

# Development of Electronically-controlled Suspension System for 2020 CRF1100L Africa Twin Adventure Sports ES

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## ABSTRACT

The Honda Africa Twin is a full-scale adventure model featuring off-road and touring capabilities. As a 2020-year model, we have developed the CRF1100L Africa Twin Adventure Sports ES equipped with the new electronically-controlled suspension. Four suspension modes (HARD, MID, SOFT, OFFROAD) are provided to help ensure optimum performance in the wide variety of usage from high-speed long touring with a passenger and/or luggage up to challenging off-road riding. The riding modes are designated taking into account such five parameters as the engine power, the engine brake, the clutch characteristics (DCT model only), and the ABS characteristics in addition to the suspension modes. The rider can select any mode from the handlebar switch even when riding to adjust the motorcycle characteristics to best-suit his/her desire depending on the situation and vehicle conditions.

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## 1. Introduction

The Honda CRF1000L Africa Twin was developed in 2016 as a full-scale adventure model featuring off-road and touring capabilities. The more touring-oriented Adventure Sports (hereafter AS) type was added in 2018 to broaden the fields the customers enjoy the adventure model. Although the higher suspension performance resulting from the 20 mm longer suspension stroke was well received, the increased seat height limited the appeal of this model only to riders of certain inseam length.

The 2020 CRF1100L Africa Twin has been developed as a successor of the above-mentioned model. In this model, development was conducted on the basis of two concepts: the CRF1100L Africa Twin featuring even more polished off-road capability and the CRF1100L Africa Twin Adventure Sports featuring more comfort in touring by the addition of features for comfort<sup>(1)</sup>. In both types, a target seat height was set at 870 mm to standardize to a compact body size for off-road capabilities and easy maneuvering, and further enhance the features of both types while making it easy for the rider to set his/her feet on the ground. Regarding the suspension length, the front suspension stroke is 230 mm and the rear axle travel is 220 mm for

both types, which are derived from the 2018 CRF1000L Africa Twin (Table 1).

As a model having its roots in the Paris-Dakar Rally racer, it is a must to achieve high off-road capabilities as well as maintaining comfort in long touring. Especially the AS type is required to be more secure and comfortable under a wide variety of conditions such as cruising on motorways, negotiating through twisty mountain roads and even unpaved road. The motorcycle is subjected to a wide variety of conditions such as changing environmental conditions such as the temperatures, climate, road surface, sometimes carrying a passenger and/or luggage. We target at offering a model that can “go anywhere, go further” to realize your dream of long trip by the enhanced performance that best-suits various kinds of riding conditions to enable secure and comfortable riding. As a means to satisfy such variety of requirements, we considered an electronically-controlled suspension.

In this paper, we discuss the control system, setting, and the features of 2020 CRF1100L Africa Twin Adventure Sports ES (hereafter “newly-developed model”) equipped with the electronically-controlled suspension. Figure 1 shows the newly-developed model.

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Table 1 Specification comparison of previous models and developed models for export (US, EU)

|                         |      | 2018 model |     | 2020 model |     |
|-------------------------|------|------------|-----|------------|-----|
|                         |      | AS         | STD | AS         | STD |
| Front suspension stroke | [mm] | 252        | 230 | 230        |     |
| Rear axle travel        | [mm] | 240        | 220 | 220        |     |
| Seat height             | [mm] | 920        | 870 | 870        |     |



Fig. 1 2020 CRF1100L Africa Twin Adventure Sports ES

## 2. Aims of Product Development and Overview of System

The riding mode selection system is already applied to the Africa Twin from the 2018-year model with an aim at

offering confidence-inspiring characteristics by allowing the rider to select an optimum mode depending on the situation and vehicle conditions.

