Development of Ninja H2 Series for Excellent Acceleration Performance

To achieve the excellent acceleration performance in response to various requests for motorcycles from customers, we developed the Ninja H2R and Ninja H2 in 2015, which are equipped with a supercharged engine. Moreover, we developed the Ninja H2 SX in 2018, which has enhanced daily usability. To develop these models, we combined Kawasaki Heavy Industries Group's supercharger with aerodynamic, combustion, robot and other technologies, while developing new technologies based on craftsmanship.

Introduction

Some riders of large motorcycles want to make their life more productive through extraordinary experiences. These people enjoy riding motorcycles in their own unique ways and are seeking not only high performance but also excitement from their motorcycles.

1 Background

In response to customer's diverse requests[1)] for the kind of overwhelming acceleration that cannot be experienced in daily life, we decided to develop the Ninja H2 series and equip it with a supercharged engine[2)]. To develop the Ninja H2 series, we applied Kawasaki's supercharger technology, aerodynamic technology for achieving stability, combustion technology for preventing abnormal combustion, and other technologies and at the same time developed new production technologies based on craftmanship with the aim of pursuing uniqueness and innovation and developing motorcycles incorporating first-class technologies.

2 Product concept

We decided to first develop the Ninja H2R in the pursuit of ultimate performance, and then offer the Ninja H2 and Ninja H2 SX, equipped with enhanced equipment for riding on public roads.

(1) Ninja H2R (photo above)

Ultimate motorcycle for experienced riders

- Engine displacement : 998 cm^3
- Engine power : 228 kW {310 PS}
- Riding stability : Stable even at speeds exceeding 300 km/h
- Design : Shape that pursues functional beauty
- Finished appearance : Elaborately finished appearance that makes its owner proud
- Riding environment : Closed course
- Riding capacity : 1 person

(2) Ninja H2 (Fig. 1)

Inheriting the design concept of the Ninja H2R, the Ninja H2 has additional equipment necessary for riding on public roads (e.g., headlight, rearview mirrors, turn signal lights, equipment necessary for compliance with noise and emissions regulations).

- Engine power : 147 kW {200 PS} (2015 year model)
  : 170 kW {231 PS} (2019 year model)

(3) Ninja H2 SX/Ninja H2 SX SE (Fig. 2)

More equipment has been added to the Ninja H2 for riding on public roads.

- Riding capacity : 2 people
- Ease of loading : Can be equipped with pannier cases
- Fuel economy : Improved from the Ninja H2 by 25%
- Riding posture : More upright position

3 Development policy

To achieve high engine power and riding stability, which are the product concepts of the Ninja H2 series, we decided to develop a new supercharger, supercharged

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Fig. 1 Ninja H2

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Fig. 2 Ninja H2 SX SE

engine, trellis frame (frame structure consisting of high-tensile steel pipes arranged in truss form), aerodynamic devices, and other components. In addition, we determined to offer the product expected of us by using total-vehicle computational fluid dynamics (CFD) analysis and manufacturing based on craftmanship.

Because technical elements not used in conventional motorcycle development were needed for this development, we adopted other companies' and the Corporate Technology Division's technologies early on in the development to harness the synergy of Kawasaki's technologies. These technologies include superchargers and supercharged engines, aerodynamic devices for improved stability during high-speed riding, and robot welding for a beautiful appearance.

4 Introduction of technologies

(1) Newly developed technologies

(i) Supercharger and supercharged engine

Motorcycles have an extremely wide engine speed range of 1,200 to 14,000 min^{-1} and extremely high specific power (power/mass), so they can accelerate and decelerate rapidly, which is accompanied by rapid changes in engine speed. In addition, motorcycles are required to respond precisely and instantaneously to the rider's commands. To satisfy these requirements, we designed and developed a centrifugal supercharger exclusively for motorcycles.

Moreover, we developed the engine and supercharger at the same time, thereby achieving high efficiency with advanced matching. This has allowed us to achieve a lightweight, compact motorcycle that has high power but does not require the use of an intercooler as shown in **Fig. 3**.

