

Development of NC700 Series

Koki KOBAYASHI*

Masaaki NEGORO*

Takanori OSUKA*

Toshimasa MITSUBORI*

Tadashi OSHIMA*

ABSTRACT

The NC700 series (NC700S, NC700X and INTEGRA) was developed with the aim of realizing a well-balanced fusion of the enjoyment of riding with the convenience of a commuter-type motorcycle. Each of the three model types has a distinctive character, while utilizing the common technology such as a shared platform, a liquid-cooled in-line 2-cylinder 670 cm³ engine, that emphasizes the torque in low-to-mid speed range and has its center of gravity in lower position to increase the degree of freedom in the exterior designing, and a next-generation dual-clutch transmission which is light weighted and compact. The models created in this development offer unprecedented values not available in former models, such as combined benefits of both excellent fuel economy and the pleasant riding quality at the same time, together with values in utilities realized by equipping a larger utility compartment.

1. Introduction

The needs for middle-class motorcycles with displacement between approximately 500 and 750 cm³ in Europe and the U.S. are diversified more.

Market surveys were conducted regarding the usage and requests for motorcycles, including commuter types such as scooters, in advanced nations. The results showed that users are broadly divided into two types.

One is the familiar type of user who enjoys super-sport category motorcycles that emphasize absolute performance. These users demand enhanced power performance in the high-speed range and cornering performance on winding roads.

The other type of user is not particular about performance and displacement hierarchy, and was the motivation for developing these models. These users place the highest priority on easy handling and convenience in everyday life. They own middle class motorcycles in a reasonable price range, and enjoy relaxed, leisurely driving that also takes into account environmental performance, and riding such as touring through suburban areas. In addition, some users of scooters and other commuter types also expressed the desire to sometimes enjoy riding like on a sporty motorcycle, while still keeping the comfort and convenience of a commuter-type motorcycle. Customer's needs have become mixed and are no longer bound by traditional motorcycle or commuter categories.

This paper introduces the NC700 series, which deploys

three different model types using a shared platform to meet these needs and respond to a wide range of user demands (Fig. 1, Fig. 2, Fig. 3).



Fig. 1 NC700S



Fig. 2 NC700X

* Motorcycle R&D Center



Fig. 3 INTEGRA

2. Overview

2.1. Development Target

The development target was set as providing affordable, fuel-efficient motorcycles that are easy to handle in everyday use, and also nimble and comfortable for deeper enjoyment.

Specifically, the aim was to realize the following:

- A package that realizes nimble handling, reliable controllability and comfortable cruising
- Deployment of a three-model series to meet a wide range of customer needs, with individualistic next-generation styling designs that satisfy pride of ownership
- Amenities and an abundance of option settings that further enhance the convenience of FUN models
- Dual-clutch transmission type settings

2.2. Simultaneous Development of Three Models

In previous FUN model development, there were cases where first a core model was developed and mass produced, and then variation models with a shared platform were developed. However, there were also cases where a post-mass-production model was used as the base, but sharing was lost due to changes made to the platform to realize specifications required by later models, or other reasons.

By simultaneously developing the three NC700 series models in parallel, the specifications required to provide the performances of each type could be reflected to the platform as much as possible. As a result, the parts sharing rate could also be maximized.

2.3. Development Goals

2.3.1. Platform Concept and Packaging

Simultaneous development of three models enabled the series to share the engine, frame body, suspension, air intake, exhaust, cooling, lights and other major parts. In addition, the design enabled support of the prerequisite of a dual-clutch transmission type setting for all three models simply by changing some parts from the base normal manual transmission (MT) type. The photographs below show cutaway models of both engine types (Fig. 4, Fig. 5).

The engine also contributes greatly to efficient packaging. Increasing the fuel efficiency enabled reducing

the fuel tank size and locating the fuel tank under the seat. In addition, tilting the cylinders forward by 62° reduced the engine height and secured space above the engine. In addition, a Pro-Link type rear suspension is used and mounted in the lowest position possible.

These layout measures enabled the platform to realize both a luggage space that can accommodate a full-face helmet (NC700S/X) and a scooter-like appearance (INTEGRA) (Fig. 6).

