

Vehicle Dynamics Performance Enhancing Technology for New CIVIC

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ABSTRACT

Technology was developed for the new CIVIC with the goal of achieving the top vehicle dynamic performance in the segment.

A new rear suspension with high rear equivalent cornering power was developed to achieve a balance between handling performance and ride comfort. Road-holding cornering performance and flat ride performance were simultaneously achieved by reducing the friction and hysteresis of the suspension moving parts to reduce the force transferred from the road surface to the body, and by non-coupling various vehicle behaviors. A dual-pinion variable gear ratio electric power steering system was used and the steering support stiffness was increased to simultaneously achieve both a smooth and linear steering feel and good handling over wide steering maneuver and vehicle speed ranges. Linear handling performance and good ride comfort from initial start to long-distance driving were realized through the use of body bulkheads with a ring structure that increases torsional stiffness and a lattice frame layout that increases floor stiffness. These technologies achieved top-level vehicle dynamic performance among same-segment vehicles around the world.

1. Introduction

The 2016 year model CIVIC (new CIVIC) was developed with the grand concept of “The CIVIC” based on the three pillars of Charismatic, Soulful, and Comfortable. Charismatic means achieving an advanced, high-quality design and a package with good interior comfort. Soulful means a new power train and platform that realize impressive driving which exceeds that of European vehicles with good dynamic performance. Comfortable means providing good ride comfort, high NVH performance, and the latest comfortable and reassuring equipment. Particularly with regards to Soulful, it was decided to provide remarkable performance that exceeds customer expectations, return to the sportiness that is the CIVIC mainstream, and create a new trend for the compact segment.

Based on the above grand concept, the value of the vehicle dynamic performance provided to customers was investigated, and the goal was set as a secure feeling that exceeds customer expectations and provides an impressive agile feeling.

Secure feeling means a high suspension response that enables tires to hold the road even on uneven surfaces, and performance that reduces passenger body and head shaking

and stabilized eye level.

Agile feeling means a quick body response with good turn-in ability and a low profile with a low center of gravity that holds the intended driving line.

Specific driving scenarios to be provided to customers and the performance items in those scenarios were derived from these goals.

Directional stability that enables a secure feeling even during high speed driving, limit handling that stabilizes vehicle behavior even during sudden steering, a smooth and accurate steering feel from small steering maneuvers, and good ride comfort from the start of driving to long-distance cruising were set as representative secure feeling items.

Good response to steering input, linear handling with little lag, and cornering performance that holds the vehicle low to the road were set as typical agile feeling items. Predicted advances by competitors were derived from comparative analysis and also taken into account to set competitive physical target values.

2. Performance Building Concepts

Development was performed in accordance with the following concepts to achieve the target vehicle dynamic performance for the new CIVIC.

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- (1) Provision of high rear equivalent cornering power (CP) as the basis for simultaneously achieving both handling performance and ride comfort.
- (2) Reduction of the force transferred from the road surface to the body and non-coupling of various vehicle behaviors to achieve both cornering performance that holds the vehicle to the road and flat ride performance.
- (3) Increased steering system support stiffness and separation of assist systems to achieve both a smooth and linear steering feel and good handling from small steering maneuvers to large steering angles and from low to high speeds.
- (4) Increased body stiffness to realize linear handling performance with little lag relative to steering input and good ride comfort from the start of driving to long-distance cruising.

3. Achieved Technology

Previously developed performance design technology^{(1),(2)} was used and various new technologies were applied to achieve the target performances in accordance with the performance building concepts. The main contents are described below.

3.1. Rear Suspension

A new multi-link rear suspension was used to simultaneously achieve both handling performance and ride comfort. Figure 1 shows an overview of the new suspension.

In order to realize the high lateral stiffness needed to enhance handling performance, the suspension geometry was set so that the lateral load is mainly shared by the lower and upper arms and the longitudinal load that has a high contribution to ride comfort is mainly borne by the trailing arm (Fig. 2).

