

Fuel-efficient 670cc Engine

Second-generation Dual Clutch Transmission

Materials for Fuel-efficient 670cc Engine / Second-generation Dual Clutch Transmission

1. Introduction

Honda's 2020 Vision has the following overarching principle: "Creating products that maximize the joy of customers, with speed, affordability and low CO₂."

By "maximizing customer joy," we mean "to continuously come up with ideas for products that are not only useful and practical, but which also make the lives of people all over the world more fun." It is our aim to deliver products that move our customers by fusing this approach with the ideals that have driven Honda from the start, namely, "to serve the people of the world with our products and the technology they contain" and "to bring practicality and fun into people's lives through unique ideas that only Honda can come up with."

A recent survey we conducted into the use of, and expectations for, medium displacement motorcycles in developed countries revealed an increase in the number of users whose overriding interest is not super sports bikes. What they want instead is a motorcycle that is first and foremost for daily use. It therefore needs to be practical, easy to handle, not expensive to run and able to deliver superlative cost performance whether touring leisurely around urban areas or making the most of a winding road.

We cannot overlook the fact that we are in an era where the needs of two previously distinct users, the fun user and the commuter user, are merging. The fun user has always been regarded as a person for whom a bike is far more than a simple means of transportation – it is a valued possession that injects emotional excitement into their daily lives. The commuter user, on the other hand, has always been regarded as a person who wants a practical, comfortable machine that will get them from A to B. Our survey shows how times, and the needs of these motorcycle users, have changed.

Therefore, we at Honda set ourselves the target of delivering a mid-class machine that would satisfy the overlapping needs of our customers across the globe by being both easy to ride, fuel-efficient and exceptionally kind to the environment. The Honda development team evaluated numerous engine types in their quest to deliver a high-quality, easy-to-handle ride with primary emphasis on a low centre of gravity and torque in the low- and mid-speed ranges, and opted for a liquid-cooled, in-line, 2-cylinder engine that would also offer a high degree of freedom in body layout. The team then went on to develop a new 670cc engine.

Developed in parallel with the engine was a second-generation dual clutch transmission that has the same level of performance and transmission efficiency as its predecessor but is lightweight, compact and affordable. Thus work proceeded in one main direction: to develop an engine that looks ahead to the next generation and which will be a benchmark for the future.

2. Development concept

In order to develop this fuel-efficient, medium-displacement engine, the development team measured and analyzed the data from a range of engines used by mid-class customers in all kinds of situations, including riding in urban areas and on the highway as well as commuting and touring. We discovered that

- 90% of total usage was at speeds of 140 km/h or less.
- 80% of total usage was at 6,000 rpm or less.

Therefore, in order to give maximum enjoyment to our customers in the speed and rpm ranges that they use the most, we established the following development concept:

A fuel-efficient engine with easy-to-handle output characteristics that delivers powerful torque in the most-used rpm range

In order to build an overwhelmingly fuel-efficient engine with universal appeal that transcends regional boundaries, that looks ahead to the next generation and which is easy to handle in the rpm range our customers use most frequently on a daily basis, the development team considered and exhaustively debated, without clinging to conventional ideas, the following questions from a customer's viewpoint:

- (1) What is the next-generation, fuel-efficient, mid-class engine?
- (2) What kind of engine will contribute to a higher degree of freedom in body layout and generate useful space?
- (3) What kind of engine is lightweight, compact and easy to handle in the main rpm range while also having a high-quality ride feel?

In other words, the team was looking to create a motorcycle that would retain the economic efficiency and easy control of a medium-displacement engine while meeting the demands of every day use by being nimble, dependable and easy to ride and handle. After exhaustive discussions of numerous engine types, all of which were compact and able to facilitate the layout of other functional parts, the team opted for a liquid-cooled, in-line, 2-cylinder, 670cc engine with a forward-leaning angle of 62°.

We did not focus solely on absolute performance factors that depend on rider skill such as maximum output with this engine because we were aiming for power in the low and middle rpm ranges and a machine that would have a comforting throb and a great exhaust sound, making it a pleasure to be on whether during frequent daily use or emotionally-charged fun riding. The team also intentionally set itself a lofty target - to improve fuel efficiency by more than 50% in comparison with conventional engines in the same displacement class. This would enable the use of a lower volume, more compact fuel tank that would still deliver ample riding range while creating space for large-capacity storage and dramatically improve freedom of design. In short, based on a development concept founded on users' needs, development was aimed at an engine that would be highly practical, tasteful, easy to handle, and of course fuel efficient.