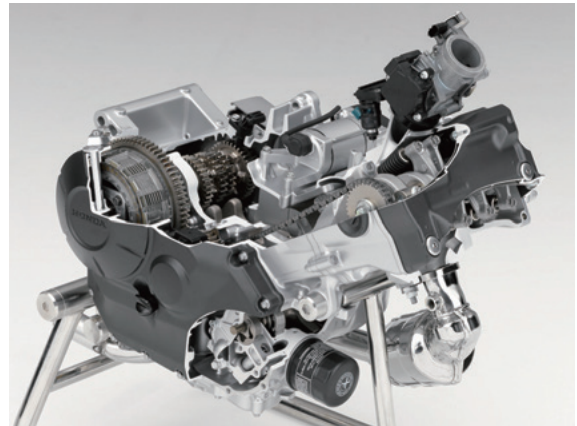


Fig. 4 Cutaway model of engine (manual transmission)

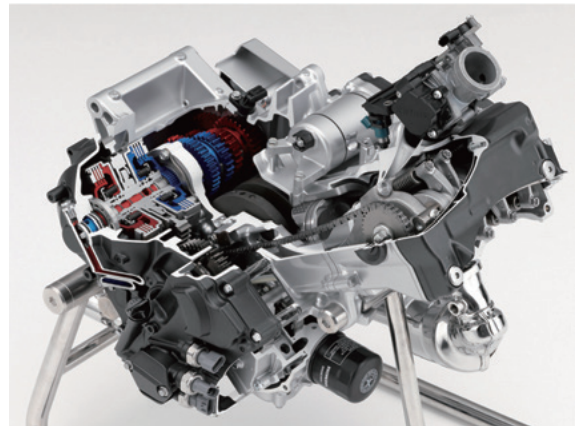


Fig. 5 Cutaway model of engine (dual clutch transmission)

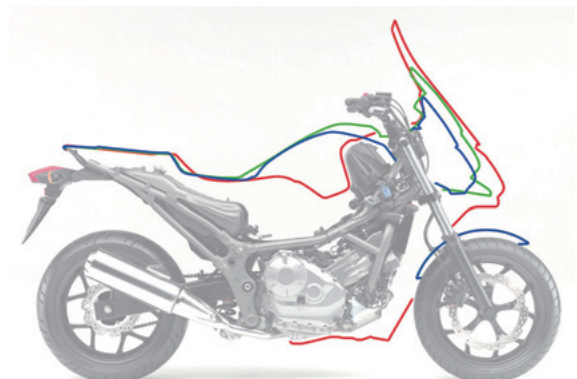


Fig. 6 NC700 platform

2.3.2. Overview of NC700S model

The NC700S aimed for a user-friendly “Neo-FUNCTIONal Motorcycle” that lets users more easily enjoy the exhilaration and maneuverability of FUN riding while also providing comfort.

The NC700S fuses a dynamic, powerful design based on the modern and simple silhouette of a naked sporty model, with natural handling characteristics that enable users to experience the pleasure of riding inherent to motorcycles. This model combines a slightly forward-leaning riding position and a low seat height that provides good ground reach and a sense of security with an agile naked style. This enables users to enjoy relaxed, stress-free riding while still maintaining a sporty ambience.

In addition, even though the NC700S has a 21 L luggage compartment that can hold a full-face helmet, the fit between the rider and the motorcycle, as represented by knee grip, is the same level as that of a conventional model.

2.3.3. Overview of NC700X model

The NC700X aimed for a New Crossover Motorcycle that provides new value by fusing different types of attractiveness.

The NC700X has longer front and rear suspensions compared to the NC700S, and combines a dynamic, powerful and sophisticated design that looks attractive in both the city and the countryside, an upright riding position that provides good visibility and on-road comfort, and maneuverability that expands the sphere of activities.

A frame-mounted fairing and small windscreen that do not interfere with handling in the city realize freedom and broad usability that provide mobility for commuting to work or school in urban areas, while also enabling users to enjoy occasional long-distance touring.

In addition, the NC700X also has luggage space equal to that of the NC700S in consideration of everyday convenience.

2.3.4. Overview of INTEGRA model

The INTEGRA aimed for a Scooting Motorcycle that fuses the enjoyment of riding a motorcycle with the comfort and convenience of a commuter type.

Good handling characteristics provide the enjoyment of maneuverability inherent to motorcycles, and the second-generation dual-clutch transmission realizes an exhilarating ride with a powerful, direct feel even in automatic mode.

Passenger comfort was pursued in addition to cutting-edge styling. These measurement make the INTEGRA model attractive to even more customers by simultaneously providing the exhilaration and maneuverability of a motorcycle with the convenience of a commuter type, and also letting users discover new ways of enjoyment based on a free concept unbounded by any category to date.

