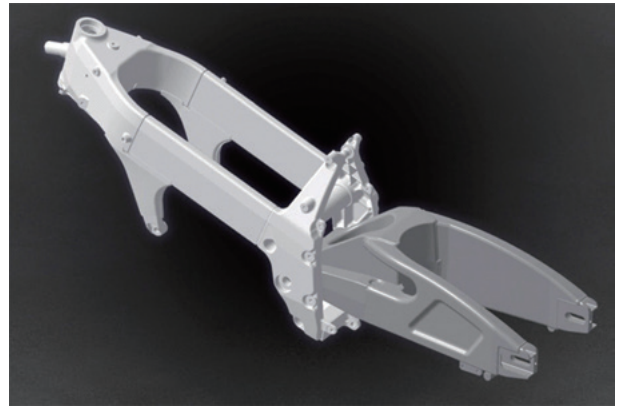


Fig. 17 Frame body and swing arm

6. Conclusion

The NSF250R utilizing the technology introduced in this paper not only manifests the stable, high performance befitting a top-end machine, but also makes this performance easily available to almost anyone, and Honda is confident that it can meet the demands of all riders.

Like the RS125R, it is hoped that the NSF250R will vitalize the Moto3 class, thereby broadening the base of motorcycle sports, sharing dreams and emotion with spectators, and creating the chance for riders to become future MotoGP champions.

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