

Development of Ride Modes for Various Conditions for 2018 Gold Wing

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ABSTRACT

With its well-balanced riding comfort and sportiness, Honda's grand tourer model Gold Wing has gained good reputation for decades. In the 2018 Gold Wing GL1800, in addition to bringing the comfort and sportiness to a new height, a target was set to provide the rider with more performance benefits by offering selectable ride modes to adjust to various riding conditions such as the sport ride, the riding on suburban road, in rain, etc. To achieve the target, various factors such as the engine power response have to be altered. When the number of factors to alter increases, it is not easy for the rider to combine such factors and adjust to the riding conditions and rider needs. Accordingly developed in this model is world's industry first (according to Honda's research) new system for the motorcycle to allow the rider to select a ride mode for each condition by the integrated control of five factors (engine power response, characteristic of driving force, gear shift timing, suspension damping, front/rear brake force distribution). The newly-developed system provides the riding performance that allows the rider to control the motorcycle as the rider wants in various conditions.

1. Introduction

The Gold Wing is a grand tourer model of Honda motorcycles. The previous fifth generation Gold Wing has a good reputation by its well-balanced riding comfort and sportiness. In the sixth generation 2018 Gold Wing GL1800, a target was set at "the motorcycle most enjoyable to ride in the history of Gold Wing." Our interpretation of "the most enjoyable to ride" is to offer such characteristics that allow the rider to control the motorcycle as he wants in various types of riding such as the sport ride, the riding on suburban road, in rain, etc. As shown in Fig. 1, we aimed to expand the range of performance that riders can enjoy. To achieve the goal, it is necessary to alter variables such as the suspension setting, engine power response, etc. to adjust the characteristics of the motorcycle to the conditions and rider needs. In the case of Gold Wing, we considered it was necessary to alter a large number of variables to adjust to the wide variety of riding conditions and rider demands. When the variables to alter are increased, it is not easy to achieve a good combination of various levels of setting that best suits the riding conditions and rider needs. Accordingly developed in this model is the system that allows the rider to select a ride mode that best suits the conditions by the integrated control of five factors (engine power response,

characteristic of driving force, gear shift timing, suspension damping, front/rear brake force distribution) that are world industry first, according to Honda's research (hereafter referred to as "ride modes for various conditions"). The details of the system are discussed in this paper.

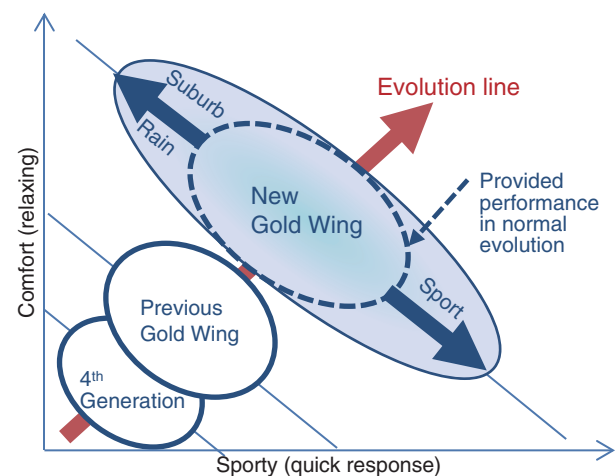


Fig. 1 Target zone

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2. Target Setting

In the sixth-generation Gold Wing, the setup in which the comfort and sportiness under various conditions are well-balanced is referred to as the TOUR mode. Using the TOUR mode as a basis, three other ride modes, SPORT, ECON, and RAIN are set to allow adjustment to specific riding conditions. With an aim at extension of performance zone that the rider can enjoy, one of these modes is selectable by the rider using the select switch when riding. The presumed conditions and the riding characteristics in each mode are shown in Table 1, the performance positioning image in Fig. 2. Using the TOUR mode as a basis, the specific aims of three modes are as per the following.

- (1) SPORT: Enhancing dynamic performance such as acceleration
- (2) ECON: Enhancing rider's comfort such as quietness, better fuel economy
- (3) RAIN: Enhancing secure feel by retention of rear tire grip on slippery surface

Table 1 Presumed conditions and riding characteristics

Mode	Condition	Characteristic
TOUR	Versatile	The most balanced in various situations (The Gold Wing)
SPORT	Winding / Solo riding	Exciting with quick response
ECON	Suburb / Congested (urban)	Comfort and relax with mild response
RAIN	Wet / Dirt	More secure in low μ road condition