3. Overview of Engine

The engine development goals were set as follows.

- An easy-to-handle, fuel-efficient engine that combines powerful torque characteristics in the normal engine speed range with a wide gear ratio
- A lightweight, compact engine that can be shared by three models in different categories

To achieve these goals, the NC700 series uses a 670 cm³ liquid-cooled OHC in-line 2-cylinder engine, helping to increase the degree of freedom in body layout.

The engine specifications use a long stroke with a $\phi 73 \times 80$ mm bore and stroke. In addition, optimization of the combustion chamber shape and valve timing, friction reduction, and other measures achieved a fuel efficiency of 27.9 km/L (WMTC mode) while pursuing riding enjoyment in the normal engine speed range.

Furthermore, as mentioned previously, both MT and dual-clutch transmission can be set simply by changing some parts (Fig. 4, Fig. 5).

4. Engine Details

4.1. Engine Layout

The demands on engine layout shared by the three models were as follows.

- A layout that can provide luggage space above the engine
- A narrow engine width that provides space for the rider to position their feet like a scooter

To meet these demands that contribute to body layout, an in-line 2-cylinder engine with the cylinders tilted forward by 62° (engine mounting angle) was selected.

4.2. Provision of Riding Enjoyment in the Normal Engine Speed Range

4.2.1. Power characteristics

The power characteristics emphasize performance in the normal engine speed range rather than absolute performance. For this reason, lower engine speed power characteristics are used compared to the conventional sports type engine, which realizes powerful torque characteristics in the normal engine speed range (Fig. 7). In addition, the gear ratio is also higher than that of the conventional engine, which lowered the normal engine speed.

4.2.2. 270° phase crankshaft

To realize the pulsating engine feel that is one of the attractions of motorcycles, an in-line 2-cylinder engine with a 270° phase crankshaft that results in uneven-interval combustion (Fig. 8) and cylinder head branched intake ports (Fig. 9) were used. As a result of this combination, the second cylinder, which has a short firing interval following the first cylinder, receives the effects of the intake negative pressure of the first cylinder during low-load operation, so the pressure inside the intake start port is lower than that of the first cylinder. This means that the second cylinder

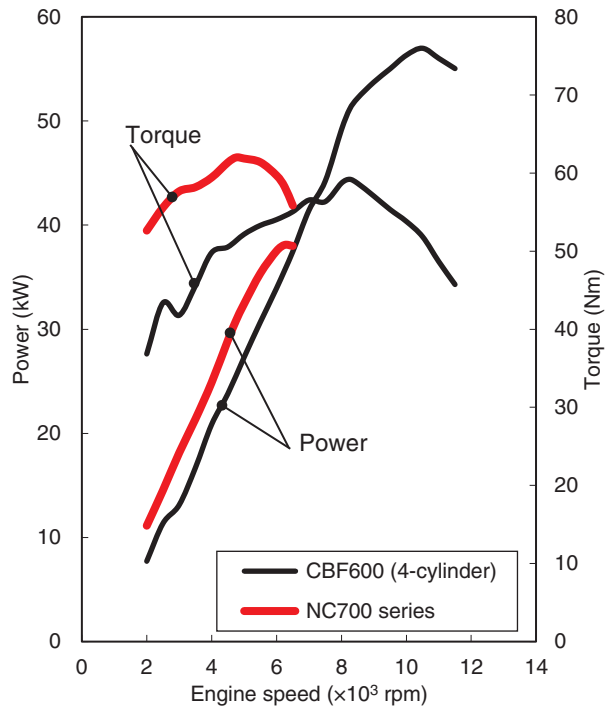


Fig. 7 Engine performance

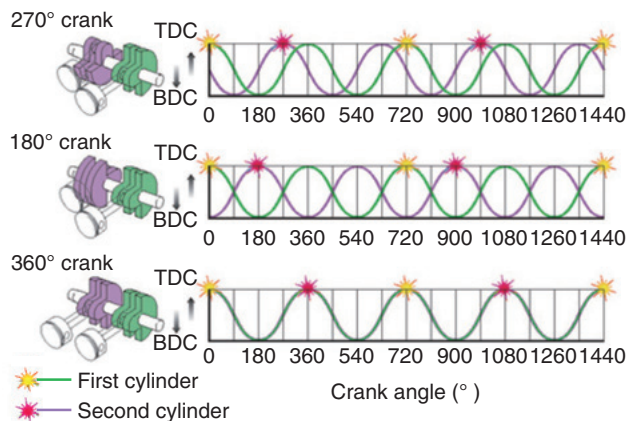


Fig. 8 Comparison of ignition timings



Fig. 9 Branched intake port

has a lower charging efficiency compared to the first cylinder, which produces a difference in the amount of work performed between the cylinders. This action plus the torque fluctuation with a 90° phase difference gives this engine a pulsating feel close to that of a V-shaped 2-cylinder engine.