The riding mode system in the preceding model was composed of a combination of engine-related characteristics such as the engine power, the engine brake, and the driving force characteristics. In the newly-developed model, the system has been modified to integrate three essential functions for control of a motorcycle: run, turn, and stop. This system features an integral control of a total of five parameters such as the engine power, the engine brake, the clutch characteristics (DCT model only), the ABS characteristics, and the suspension characteristics. Figure 2 shows presumed situation of each mode and the characteristics of complete motorcycle.

The rider can select any mode from the left handlebar switch even when riding. Turning the throttle grip fully to the closing direction completes a mode shift. Note that when the motorcycle is stopped, the mode can be selected by touching the screen on the multi-information display composed of the 6.5-inch TFT LCD panel (Fig. 3).

To satisfy the demands under a wide variety of situation and vehicle conditions under which the Africa Twin is supposed to be used, the demands on the suspension also vary widely. In the newly-developed model, we pursued a wide damping force setting range for a high degree of setting freedom to allow control of vehicle behavior by changing the damping force on a real-time basis responding to rider's input and vehicle's running conditions. Taking advantages of the electronically-controlled suspension SHOWA EERA that satisfies the said demands, we decided to realize such a motorcycle as if equipped with a number of different suspensions having various setups.

Regarding the suspension modes that are linked with the

| Riding mode |                                                                                     | Suspension mode | Road condition           | Characteristic                                                       |
|-------------|-------------------------------------------------------------------------------------|-----------------|--------------------------|----------------------------------------------------------------------|
| TOUR        |  | HARD            | On-road                  | More sportier and stable riding even with passenger and full luggage |
| URBAN       |  | MID             | Variety                  | The most balanced in various situations (The Africa Twin)            |
| GRAVEL      |  | SOFT            | Uneven road, gravel, wet | More secure and comfortable on unstable roads                        |
| OFFROAD     |  | OFFROAD         | Off-road                 | Maximize real off-road performance                                   |

Fig. 2 Presumed situations and riding characteristics

riding modes, the MID mode that excels in the total balance of riding comfort and handling in various situations along with the HARD, SOFT, and OFFROAD modes optimum for a specific situation are designated. Figure 4 shows various situations and recommended suspension modes. The aims of each mode are as per the following:

- (1) **HARD:** The mode specifically for on-road touring  
Reduces excessive pitching motions for comfort when carrying a passenger and/or luggage and stability in high-speed for on-road
- (2) **MID:** The mode having a best total balance  
Features total balance of riding comfort and handling in various situations
- (3) **SOFT:** The mode specifically for rough roads or slippery surfaces  
Features smooth and soft ride for comfort and to inspire confidence
- (4) **OFFROAD:** The mode specifically for agile handling on off roads  
Excels in tracking rugged road surfaces and absorbing large impacts to increase off-road capabilities

### 3. System Composition

### 3.1. Basic Configuration of Electronically-controlled Suspension

The electronically-controlled suspension system to employ in the Africa Twin is required to be durable and reliable under severe conditions where the components are subjected to scattering of gravels and sticking of mud. A light unsprung weight is also essential for a suspension with high tracking-ability. To satisfy such requirements, the front fork is based on the SFF-CA<sup>(2)</sup> construction in which the sensing system containing the stroke sensor in the right-side front fork leg is separately provided from the damping force control system having the cartridge and the electronically-controlled valve in the left-side fork leg. The rear shock absorber is based on the BFRC<sup>(3)</sup> construction in which the mechanical valve and the electronically-controlled valve are laid tandem in the upper part outside of the cylinder. This allows mounting of all related parts such as the stroke sensor, the electronically-controlled valve, and the wire harnesses on the upper part of the motorcycle, which



Fig. 3 Multi-information display and left handlebar switches

[illegible]

Fig. 4 Optimized conditions image

increases protection and contributes to the higher durability and reliability as well as reducing unsprung weight. Both in the front and rear suspensions, the electronically-controlled valve, which is activated by the linear solenoid, is laid in the damper oil passage. The damping force is induced by both of the electronically-controlled valve and the mechanical valve. Figure 5 shows the configuration of the front and rear suspensions.