Honda has been conducting research and development into new automatic transmission mechanisms for many years now, based on the conviction that in the future, demand for automatic transmissions in fun models would also have to increase if motorcycles were to continue to exist as a moving form of enjoyable mobility that can cater to customers' highly personal tastes. Against this backdrop, a shift in the age of motorcycle enthusiasts has seen a growing interest in automatic-transmission motorcycles as recreational vehicles for discerning adults of a certain age.

In 2009, in response to calls from our customers for such machines and in order to offer a new way to enjoy motorcycles, Honda announced the development of the world's first Dual Clutch Transmission (with automated clutch and gear-shift operation) for motorcycles, an intimate fusion of the easy operability of automatic with the superlative efficiency of manual transmission. Our Dual Clutch Transmission is a lightweight, compact system that can be integrated with existing engine layouts without the need for significant modification.

It employs electronic control technology to deliver the precise acceleration control required of motorcycles, with a direct feel for naturally smooth starts and gear changes.

When developing our second-generation Dual Clutch Transmission, we made it our aim to deliver a more lightweight and compact system at an even more affordable price, without losing any of the first generation DCT's superlative transmission efficiency. We did, however, make it more intelligently responsive to riding conditions and hope that as many of our customers as possible, both those who ride bikes for fun or who use them for commuting, will try out the new DCT and discover for themselves the hitherto unknown joy and thrill of an automatic ride with direct feel.

3. Technical explanation: Fuel-efficient 670cc Engine

Looking ahead to the next generation, Honda has developed a liquid-cooled, 2-cylinder, 670cc OHC engine that is lightweight and compact and delivers lots of torque in the low and middle rpm ranges with a comforting throb. We were aiming at output characteristics that would result in a nimble yet "cultivated" motorcycle that would have universal appeal while retaining the economic efficiency and easy handling of a medium displacement engine.

Delivering a smooth, high-quality ride with easy handling that will satisfy our customers all over the world, Honda has created a fuel-efficient, environmentally-responsible engine with forward-looking features such as a more compact, lower-volume fuel tank that provides both ample riding range and greater scope for layout, design and storage innovations.

In terms of environmental performance, the introduction of advanced technologies, such as PGM-FI and a catalyzer placed directly beneath the exhaust ports to boost purification efficiency through precise control of the (stoichiometric) air-fuel ratio during idling, has resulted in significantly reduced levels of CO (carbon monoxide), HC (hydrocarbon) and NOx (nitrogen oxides) in exhaust emissions.

The toxicity level of these emissions is in fact half that required by European emission standards (Euro 3), which means that without sacrificing its smooth and powerful output characteristics, the engine delivers a world-class environmental performance.

Key specific technical methods include:

- 1) Liquid-cooled, OHC, in-line, 2-cylinders with forward leaning angle of 62°: Uneven-interval firing produced by a 270° phase crank**
- 2) Uniaxial primary balancer**
- 3) Consolidated intake ports inside the cylinder head**
- 4) Valve timing**
- 5) Combustion efficiency**
- 6) Exhaust emission purification system**
- 7) Reduced friction**
- 8) Downsizing**

- 1) Liquid-cooled, OHC, in-line, 2-cylinders with forward leaning angle of 62°: Uneven-interval firing produced by a 270° phase crank**

The development team wanted to create a medium-displacement motorcycle with "an engine that was not about absolute performance, but about enabling users to fully enjoy the profound sensation of powerful low- and mid-range torque without feeling any stress." To this end, the team decided on the following concept:

In pursuit of a ride to suit cultivated tastes, aim for a lightweight, compact engine layout

The pursuit of this concept was to result in a hitherto unknown ride sensation and “a compact, fuel-efficient engine that delivers a world-class environmental performance.”

To achieve a “ride to suit cultivated tastes,” development began with discussions about the basic layout. In-depth discussions took place to determine what kind of engine would deliver the desired characteristics. Topics discussed at length included displacement, the number of cylinders (one to four cylinders), engine type (single cylinder, in-line, V-shaped, horizontally opposed/OHC, DOHC) and balancers (primary-secondary balancers, coupling balancer). In the end, it was concluded that the optimal engine to achieve the goal would be a liquid-cooled, in-line, 2-cylinder, 670cc, OHC engine with a 62° forward lean.