4.3. Environmental Performance

A fuel efficiency performance of 27.9 km/L (WMTC mode), which is an increase of 40% or more compared to a conventional motorcycle in the same class (XL700V TRANSALP), was achieved by measures such as enhancement of combustion efficiency, friction reduction, and use of a wide gear ratio. Figure 10 shows the position of the fuel efficiency performance.

4.3.1. Enhancement of combustion efficiency

In a conventional middle-class engine, combustion becomes unstable (large combustion coefficient of variance (COV)) during low engine speed, low-load operation such as idling, so combustion was stabilized by richening the air-fuel ratio to around 13. To achieve the target fuel efficiency, this engine adopted the following measures, enabling realization of combustion stability equal to or better than that of the conventional engine, even at the theoretical air-fuel ratio (A/F14.7) (Fig. 11).

- $\phi 73 \times 80$ mm long stroke
- Optimization of the valve timing
- Use of wide-gap spark plugs

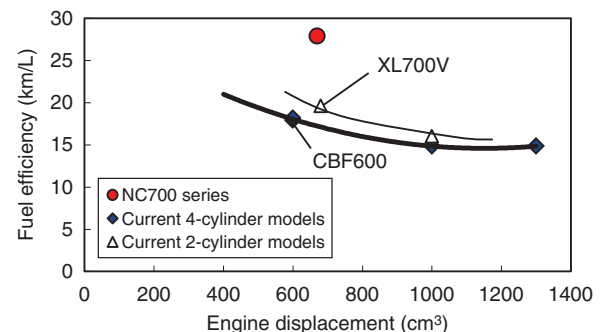


Fig. 10 Comparison of fuel efficiencies

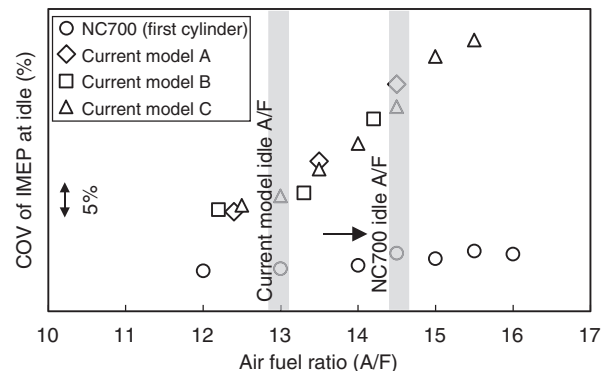


Fig. 11 Comparison of coefficients of variance (COV)

4.3.2. Friction reduction

Friction reduction technology that helped to enhance fuel efficiency included coating the pistons with resin and reducing the piston ring tension to 40% of that of a conventional motorcycle in the same class (XL700V TRANSALP). In addition, the rocker arm is a roller type that uses aluminum materials for the first known time in a motorcycle (as investigated by Honda).

Furthermore, the reduction of the auxiliary driving loss and the reduction of the number of parts were realized by functional concentration such as driving the oil pump using the balancer shaft and the water pump using the camshaft. (Fig. 12, Fig. 13).

As a result of these measures, friction loss was reduced by 20% at an engine speed of 3000 rpm in terms of friction mean effective pressure P_{mf} compared to a conventional motorcycle in the same class (Fig. 14).



Fig. 12 Oil pump driven via balancer shaft



Fig. 13 Water pump driven via camshaft

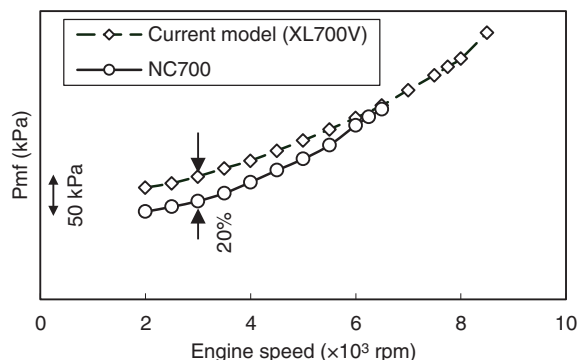


Fig. 14 Comparison of friction loss

4.4. Dual-Clutch Transmission Type Setting

In addition to the normal manual transmission type, a dual-clutch transmission type was also set for the NC700 series engine. Figure 15 shows this configuration.