### 3.2. Electronically-controlled Suspension System

The mode of the electronically-controlled suspension is linked with the riding mode the rider selects. The conditions of the motorcycle are constantly monitored by the front fork stroke sensor, the Inertial Measurement Unit (IMU), and the FI-ECU, and the information is transmitted to the exclusive suspension ECU. The current from the suspension ECU activates the linear solenoid to change damping force by changing the oil passage in the electronically-controlled valve on a real-time basis. Figure 6 shows overview of the electronically-controlled suspension system.

Discussed hereafter are the features of the SHOWA EERA we consider suitable for the newly-developed model. The first feature is the VP-MAP control in that the suspension stroke speed (velocity of piston: VP) is first calculated by the input from the suspension stroke sensor, and then the damping force is changed by activating the control valve in accordance with the VP. This allows setting of damping force at any level within the adjustable range. The second one is the high-speed response that takes a maximum of 15 millisecond (0.015 sec) from sensing of

vehicle conditions until changing of the damping force.

Taking advantages of the first feature, the four suspension modes are designated to satisfy the demands from a wide variety of situations and vehicle conditions the Africa Twin is presumed to be used as well as making the differences of riding comfort and handling clearly distinguishable. Additionally, the damping force is set very low only when the VP is extremely low to allow

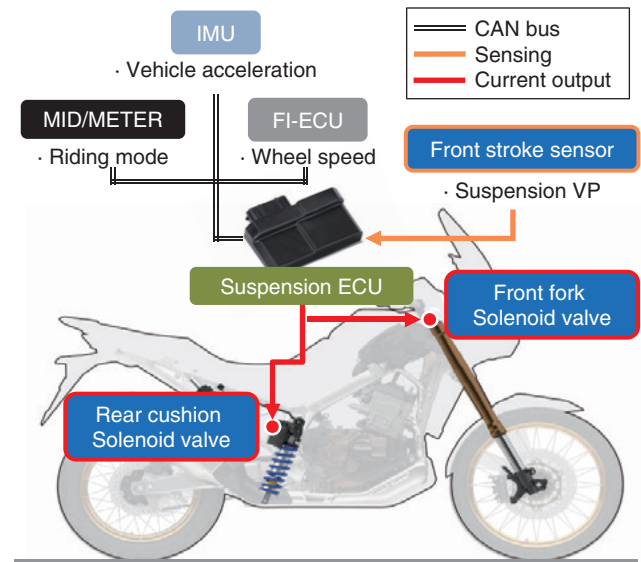


Fig. 6 Overview of control system

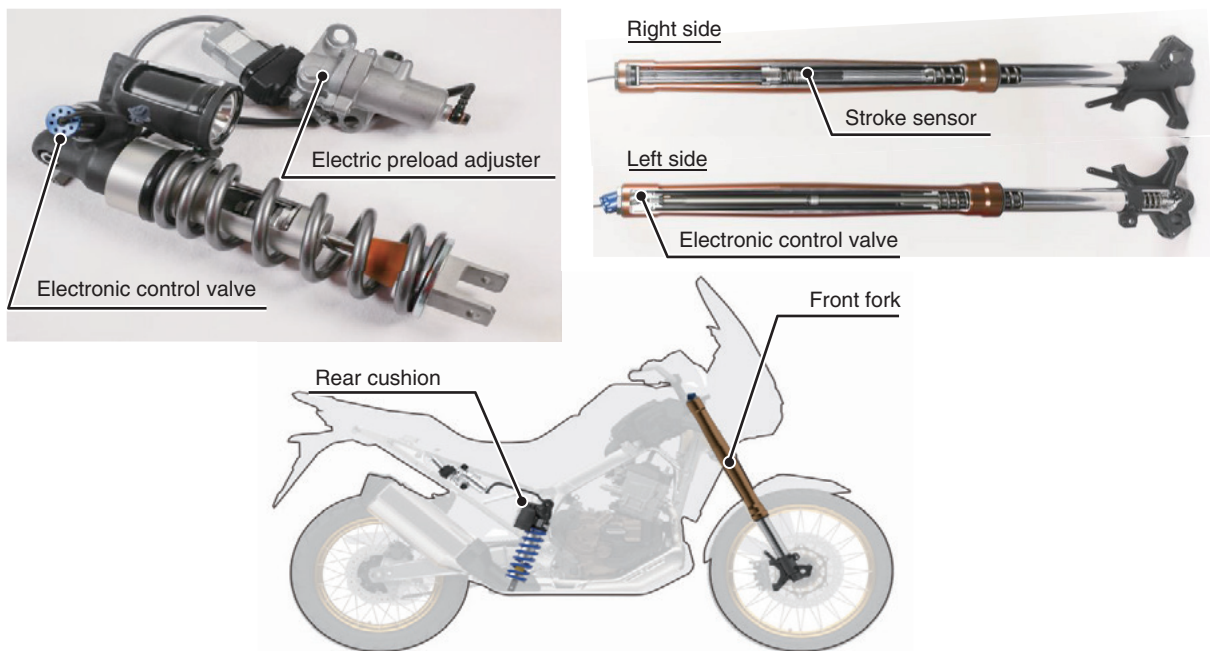


Fig. 5 Electronically-controlled front fork and rear cushion

quick shifting of suspension from rebound to compression and vice versa, providing smooth suspension actions and contributing to the superb riding comfort.

Taking advantages of the second feature, the extent of damping force change and the timing of change are set at an optimum level on the basis of the input from the stroke sensor, IMU, and FI-ECU. Conducting actual running tests over and over in various kinds of presumable situations, the system is tuned so as to control rapid changes to help ensure gradual changes while instantly responding to rider's operation and/or changes of terrain and changing damping force. This gradual change of damping force helps eliminate an unnatural sensation when the electronic control intervenes.

