

Development of the New Civic Suspension

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ABSTRACT

New front and rear suspensions have been developed for the new Civic to achieve a highly efficient package layout and good vehicle dynamic performance. The reduced front overhang of 60mm, collision safety target and linear front suspension toe curve are achieved by adopting a strut suspension with a steering gearbox that is mounted 250mm higher than the usual strut suspension. The increased rear luggage room width of 142mm and linear rear suspension toe curve are achieved by adopting an in-wheel double wishbone suspension with a lowered rear damper position. By having these suspension characteristics, the new Civic has enhanced handling and riding comfort performance over the previous Civic.

1. Introduction

Since the development of the original Honda Civic in 1972, Honda's engineers have sought to continue to develop highly efficient package layouts that embody the concept of "Maximum passenger space, minimum mechanical space," while also providing a nimble, sporty ride worthy of the Civic name. The success of these efforts can be measured by the fact that the Civic is held in high regard by customers in 140 countries around the world.

In order to advance these characteristics even further in the new seventh generation Civic, basic development work focused not only on establishing a stylish design and excellent safety and environmental performance, but also on the following two concepts:

- Smart utility:

Maximizing space and facilitating the use of that space

- Smart driving:

Ensuring excellent handling and stability, as well as a smooth ride

In order to realize these goals, new front and rear suspensions were developed that achieved the dual aims of a highly efficient package layout and outstanding handling and stability coupled with a smooth ride.

2. Development aims

Because the Civic is manufactured in at least 12 countries around the world, it has traditionally been necessary during the course of development to consider local parts procurement and the production capabilities of each of the manufacturing centers. However, during the development of these new suspensions, the following two goals, involving elements of product appeal that concern customers directly, were given priority:

- (1) The suspensions should be compact enough to achieve the highly efficient package layout that is demanded in next-generation passenger vehicles. Reducing the height of the front suspension increases the flexibility of the hood design. Furthermore, widening the lateral distance of the suspension while limiting its size in the longitudinal direction would result in a compact design that ensures enough body frame layout space to achieve collision safety performance.

Minimizing the encroachment of the rear suspension on the rear luggage compartment would maximize trunk room, while also providing space for a large-capacity fuel tank and an exhaust prechamber.

- (2) The suspensions should provide excellent handling and stability as well as the comfortable ride that is essential in a next-generation passenger vehicle.

Specifically, both the force steer and the longitudinal compliance characteristics for both the front and rear suspensions were balanced in the course of optimizing the suspension geometry and the spring/damper performance. This was done in order to achieve a degree of handling and stability as well as smoothness that goes beyond what has previously been seen in mass production vehicles.

In order to achieve these goals in the new Civic, a McPherson strut suspension was adopted for the front suspension and a double wishbone suspension was adopted for the rear suspension.

3. Structural features

3.1 Front suspension

As shown in Fig. 1, the basic structure of the front suspension is that of a McPherson strut suspension. However, the steering gearbox is now positioned about 250mm higher

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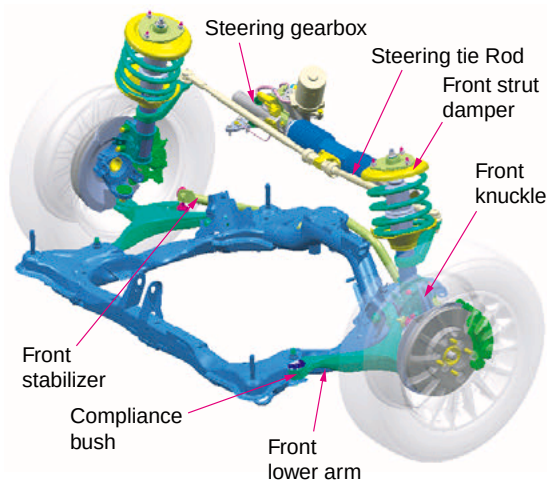


Fig. 1 Front suspension

than in the previous models, where it is roughly the same height as the normal front wheel center. This was done for the two purposes described below.

(1) Reducing the length of the nose

In the case of a typical strut suspension, because the tip of the steering tie rod must be positioned near the rearmost portion of the inside of the wheel in order to provide articulation space, the steering gearbox and the tie rod are positioned at roughly the same height as the center of the wheel.

In addition, The area of the transmission with the maximum outer diameter roughly matches this height. Therefore, if this design, wherein the transmission and the steering box are positioned in a straight line, were used in the new Civic there would be less crush space in the longitudinal direction in regard to a frontal collision. Therefore, if this design were used additional crush space would be needed in the nose of the new Civic.

