

Development of 7-speed Dual Clutch Transmission for 2018 Gold Wing

Taku HIRAYAMA*

Yukio YOKOGAWA**

Yasushi FUJIMOTO**

ABSTRACT

The Gold Wing, Honda's grand tourer motorcycle, has been highly praised for its quality feel and quietness. The 2018 Gold Wing GL1800 is offered with either the manual transmission or a newly added 7-speed dual clutch transmission, which allows for comfortable, yet sporty and enjoyable shifting. The transmission ratios are optimized for enhanced quality feel and quietness, and shifting become even quieter thanks to shift controls coordinating the clutch and throttle-by-wire and added dampers to absorb shifting noise. In addition, the reverse mechanism, a Gold Wing exclusive feature, was changed from the existing motor-driven system to an engine-driven system utilizing the architecture of the dual clutch transmission, producing a lightweight and compact engine package. Further, a new forward/reverse walking speed mode was added, capable of both forward and backward creep at very low speed with just the push of a handlebar switch. These changes have made the Gold Wing more convenient by making it easier to turn around and park.

1. Introduction

The sixth generation Gold Wing GL1800 has been newly redesigned to achieve its concept: The Honda Premium Tourer-Impress couples with more brilliance and fullness. The Gold Wing inherits the same water-cooled four-stroke horizontally-opposed six-cylinder, longitudinally-mounted engine (hereinafter the "F6") architecture from the previous model.

Transmission offerings include a manual transmission (MT) and a newly-developed dual clutch transmission (DCT). As with the existing motorcycle specifications, the transmission is set in the same case as the power unit.

The motorcycle DCT relieves riders from clutch and shifting operations to concentrate on the acceleration, cornering, braking, and other actions that make for a fun ride. It also gives the motorcycle a sporty feel with its direct and linear power transfer in response to throttle operation.

The VFR1200F⁽¹⁾ was the first mass production model equipped with a DCT, followed by subsequent updates in the NC700/750 series⁽²⁾ and CRF1000L Africa Twin⁽³⁾.

The DCT in the sixth generation Gold Wing stays true to its concept while adding new features and enhancing quality feel.

Now, for the first time in a motorcycle DCT, we applied a 7-speed gear mission for the Gold Wing DCT specifications to fit a wider variety of applications and enhance quietness. The Gold Wing's unique reverse feature now utilizes the DCT's original structure for an engine-driven reverse gear, replacing the previous model's motor-driven system for a weight reduction. (The MT model retains the motor-driven reverse system from the previous model.) Also, the Gold Wing offers a completely new forward/reverse walking speed mode, which allows riders the added convenience of creeping forward and backward at a very low speed with just the push of a handlebar switch.

The Gold Wing that requires high quality feel needs to be further reduced in transmission shifting noise and operating noises than the existing DCT. Therefore, dampers was installed on those sections responsible for tapping noises when shifting, enhancing both quality feel and quietness.

Additionally, in aims for a sportier ride in this Gold Wing, clutch control and throttle-by-wire (TBW) control was cooperated for quicker shifting.

This paper will contain detailed explanations of the unique structure and unique technology introduced for the DCT equipped on this model.

* Honda Motor Co., Ltd.

* Motorcycle R&D Center

2. Unique Technology for Gold Wing DCT

The following unique technologies were developed for applying the DCT for the Gold Wing:

- (1) Engine-driven reverse mechanism by cooperated clutch and TBW control. Also, a reverse chain was used to achieve lightweight and compact both reverse mechanism and transmission configuration.
- (2) Walking speed mode for enhancing maneuverability at walking speed in situation like parking or K-turn
- (3) Enable sporty shifting that is smooth, yet occasionally shows an aggressive side by cooperated clutch and TBW control.
- (4) First time 7-speed motorcycle DCT and reducing shifting noise for enhancing quality feel with quiet and smooth shifting while riding.

3. DCT System Configuration

An explanation of the unique basic configuration of the DCT equipped on the Gold Wing in this paper follows below.

3.1. DCT Placement

As shown in Fig. 1, the crankshaft and drive shaft are mounted longitudinally to the body as in the previous model. To make it more compact, DCT system parts were placed inside the engine.

In the interest of reducing weight, the reverse mechanism uses an engine-driven system fully mounted within the engine. By eliminating need for an electric motor or control driver, this reduces weight by approximately 1.3 kg from the motor-driven system.