The use of 6-point rigid connection between the rear subframe and the body increased the lateral coupling stiffness, which has a high contribution to enhancement of handling performance, and a high spring rate was set for the

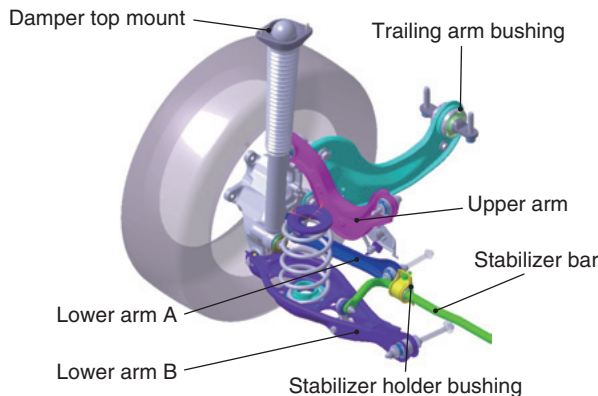


Fig. 1 Overview of new rear multi-link suspension

radial direction of the bushing that bears the lateral load.

As a result, in consideration of the balance with damping of disturbance, the equivalent CP gain was increased by reducing changes in alignment due to rolling and increasing changes in alignment due to lateral force compared to the previous model (Fig. 3).

Addition of a drawing bushing and intermediate plate to each bushing that supports the lateral force simultaneously achieved a high radial direction spring rate and a low torsional spring rate, and reducing the friction and the hysteresis element of the suspension moving parts achieved a smooth initiation of motion. In addition, a low spring rate was set for the trailing arm bushing, which has a high contribution to enhancement of ride comfort. This enabled simultaneous achievement of handling performance and ride comfort (Fig. 4).

Use of an input force dividing-type damper top mount enabled use of low-density, low-compression materials while still maintaining durability. Furthermore, changing from rubber materials to urethane materials enhanced the damping characteristic in the large amplitude range and

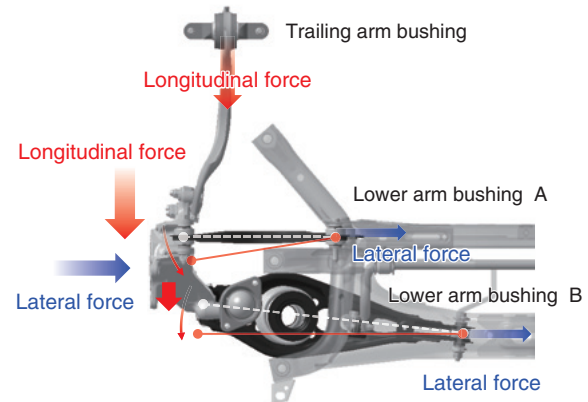


Fig. 2 Features of new rear suspension

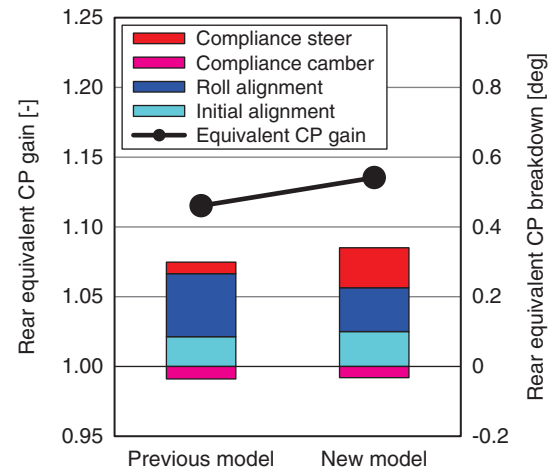


Fig. 3 Rear equivalent CP of new rear suspension

enhanced the vibration-damping characteristic to near the natural frequency of sprung mass.

In addition, the input to the body increases for grades equipped with a tire size of 17 inches or more, so a hydraulic trailing arm bushing was applied. This reduced body vibration enhanced road-holding ability when driving at high speeds, and enhanced damping of harshness (Fig. 5).

3.2. Front Suspension

A strut-type front suspension was used as in the previous model, but the suspension geometry was reviewed to achieve the target linear handling performance with little lag relative to steering input (Fig. 6).