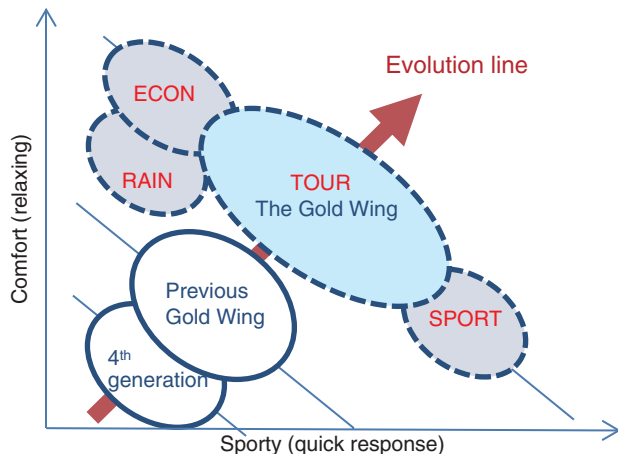


Fig. 2 Performance positioning image

3. Methods

Explained here are the methods to achieve the targets of various ride modes. While this system is applied both in the manual transmission model and the Dual Clutch Transmission (DCT) model, this paper discusses about the system incorporated in the DCT model.

3.1. Technical Measures

Choosing the variables from the typical riding style in each mode to attain the performance the rider wants, the technical measures was selected. The technical measures to adjust the five factors to the demands of each mode are shown in Fig. 3.

3.1.1. SPORT mode

When performing a sportier riding on a winding road, it is necessary to prepare for a corner entry by a quick, sure shifting of gear and/or stabilize the motorcycle by applying the brake in the deceleration zone before entering the corner. In such a condition, the gear shift timing, the front/rear brake force distribution, and the suspension damping are the variables affecting motorcycle stability.

When accelerating from the corner exit, appropriate throttle control and gear shift timing are required to help prevent tire slip for quick acceleration. In such a case, the engine power response to the throttle grip operation, the characteristic of driving force, and the gear shift timing are the factors that affect acceleration.

3.1.2. ECON mode

The ECON mode presumes riding suitable in congested roads and/or suburban roads. As starting and stopping are repeated on a congested road, a gentle response of motorcycle movement to opening/closing of throttle is required. In such a case, the engine power response when the throttle is opened or closed is the factor that affects motorcycle movement. When cruising on a suburban road at a relaxing pace under 100 km/h, quietness is important in addition to the gentle motorcycle movement. A reduction of noises when riding is therefore required. In such a case, the gear shift timing is the factor that helps reduction of engine noises.

3.1.3. RAIN mode

To obtain a higher secure feel on slippery surfaces, a gentle response of motorcycle movement when the throttle is opened or closed is required just like in the ECON mode. The stability of motorcycle is also required when the rear tire slips by an abrupt throttle operation. In such a case, the engine power response to the throttle grip operation, the suspension damping, and the characteristic of driving force at the time of slippage are the factor that affect changes of motorcycle movement and reduction of tire slippage.

In view of the above, five factors; the engine power response, the characteristic of driving force, the gear shift

timing, the suspension damping, and the front/rear brake force distribution, which are contributing variables to satisfy rider demands in each mode, have been chosen.

3.2. Control System

The overview of the system to simultaneously control the five technical measures is shown in Fig. 4. The system is configured to allow integrated control by the use of CAN for the communication among the control units that control various devices. The rider selects a mode from the right handlebar switch. The mode selection is allowed even when riding. The switching of mode is completed when the throttle grip is fully closed after operating the mode switch.

4. Setting of Control Items in Each Mode

Explained hereafter are the details of the technical measures to achieve the goals of each of SPORT, ECON, or RAIN mode.

4.1. Throttle by Wire (TBW)

As shown in Fig. 5, TBW is such a system that determines throttle opening from the throttle grip angle detected by the accelerator position sensor (APS) in the right hand switch housing, the engine speed, etc. to regulate engine power. The engine power characteristics corresponding to various throttle grip angle at the certain