(ii) Trellis frame

Even with high engine power, the rider cannot ride with a sense of security if the vehicle does not have high stability. To ensure stability, the Ninja H2 series adopts a frame structure consisting of high-tensile steel pipes arranged in truss form (trellis frame) as shown in **Fig. 4**.

In general, the characteristic values for the vehicle frame are increased to ensure stability. The ZX-10R series uses aluminum materials with relatively low specific gravity, and in addition, adopts a frame made from hollow casting to achieve a lightweight, high rigid frame. A feature of this frame is that it can provide high stability in a high-speed range, but it may cause the vehicle to have high-frequency behavior if the vehicle is disturbed due mainly to bumps in the road and rapid road surface changes. For racing vehicles, emphasis is placed on weight reduction, but this high-frequency behavior causes general riders to feel uneasy. Therefore, for the Ninja H2 series, we adopted high-tensile steel pipes that have higher specific gravity than aluminum and high-strength materials to decrease the stiffness and characteristic values by bringing the thickness down to a minimum, thereby contributing greatly to developing a main frame with the concept of “avoiding disturbances with agility.”

In addition, the Ninja H2 series has a bolted swing arm

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Fig. 3 Supercharged engine for Ninja H2 series

Fig. 4 Trellis frame

support at the rear of the engine crankcase as shown in **Fig. 5**. This has made it possible to efficiently absorb the reaction force from the drivetrain, thereby making it possible to reduce the weight of the main frame. This has also made it possible to optimize the stiffness around the swing arm pivot, greatly contributing to our ability to "parry disturbances lithely."

(iii) Aerodynamic devices

The Ninja H2R is required to run stably even at high speeds exceeding 300 km/h. In general, as motorcycles run faster the sense of contact between the front wheel and the ground decreases as lift increases. To prevent this and achieve high stability, we adopted aerodynamic devices that generate a downforce with wings.

Dog teeth, strakes, and other devices used on airplanes as shown in **Fig. 6** are aerodynamic devices that can satisfy the requirement that a downforce be generated with a minimum increase in air resistance. As shown in **Fig. 7**, the Ninja H2R has slotted flaps on its sides and wings that have strakes and dog teeth designed taking the cowl shape of the Ninja H2R at the upper front of the vehicle into consideration. When designing them, we used the automatic optimization technology with multi-objective genetic algorithm developed by the Aerospace Systems Company to increase the downforce through optimization.

(2) Total-vehicle CFD analysis

In the development of the Ninja H2 series, we conducted total-vehicle CFD analysis many times to enhance the engine cooling performance, reduce the running resistances and the lift, and ensure the rider's comfort. This analysis is intended to simulate with a computer how air or heat flows in and around all components during running, including the engine and chassis, and the rider.

In the past, conducting these measurements required making prototypes but today, with this analysis, we can conduct these measurements with 3D models created based on the drawings, enabling specifications to be selected in the conceptual stage.

(i) Study on engine cooling performance

The amount of air that passes through the radiator is an important factor in ensuring engine cooling performance, and it depends greatly on the cowl shape. We conducted total-vehicle CFD analysis as shown in **Fig. 8** to study the cowl shape, thereby successfully ensuring the required cooling performance without increasing the radiator size from the previous models.

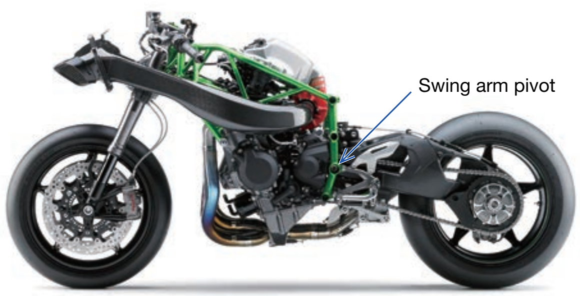
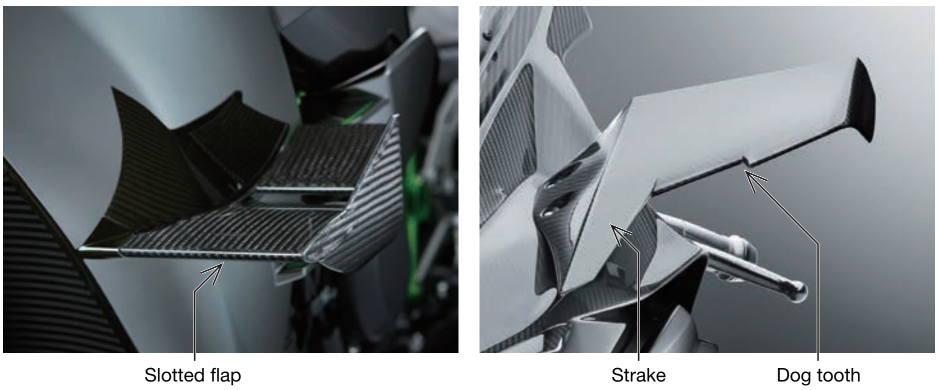