The new model used an L-shaped lower arm to separate each bushing function.

Figure 7 compares the previous model and the new model.

In the previous model [Fig. 7(a)], it was not easy to reduce the spring rate of the compliance bushing, which has

a high contribution to ride comfort, because the lower arm bushing and the compliance bushing needed to have high lateral stiffness to support the load with respect to the lateral direction that is required for handling performance.

In contrast, the new model [Fig. 7(b)] uses an L-shaped lower arm, so the lateral force is borne by the high-stiffness

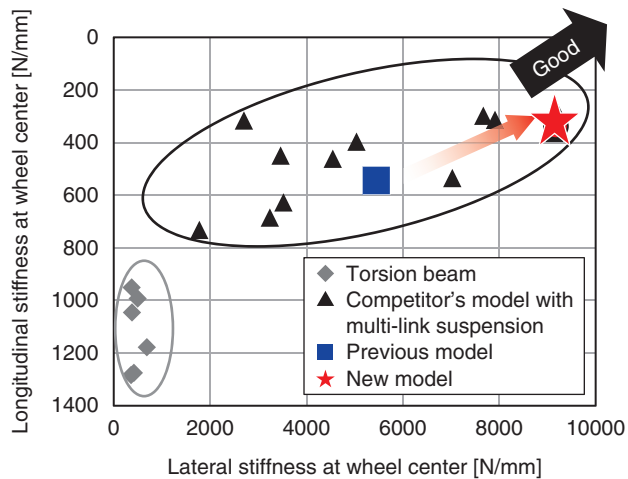


Fig. 4 Rear suspension lateral and longitudinal stiffness at wheel center

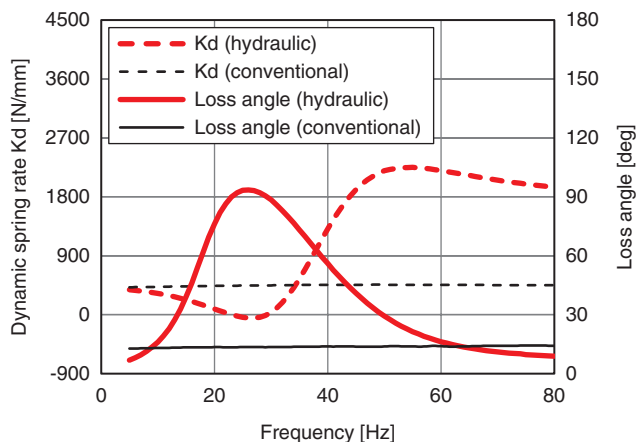


Fig. 5 Characteristics of rear hydraulic trailing arm bushing

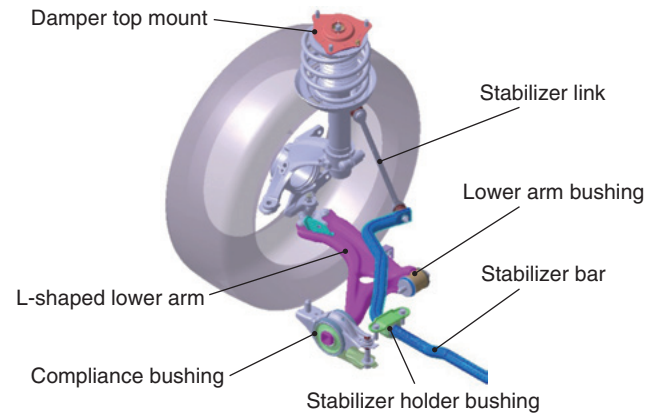
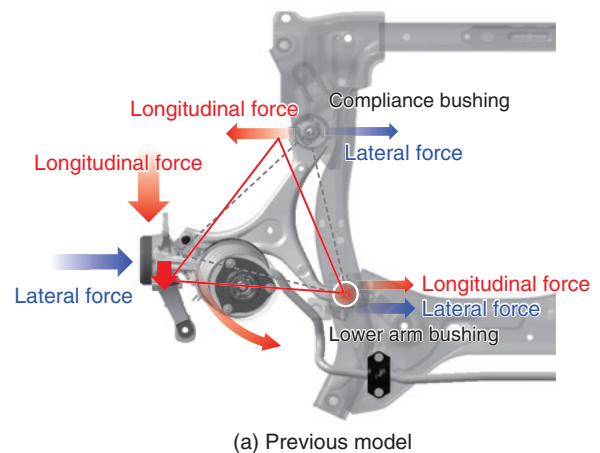
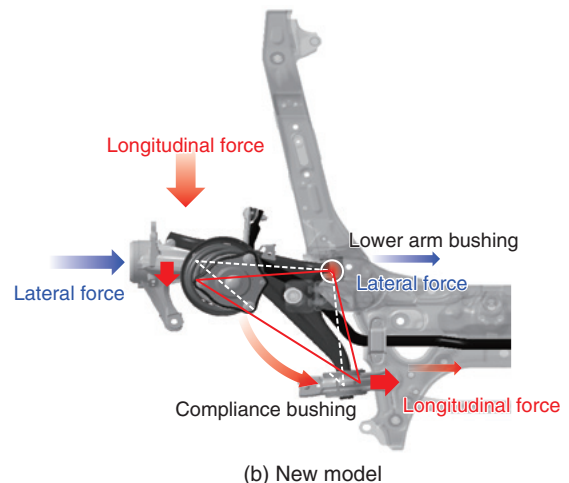