However, in the case of the new Civic, in which the gearbox is positioned at a higher level, the gearbox moves into the space between the intake manifold and the transmission in the event of a front-end collision. This means that, in the event of a frontal collision, the area of the vehicle at issue can be reduced in the longitudinal direction, allowing for good collision performance. As a result, the new Civic was able to clear strict development standards for both the full frontal and frontal offset collisions, while still allowing the nose to be shortened by 60mm compared to previous Civics, as shown in Fig. 2.

In addition, because the use of struts allowed us to move the dampers farther outside than was possible with the double wishbone suspension used in earlier Civics, it was possible to extend the space between the left and right suspensions by 80mm at the height of the side frame. This, in turn, permitted greater flexibility in the cross-section design of the side frame, which also helped to reach collision performance targets.

(2) Making the toe curve linear

The linearity of the toe curve is one parameter of the suspension characteristics that is extremely important in achieving linear handling. In the case of a typical strut

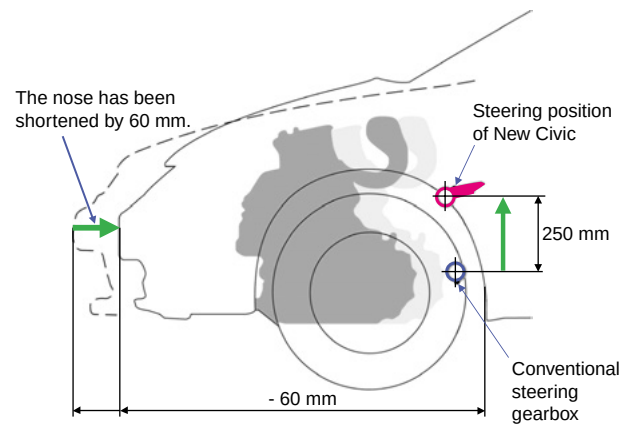


Fig. 2 Position of steering gear box

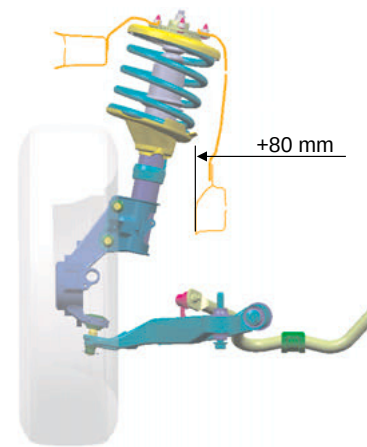


Fig. 3 Front suspension width and side frame

suspension, the ideal method for making the toe curve more linear is to place the lower arm at the same height as the steering gearbox. In a front-wheel drive vehicle, however, the presence of the drive shaft restricts the placement of the lower arm. This inevitably results in the toe change curve having a "C" shape.

The layout in the new Civic, in which the gearbox is placed in a higher position, has a center takeoff construction in which the joint on the gearbox side of the tie rod is centered on the gearbox. By extending the length of the tie rod by about 220mm, it was possible to achieve a toe curve with linearity approaching that of a double wishbone suspension within the range of normal usage (Fig. 4).

In terms of the actual construction, the tie rod arm, which is normally part of the knuckle, was welded to the center of the damper.

More leg room was created for the front seat passengers by moving the lower arm compliance bushing from its position behind the front axle in earlier Civics to a position in front of the front axle. In addition, by setting the bushing characteristics so that there are different spring rates in different directions, it was possible to optimize both the steering characteristics when lateral forces and braking forces are input, as well as the compliance characteristics in the longitudinal direction, balancing a smooth ride with handling and stability.

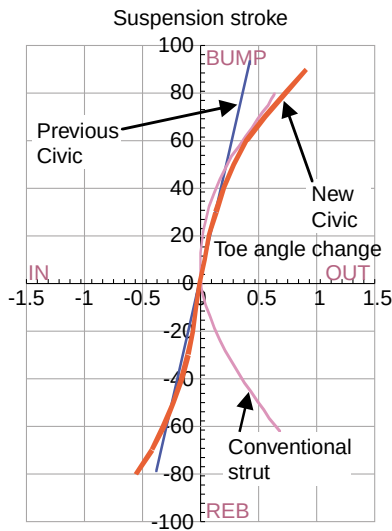


Fig. 4 Front suspension toe curve

In the front damper mount shown in Fig. 5, designing the damping force input to go through the bushing and adopting a construction that directs the spring and bump stopper input loads directly to the body resulted in increased flexibility in setting the bushing characteristics, and made it possible to optimize the bushing spring rate for the damping force input from the damper.

For the front lower arm, a welded construction of stamped components with a closed cross section was adopted in order to reduce the weight while maintaining stiffness.