3.2. Reverse Mechanism and Transmission Configuration

Just as in conventional motorcycle DCTs, a twin-shaft architecture comprising a two-element main shaft and a countershaft has been adopted for the Gold Wing transmission. The transmission has eight gears in total: seven forward gears and reverse. As seen in Fig. 1, no gears are used for the reverse mechanism, instead opting for a wear-resistant silent chain for reduced weight.

A chain-driven architecture was adopted here, eliminating the need for an idler shaft and idler gear for a more compact, lightweight reverse mechanism. When driven by a gear, the countershaft rotates counter to the main shaft during forward motion (Fig. 2-a). Driving in reverse requires an added idler shaft and idler gear between the main shaft and countershaft to rotate the countershaft clockwise (Fig. 2-b). Meanwhile, if chain-driven, both the main shaft and countershaft will rotate clockwise (Fig. 2-c).

The speed reduction of the chain alone will not provide the required reduction gear ratio, however. Thus, speed is reduced a total of three times between the main shaft and countershaft to reach the required reduction

gear ratio when in reverse. A special drive path is used for this purpose.

The power transmission paths in forward and reverse are shown in Fig. 3. The reverse path starts with the odd-number #1 clutch, proceeding through the odd-number main shaft to the first speed reduction (first gear), then

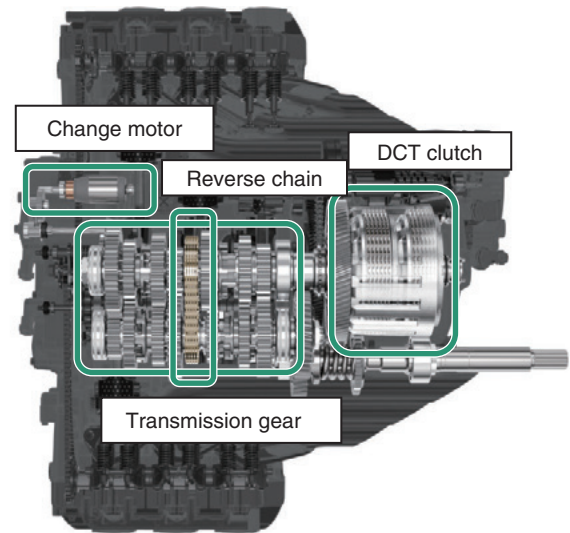


Fig. 1 Cutaway drawing of developed transmission

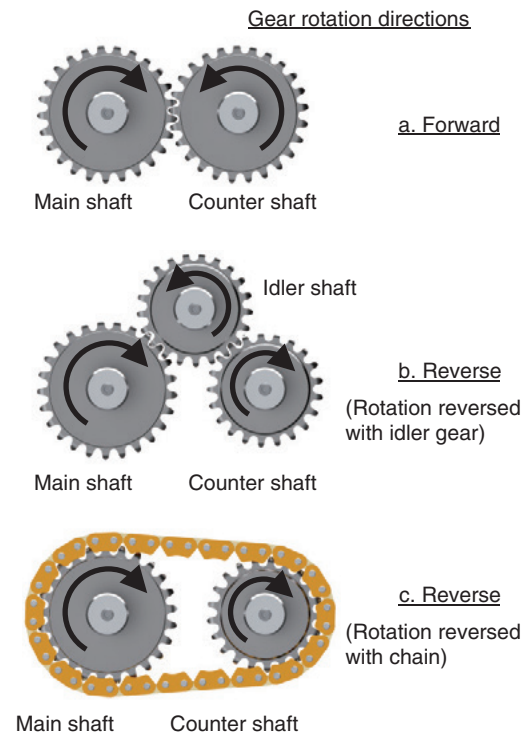


Fig. 2 Direction of shaft rotation (image)

the second speed reduction (reversing rotation with the reverse chain), then onto the even-number main shaft, and finally to the third speed reduction (second gear). For forward gears, the path goes from the even-number #2 clutch to even-number main shaft and then the first speed reduction (second gear).

Thus, the power transmission path for the two clutches proceeds through the odd-numbered gears for reverse and the even-number gears for forward motion. This structure allows for switching between reverse and forward motion simply by engaging the clutch without any need to change gears.

The transmission architecture is unprecedented, using a chain to link the two-element main shaft and the countershaft with a special layout between the gears and reverse chain of 7-3-5-1-R-6-4-2.