Also, as a consideration in the employment of electronically-controlled suspension, the system is basically configured so as to hold the damping force at the middle between the MID mode and the HARD mode when a malfunction such as a broken wire or other damage occurs in the electronically-controlled system. The damping force will not be fixed at the maximum or the minimum. Therefore, even when the system malfunctions during a travel, the system permits the customer continue the travel just like having a conventional suspension and maintains the riding comfort and handling.

This is the optimum electronically-controlled suspension system that satisfies a variety of performance demands of this adventure model including the durability and reliability under severe conditions.

#### 4. Suspension Tuning for Each Mode and Applied Technical Measures

The MID mode excels in the total balance of comfort and handling under various riding conditions the Africa Twin is presumed to be used. Using the MID mode as a reference, the aims and the setup of three other modes are discussed below.

- (1) OFFROAD mode: The damping force increases gradually in accordance with the suspension VP. Also controls the damper when jump landing.
- (2) HARD mode: The highest damping force among these modes is most suitable for high loads and/or high speeds. Also controls the damper for deceleration.
- (3) SOFT mode: The lowest damping force among these modes for riding comfort. The damper control is linked with the vehicle speed.

The features of each mode are indicated by the data measured from actual running tests. The model for comparison in this chapter is 2020 CRF1100L Africa Twin Adventure Sports (hereafter as “the type without ES”), which has the same front and rear suspension stroke and has no electronic control.

##### 4.1. OFFROAD Mode (Riding Mode: OFFROAD)

In the OFFROAD mode, the setup is exclusively for off-

road use to help ensure agility on off roads. In the off road where the road is very bumpy and the rider continuously encounters various gaps from large ones to small ones, the suspension should be such that helps to keep the wheels on the road surface as well as absorbing big impacts.

