

Presentation of RC211V Equipped with 4-stroke Engine

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ABSTRACT

The 4-stroke engine road racer, RC211V, has been developed with the concept “Launching Honda’s own advanced technology in pursuit of speed and functionality.” Employing a lightweight, compact 4-stroke V-type 5-cylinder engine for the first time in the world, the aim was to realize linear torque characteristics, easy operational traction characteristics, highly controllable handling and improved turning ability when compared to 2-stroke road racers. A semi dry sump crankcase utilizing the transmission room for the oil tank, and a pressure controllable fuel injection system were adopted to achieve the engine performance targets. In addition, the specified minimum weight of 145 kgs for 5-cylinder engine motorcycles was satisfied by employing a new type of aluminum twin spar frame, a low gravity fuel tank, and a Unit Pro-link suspension, as well as through weight reductions for each of the parts.

1. Introduction

The WGP500, the pinnacle of motorcycle road racing world championships, became known as the Moto-GP in 2002. In meeting the new regulation standards that allow 4-stroke engine configurations with a maximum displacement of 990 cm³, Honda has developed a road racer configured with a new type 4-stroke engine instead of the conventional 2-stroke type.

2. Development Concept

On the WGP road racing circuit, even on models

configured with an exceptionally powerful engine, motorcycles tend to suffer from fast tire wear if they are not provided with linear torque and easy operational traction characteristics. Since tire wear is directly related to a reduction in lap time performance, it is imperative that the load exerted on the tires be reduced. Moreover, motorcycles need to be easy to control in progressive tire wear conditions in order to maintain a stable fast speed through to the final stages of the race. Taking these points into consideration, a design featuring an engine offering maximum power and operational ease, a body frame offering highly controllable handling, and a suspension system offering favorable traction characteristics were targeted to enable a fast pace ride over the entire race circuit.

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3. Overview of RC211V

Figure 1 shows an external view of the RC211V and Table 1 lists the major specifications. The size of the RC211V frame is similar to the lightweight compact 2-stroke engine configured NSR500, which has won both individual and manufacturer's titles at the WGP500 seven times over the last eight years. A study of vehicle weight and maximum power output was conducted by comparing engine sizes with different cylinder configurations and types, and by the positioning of power/weight ratios standardized in accordance with new regulation guidelines. Under the new regulation standards, a multi cylinder engine configuration, which is advantageous in terms of its power output, becomes disadvantageous in terms of vehicle weight. Conversely, an engine configuration with fewer cylinders offers an advantageous vehicle weight but suffers from insufficient engine power output. As the vehicle weight and engine power are increased, there is a greater tendency toward tire wear as previously described. After considerable



Fig. 1 External view of RC211V

Table 1 Major specifications

Items		Specifications
Overall length	(mm)	2 050
Overall width	(mm)	600
Overall height	(mm)	1 130
Wheelbase	(mm)	1 440
Ground clearance	(mm)	130
Vehicle dry mass	(kg)	145
Engine type		Liquid cooled 4-stroke DOHC five cylinder
Engine displacement	(cm ³)	Under 990
Valve train		DOHC 4 valve
Max power		Over 160kW
Throttle body type		GQ type
Fuel capacity	(Liter)	24
Clutch type		Dry multi-plate type
Transmission		6 speed constant mesh
Tire size	Front	12/60-17
	Rear	19/67-16.5
Brake system	Front	Double, Carbon disk
	Rear	Single, SUS disk
Suspension	Front	Telescopic
	Rear	Unit Pro-link
Frame type		Aluminum twin-spar

deliberation, the most compact V-type 5-cylinder engine was selected for its superior balance of engine output and complete vehicle weight. Table 2 lists the regulation specifics and Fig. 2 shows a comparison of the power-weight ratio for the respective engine configurations.