Additionally, as adopting a reverse chain makes assembly impossible with the main shaft and countershaft separated, the main shaft and countershaft need to be pre-mated before mounting to the engine during assembly. Therefore, the cassette transmission architecture shown in Fig. 4 was adopted to facilitate assembly.

3.3. Shift Mechanism

With the addition of seventh gear and reverse positions, the number of shift drum positions has changed from 12 in the existing 6-speed DCT to 15, as seen in Table 1. This change has shifted the shift drum angle per position from 30° in the existing DCT to 24° , not leaving enough room on the periphery of the shift drum for the full length of the shift fork lead groove. As a workaround, the shift drum outer diameter was enlarged from 42 mm to 58 mm.

Bringing the lead groove length of the outer periphery

of the shift drum per 1 position was made equivalent to the existing 6-speed DCT specification.

To keep the engine compact, the gear shift actuation motor was arranged to face the engine interior (Fig. 1).



Fig. 4 Cassette transmission architecture

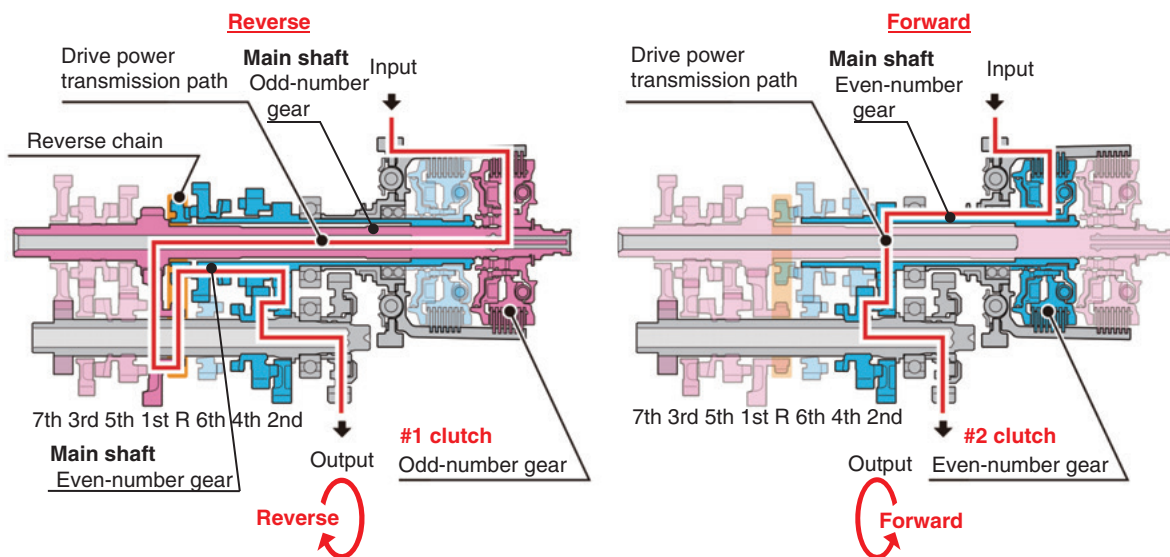


Fig. 3 Power transmission path

Table 1 Shift drum positions

Shift drum positions of developed model				Shift drum positions of other DCT models			
Shift drum position #	Gear shift conditions	Engaged gear		Shift drum position #	Gear shift conditions	Engaged gear	
		Odd-numbered gears	Even-numbered gears			Odd-numbered gears	Even-numbered gears
1	Rvs	N	R, 2	1	Neutral	N	N
2	Neutral	N	R	2	Start, 1st	1	N
3	Start, 1 st	1	N	3	1st ⇄ 2nd shift	1	2
4	1st ⇄ 2nd shift	1	2	4	2nd	N	2
5	2 nd	N	2	5	2nd ⇄ 3rd shift	3	2
6	2nd ⇄ 3rd shift	3	2	6	3rd	3	N
7	3 rd	3	N	7	3rd ⇄ 4th shift	3	4
8	3rd ⇄ 4th shift	3	4	8	4th	N	4
9	4 th	N	4	9	4th ⇄ 5th shift	5	4
10	4th ⇄ 5th shift	5	4	10	5th	5	N
11	5 th	5	N	11	5th ⇄ 6th shift	5	6
12	5th ⇄ 6th shift	5	6	12	6th	N	6
13	6 th	N	6				
14	6th ⇄ 7th shift	7	6				
15	7 th	7	N				

4. Unique technologies for Gold Wing DCT

This section will explain the developed unique technologies.