To concretely arrive at a “ride to suit cultivated tastes,” a choice had to be made between even and uneven firing intervals. Uneven-interval firing with a 270° phase crank was chosen over orderly and smooth even-interval firing in order to achieve a throb close to that of a 2-cylinder V-engine, because this would result in an emotional yet comforting means of daily transportation.

The engine design employs the 270° phase crank technology already patented by Honda in 1985. Because of the crank’s 270° phase, manufacture using conventional top-and-bottom-half forging techniques generates considerable waste in the crank web section. Furthermore, because the crank web section is difficult to fully machine, this method produces a heavy crank, which was not consistent with the development concept and would have resulted in cost increases.

To resolve this issue, the development team undertook the challenge of manufacturing a “twisted crank.” The team’s manufacturing method involved forging the top and bottom halves of a crank at 360° to keep waste to a minimum, and then, before the crank journal portion cooled down, immediately twist it an additional 90°, to make the angle 270°.

This “crank-twisting” method of manufacture had already been successfully used to add a 60° twist to the crank for Honda’s 6-cylinder V-engine used in automobiles. Collaboration between engineers in Honda’s automobile and motorcycle R&D centres meant it was possible to build the technology for a 90° twist and as a result successfully avoid cost increases by producing, without machining, a lightweight crank web with an optimal balance.

2) Uniaxial primary balancer

With a 270° phase crank, eliminating primary vibration through the mutually reciprocating motion of pistons between two cylinders is theoretically impossible; however, secondary vibration can be eliminated in this way. By adding a uniaxial primary balancer, however, it is possible to eliminate both the primary and secondary vibrations with a 270° phase crank.

Incidentally, when a balancer is uniaxial, a primary coupling vibration proportionate to the distance between the crank and the balancer shaft remains, but if a second axis is introduced using a biaxial primary balancer, it is possible to eliminate this vibration. Since the 270° phase crank does not generate any secondary vibration, elimination of the primary vibration allows the engine to have as little vibration as the CBR1000RR’s in-line, 4-cylinder engine with a secondary balancer attached or the GL1800 GOLD WING’s horizontally opposed, 6-cylinder engine.

However, in order to achieve the emotional comfort of a slightly rough throb and satisfy the development concept of a “ride to suit cultivated tastes,” the team made a deliberate decision to keep the vibration and go with the uniaxial primary balancer instead of its vibration-eliminating biaxial cousin.

3) Consolidated intake ports inside the cylinder head

In order to achieve a “ride to suit cultivated tastes,” in addition to the combination of a 270° phase crank and uniaxial primary balancer, the team altered the intake-port layout inside the cylinder head to produce precisely calculated combustion timing variations. In-line, 2-cylinder engines have two air intake channels that are adjacent but designed to act independently so that neither channel interferes with the air intake process of the other. In this engine, however, the air intake processes have been intentionally designed to interfere with each other to generate subtle combustion variations, resulting in the “cultivated taste” called for by the development concept.

This idea of consolidated intake ports inside the cylinder head presented many challenges for the manufacturing process. In particular, how to solve the issue of distortion in the shape of the left and right ports that results from uneven cooling of molten aluminum due to the thickness of the metal around the two “consolidated” ports. Manufacturing precision to eliminate distortion was secured through exhaustive calculation and by adding cooling analysis to cutting-edge CAE mould flow analysis.

4) Valve timing

To facilitate a subtle interference in air intake volumes and enhance a “ride to suit cultivated tastes,” the optimal open and close timing of the inlet valve is set separately for each cylinder. In-line, multi-cylinder engines do not usually have their valve timing set separately, but the manufacture of different camshafts that change the valve timing for each cylinder does not significantly increase the workload in the machining process of 2-cylinder V-engines with a dedicated camshaft for each cylinder.

In this engine, two kinds of inlet valve timing have been set up for the cam in order to change the reciprocal in-line 2-cylinder valve timing on each camshaft. As explained above, setting up two kinds of inlet valve timing for one camshaft does not create a manufacturing problem. But it does lead to a cost increase because it requires a process that is not normally performed.

Therefore, in order to manufacture the camshaft at an optimal price, various issues including those surrounding cost were successfully resolved by referring to a variety of manufacturing methods, such as those employed in automobiles with a multiple-valve-timing cam and one camshaft.