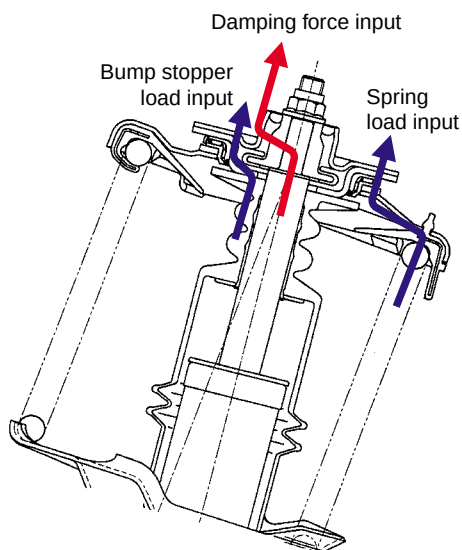


Fig. 5 Front damper mount rubber construction

3.2 Rear suspension

The last three generations of the Civic have utilized a double-wishbone suspension for enhanced handling and stability as well as a comfortable ride. The damper mounts, however, encroach on the passenger compartment, and were a drawback from the standpoint of expanding the trunk space.

In order to retain the handling and stability as well as the

ride of the earlier Civics, the double wishbone suspension is still used in the new Civic, as shown in Fig. 6. However, because it was important to minimize the extent to which the suspension components encroach on the trunk space, considerable effort was devoted to determining how to lower the suspension components and move them as far outside as possible

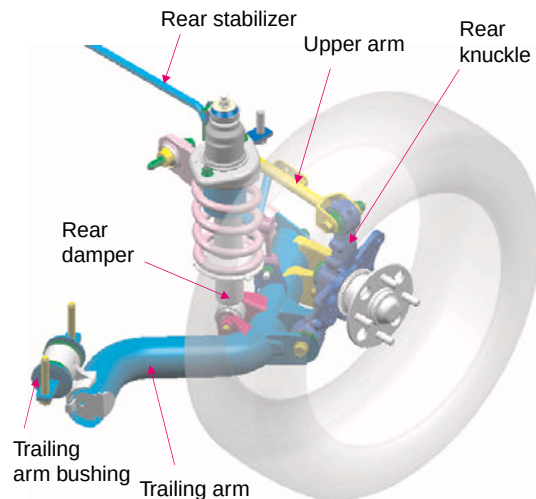


Fig. 6 Rear suspension

By using an in-wheel double-wishbone suspension, in which the upper arm, which was positioned adjacent to the tire in earlier models, is now positioned inside the wheel, it was possible to reduce the overall height of the suspension. In addition, by changing the damper mount base to a deep draw shape and lowering the surface at which it mounts on the body while keeping it roughly perpendicular to the inner face of the tire, it was possible to extend the distance between the damper mounts by 142mm when compared with earlier Civics, as shown in Fig. 7. This resulted in a 40-liter increase in trunk capacity versus earlier models, and also helped to make the trunk space a more useful shape.

The toe curve characteristic when braking force is input is a very important characteristic of a suspension in regards to maintaining stability while a vehicle is being driven. The new rear suspension is constructed so that it allows the toe

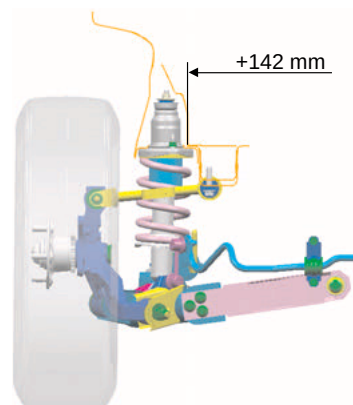


Fig. 7 Rear suspension and rear damper width

control arm to flex longitudinally. The spring rate in the direction of the articulation axis of the bushing at the end of the arm can be set to a softer level, while the characteristics in the perpendicular direction can be simultaneously set to a stiffer level. Doing so provided enough space for the compliance stroke in the longitudinal direction, and, by displacing the end of the trailing arm at an inward angle when braking force is input, also provided stability when the brakes were applied with the tires turned severely in the “toe-in” direction. These concepts are illustrated in Fig. 8.

By changing the mechanical compliance angle from 0.5 degrees to 4.4 degrees as shown in Fig. 9, it was possible to achieve a reduction in harshness, especially when the vehicle drives over a large bump.