The weight and size were reduced without a loss of the direct feel, powerfulness and other performances compared to the VFR1200FD (motorcycle equipped with dual-clutch transmission)⁽¹⁾ released in 2010. Furthermore, 85% of the engine parts are shared with the manual transmission type, which also reduced cost.

4.5. Evolution of Dual-Clutch Transmission

4.5.1. Hardware

Hardware evolution focused on the hydraulic circuit that is important for dual-clutch transmission control.

The linear solenoid valve position was changed from outside the engine right side cover to inside the cover. This shortened the hydraulic circuit by approximately 40% compared to the VFR1200FD, enhanced responsiveness, and realized seamless shift characteristics. In addition, changing the solenoid valve position also helped to reduce cost and size.

Furthermore, elimination of the oil feed pump and other measures enabled reducing the number of transmission parts by approximately 20% compared to the VFR1200FD (Fig. 16).

4.5.2. Software

Software evolution focused on modification of shift control, which is directly linked to riding enjoyment.

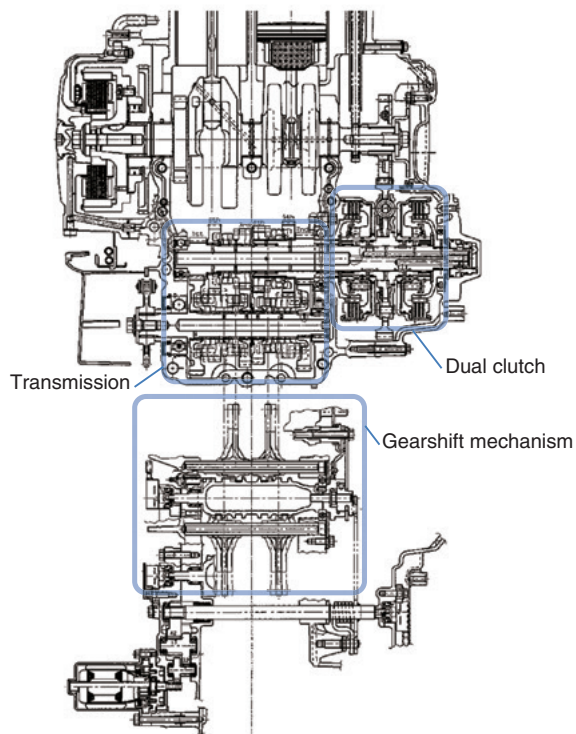


Fig. 15 Cross-sectional drawing of engine

The dual-clutch transmission enables selection of two different AT modes: D mode that also takes into account fuel efficiency when driving in urban areas, and S mode that takes into account sporty riding on winding roads. In addition, there is also an MT mode that enables riders to manually shift to select an arbitrary gear position using the Up/Down switch built into the left grip, for a total of three modes that can be selected.

NC700 series development focused in particular on differences between various driving environments and rider driving styles in D mode, and expanded the D range coverage to support a wider range of driving styles. That is to say, when D mode is selected, the optimal shift control is automatically performed in accordance with the rider's driving style, enabling support of a wide range of driving styles, from relaxed riding in urban and suburban areas to brisk FUN riding (Fig. 17, Fig. 18).

In addition, manual shifting can be performed using the Up/Down switch even when AT mode is selected, and control was incorporated that uses an auto return function to return to AT mode at the optimal timing according to the running status after manual shifting.

The addition of these control functions enabled more comfortable riding (Fig. 19, Fig. 20).