4. Engine

In approaching engine design, the three component motion characteristics, the inertia momentum of roll, pitch and yaw were targeted for reduction while improving maneuverability. Toward this end, the vehicle's structural assembly was taken into consideration and a design closely approximating a sphere form was finally decided upon. Conclusively, the V-type 5 cylinder configuration, taking up the smallest sphere layout, was adopted. Figure 3 shows the comparison results of the different engine sizes and Fig. 4 shows a cutaway drawing of the engine. Figure 5 shows the analysis model of the crankshaft. This engine is designed to cancel out the primary and coupling vibrations without a balancer mechanism. The engine is configured with a counter weight that weighs 50% of the reciprocating parts on each cylinder. Imbalances are cancelled out in cylinders 1 and 2 and 4 and 5 by 25% each and the remaining 50% imbalance (25% + 25%) was cancelled on cylinder 3. This has effectively cancelled out the primary vibration. Figure 6 shows a schematic diagram of the crank balances. As cylinders are positioned symmetrically centered around cylinder 3, the coupling oscillation is logically zero. Eliminating the balancer from the engine and reducing relentless concerns with a lack of strength in frame body parts caused by engine vibration have contributed to a reduction of the overall vehicle weight. Computer analysis was applied and optimal settings for valve timing and the various intake and exhaust system specifications were obtained in order to achieve a greater level of power output without losing the flat torque characteristics associated with the 4-stroke engine configuration. As a result, the targeted output level has been achieved. The output and torque values have been increased significantly over those for conventional 2-stroke engines and the amount of fuel flow has been considerably reduced. Figure 7 shows a comparison of the performance curves for the NSR500 and RC211V.

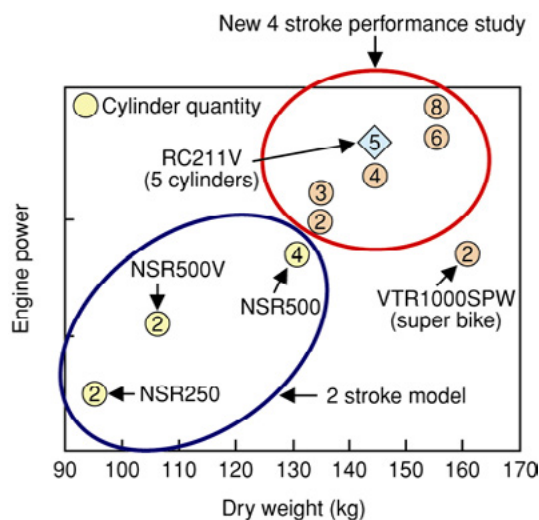


Fig. 2 Comparison of power-weight ratio

Table 2 Regulation of Moto-GP (from 2002)

Engine type	4-stroke			2-stroke		
Engine displacement (cm ³)	Maximum 990			350 ~ 500		
Cylinder quantity	Free			Maximum 4		
Supercharging	Prohibition			Prohibition		
Vehicle dry mass (kg)	Over 6 cylinder	4 ~ 5 cylinder	Under 3 cylinder	4 cylinder	3 cylinder	2 cylinder
	155	145	135	131	116	101
(Oval piston)	155	155	145			
Fuel capacity (Liter)	Maximum 24			Maximum 32		
Noise (dB)	Maximum 125			Maximum 113		