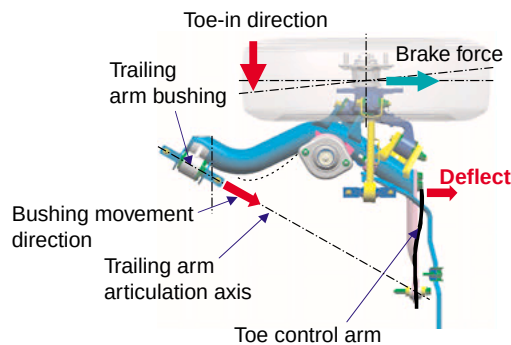


Fig. 8 Rear suspension toe curve with brake force applied

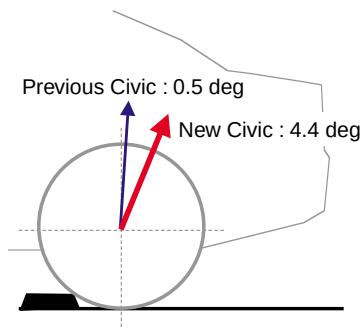


Fig. 9 Mechanical compliance angle

A straight and pipe cross section construction for the upper arm was applied in order to maintain the camber stiffness. This in combination with an optimized bushing spring rate, resulted in a more responsive rear suspension during turns.

Regarding the camber stiffness of the suspension, full consideration was given to the bushing construction (linking the knuckle and the trailing arm), the spring rate, and the articulation axis angle setting when the placement of the bushing axis was determined. As shown in Fig. 10, it was possible to achieve a linear toe curve, while at the same time enhancing the lateral force stiffness by 22% compared to earlier Civics, as shown in Fig. 11.

This construction can also be adapted to the rear suspension of a four-wheel drive vehicle simply by changing the rear knuckle. In addition, the trailing arm itself does not

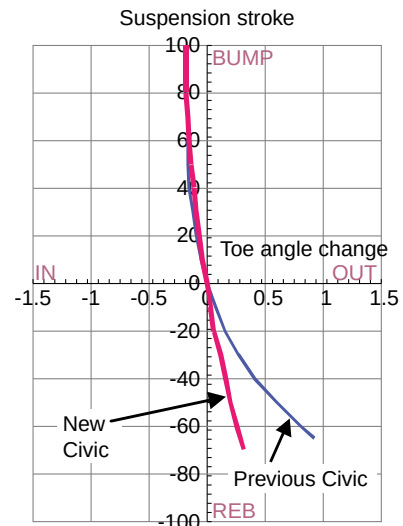


Fig. 10 Rear suspension toe curve



Fig. 11 Suspension lateral stiffness at tire contact point

have a typical press weld construction. Instead, it is constructed by bending pipes, thereby achieving a reduction in weight.

4. Achieved performance

Some representative vehicle characteristics that were achieved by adopting the suspension described in the previous sections are described below.

4.1 Handling and stability

(1) Steering feel

In previous Civics, although the steering had a high response to the initial steering input, turning the steering wheel further produced a response that was less than the initial response, resulting in not as much linearity in the feel of the steering. In the new Civic, by tuning the strut damper stiffness and the characteristics of each bushing, including the steering mount bushing, it was possible to optimize the aligning torque stiffness, resulting in a more linear relationship between the yaw rate change and the steering angle as shown in Fig. 12.