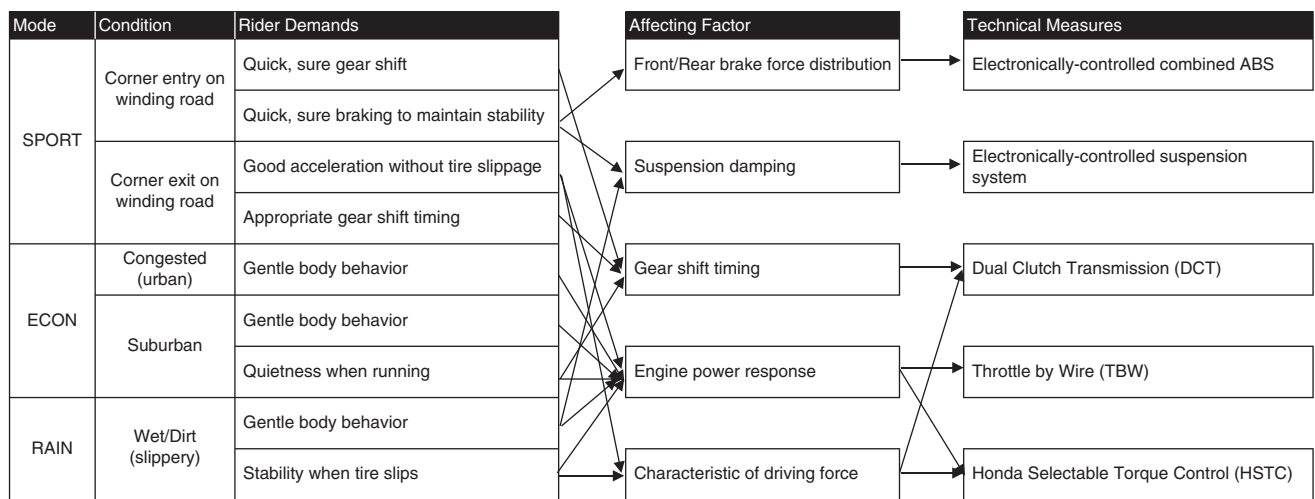


Fig. 3 Technical measures to adjust five factors to demands of each mode

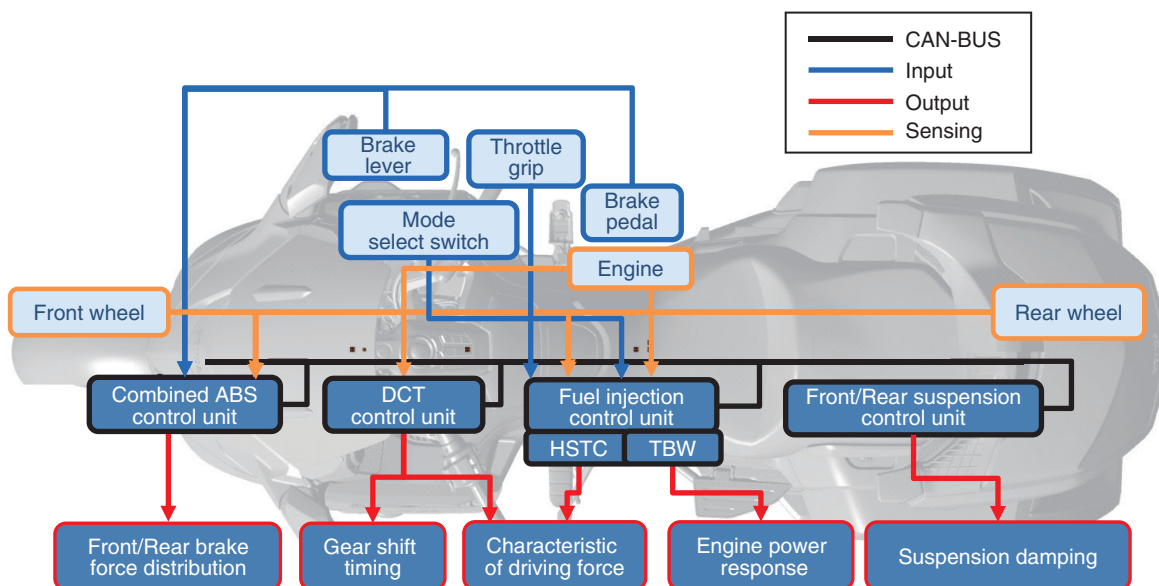


Fig. 4 Overview of system to control five factors

engine speed in each mode are shown in Fig. 6. Compared to the basic TOUR mode, the engine power rises more quickly when the throttle grip is opened in the SPORT mode to allow the rider to enjoy quicker acceleration. In the ECON mode, the engine power rises moderately to prevent abrupt changes of engine power when the throttle grip is opened. In the RAIN mode, the engine power response when the throttle grip is opened is further moderated from the ECON mode to ensure secure feel on slippery surfaces. The relationship between the throttle grip opening and the throttle valve opening to obtain the above-mentioned engine power characteristics is shown in Fig. 7.

4.2. Honda Selectable Torque Control (HSTC) System

HSTC is such a system that helps prevent excessive slipping of the rear tire by calculating rear wheel slip ratio from the vehicle speed signals detected by the wheel speed sensor located in the front and rear wheels, and regulates engine torque when the slip ratio exceeds the threshold. The engine torque is controlled by regulating the throttle