4.1. Walking Speed Mode

In DCT-equipped models, a walking speed mode has been added along with the switch in the reverse feature from the electric motor-driven system in the previous model to an engine-driven system.

Reversing on a motorcycle requires the rider to creep at very low speed while on the motorcycle. In manual motorcycles, installing an engine-driven reverse mechanism would require fine speed adjustments on the part of the rider to manipulate the throttle and clutch similar to driving forward at low speed. This made it challenging to use the engine as the power source for reverse mechanisms⁽⁴⁾.

The Gold Wing DCT specifications enabled an engine-driven reverse mechanism with TBW-linked control, where the clutch and throttle are operated simultaneously to allow for finer speed adjustment.

Also, as previously mentioned, riders can switch between reverse and forward motion simply by engaging the clutch without any need to change gears. Utilizing this feature, a switch-activated walking speed mode was developed, capable of forward and rearward creep at very low speed. Next, the below is an explanation of walking speed mode. With the transmission in neutral, once activating walking speed mode with the walking speed mode switch, riders can move forward by pressing the shift up switch or backward by pressing the shift down switch. A view of the switch cluster on the left handle grip is shown in Fig. 5. The motorcycle moves at a creep when either switch is pressed.

Walking speed mode enhances maneuverability at very low speed, for situations like parking and K-turns to change direction. For more stability when creeping with the switch activated, clutch torque transfer is finely adjusted by vehicle speed feedback control. However, if the motorcycle builds up speed going downhill, the clutch will eventually be released as vehicle speed feedback control gradually continues to reduce the clutch torque transfer. The motorcycle will ride free, unable to maintain the target speed. Thus, driving power can be used in both the advancing and opposite directions to reduce motorcycle speed by engaging either the forward clutch if moving in reverse or the reverse clutch if



Fig. 5 View of left handle grip switches

moving forward. With this in mind, controls were also implemented to engage the opposite direction clutch instead of the advancing direction clutch when vehicle speed exceeds the target speed to restrict vehicle speed from exceeding a certain level (Fig. 6).

Also, in walking speed mode, feedback control with TBW puts engine speed slightly higher than idle at approximately 1000 rpm even if engine load increases when the clutch is engaged.

Thus, walking speed mode reduces the need for the rider to make fine input with the throttle grip so that they can focus on maneuvering the motorcycle.

4.2. Sporty Shifting Control

In a DCT, the clutch connected to the previous gear is released at the same time as the clutch connected to the next gear is engaged for smooth shifting with no interruption in drive force. This Gold Wing model has four ride modes for various conditions. One of the four modes offered is SPORT. In this mode, new controls have been implemented, cooperating with TBW control to shorten shift times for a sportier ride while leaving shift shock during an up shift equivalent to that in other modes.

Clutch engagement times could also be shortened in conventional DCT controls by increasing the torque transfer from the clutch when engaged. However, shortened engagement times resulted in an increased engine speed reduction rate (crankshaft angular acceleration), increasing inertial torque in the crankshaft system. When transferred to the rear wheel, this inertial torque changes chassis longitudinal g-force and the rider feels shift shock. This made it challenging to shorten clutch engagement

times with conventional shift control as it would require restricting shock from clutch engagement to within rider tolerances (Fig. 7-a, b).

Thus, as shown in Fig. 7-c, TBW control was linked and the throttle closed when the clutch is engaged, resulting in less increase in engine torque from inertial torque generated by quicker shifting. Shift time has thus been reduced 200 ms from 300 ms, approximately 35% (at throttle opening 25 degree and engine speed 3000 rpm) with no increase in shift shock.

4.3. Enhanced Transmission Quietness Due to Additional Speed and Ratio Distribution Optimization

To reduce shift shock and enhance quietness, a seventh gear was added to the transmission with newly optimized ratios for each gear.