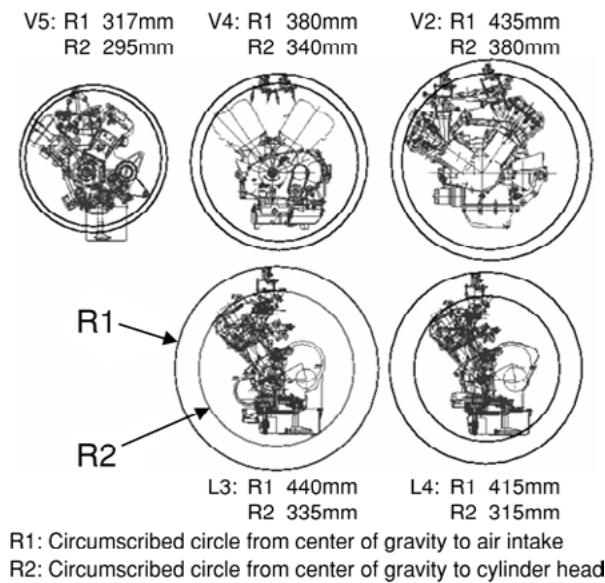


Fig. 3 Comparison of engine size

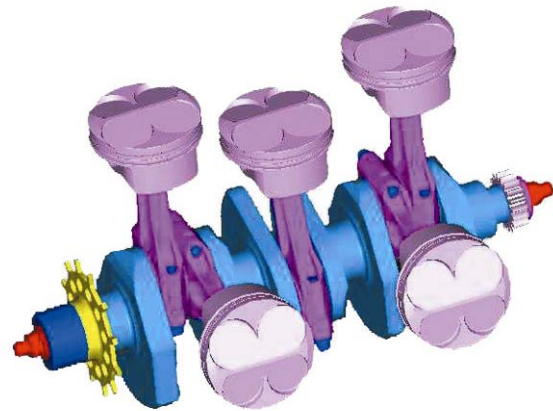


Fig. 5 FEM analysis model of crankshaft

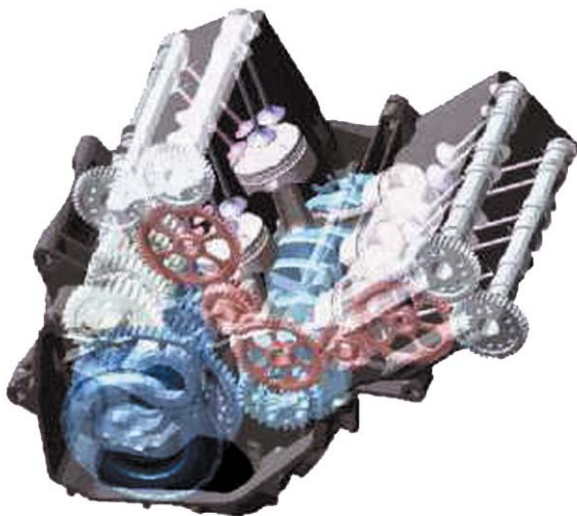


Fig. 4 Cutaway drawing of RC211V engine

The crankcase is constructed of aluminum casting and a semi dry sump crankcase has been configured to use the transmission room for the oil tank. Each crank chamber throw is sealed. Three scavenging oil pumps have been placed to each of the throws. These pumps have fortified the discharge of the oil and blow-by gas from the oil feed fitted beneath the oil separator plate to the transmission case. The discharged oil is directed into the oil pan from the transmission room. A constant negative pressure of about 70 kPa is generated in the crankcase while the engine is being driven. Figure 8 shows the structure of the crankcase and lubricating mechanism. Adopting this mechanism has reduced the pumping loss that occurs behind the pistons and the oil agitation loss in the crank system compared with the conventional wet sump configuration. Also, the maximum output has been improved by 4% and friction has been reduced by 19%. Figure 9 shows a correlation between the output and friction. A complete dry sump configuration requires a separate oil tank and oil piping which increases the overall weight of the vehicle. On the other hand, the semi dry sump configuration incorporates a layout design that is integrated with the engine, making it approximately 1 kg less than the complete dry sump configuration.