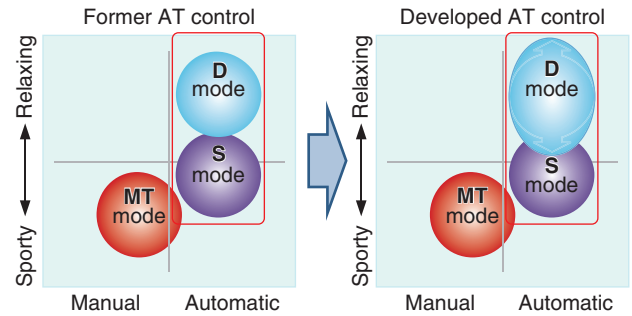


Fig. 17 Expanded D mode coverage

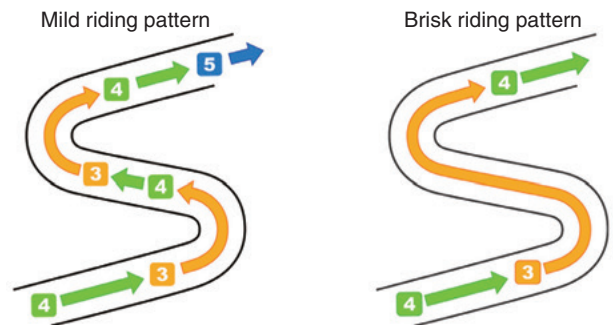


Fig. 18 Gear shifting patterns with driving inclination detection

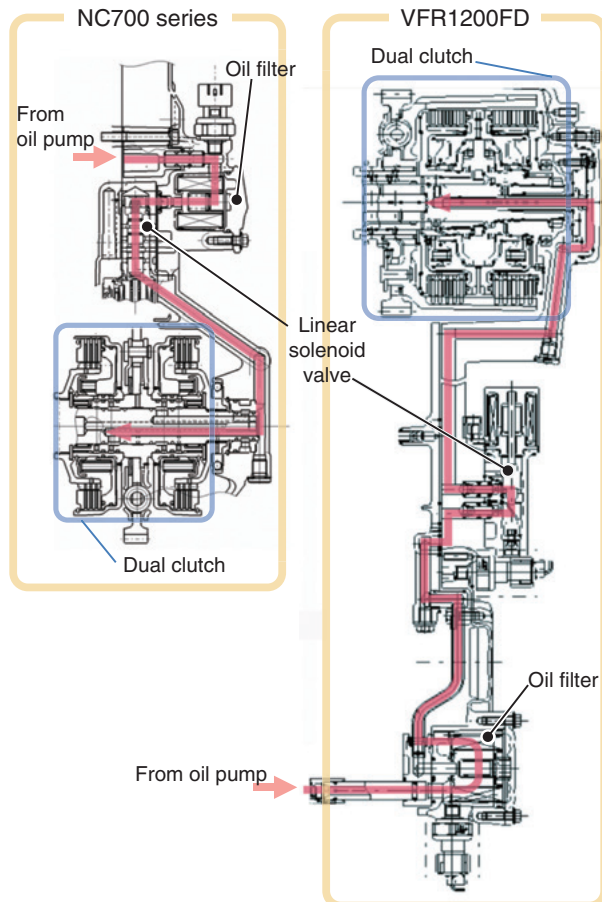


Fig. 16 Comparison of clutch oil lines

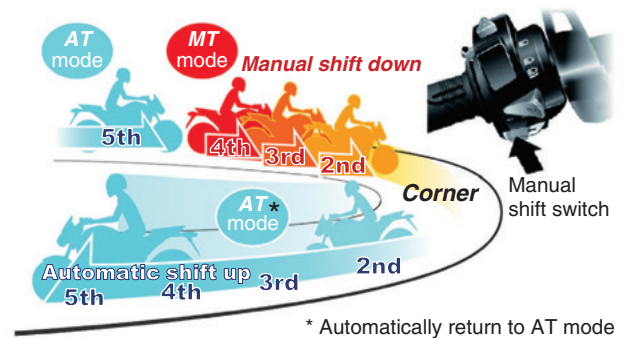


Fig. 19 Automatic return to AT mode function

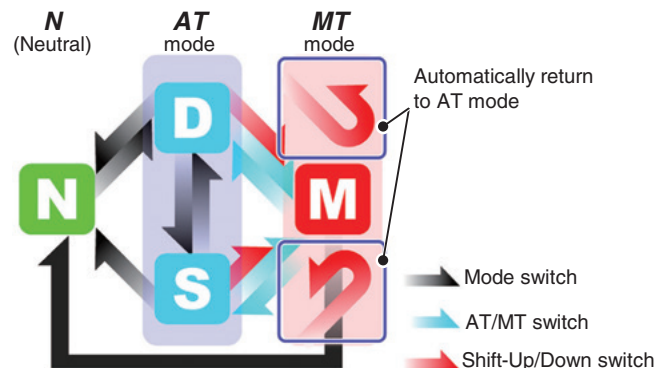


Fig. 20 Shift mode management

5. Establishment of a Frame Platform and Shared Packages

The frame body shapes of straddle riding type motorcycles and scooters differ greatly as shown in Fig. 21 and Fig. 22. In addition, due to the differences in these silhouettes, the shapes and placement of various parts also differ greatly. The greatest issue for body design in this development was to establish a frame body platform and a shared package for various parts that can be used by three different model types.