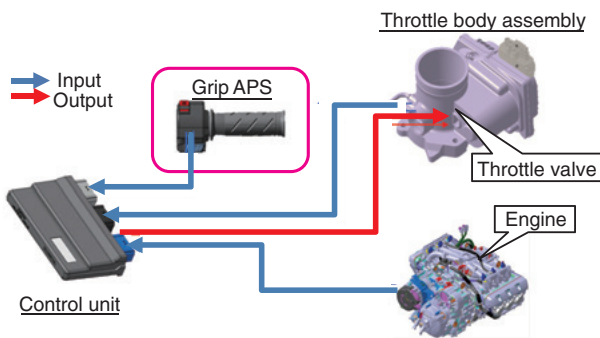


Fig. 5 TBW system

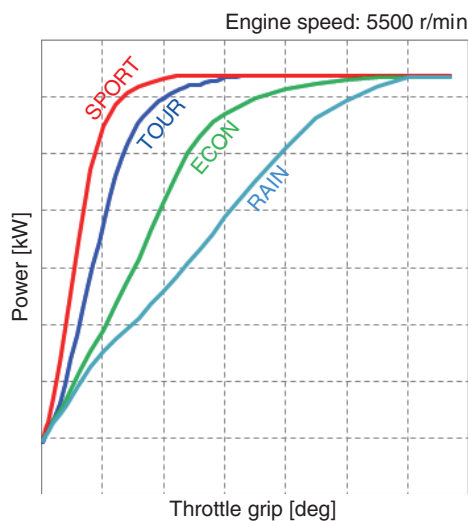


Fig. 6 Engine power characteristic in each mode

opening by TBW and adjusting fuel injection volume. This system controls engine torque in two stages; when the slip ratio exceeds the threshold, the control by TBW intervenes first, and as the slip ratio increases further and passes the next threshold, the control by fuel injection volume comes into play.

The relationship between the slip ratio and the engine torque in various modes is shown in Fig. 8. Due to the character of this model as an on-road tourer, the slip ratio threshold is set at the same level in all modes. The target of engine torque control is set differently in the SPORT mode from other modes. Compared to the TOUR mode in which the priority is given to a quick ceasing of tire slip on slippery surfaces, the target torque is set higher in the SPORT mode to allow quick acceleration even when the tire is slipping. Although the torque control setting is the same in the ECON and RAIN modes as in the TOUR mode, as the engine power response when the throttle grip is opened is set moderately as mentioned earlier, a wheel slippage is less likely.

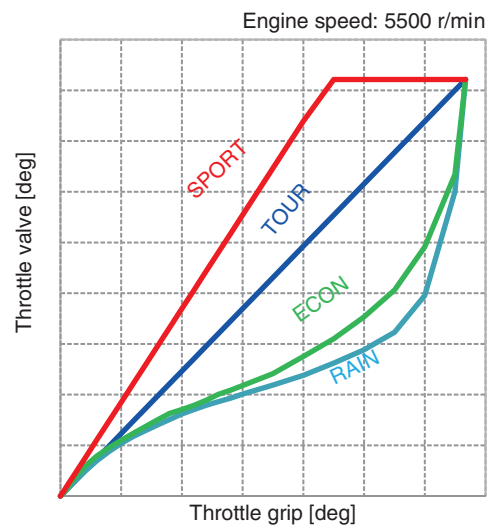


Fig. 7 TBW characteristics

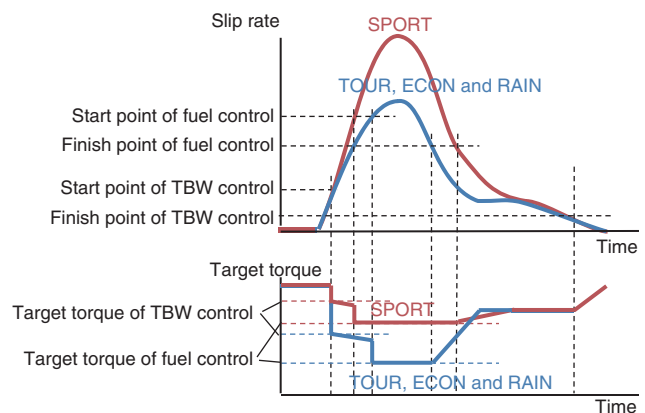


Fig. 8 Slip ratio threshold and target torque

4.3. Electronically Controlled Suspension

The electronically controlled suspension is such a system that alters damping of the front and rear suspensions by incorporating the stepping motor into the damping adjuster of the shock absorber. The damping characteristics of the front and rear shock absorbers are shown in Fig. 9. The damping force is altered only in the tension side. Compared to the basic TOUR mode, the damping force is set higher in the SPORT mode to reduce pitching motions from a hard acceleration or deceleration. In the RAIN mode, the damping force is set low to reduce changes of tire contact pressure on the road surface.

4.4. Electronically Controlled Combined ABS

The brake system applies the electronically controlled combined ABS in which the ABS is added to the dual combined brake that achieves optimum distribution of brake force in the front and rear wheels⁽¹⁾. The overview of the system is shown in Fig. 10. When the front brake lever is held, the brake force occurs in the front wheel. At the same

time, the hydraulic pressure in the rear caliper is increased by the ABS modulator having the pressure booster in it to generate brake force in the rear wheel. When the rear brake pedal is stepped, the hydraulic pressure in the rear brake master cylinder is distributed to the front and rear calipers after having the pressure regulated by the modulator.