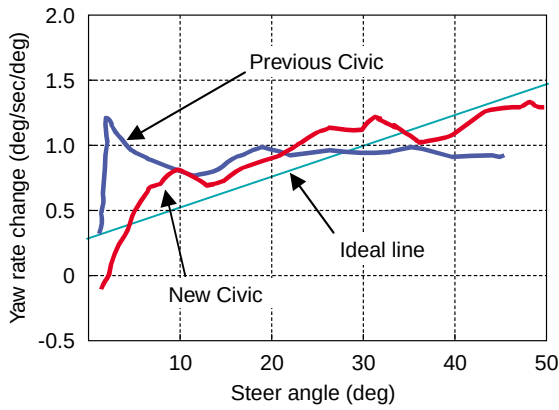


Fig. 12 Steer angle and yaw rate change

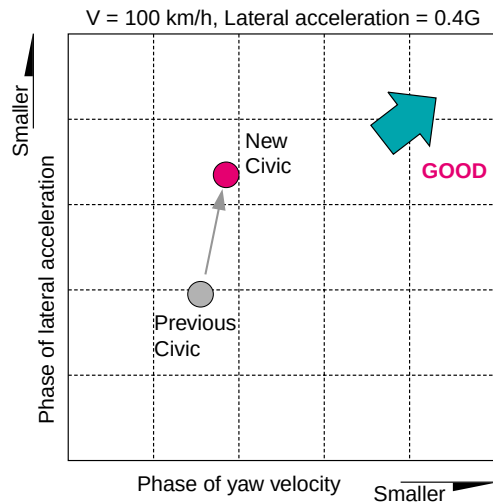


Fig. 13 Yaw rate and lateral acceleration phase

(2) Linear response characteristics

Achieving linear vehicle response requires minimizing the phase delay between the yaw rate and the lateral acceleration during steering. During the development of the new Civic suspension, it was found that by ensuring the camber stiffness of the rear suspension and by controlling the front to rear ratio of the theoretical roll arm length, it was possible to reduce the phase delay between the yaw rate and the lateral acceleration as shown in Fig. 13, and to increase the yaw natural frequency while maintaining an appropriate level of yaw gain, as shown in Fig. 14. As a result, it was possible to achieve linear response and stability during normal driving over a range of steering inputs.

(3) Turning roll axis

By controlling the theoretical roll arm length of the front and rear suspension and revising the setting of the roll center height in order to gradually reduce the pitch angle of the car body in turns as shown in Fig. 15, it was possible to hasten the onset of cornering power of the rear tires, achieving a more comfortable roll feel.

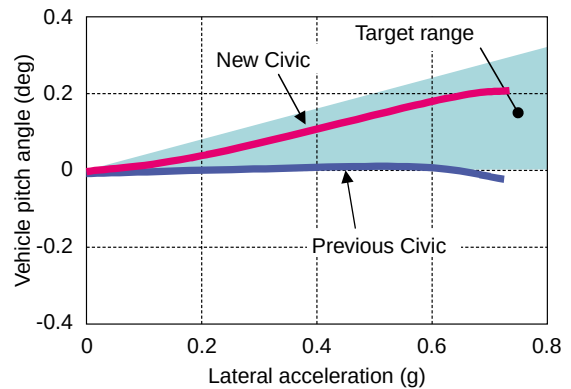


Fig. 15 Lateral acceleration and pitch angle

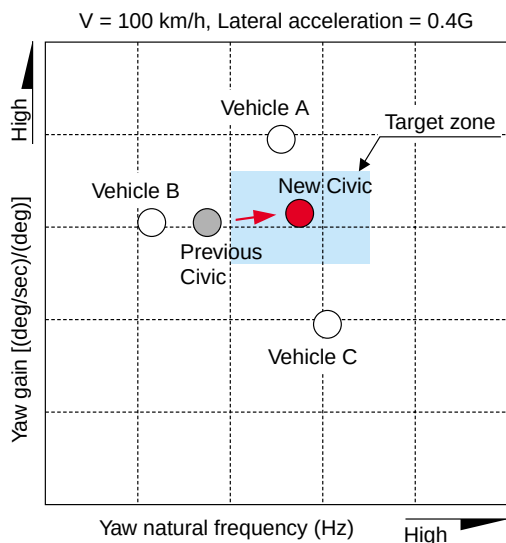


Fig. 14 Steering response

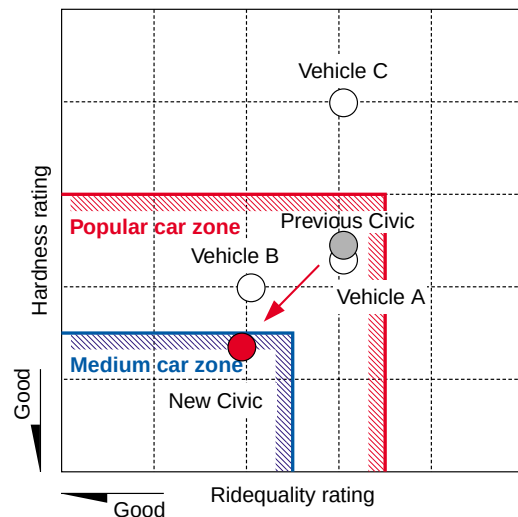


Fig. 16 Ride quality rating and hardness rating

4.2 Ride

Adding the elemental technologies described herein increased the flexibility when setting a smooth vertical movement in the suspension by increasing the margin for the handling range. In addition, by optimizing the compliance bushing spring rate characteristics and enhancing the mechanical compliance angle, it was possible to achieve a ride quality that far surpasses other cars in the same class.

Fig. 16 shows the overall ride quality on the horizontal axis, and the harshness rating (which reflects the ride quality when driving over a bump) on the vertical axis.

5. Conclusions

New front and rear suspensions that meet objectives for the new Civic package layout and vehicle performance have been developed.

By adopting a strut suspension system in the front with the position of the steering gearbox raised by approximately 250mm versus the earlier suspension, and an in-wheel double-wishbone suspension with a toe angle control function in the rear, it was possible to achieve a highly efficient package layout while also achieving outstanding vehicle performance.

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