To address this issue, the engine, air cleaner and fuel tank layout and other elements were fundamentally revised, and an unconventional new frame body structure was investigated.

5.1. Engine Mounting Position

The engine mounting position in a motorcycle is an important factor determining the longitudinal weight balance, which contributes in particular to handling and stability. The engine with 62° forward-tilting cylinders mounted in the NC700 series has a low overall height but a long longitudinal length, so the degree of freedom in mounting position in the longitudinal direction is limited.

Therefore, the cylinder head cover was set to a concave shape that matches the radiator shape. This enabled securing of clearance between the front fender and the radiator when the front suspension is fully bottomed, while at the same time positioning the engine toward the front of the body (Fig. 23).



Fig. 21 Example of frame body for ride on type motorcycle



Fig. 22 Example of frame body for scooter

5.2. Air Cleaner Case

The air cleaner case is located directly above the forward-tilting cylinder head while still securing sufficient handlebar turning space, luggage space (NC700S, NC700X) and seat opening and closing space (INTEGRA). The total air cleaner capacity was set at 5.8 L, which helped to achieve power, driving, noise and other performances. Figures 24 and 25 show the layout around the air cleaner case.

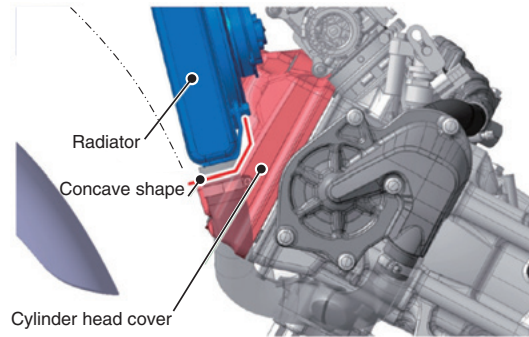


Fig. 23 Cylinder head cover shape that does not interfere with radiator

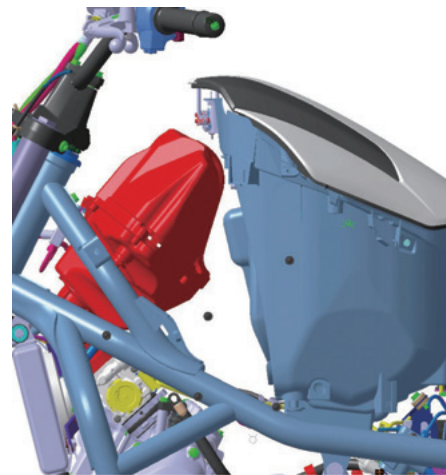


Fig. 24 Layout around air cleaner case (for NC700X)



Fig. 25 Layout around air cleaner case (for INTEGRA)

In addition, to make effective use of space, the air filter is placed so that it protrudes above the packing surface of the air cleaner case. This increases the clean side capacity downstream from the air filter, which realizes a powerful torque feel (Fig. 26).

5.3. Frame Body

The frame body uses normal steel instead of high tensile strength steel in consideration of enabling procurement and manufacture in various countries around the world in the future.

In addition, a shape that satisfies the requirements of each of the three models was investigated, and the main pipe was given a diamond type and positioned lower than that of a conventional model. Figure 27 compares the new frame body piping with that of a conventional model.

CAE analysis was performed on the frame body, and the pipe size, metal thickness, and pipe bending positions were determined to simultaneously achieve both rigidity and flexibility. Figure 28 shows an example of CAE analysis.