In the SPORT mode, the rear brake force is set high when the front brake lever is held to control excessive pitching motions from the higher deceleration. The rear caliper pressure when the front brake lever is held is shown in Fig. 11.

4.5. The Difference of DCT Shift Timing for Each Ride Mode

The DCT is such a system in which the benefits of an automatic transmission are added to the manual transmission while maintaining the direct transmission of traction. Details of the DCT for this model are discussed in “Development of 7-speed Dual Clutch Transmission for 2018 Gold Wing”⁽³⁾. The control of shift timing

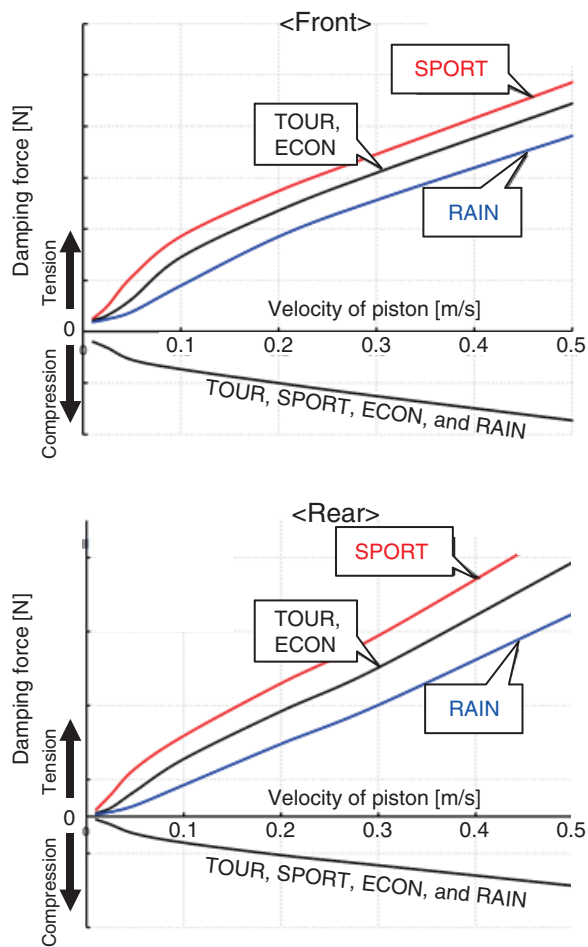


Fig. 9 Damping characteristics of front and rear shock absorbers

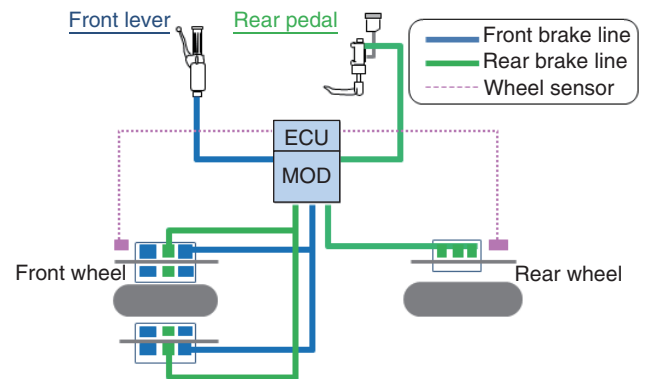


Fig. 10 Electronically controlled combined ABS

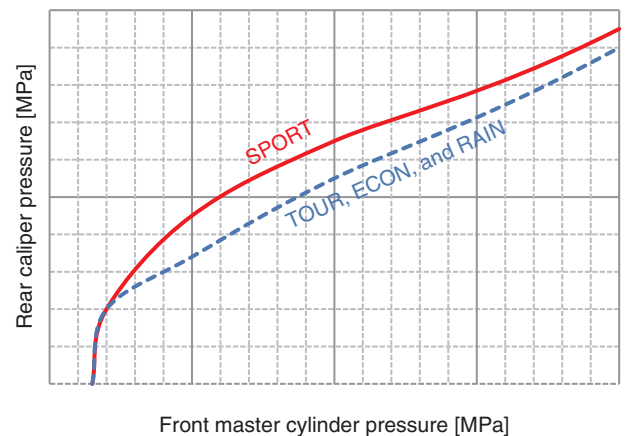


Fig. 11 Rear brake pressure when front brake lever is held

Table 2 Setting of each item in each mode

Mode	Condition	Characteristic	Engine power response (TBW)	Characteristic of driving force (HSTC)	Gear shift timing (DCT)	Suspension damping (Suspension)	Brake force distribution (Combined ABS)
TOUR	Versatile	The most balanced in various situations (The Gold Wing)	Throttle grip $\approx$ Throttle valve Response = Normal	Controls torque at rear wheel slip Control amount = Large	Optimum low speed cruise Shift timing = Normal	Offers riding comfort in various situation Damping force = Normal	Controllable brake characteristics having stable performance Rear brake pressure = Normal
SPORT	Winding Solo riding	Exciting with quick response	Throttle grip < Throttle valve Response = Quicker	Controls torque at rear wheel slip Control amount = Small	Holds gear up to high engine revolution Shift timing = Later	Controls pitching Enhances stability at acceleration/deceleration Damping force = Higher	Brake characteristics coping with frequent acceleration/deceleration Rear brake pressure = Higher
ECON	Suburb Congested (urban)	Comfort and relax with mild response	Throttle grip > Throttle valve Response = Milder	Controls torque at rear wheel slip Control amount = Large	Shift up at earliest timing Shift timing = Earliest	Offers riding comfort in various situation Damping force = Normal	Controllable brake characteristics having stable performance Rear brake pressure = Normal
RAIN	Wet/Dirt	More secure in low μ road condition	Throttle grip > Throttle valve Response = Mildest	Controls torque at rear wheel slip Control amount = Large	Shift up at earlier timing Shift timing = Earlier	Reducing changes of tire contact area on road surface Damping force = Lower	Controllable brake characteristics having stable performance Rear brake pressure = Normal