5) Combustion efficiency

We referred to automobile engine combustion technology, with its complementary focus on the low and middle rpm ranges, to improve fuel efficiency but still deliver a powerful ride through surer combustion. In engines where the aim is to boost output, it has been common practice to prioritize intake efficiency in the high rpm range. In our engine, however, where the non-conventional emphasis was on the low and middle rpm ranges, we focused on low- and mid-range rpm combustion efficiency instead of high-rpm intake efficiency. The result was 73X80mm bore and stroke.

Sure and stable combustion in the low and middle rpm ranges was achieved by marrying this ideal bore and stroke combination with an ideal shape for the combustion chamber and optimal valve timing. Furthermore, core research into idle combustion using a similar engine with the same level of displacement accumulated the basic data required to achieve stable stoichiometric (theoretical air-fuel ratio) combustion. Effecting stoichiometric combustion from idle rpm was a significant contributory factor to the engine’s superlative fuel efficiency.

6) Exhaust emission purification system (consolidated exhaust ports with catalyzer placed directly beneath)

To maximize purification efficiency, the catalyzer (three-way catalyst) has been located directly beneath the exhaust ports and is activated early when the engine starts. This design lets the combustion gas pass through the catalyst while it is still hot. Although locating a catalyzer directly beneath the exhaust ports in this way was a first for large motorcycles, research into such catalyzers for small-displacement cub engines had been ongoing for some time. However, because of differences in absolute values such as heat load for large-displacement engines, adapting this technology was far from straightforward.

One of the reasons for this is that whereas in the case of just a 2-cylinder engine, a catalyzer can simply be placed directly beneath the two exhaust ports, it is difficult to locate the catalyzer efficiently within the limited space available on a motorcycle, and also disadvantageous in terms of cost. So in this engine, the two exhaust ports have been brought together inside the cylinder head and consolidated into a single port, directly beneath which it has been possible to efficiently place a single catalyzer of sufficient capacity.

The design of a catalyzer unit capable of withstanding the heat capacity involved, and the optimal port shape and layout, were arrived at using automotive heat analysis technology (CAE) to determine the optimal specifications for a motorcycle. Consolidating not only the air intake ports, as mentioned earlier, but also the exhaust ports, enabled us to arrive at our engine's streamlined and compact intake/exhaust layout.

7) Reduced friction

To reduce friction, not only have we applied a resin coating to the pistons in this engine, but also, for the first time in a motorcycle, we have used a lightweight aluminium material for the roller rocker arm. Friction has been further reduced to the limit by integrating functions such as running the oil pump using the balancer shaft and the water pump using the camshaft, which reduced the overall number of shafts required.

8) Streamlining – Locating the water pump on the cylinder head enables a more compact water channel

The oil pump is normally situated in the lower part of the engine close to the oil sump to facilitate pumping the oil that has accumulated there. The water pump is also normally located in the lower part of an engine because both pumps share the shaft that drives them.

In this engine, so as to obtain rotational driving force from the camshaft, the water pump is located on the left-hand side of the cylinder head in the upper part of the engine. This layout has made it possible to considerably shorten and reduce the water piping, resulting in a water hose which is one-third shorter in overall length than that used in a conventional layout. Accordingly, cooling water volume has been reduced, contributing to both weight reduction and more elegant piping.

Thanks to the emphasis placed by the engine development concept on low and middle, instead of high, rpm, it has been possible to circulate water with a water pump that is optimally driven by the rotating speed of the camshaft, which has in turn resulted in effective streamlining.

With the aim of offering products that play a useful role in the lifestyle of its customers, Honda launched the Super Cub C100 (50cc) in 1958. Equipped with an automatic centrifugal clutch mechanism which allowed gear shifting without the need for clutch operation, the Super Cub C100 was a pioneer in the era of automatic systems. In 1962, the Juno M85, which was equipped with a continuously variable hydraulic transmission, was launched. The Eara (750cc) released in 1977 was the first large motorcycle in Japan to feature a torque converter automatic transmission. In

1980 that was followed by the Tact, a machine equipped with the Honda-original continuously variable transmission, the V-Matic. To this day, Honda has continued to develop and market motorcycles equipped with a variety of automatic transmission mechanisms.

Based on the conviction that the demand for automatic transmissions will increase in the future, even for very sporty models, as people come to regard motorcycles as vehicles that cater to their highly personal tastes, Honda has been conducting research and development into new automatic transmission mechanisms suitable for sports motorcycles for many years now. Against this backdrop, a shift in the age of motorcycle enthusiasts has seen a growing interest in automatic-transmission motorcycles as recreational vehicles for discerning adults of a certain age.