Fig. 6 Overview of front strut suspension



(a) Previous model



(b) New model

Fig. 7 Features of new front suspension

lower arm bushing and the longitudinal force is borne by the low-stiffness compliance bushing. This made it possible to simultaneously achieve handling performance and ride comfort.

Figure 8 shows the relationship between the lateral stiffness and longitudinal stiffness of the suspension at the wheel center position. The new suspension made it possible to achieve both a high lateral stiffness and low longitudinal stiffness that are the top level in the segment.

The axis of the compliance bushing was changed to fit its torsional direction to the suspension vertical stroke, and the torsional spring rate was reduced. Furthermore, use of a hydraulic type enhanced the damping characteristic in the wheel center longitudinal resonance range (10 to 20 Hz), which reduced steering shimmy and body vibration when driving at high speeds and enhanced harshness damping (Fig. 9).

In addition, the stabilizer spring rate was increased and the spring rate of the main spring was reduced compared

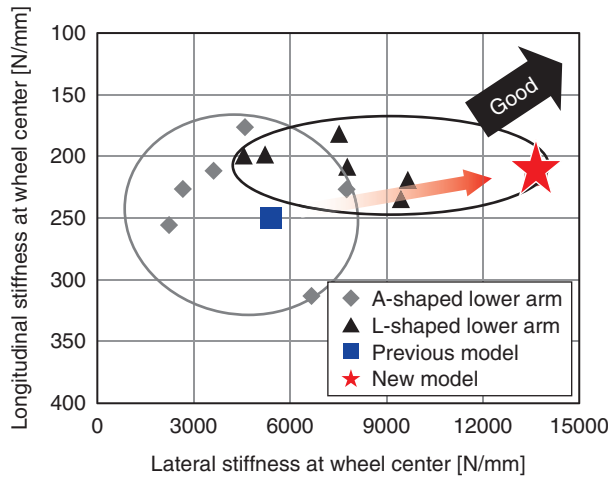


Fig. 8 Front suspension lateral and longitudinal stiffness at wheel center

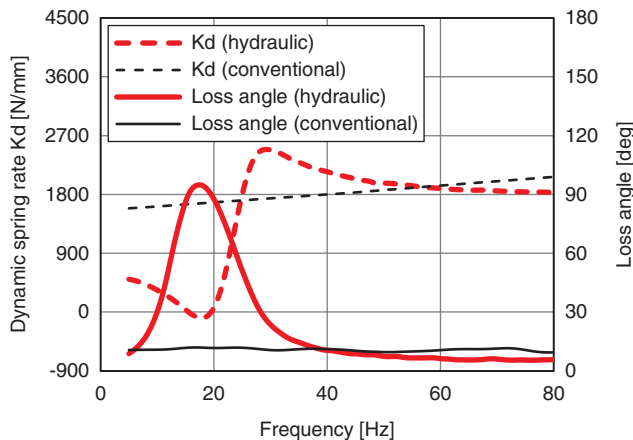


Fig. 9 Characteristics of front hydraulic compliance bushing

to the previous model. This lowered the bounce and pitch natural frequency while increasing the roll natural frequency of the body, which achieved non-coupling.