and the adaptive clutch capacity in each ride mode are discussed here.

Among the shifting characteristics, the gear shift timing is set for each ride mode as per the following. In the SPORT mode, the gear shift timing is set at higher engine speeds than in the basic TOUR mode to maintain lower gear to allow the rider to enjoy strong acceleration. In the ECON mode, the gear shift timing is set at lower engine speeds to quickly shift to the higher gear to enhance quietness and fuel economy. In the RAIN mode, the rear wheel traction is controlled by shifting the low-speed gears at the engine speeds close to the ECON mode to ensure smooth speed control by the throttle grip operation and to enhance controllability on slippery surfaces. Meanwhile in the high-speed gears, the gears are shifted at higher engine speeds close to that of TOUR to ensure an appropriate engine brake effect on slippery surfaces when the throttle grip is closed. The engine speeds to shift gears in each mode are shown in Fig. 12.

The dog clutches are applied in the DCT gears. The dog clutch has a free play in the direction of rotation. Accordingly, a big change of rear wheel torque occurs from colliding of dogs in the gears when the throttle grip is opened or closed, causing erratic motions of the motorcycle. To cope with this issue, the adaptive clutch capacity control is applied. The adaptive clutch capacity control is such that allows momentary slip of the clutch by lowering the clutch torque from the normal level when the throttle is opened or closed⁽²⁾ to reduce large torque fluctuations on the rear wheel when the dogs collide. As shown in Fig.

13, the clutch capacity in the RAIN mode is set 10% lower than in the TOUR mode. As a result, the rear wheel torque fluctuations by the throttle grip operation are reduced. Moreover, coupled with the TBW control characteristics shown in the earlier Fig. 6, the controllability of motorcycle on slippery surfaces is enhanced. Meanwhile in the SPORT mode, the clutch torque capacity is increased by 5% from the TOUR mode to achieve more direct feeling while reducing shocks from throttle operations.

The setting of control items in various modes are discussed so far.

The setting of each item in each mode is shown in Table 2.

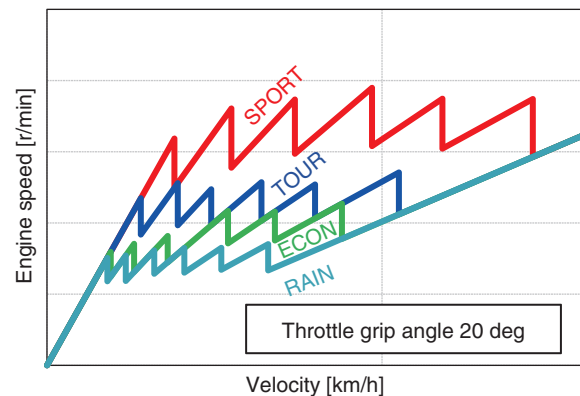


Fig. 12 Shift timing in each mode

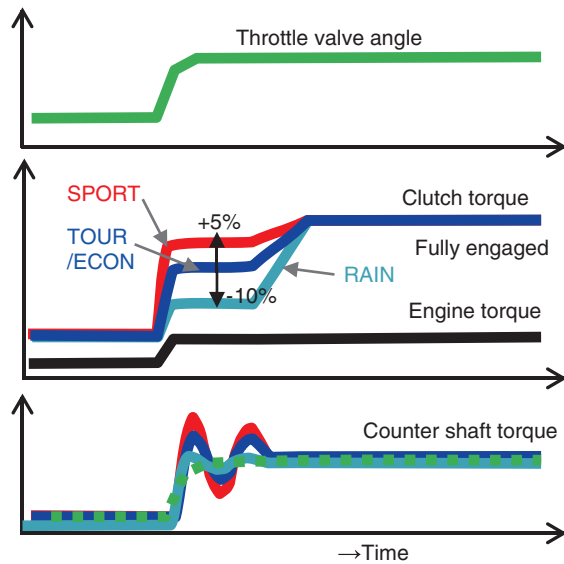


Fig. 13 Adaptive clutch torque in each mode

5. Effectiveness

Effectiveness of the control systems is discussed hereafter.