In response to such views voiced by our customers and in order to offer a new way to enjoy motorcycles, Honda launched the DN-01 large sports cruiser motorcycle in 2008. This model was the embodiment of a brand-new concept and came equipped with the Human-Friendly Transmission (HFT), a new automatic transmission which incorporated technology developed independently by Honda. Following that, in 2010, Honda launched a large sports tourer motorcycle, the VFR1200F Dual Clutch Transmission, which came equipped with a Dual Clutch Transmission with automated clutch and shift operation, a world's first for motorcycles. This Dual Clutch Transmission is a lightweight, compact system that can be mounted without requiring major modification to the existing engine layout. It employs electronic control technology to deliver the precise accelerator control required of motorcycles, with a direct feel for naturally smooth starts and gear changes.

We hope that as many customers as possible will try out this system and experience the direct ride feel and power of our Dual Clutch Transmission system and to that end will continue to make it more lightweight, compact and affordable without impairing its performance.

4. Technical explanation: Second-generation Dual Clutch Transmission

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Second-generation Dual Clutch Transmission

The development team exhaustively discussed what would constitute a second-generation Dual Clutch Transmission consistent with the concept of aiming for a “lightweight, compact engine layout in pursuit of a ride to suit cultivated tastes.” The team arrived at the following two directions, which have been strategically explored.

1. Normal Dual Clutch Transmission Evolution

Further evolution of existing Dual Clutch Transmission technology

2. Exploration of the optimal specifications to realize the development concept

Review of the specifications required to achieve “a ride to suit cultivated tastes”

1. Normal Dual Clutch Transmission Evolution

Hardware

In order to simplify the hydraulic circuit and realize greater responsiveness and seamless operation, shorten the hydraulic circuit by 40% by integrating a linear solenoid into the right-hand-side cover. This design drastically reduces cost compared with an external linear solenoid.

Software

Add a learning function for optimal automatic clutch and gear shift control to determine, in the same mode, whether the vehicle is running on a street or through a mountain pass. Furthermore, riding is made more user-friendly with the addition of a return function, which returns to automatic mode under certain conditions after the rider overrides automatic mode and manually shifts gears in order to accelerate or decelerate while running in automatic mode.

2. Exploration of the optimal specifications to realize the development concept

Compared with high rpm large-displacement engines, gear change shock can be softened when low and middle rpm medium-displacement engines are coupled with a lightweight body.

In keeping with the engine development concept, we designed a dedicated clutch to reduce such shock and deliver, on a mid-class machine, a high-quality gear change feel on a par with that of VFR1200F.

Furthermore, by adopting a layout already applied to ATVs in which the primary driven gear is sandwiched between two clutches (sandwich structure), it was possible to make each component, including the main shaft, more compact and lightweight, and reduce the overall cost.

In the pursuit of “a ride to suit cultivated tastes” we have evolved a Dual Clutch Transmission system that is more lightweight and compact. It delivers stable fuel efficiency, regardless of the rider’s skill, through uninterrupted, clutch-less and seamless gear changes with a direct feel on a par with a manual transmission. And we have made it affordable in the hope that as many of our customers as possible across the globe will try it out and experience for themselves its user friendliness.

5. Patents

Cylinder head that contributed to downsizing the vehicle

(1) The vehicle is reduced in size by placing the radiator and the engine in close proximity through the addition of a concave area where the radiator cuts into the cylinder head cover.

(2) The vehicle is reduced in size by reducing the amount of high tension cord sticking out from the cylinder head through the addition of a notch where the high tension cord is housed.

Air intake system delivering a powerful ride in the low/ mid rpm ranges

(1) Long intake channel is secured while downsizing the air cleaner by adopting a layout where the air intake duct and intake pipe that channels the flow of air intake form a reverse “S” shape. A powerful ride in the low/mid rpm ranges is realized by optimizing air intake inertia.

(2) Air cleaner can be downsized by stretching the air intake duct along the air cleaner cover.

Additional patents pending for intake system.

Second-generation Dual Clutch Transmission ensuring a lightweight and compact engine

(1) Engine reduced in size by placing the clutch and the clutch actuator in close proximity by embedding the clutch actuator in the clutch cover.

(2) Compact oil passage structure being prepared for patent application; to be documented as soon as the contents are finalized.

(3) Shift actuator layout that contributes to downsizing.

(4) Shift sensor layout that contributes to downsizing.