As a result, the roll response and road-holding ability were enhanced and the ground load fluctuation and roll amount were reduced.

The front roll center height was also reduced to half or less than that of the previous model to realize a cornering feel that holds the road with a low position.

3.3. Steering

A dual-pinion electric power steering system in which the motor assist mechanism is separate from the steering gear was used to achieve the goal of smooth and accurate steering feel from small steering maneuvers (Fig. 10).

Stays were added and the gearbox connection stiffness was increased in order to increase the lateral support stiffness that contributes to the steering feel (Fig. 11).

In addition, the steering shaft and steering hanger pipe diameters were increased, the column support stiffness was increased, and the vertical support stiffness was increased to reduce the vertical and lateral vibration on the steering wheel (Fig. 12).

Furthermore, the use of a variable steering gear ratio achieved both good turn-in ability at low speeds and stability at high speeds (Fig. 13).

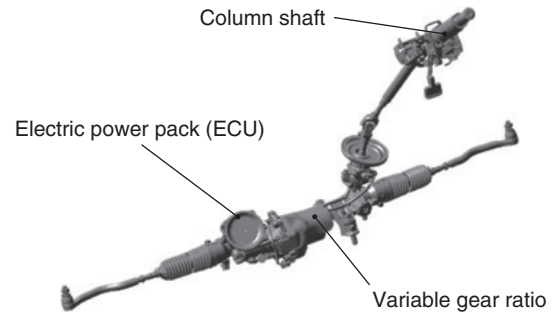


Fig. 10 Overview of dual pinion variable gear ratio electric power steering system

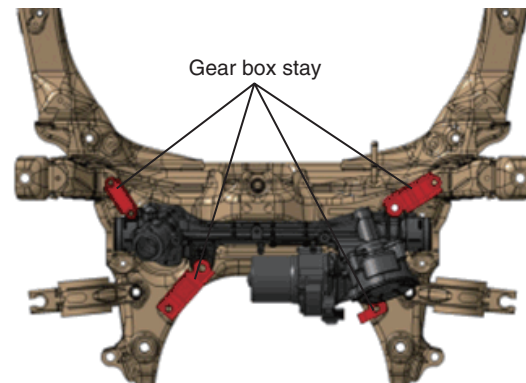


Fig. 11 Steering gear box stays

3.4. Body Stiffness

To achieve both linear handling performance with little lag relative to steering input and good ride comfort from the start of driving to long-distance cruising, body structures were reviewed for the new model to transfer the load input from the suspension to the body smoothly based on the concept of continuity of the structure and contour lines from the suspension input points to the cabin.

To achieve linear handling with little lag relative to steering input, the front and rear bulkheads were changed to ring structures to reinforce the torsional stiffness, centering on increased stiffness around the suspension connecting points that transmit the input from the road surface (Fig. 14).

To reduce vibration at the floor surface that contacts passengers' feet, a lattice frame was applied to the floor