5.1. SPORT Mode; Enhancement of Dynamic Performance

The acceleration performance is one of the representative indicators of dynamic performance enhancement in the SPORT mode. The measured acceleration performance is shown in Fig. 14. When setting the test mode, conditions such as exiting a corner of a winding road, a general merge

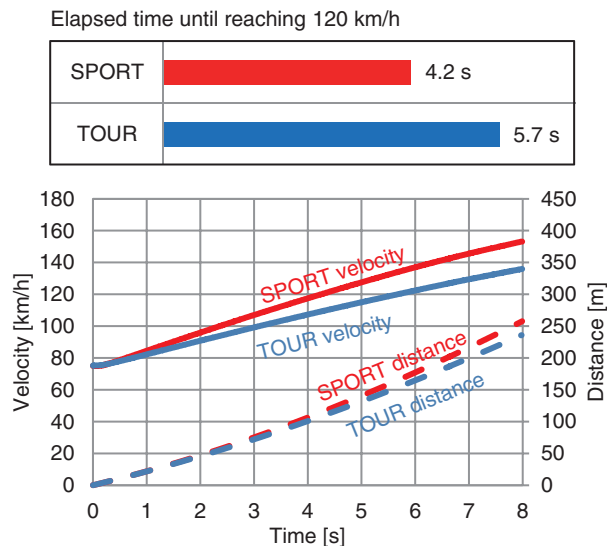


Fig. 14 Acceleration performance

into a freeway in the USA were presumed. Opening the throttle grip up to 75% in one second from the steady speed of 75 km/h (45 mph), the elapsed time until reaching 120 km/h (75 mph) was measured. In the SPORT mode, the time until reaching 120 km/h (75 mph) was shortened by 1.5 seconds from that in the TOUR mode. As shown in Fig. 15, when the throttle grip is opened in the same manner, while the throttle valve opening is restricted to 80% in the TOUR mode, it is 100% in the SPORT mode. The DCT shift pattern in the SPORT mode is such that selects a lower gear when accelerating. Due to the above-mentioned setup, the better acceleration has been achieved.

5.2. ECON Mode; Enhancement of Comfort and Economy

To clarify enhancement of comfort and economy in the ECON mode from the basic TOUR mode, the noise at rider's ears and the fuel consumption were measured. The measured noise level at rider's ears when traveling at the constant speed (75 km/h) is shown in Fig. 16. The cruising on general suburban roads in the USA was presumed for the test. The noise level at rider's ears is reduced by 3 dB (3.6%) in the ECON mode. This noise

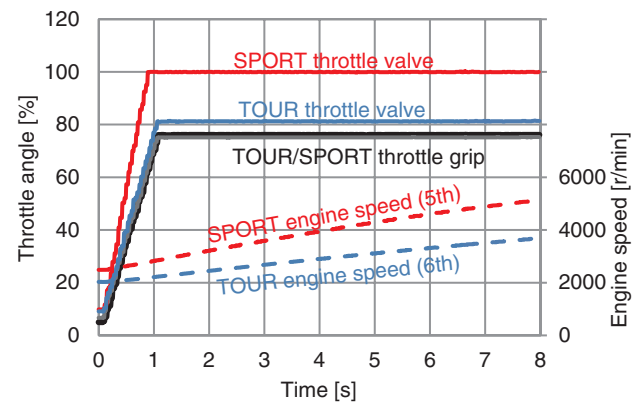


Fig. 15 Throttle angle and engine speed in each mode

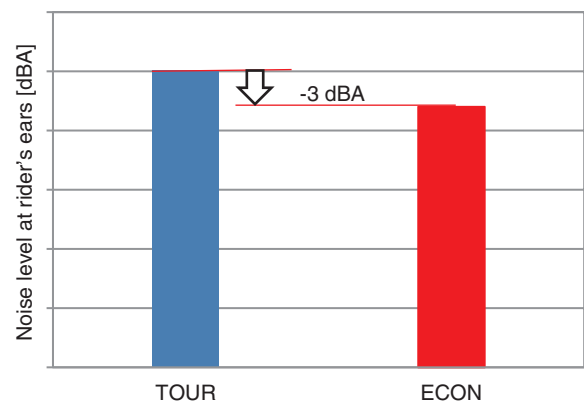


Fig. 16 Noise at rider's ears

reduction has been achieved by setting the DCT shift timing in such a manner that selects a higher gear than in the TOUR mode to lower the engine speed when running. The fuel economy measured in the test mode is shown in Fig. 17. For the tests, the US LA4 mode and the international standard WMTC mode were used. As the control of gear shift timing by the DCT is set in such a manner that allows running at higher gears when measuring fuel consumption in the ECON mode, the fuel consumption has been enhanced by approximately 3% in each mode.