Fig. 5 Frame for Ninja H2R

Fig. 6 Aerodynamic devices used for aircraft



(a) Side

(b) Upper front

Fig. 7 Aerodynamic device shape of Ninja H2R

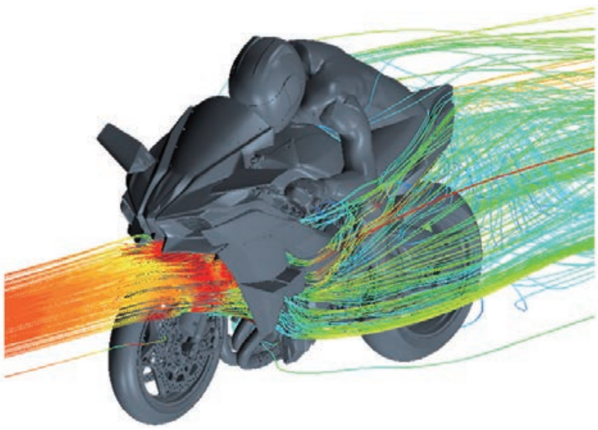


Fig. 8 Analysis results of engine cooling study

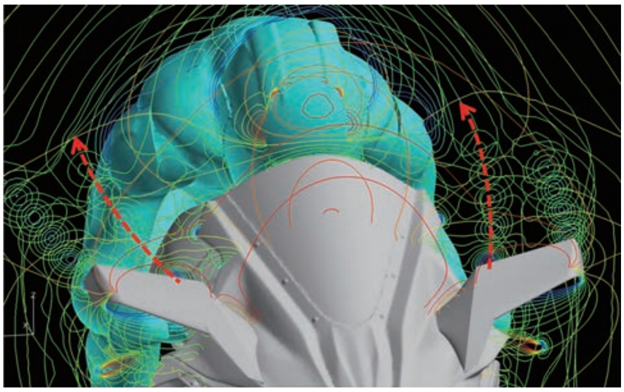


Fig. 9 Visualization of vortex flow using total-vehicle CFD analysis

(ii) Study on aerodynamic devices

In order to maximize the effects of the aerodynamic devices, it is effective to install the aerodynamic devices where the air flow velocity is high. We conducted total-vehicle CFD analysis to determine the most effective positions. In addition, we conducted total-vehicle CFD analysis to study the shape of each aerodynamic device, thereby successfully reducing the lift significantly. Moreover, we designed the strakes shown in **Fig. 7 (b)** so that the vortexes generated by air discharged from the strakes do not collide with the rider as shown in **Fig. 9** because the rider's comfort is adversely affected if these vortexes collide with the rider.

(3) Manufacturing based on craftmanship

The Ninja H2 series was manufactured and finished elaborately based on a design that pursues functional beauty and craftmanship so that not only its ride, but its very presence excites the rider.

(i) Machining for the supercharger

The supercharger was developed, machined, assembled, and inspected at the Akashi Works in an integrated manner, thereby achieving high compression performance and efficiency.

Especially for the machining of the impeller shown in **Fig. 10**, the impeller blades have an extremely small thickness of approximately 1 mm and has a complicated curve shape that changes continuously in a spiral, which is likely to adversely affect the tool life and surface integrity and cause chattering vibration. For surface integrity, even an error of 10 μm greatly affects the supercharger performance, which could be felt by the rider during running. Therefore, we tested cutting tools of various shapes and conducted inspections well correlated with the riding performance, thereby achieving stable performance.