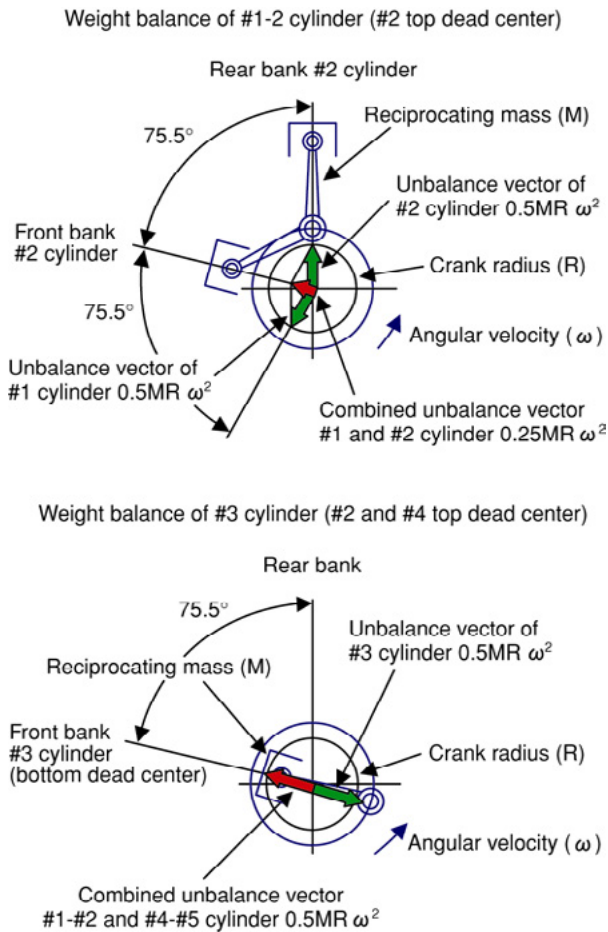


Fig. 6 Weight balance of cylinder

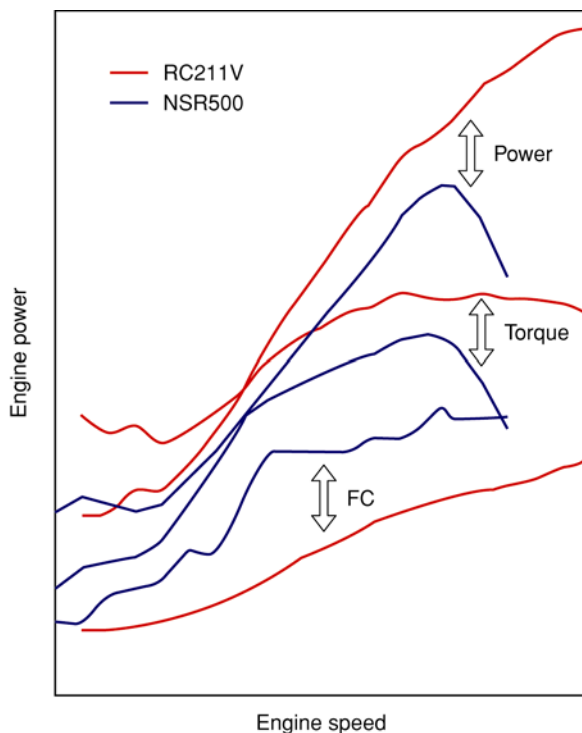


Fig. 7 Engine performance curve

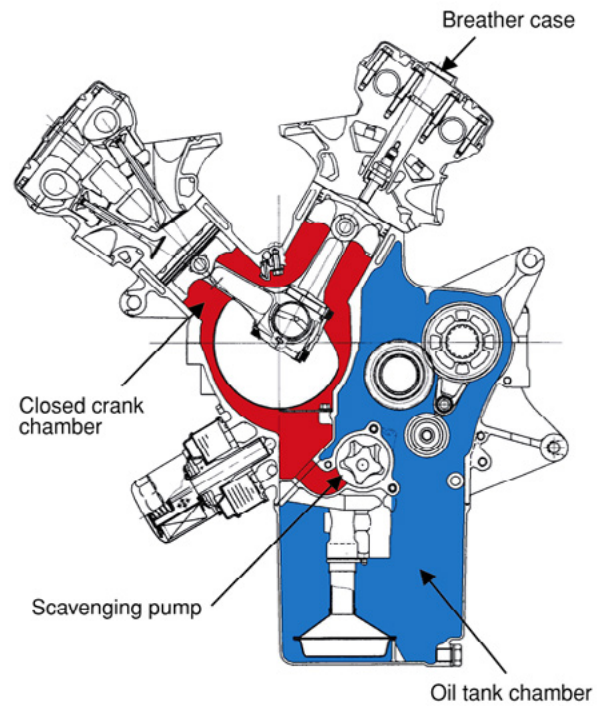


Fig. 8 Structure of crankcase

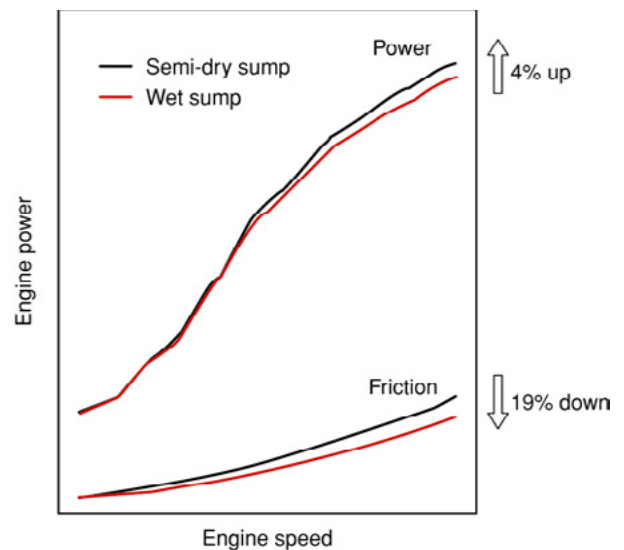


Fig. 9 Effect of new crankcase

5. Fuel System

The throttle body is configured with a deflective multi-hole twin injector. An injector is fitted to the upper and lower sides of each cylinder. Sharing the fuel injector for both the low load and high load areas has been instrumental in achieving driveability and greater output. Figure 10 shows the structural overview of the twin fuel injectors.

Employing a fuel pressure regulator that enables the injector pressure to change continuously has improved the output transient characteristic. Figure 11 shows a structure view of the pressure regulator and Fig. 12 shows examples of fuel pressure programs.

As the throttle opens and closes, there is inevitably some fuel remaining in the inlet port. Estimation control of this adherent fuel amount that flows in the next combustion cycle was employed to optimize the air fuel ratio mix and has improved drivability and fuel consumption.

6. Frame Body

In conventional 2-stroke engine road racers, the fuel tank is fitted above the engine and in front of the rider. A full tank of gasoline in the early stages of a race provides a high center of gravity, which causes sluggish handling and makes it difficult to travel the race circuit from the start at a fast pace. Furthermore, as the remaining gasoline is consumed dramatic shifts in handling and stability occur which creates a handicap in terms of balanced lap times. On the RC211V,