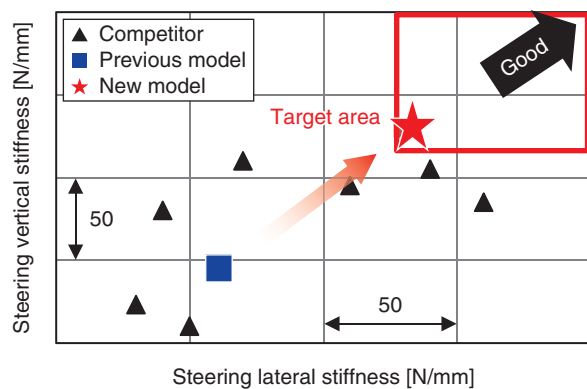


Fig. 12 Steering lateral and vertical stiffness

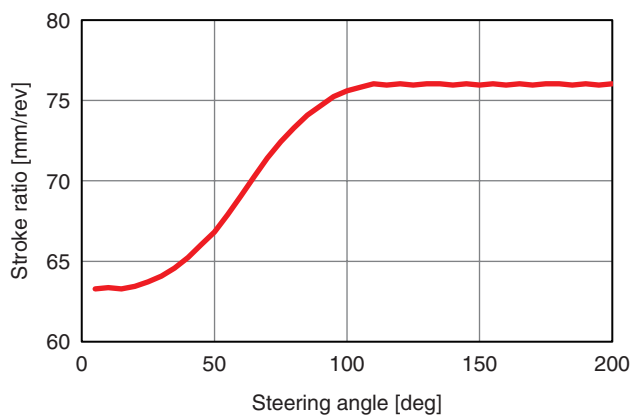


Fig. 13 Steering ratio characteristics

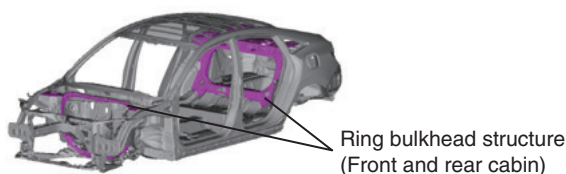


Fig. 14 Front and rear bulkhead structure

(Fig. 15) and the panel thickness was increased by approximately 60% compared to the previous model to increase the cabin bending stiffness and the floor stiffness.

In addition, the tunnel mode level was reduced by adding floor braces as shown in Fig. 16⁽³⁾.

Furthermore, locations with high sensitivity to input from the suspension were extracted using CAE, and countermeasures were taken to reduce stress concentration. However, regarding dynamic performance, there are some locations with high sensitivity for handling performance and ride comfort that are a challenge to express using CAE. The details for these locations, such as reviewing shapes and adding welding spots, were determined based on the test driver sensibilities (Fig. 17).

These countermeasures increased the static torsional stiffness by 25% and the floor bending stiffness by 57% compared to the previous model.

The results of bench tests using a 4-pillar shaker indicated that the transfer sensitivity from the front damper connecting point to the front seat connecting point could be reduced compared to the previous model as shown in Fig. 18.