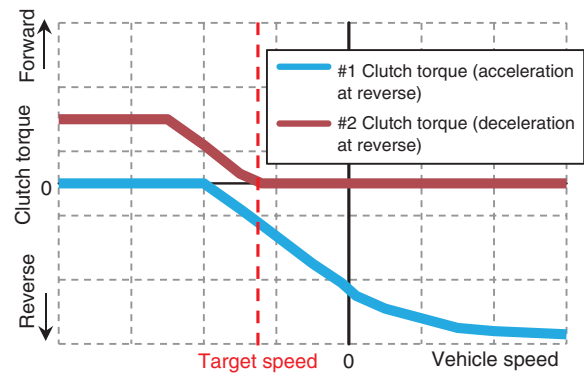


Fig. 6 Clutch torque at reverse

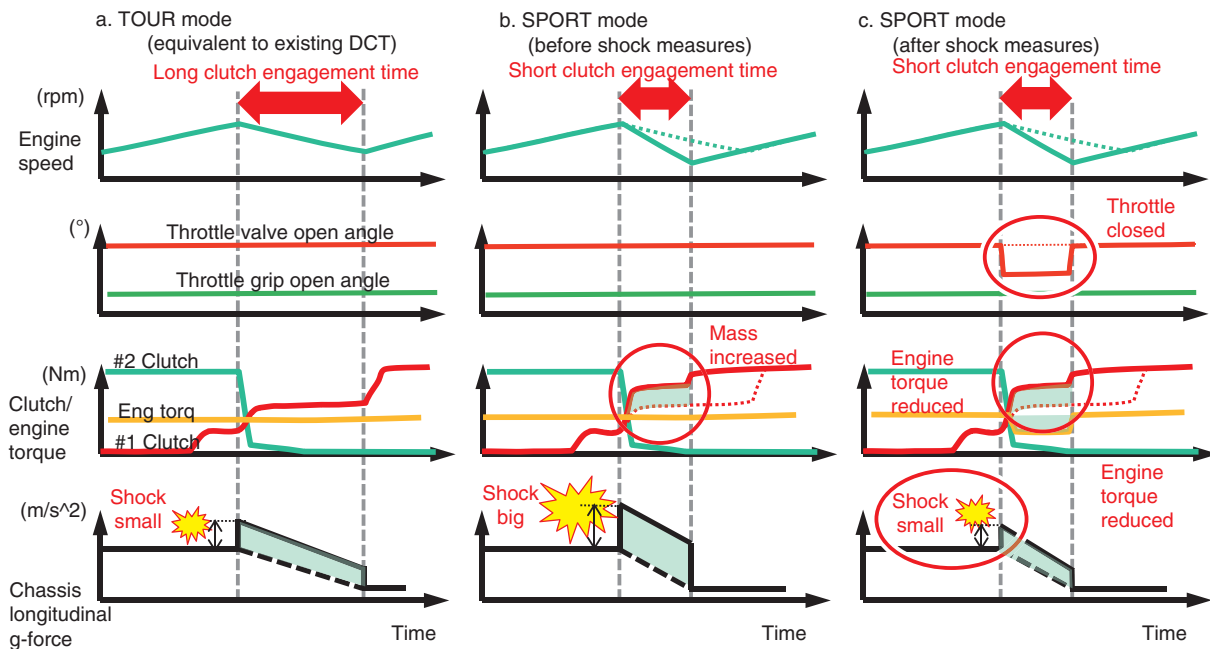


Fig. 7 Shift times and control

In the low speed range, where less driving noise makes operation noise during shifts readily audible, a gear was added for a closer ratio than the previous model. This is depicted in Fig. 8. These changes reduced shifting noise by reducing the engine speed differences between gears before and after shifting. In addition, the closer ratio reduced the change in driving force between gears before and after shifting, which mitigates shift shock and enhances quality feel.

Meanwhile, at the high speed ranges most frequently used in touring, an additional speed was added to keep engine speed low and enhance quietness when cruising.

As seen in Fig. 8, the previous model ran at approximately 2600 rpm in fifth gear when driving at 100 km/h; this has been reduced to approximately 2000 rpm in seventh gear for a reduction of 600 rpm. When cruising at 100 km/h, this gearing has thus reduced noise levels at the rider's ear by approximately 5 dB from the previous model.

4.4. Reducing Tapping Noise during Shifts

Clutch center dampers were equipped for enhanced quality feel. These dampers work to reduce the exciting force and vibration frequency when the dog clutches of each gear strike during shifts to reduce tapping noise. A structural drawing of Gold Wing clutch is given in Fig. 9.