On the front end, the damping force is set low when the suspension moves slowly to keep the wheels on the road surface. For absorption of large impacts and a quick convergence of vehicle body movement, the damping force is set high when the suspension moves quickly. Unlike in three other modes as Fig. 7 shows, the characteristics is progressive in that the damping force increases gradually in accordance with the suspension VP. In a soft terrain like on sand, the handle bar tends to shake right and left because the front wheel sinks in the sand and the weight shifts toward the front end. To deal with this issue, the front compression damping force is set high from a low VP. The damping force on the rear end is set higher than in the SOFT mode across the entire region for a higher ride-ability under even more severe road conditions.

With an aim at reduction of shocks when landing from a jump, we incorporated the jump landing control. The

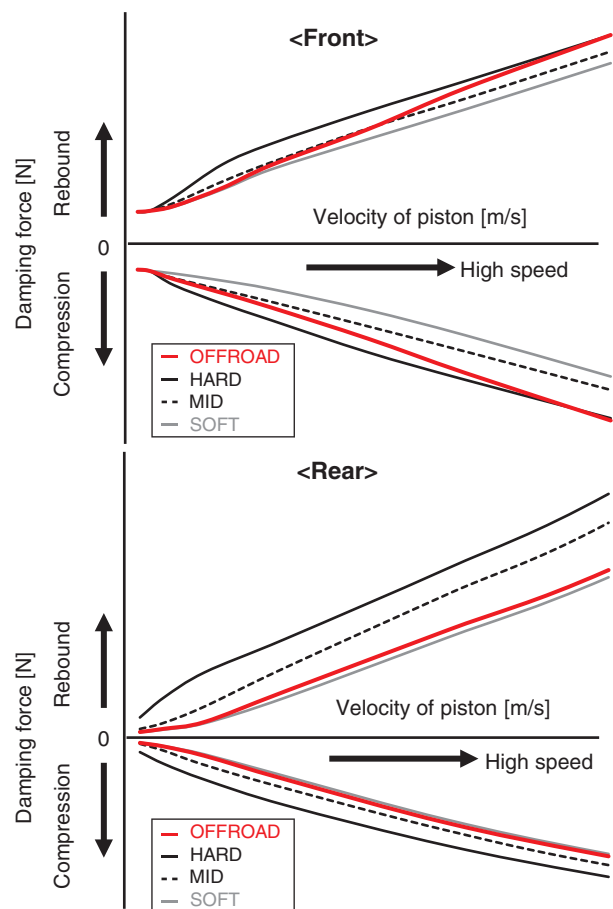


Fig. 7 Comparison of damping force characteristics of each mode

system identifies a jump from the total acceleration data in three axes from the IMU, and instantly increases damping force of front and rear suspension to prepare for landing. Figure 8 shows the data taken from in-house jumping test ramp. In the OFFROAD mode, the vertical acceleration of the sprung mass at the time of landing is less by 41% than the type without ES, which means a reduction of landing impact. This reduces suspension bottoming impacts when jumped unexpectedly from a large gap or during a fun ride on off roads, and provides the rider with a sense of security.

#### 4.2. HARD Mode (Riding Mode: TOUR)

The HARD mode is exclusively tuned for on-road touring to help ensure comfort even under high-load conditions where the sprung mass increases such as when carrying a luggage and/or a passenger. Aims are also set at such characteristics that show stability when riding on twisty roads at a brisk pace or cruising on motorways at high speeds.

Accordingly, the damping force is set at the highest from the low VP to stabilize vehicle behavior by controlling excessive vehicle body movement at the time of acceleration and cornering (Fig. 9). In the low VP region that largely affects the handling, the damping force is increased by 25% in the front compression, 20% in the rebound, 40% in the rear compression, and 75% in the rebound from the MID mode. Especially the largely increased rear damping force helps ensure impact absorption and gentle convergence of vehicle body movement even when the sprung mass is increased by the luggage or the passenger.