5.3. RAIN Mode; Enhancement of Secure Feel

The rear tire slip ceasing is one of the representative indicators for enhancement of secure feel in the RAIN mode. The ceasing of tire slip was measured and shown in Fig. 18. The tests were conducted on a medium friction surface having a friction coefficient of 0.4, and the vehicle speed approximately 35 km/h (first gear) which is the engine speed at 80% where the maximum torque occurred, the throttle grip was opened fully in 0.3 second. The time period from the start of the torque control until the once-increased rear tire slip ratio lowered to 30% was measured. It was clarified that the tire slip ceasing time in the RAIN mode was approximately 200 msec, which was the shortest. The tire slip ceasing time in other mode is also within the level that ensures secure feel for the rider (SPORT: approx. 300 msec, TOUR/ECON: approx. 250 msec).

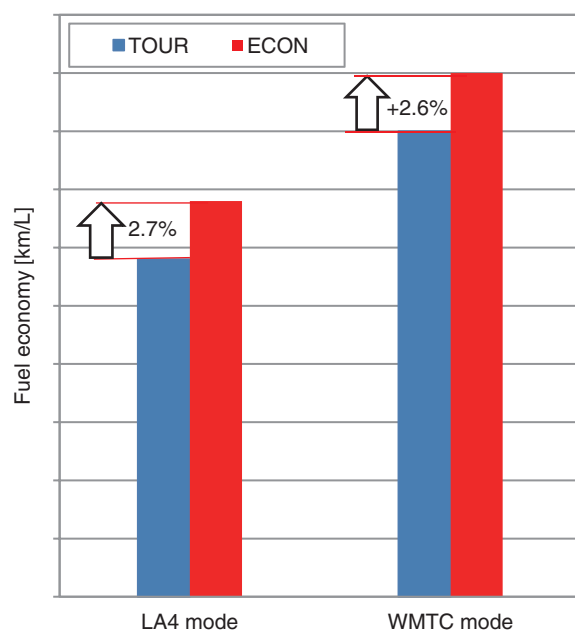


Fig. 17 Fuel consumption

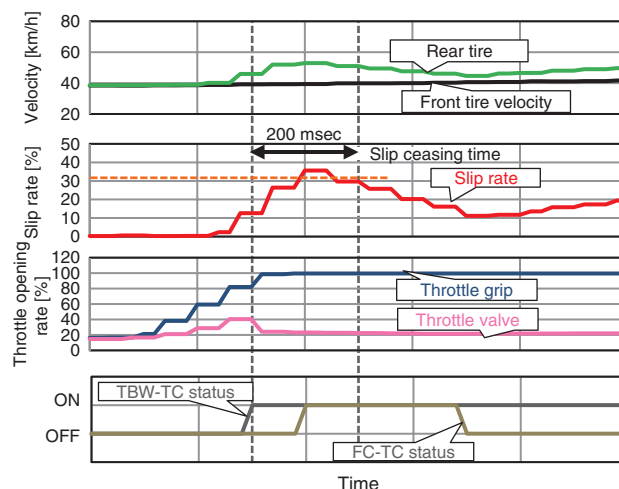


Fig. 18 Test result of tire slip ceasing

6. Conclusion

The following three, which are the aims of development of ride modes for various conditions, have been accomplished, allowing extension of performance zone that the rider can enjoy.

In the SPORT mode, the acceleration from the steady speed has been enhanced, which is an indication of an enhancement of the dynamic performance in comparison with the TOUR mode.

In the ECON mode, the noise level at rider's ears when running at the steady speed has been lowered, and the fuel economy in the test modes has been enhanced, which are an indication of enhancement of comfort and economy in comparison with the TOUR mode.

In the RAIN mode, a quick ceasing of tire slip on the medium friction surface has been confirmed to ensure secure feel for the rider in comparison with the TOUR mode.

The world's first commercial motorcycle (according to Honda's research) having the ride modes for various conditions has been realized by the integrated control of five factors (engine power response, characteristic of driving force, gear shift timing, suspension damping, front/rear brake force distribution). The newly-developed system provides the riding performance that allows the rider to control the motorcycle as the rider wants in various conditions.

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