(ii) Assembly of the supercharger

The impellers rotate at an extremely high speed of 120,000 min^{-1} or higher. To prevent damage or noise due to

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Fig. 10 Supercharger impellers

vibration, advanced balance adjustment is required. We fabricated a dedicated dynamic balancer and combined it with operators' advanced skills to adjust the balance to an accuracy of milligrams.

The supercharger performance also depends on the clearance between the impeller and housing. Therefore, the part shape was measured to an accuracy of micrometers to control the clearance between the impeller blade's end and housing inner wall.

All the finished superchargers are inspected with a special performance tester to check if the required performance is satisfied.

(iii) Frame welding

A typical example of craftmanship is frame welding with the emphasis on a beautiful finish. Conventional frame welding focuses on achieving the required joint strength, but for the Ninja H2 series, the focus was placed on the beauty of the weld beads in addition to the weld strength. The frame welding is evaluated on the following three points: the bead surface and width must be flat and constant; there must be no foreign matter such as weld spatter; and the start and end points of a weld must not be visible from the outside.

The Ninja H2's frame consists of thin pipes assembled in a complicated shape that can been seen on the finished vehicle. In metal active gas (MAG) welding, it is important to control the welding torch that is used to supply welding current and shield gas.

In order to achieve a flat, smooth bead surface, we first conducted basic tests to select the welder, welding conditions, welding wire, and shield gas. We then finely controlled the feeding of the welding wire at the start of welding and the welding current to reduce spatter. In addition, we improved the movement of the torch so that the start and end points of a weld overlap with each other where it is not visible from the outside as shown in **Fig. 11**.

To stably achieve such skillful welding, we developed a multi-axis coordinated-control welding robot cell shown in **Fig. 12**, which consists of a robot and workpiece positioner we produced ourselves. The robot cell controls the positions of the workpiece and torch so that they are always in the optimal positions.

(a) Conventional welding (b) Desired welding

Fig. 11 Appearance of weld beads

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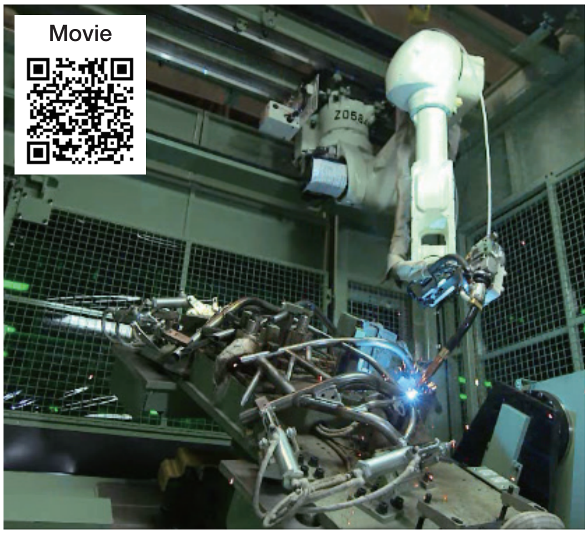

Fig. 12 Multi-axis coordinated-control welding robot cell

(iv) Chassis assembly

To enable mass-production of a motorcycle that gives top priority to achieving ultimate performance and functional beauty, we developed a new dedicated assembly line that is not subject to constraints caused by giving priority to productivity, including ease of assembly and standardization with other models, where assembly is done manually by experienced operators (craftsmen).

For this assembly line, we adopted the semi-automatic system for the first time where, unlike the continuous conveyor system adopted for other assembly lines, a self-propelled carrier having a hoisting function is moved to the next work place by the operator each time he or she has finished a task as shown in **Fig. 13**. With this system, the operator is able to assemble the parts with the vehicle

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Fig. 13 Self-propelled carrier

stationary, so they can consistently work with the same posture, thereby achieving stable assembly quality.