The control of damping at the time of deceleration is also incorporated to reduce “nose dive,” which is such a phenomenon in that the front end of the motorcycle sinks and the motorcycle tilts to the front when braking. It is such a control that temporarily increases the damping

force in the compression side of the front suspension and the rebound side of the rear suspension depending on the degree of deceleration detected by the IMU. Figure 10 shows the measurements taken in the HARD mode when braking from 80 km/h on the flat paved road. Compared to

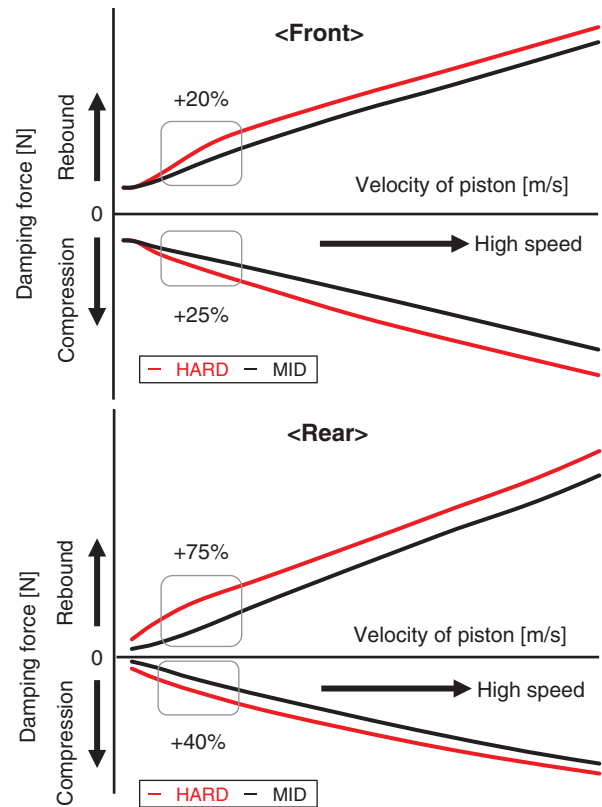


Fig. 9 Damping characteristics of HARD mode

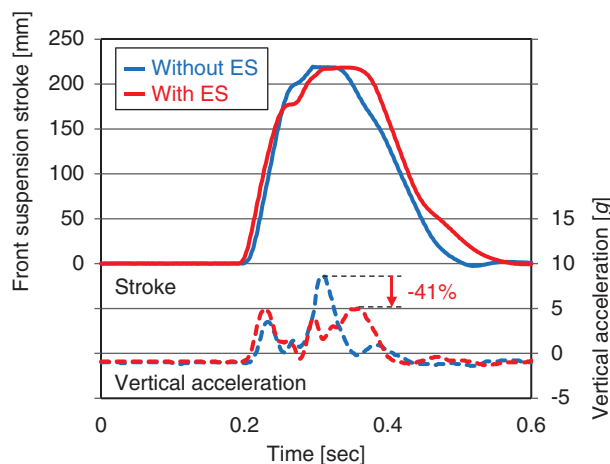


Fig. 8 Front suspension stroke and vertical acceleration of sprung mass when jump landing

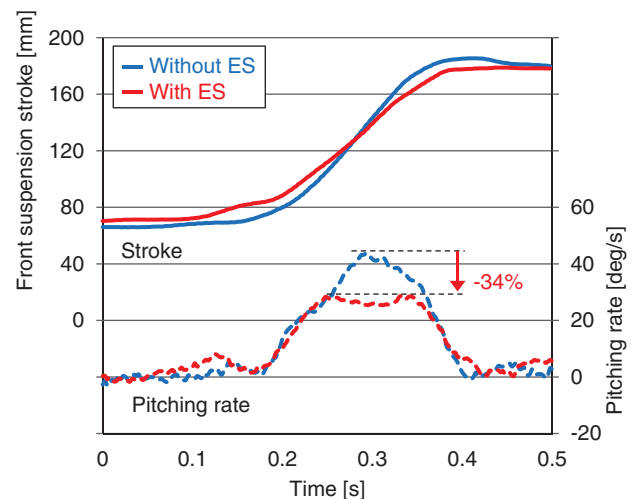


Fig. 10 Front suspension stroke and pitching rate when braking hard

the type without ES, the changes of front suspension stroke at the time of braking is moderate, reducing the pitching angular velocity of the vehicle by 34%. The nose dive at the time of braking is thus controlled to moderate pitching motions.