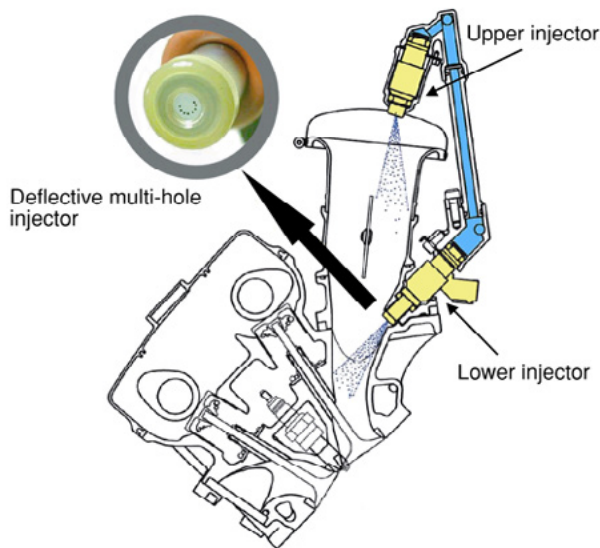


Fig. 10 Twin injector

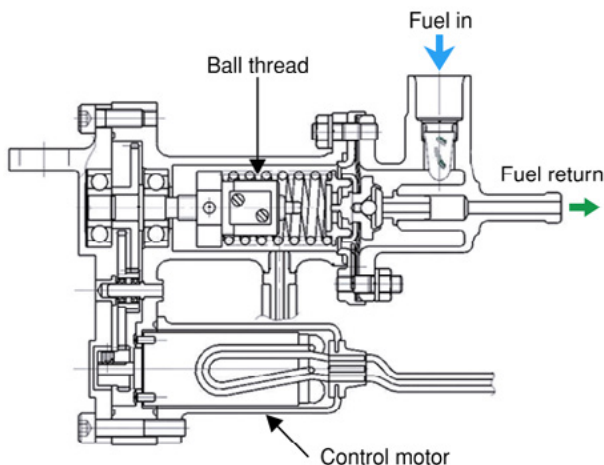


Fig. 11 Structure of fuel pressure regulator

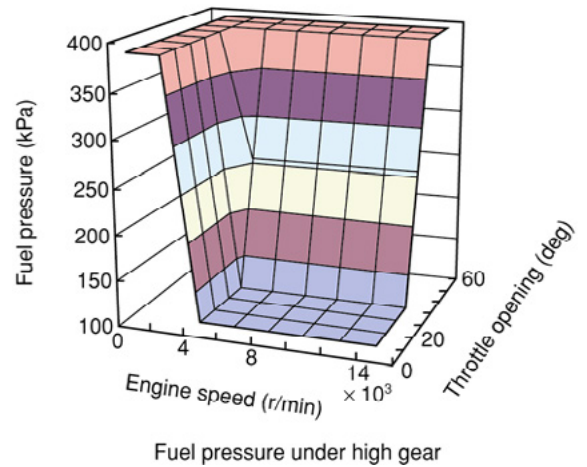
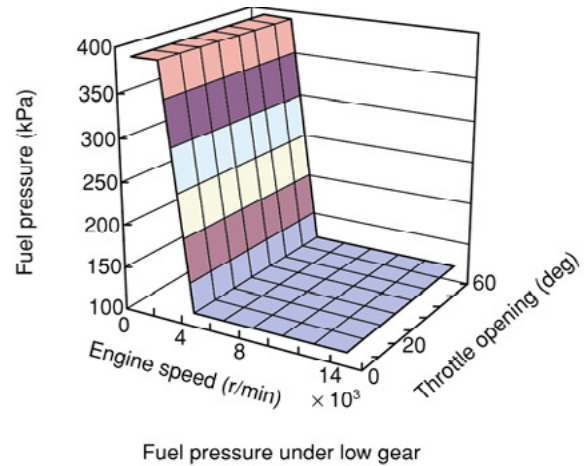


Fig. 12 Program of fuel pressure control

part of the fuel tank is positioned beneath the sheet cowl which lowers the positioning of the stored gasoline to concentrate the vehicle's mass. This also serves to provide ease of handling in full tank conditions and provides a minimal level of gravitational fluctuation as the fuel level decreases during the race. This configuration has enabled a dash start in the early stage of the race and also promotes a stable lap time over the duration of the race. To lower the positioning of the stored gasoline while preserving the capacity of the air box located above the throttle body and the 24 liter tank capacity, there is a need to keep as much space as possible beneath the sheet for the fuel tank. Adopting a unit pro-link suspension system on the RC211V has removed the need for a suspension mount on the top side of the body frame. This has created a large space for the fuel tank beneath the sheet. Figure 13 shows the structural layout of the motorcycle. In designing the basic body frame structure, CAE analysis was conducted based on a new theoretical approach to fabricating a suitable level of structural stiffness. The analysis has yielded a completely new set of measurements. The resultant design incorporates a 17% lateral flexure increase and 23% improved resistance to twisting in comparison to the NSR500. This has served to attain a frame body stability that is able to support high engine output exceeding 160 kW, and to improve the turning