However, the workload per person for this assembly line is higher than that for other assembly lines, and therefore, we introduced Adrec's work assistance system for the first time so that standardized work is performed properly by each operator. This system displays the work content, the tools needed for the work, and other necessary information as text and images corresponding to the progress on the monitor installed at eye level to assist each operator in performing standardized work properly. In addition, this system has a traceability function to record work history, including the tightening torques and installation of critical parts, so that such information can be confirmed even after sales. This system was developed by modifying the system used for assembling the Trent1000 engine in the Aerospace Systems Company for use with motorcycles.

In addition, we paid particular attention to lighting to achieve the same appearance as under sunlight and have experienced inspectors keep a close watch to prevent defective products (flaws, etc.) from being shipped.

(v) Silver mirror painting

In mass production, we adopted silver mirror painting for the first time in our industry. Silver mirror painting uses a silver mirror reaction to form a real silver film, thereby expressing a "true" metallic feeling unlike conventional metal-like painting. Until now, silver mirror painting has not been used for exterior parts mainly because it was difficult to get another paint to bond to the silver film and the silver film would cause the paint film to deteriorate easily when exposed to sunlight. However, we were finally able to solve these problems and have successfully applied silver mirror painting to mass production. In addition, we reduced the thickness of the silver film so that the black undercoat could be seen through the silver film as shown in **Fig. 14**, thereby expressing "next-generation decorative painting with a luxurious look" with unique colors and shades.

(vi) Highly durable paint

To maintain the beauty of silver mirror painting and satisfy customers, we jointly developed a new paint with a paint manufacturer focusing on self-resilience, which means the ability to recover from scratches. This highly durable paint can recover from scratches with its elastic resilience as shown in **Fig. 15**. We developed this paint with an emphasis on the speed of self-recovery so that the customer could experience the recovery from scratches. At first, none of the paint films with quick recovery could satisfy Kawasaki's quality standards, but we successfully developed Kawasaki's unique self-recovering paint by optimizing the paint composition. We verified the effectiveness of the self-resilience by scraping the fuel tank of the Ninja H2 with wire brush as shown in **Fig. 16**. This highly durable paint has enabled the beauty of silver mirror painting to last longer.

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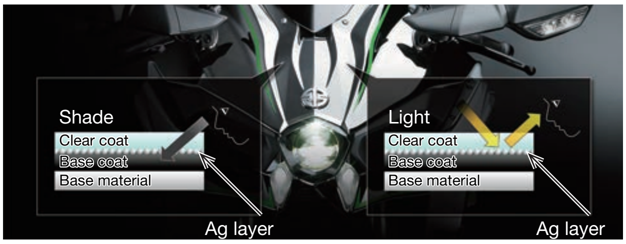

Fig. 14 Silver mirror Paint

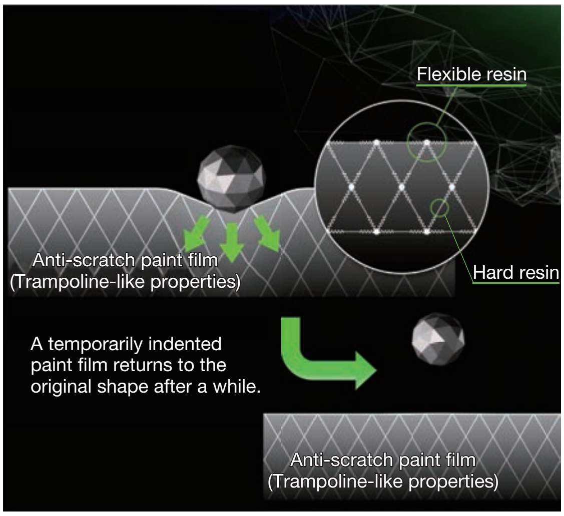

Fig. 15 Recovery mechanism

Fig. 16 Vehicle test results

Conclusion

For the Ninja H2 series, we realized motorcycles incorporating first-class technologies with the synergy of Kawasaki's own technologies, including supercharger technology. At a test-ride event for riders who are motorcycle magazine writers, the Ninja H2 series was highly regarded for its incredibly strong acceleration and ease of riding.

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With further improved fuel economy and daily usability, The Ninja H2 SX has enhanced rider's convenience in a wide range of applications.

We will develop motorcycles that offer riders around the world fulfilled lives and ambitious dreams based on the concepts, "Fun to ride," "Ease of riding," and "Environment."

Reference

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