#### 4.3. SOFT Mode (Riding Mode: GRAVEL)

The SOFT mode is tuned exclusively for the specific purpose of the adventure tourer, i.e., for softer rides so that the rider can comfortably ride the motorcycle with a sense of security even when the road surface conditions are unstable. When riding on rough surfaces or slippery surfaces, it is necessary to always stabilize tire-to-ground contact pressure by tuning the suspension in such a manner that lets the suspension work smoothly to absorb impacts to the rider to help ensure compliance.

Hence, the damping force is set at the minimum in the SOFT mode. In the medium VP region that largely affects the riding comfort, the damping force is less than in the MID mode by 20% in the front compression, 10% in the rebound, 15% in the rear compression, and 30% in the rebound. On the other hand, an excessively low damping force slows convergence of vehicle body motions at high speeds. To achieve stability at high speeds and riding comfort at low speeds, the speed-dependent control system is incorporated in that the two different damping force characteristics are provided and used depending on the vehicle speed. Incorporating two damping force characteristics for the low speeds of 80 km/h or under (V0) and those for high speeds of 130 km/h or above (V1), and gradually changing the characteristics when the speed is between the two thresholds, the motorcycle motions are maintained as natural as possible. Figure 11 shows image pictures of the damping force characteristics of V0 and V1. The damping force at V1 is higher than at V0 in the front compression and front/rear rebound.

The average vertical acceleration of the sprung mass when traveling straight at 60 km/h on the cobble stone road, on which small bumps and depressions appear continuously, is compared (Fig. 12). In the SOFT mode, the acceleration is 15% less than the type without ES, which means that the shock transmission to the rider is reduced. The soft rides are evident from the data.

#### 4.4. ABS-linked Control

When braking hard and the ABS intervenes, pitching motions that rock the motorcycle back and forth sometimes occur aside from the kick back that notifies the rider of the ABS intervention. That occurs because the moment the brake fluid pressure is lowered by the ABS, the increased ground-contact pressure of the front tire from the hard braking is reduced, causing the front suspension to change stroke direction from compression to rebound. If the rebound motion can be controlled at a minimum, the ground-contact pressure of the tire at the time of hard braking is stabilized, allowing control of pitching motions.

This system has a newly developed ABS-linked damper control that increases damping force in the front rebound to control extending motions when a hard braking that causes the ABS to function is detected and the brake fluid pressure is lowered. The ABS-linked damper control is applied to all