In the process of making different sections of the Gold Wing quieter, tapping sounds during shifts which were unintrusive on the existing model became relatively more noticeable. Therefore, rubber dampers were installed for those sections causing the tapping during shifts.

During shifts, the end face of the shift fork shaft was dragging against the shift fork, resulting in a tapping noise when it hit the engine case. Dampers were attached to both ends of the shaft to muffle the tapping noise (Fig. 10).

Also, the master arm, which rotates the shift drum

during shifts, was making noise when it hit the stopper pin restricting master arm rotation. To reduce this noise, more dampers were attached to the master arm (Fig. 11).

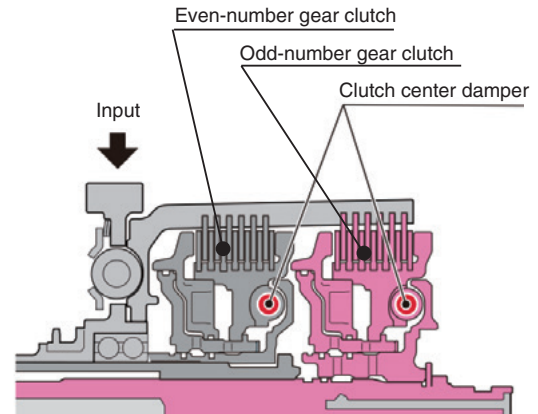


Fig. 9 Structure of dual clutch

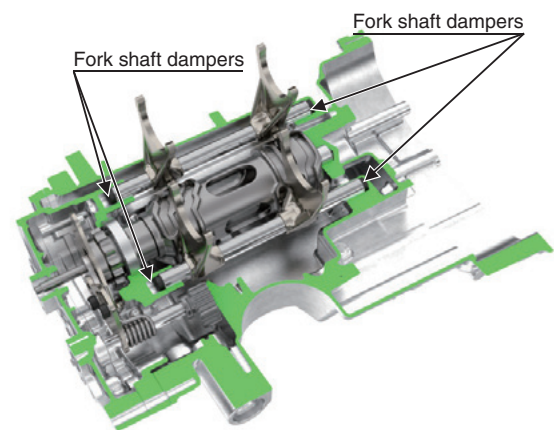


Fig. 10 Fork shaft dampers



Fig. 8 Speed diagram

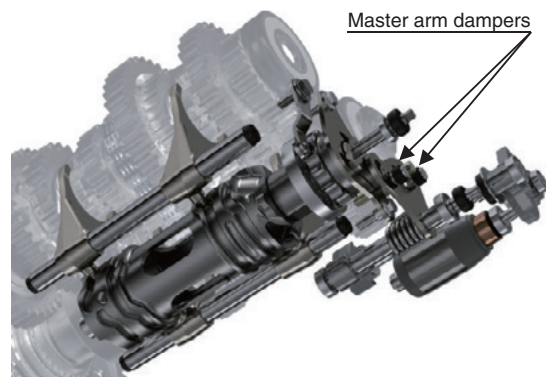


Fig. 11 Master arm dampers

5. Conclusion

This paper introduced the following developed unique technologies of DCT for the sixth generation Gold Wing.

- (1) Cooperated clutch and TBW control enabled use of an engine-driven reverse mechanism.

Also, a reverse chain was used to achieve a lightweight, compact F6 engine.

This reduces weight by approximately 1.3 kg from the motor-driven system.

- (2) Walking speed mode enabled riders to creep forward and backward at a very low speed with just the push of a handlebar switch.

This has enhanced vehicle operability at walking speed for situations like maneuvering the motorcycle in tight spaces or when parking.

- (3) Cooperated clutch and TBW control permits shift shock to be restricted with 35% quicker shift times for smooth, yet sporty shifting in SPORT mode.

- (4) A seventh gear was added, and the gear ratio was adjusted for enhanced quietness.

This gearing has thus reduced noise levels at the rider's ear by approximately 5 dB from the previous model.

Dampers were installed for sections causing the tapping during shifts, enhancing quality feel with quiet and smooth shifting while driving.

Adopting those technologies have helped to make this the motorcycle with the most enjoyable maneuverability throughout all the models appeared in the chronicle of the Gold Wing to drive, balancing sporty handling, quality feel, and quietness.

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■ Author ■



Taku HIRAYAMA



Yukio YOKOGAWA



Yasushi FUJIMOTO