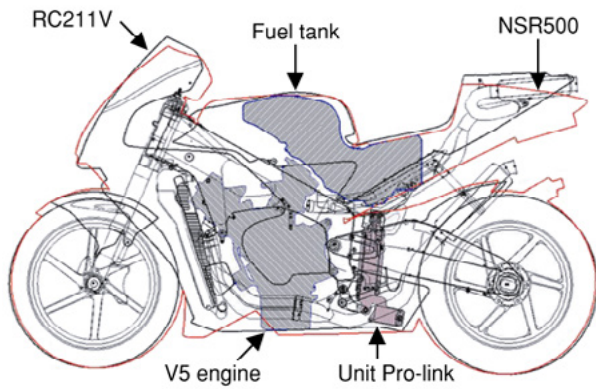


Fig. 13 Comparison of motorcycle size

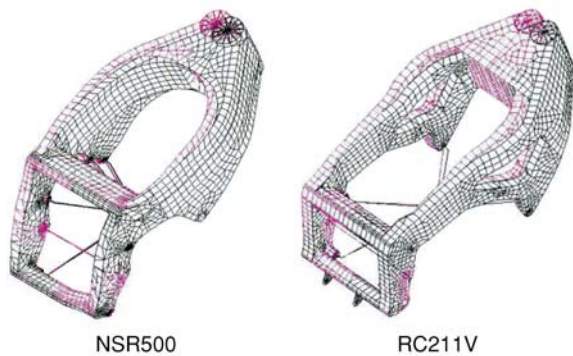


Fig. 14 Frame body stiffness model with FEM

ability. To achieve better deceleration performance than the conventional lightweight 2-stroke engine road racer, the frame stiffness in the direction of pitching has been preserved and the vehicle stability during braking has been improved. Figure 14 shows a CAE analysis model of the mainframe body stiffness.

7. Suspension

The unit pro-link suspension stabilizes the turning behavior of the motorcycle at the exit of a corner and displays superior rear traction. Also, the unit connector is attached to the topline of the swing arm instead of connecting the rear cushion unit to the topline of the frame body. This has removed the necessity for reinforcing the frame body unit connector as typically applied in conventional designs. This offers the advantage of greater flexibility in setting frame stiffness values. Figure 15 shows a comparison of rear suspension systems.

8. Fairing

Contemporary motorcycle road racers emphasize improved wind protection for the rider and lower air resistance values. While the fairing tends to envelop the entire motorcycle, it is contrary to the motorcycle's handling. The fairing on the RC211V has been designed to reduce the surface area air contact and was implemented to provide ease of handling and stability against cross winds, while achieving a balance between air resistance and wind protection. A total projection surface area and air resistance values lower than the NSR500 were achieved to provide an improved level of handling performance. Figure 16 shows an external view of the 2002 RC211V model and the NSR500 model released in 1998.

9. Electrical System

The new type ECU incorporated on the RC211V is assembled in a single unit that provides ignition timing

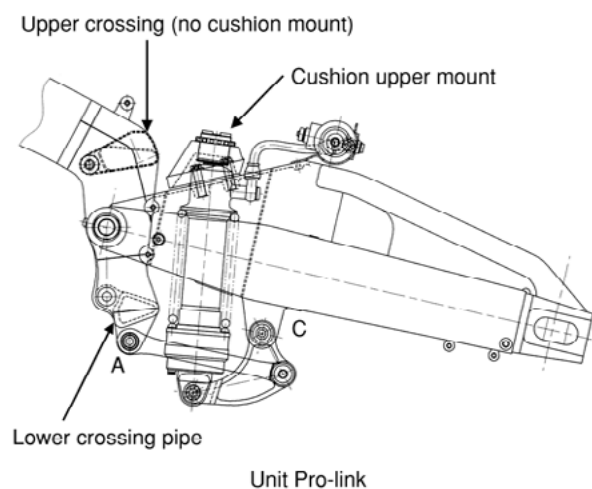
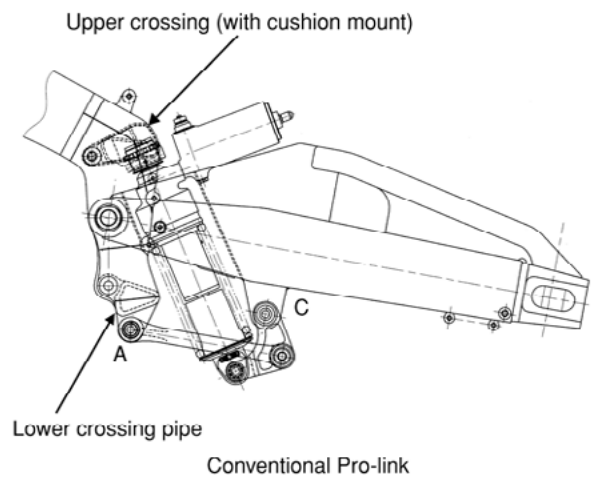