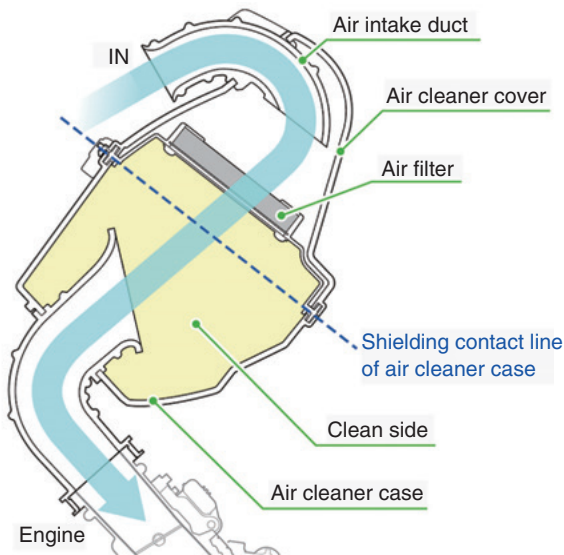


Fig. 26 Layout of air filter

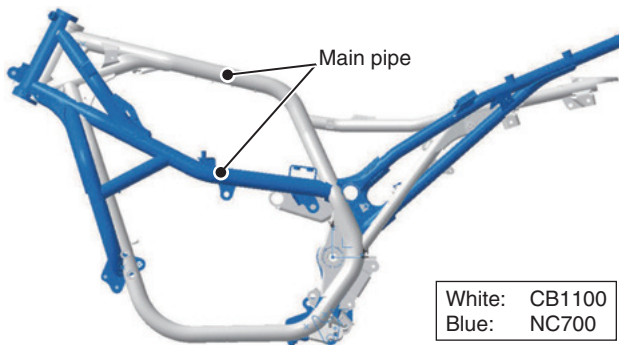


Fig. 27 Comparison of frame body pipings of CB1100 and NC700

5.4. Fuel Tank

The fuel tank is located below the seat, and uses a steel plate two-piece structure that is advantageous for securing sufficient capacity with a thin shape.

The rear frame pipes are located below the fuel tank, and the cross plate, luggage compartment stay and rear grab rail are effectively positioned so that the seat load is not directly applied to the fuel tank (Fig. 29). This structure enables the use of thinner steel plates for the fuel tank, which helps to reduce the body weight.

In addition, the new, fuel-efficient engine enables the use of a smaller fuel tank, so the fuel tank capacity was set at 14 L. This provides a cruising range of approximately 380 km per fill-up, which is the same level or better than that of the conventional model.

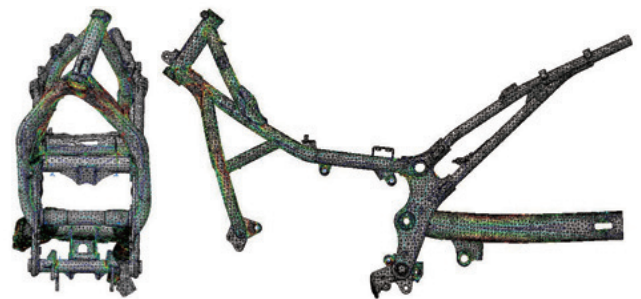


Fig. 28 Example of CAE analysis for frame body

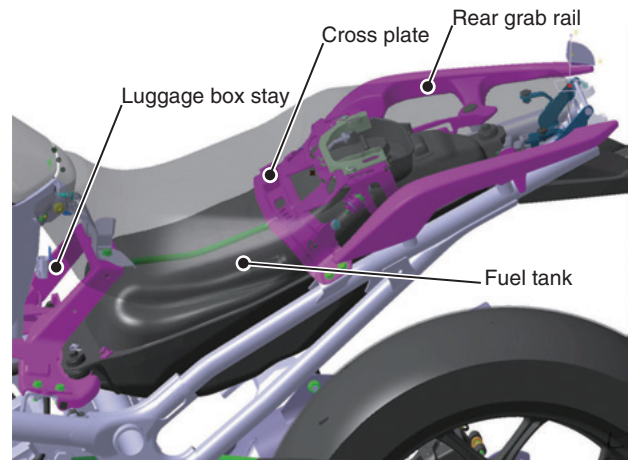


Fig. 29 Layout around fuel tank

6. Conclusion

The NC700 series was developed with the target of “providing affordable, fuel-efficient motorcycles that are easy to handle in everyday use and also nimble and comfortable for deeper enjoyment.” Three new models of motorcycle, each with its own distinctive character, were realized while using shared technology such as a platform common to all three models, emphasis on low- to mid-speed torque, a liquid-cooled in-line 2-cylinder 670 cm³

engine with a low center of gravity that helps increase both convenience and the degree of freedom in design, and a dual-clutch transmission that has the same high transmission efficiency as the conventional model, but is lightweight and compact.

This series is expected to pioneer the creation of a new motorcycle domain.

Reference

- (1) Tanaka, M., Arai, D., Watanabe, J., Fukaya, K., Kittaka, E., Tsuchiya, M.: Development of Dual Clutch Transmission for VFR1200F, Honda R&D Technical Review, Vol. 23, No. 1, p. 9-17

■ Author ■



Koki KOBAYASHI



Masaaki NEGORO



Takanori OSUKA



Toshimasa MITSUBORI



Tadashi OSHIMA