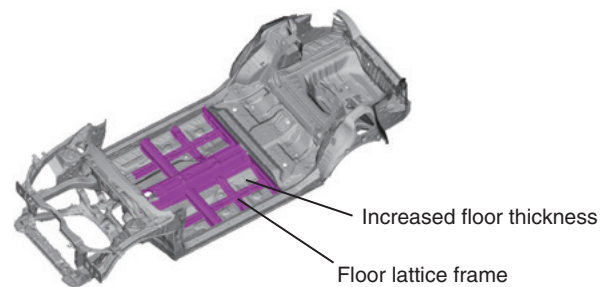


Fig. 15 Floor stiffness reinforcement items

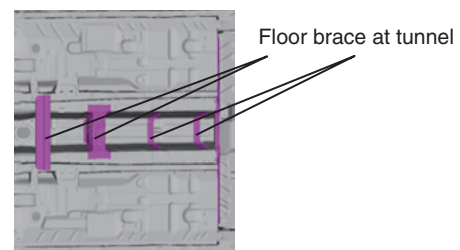


Fig. 16 Floor braces at tunnel

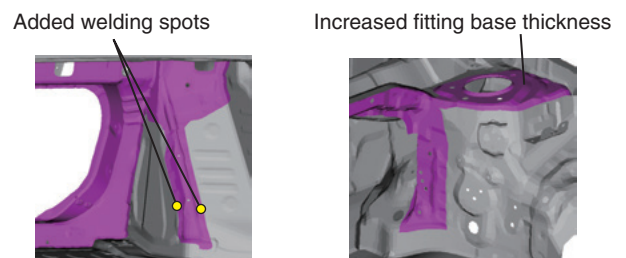


Fig. 17 Body stiffness enhancement points

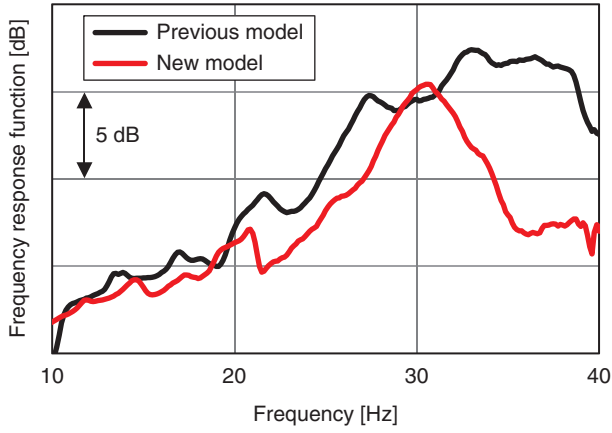


Fig. 18 Frequency response function of front input

4. Verification of Degree of Performance Achievement in Completed Vehicle

The degree of target performance achievement was confirmed by vehicle tests. Representative results are described below.

The yaw rate frequency was set as the performance for directional stability even during high speed driving, and was reduced compared to the previous model, achieving the top level in the segment (Fig. 19).

The yaw rate frequency means the average amplitude of the yaw rate fluctuation component produced when driving in a straight line.

A smooth and accurate steering feel from small steering maneuvers was realized by achieving steering torque characteristics with the target smooth and linear steering torque rise relative to the yaw rate during turn-in from 100 km/h (Fig. 20).

Flat ride in the low-frequency range (0.5 to 3 Hz) and flat ride in the mid-frequency range (3 to 8 Hz) were plotted to express good ride comfort from the start of driving to long-distance cruising, and the top level in the segment was

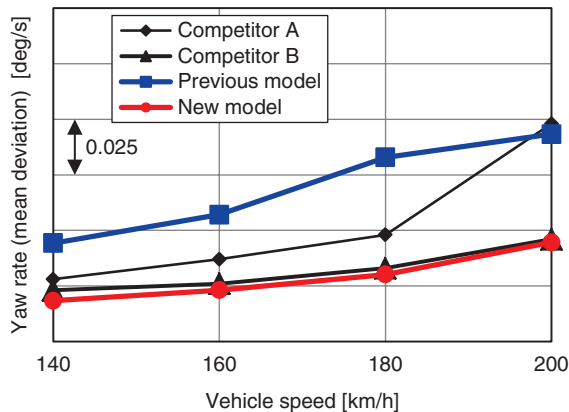


Fig. 19 High speed directional stability

achieved in terms of the in-house index (Fig. 21).

In addition, a harshness performance index was derived from the impact shock, shock sound, and damping, and the top level in the segment was achieved (Fig. 22).