Fig. 15 Structure of unit Pro-link



RC211V 2002 model



NSR500 1998 model

Fig. 16 Comparison of external view



ECU unit

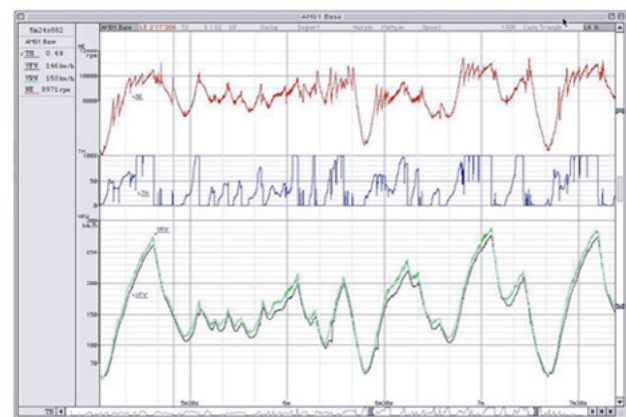
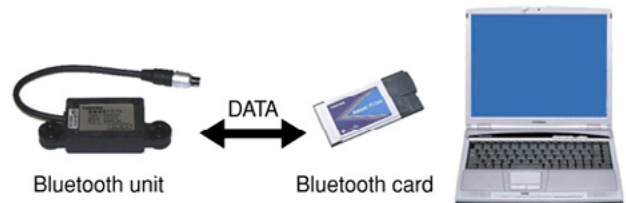


CAN meter

Fig. 17 ECU unit and CAN meter

control, FI setting control and actuators control in addition to data logger functionality. The ECU and meter offer CAN (Controller Area Network) capability developed by Robert Bosch GmbH in 1989 and transmit data according to standard serial ISO communication protocols. The meter provides multiple displays including water temperature and lap time as well as failure information and sensor condition. Display modes are controlled with the selector switch on the left side of the meter. Employing CAN capability has enabled a simple signal line design to achieve a lightweight harness. Figure 17 shows an external view of the ECU unit and meter. Bluetooth protocols have been adopted to provide condition adjustments such as fuel injection settings and mode (Map) changes. In accordance with race regulations, real time interactive communication is prohibited while the motorcycle is traveling, and allowed to operate only after the engine has stopped. Data logging settings and data uploads can be performed immediately after the engine is stopped. A quantitative analysis of any mechanical problem perceived by the rider can be performed by conducting full-time measurements of a range of engine and body related conditions including vehicular speed, engine speed, throttle opening, gear positioning, suspension stroke, etc. This enables the most accurate machine settings.

Figure 18 shows an external view of the Bluetooth unit and a sample of measured logging data.



Logging data sample

Fig. 18 Bluetooth unit and logging data sample

10. Conclusion

The RC211V is configured with a V-type 5 cylinder 4-stroke engine which provides output characteristics that are easy to handle, and has achieved the target performance including a compact configuration and superior traction performance from the Unit pro-link suspension. The machine won both individual and manufacturer titles in the 2002 Moto-GP class. We will continue to explore technologies using the RC211V, which is a leader among Honda super sport motorcycles.

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