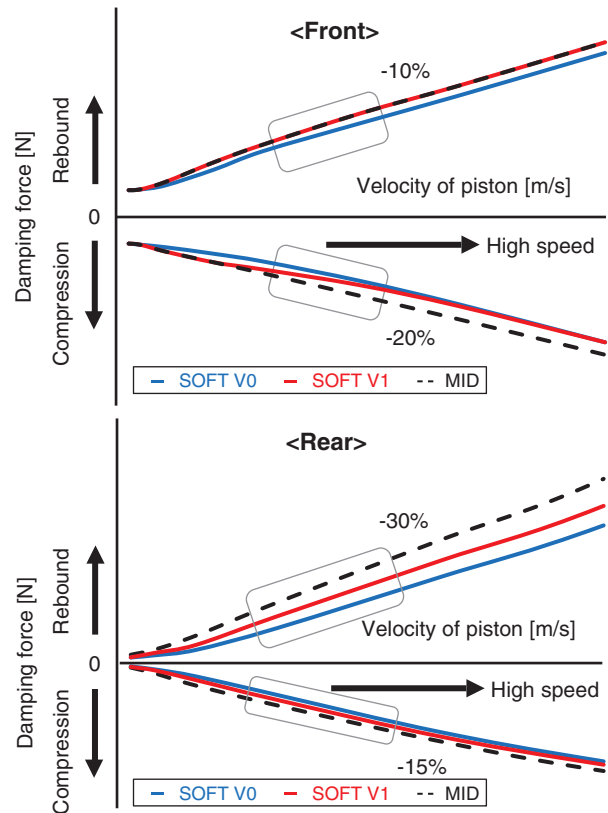


Fig. 11 Damping characteristics of SOFT mode

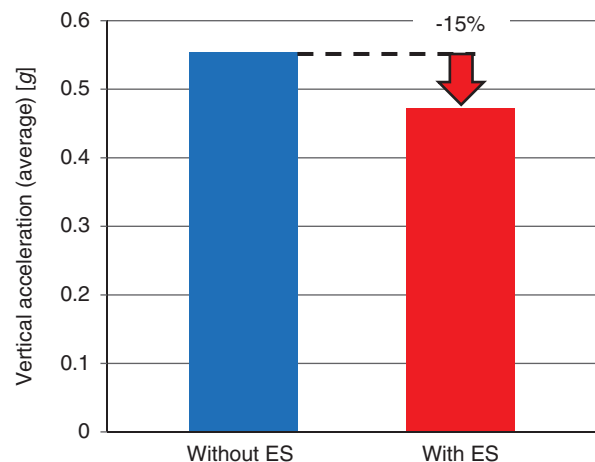


Fig. 12 Vertical acceleration of sprung mass when passing through cobble stone road

suspension modes. Figure 13 shows measurements taken in MID mode when a hard braking that activates ABS is applied from 40 km/h on the flat paved surface. The pitching angular velocity when the ABS is functioning is reduced by 45% from the type without ES. The pitching motions that rock the motorcycle back and forth when the ABS functions is thus controlled to moderate vehicle body motions.

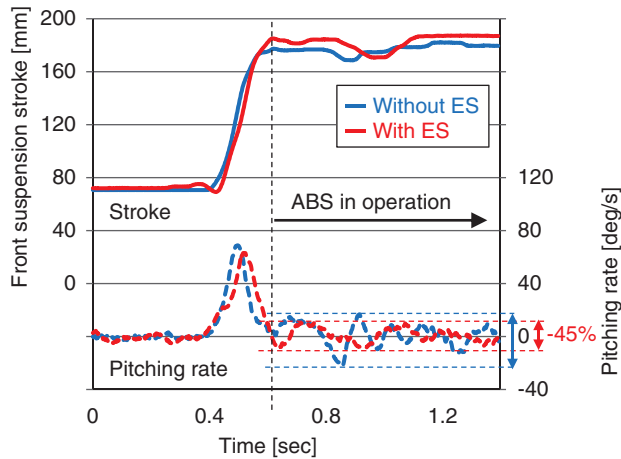


Fig. 13 Front suspension stroke and vertical acceleration of sprung mass when braking hard

## 5. Conclusion

The electronically-controlled suspension is newly developed for the 2020 CRF1100L Africa Twin Adventure Sports ES. Combining the high-degree of damping force tune-ability, which is a feature of SHOWA EERA with the control system that instantly changes damping force depending on the running conditions, the four suspension modes are designated for a wide variety of usages from the touring with a passenger and/or a luggage to the serious off-road riding. The riding modes, in which such five characteristics as the engine power, the engine brake, the clutch characteristics (DCT model only), and the ABS characteristics in addition to the suspension modes, are designated. The rider can select any mode from the handlebar switch even when riding to adjust the motorcycle characteristics to best-suit his/her desire depending on the situation and vehicle conditions. We hope this motorcycle will satisfy the owner for a long time as a partner that turns on his/her adventure spirit and motivates him/her to “go anywhere, go further.”

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