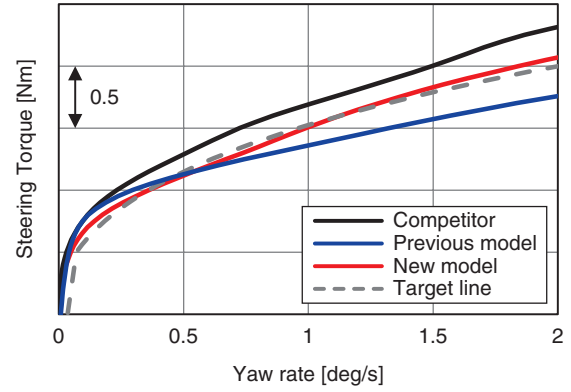


Fig. 20 Steering torque characteristics

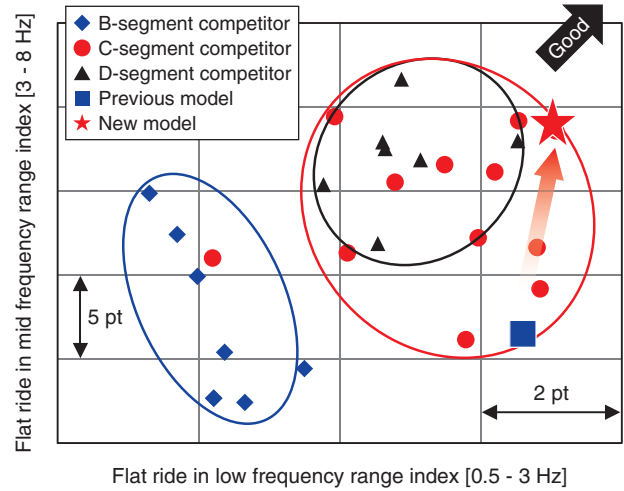


Fig. 21 Flat ride performance

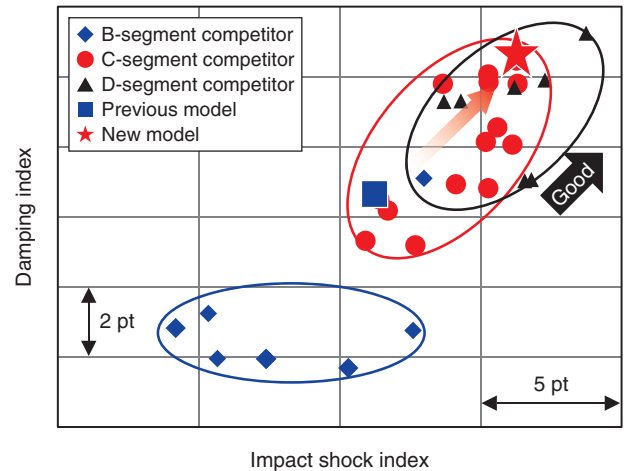


Fig. 22 Harshness performance

Linear handling performance with good response and little lag relative to steering input was expressed by the yaw rate gain and the frequency dependency of the yaw rate gain. As a result, high road-holding ability that is not dependent on the steering frequency was achieved (Fig. 23).

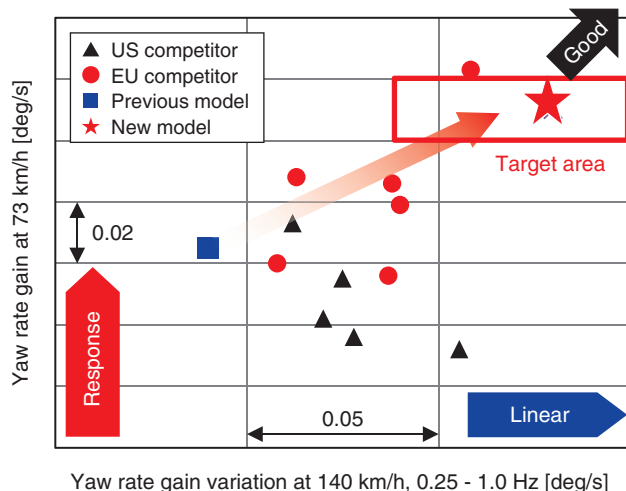


Fig. 23 Response and linearity

5. Conclusion

Technology was developed for the new CIVIC based on a new platform concept to achieve the top-level vehicle dynamic performance in the segment, including European vehicles. The achieved performance contents are as follows.

- (1) Use of a new rear suspension made it possible to separate the input force, achieve a high rear equivalent CP, and reduce the spring rate in the longitudinal and vertical directions, and together with use of a hydraulic compliance bushing enabled simultaneous achievement of both handling performance and ride comfort.
- (2) Road-holding cornering performance and flat ride performance were simultaneously achieved by reducing the friction and hysteresis of the suspension moving parts to reduce the force transferred from the road surface to the body, and by non-coupling of body roll, bounce and pitch.
- (3) Use of a dual-pinion variable gear ratio electric power steering system and increasing the system support stiffness enabled simultaneous achievement of both smooth and linear steering feel and good handling from small steering maneuvers to large steering angles and from low to high speeds.
- (4) Transfer sensitivity was reduced by the use of body bulkheads with a ring structure and by enhancing the floor stiffness, which realized both linear handling performance and good ride comfort from the start of driving to long-distance cruising.

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