

Development of New Model CR-Z Honda Small Hybrid Sports Car

Masahiro ISHIKAWA*
Kazuo ONODERA*

Masaharu HOSODA*
Keisuke MIYAHARA*

Jun TAKAHASHI*
Toru MATSUI*

ABSTRACT

The 2009 model year INSIGHT platform and hybrid system have been used to develop a fun car with a new generation hybrid configuration.

A sporty feeling was given by a 1.5-L Integrated Motor Assist (IMA) engine in combination with a six-speed transmission. The “Low, short, and wide” design emphasized its nature as a sport package, and its advanced sporty form was further realized by Honda’s very first light-emitting diode, daytime running light (LED DRL) headlights and other such advanced items. A sporty quality was produced in the interior by means of advanced three-dimensional gauges and smart sport seats, and a “soft feel” instrument panel and metallic film were used to enhance the quality. The handling was made agile for driving performance, and the adoption of a 3-Mode Drive System adapted to different driving situations realized a completely new feeling of acceleration and exhilarating driving performance.

The development achieved a high-level balance between driving performance and fuel efficiency. With a design that produces a sense of sportiness, an unprecedented small sporty hybrid car was created that possesses the new value of the IMA.

1. Introduction

The spread of ecological awareness due to global environmental issues, together with sharply rising gasoline prices, have lead to the intensification of worldwide demand for fuel-efficient vehicles. Meanwhile, the Honda brand has gradually been gaining name recognition in Europe over the past several years, while Honda had been waiting for a car that could serve to spur even further recognition. The proposal was therefore made to create a balance of fuel efficiency and sportiness in the kind of three-door small car that is popular in Europe. Such a new value vehicle would reinforce the company’s brand presence in Europe while also capturing the youth market and reducing the corporate average fuel consumption. At the same time, the aim was also to position this as a global car that could be marketed in North America and Japan, as well. This was how development of the CR-Z began.

2. The Concept

With the aim of creating a new appeal that would give form to originality and innovativeness and open the way

forward to a new era, the grand concept was formulated as “Advanced! Hybrid Café Racer” (Fig. 1). This would have hybrid technology as its core, and would seek to achieve a balance of Honda’s environmental stance and its sportiness, which can be considered an expression of the company’s DNA.

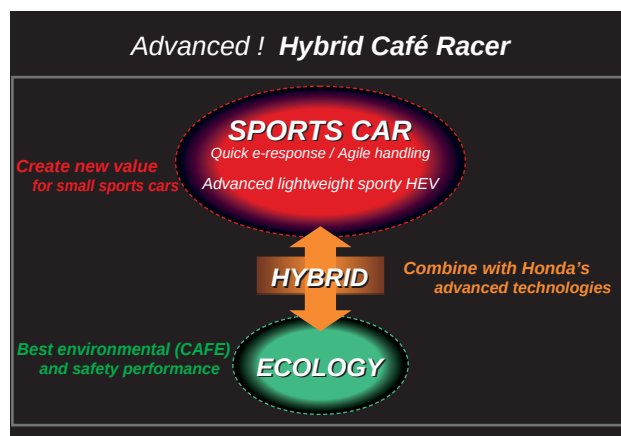


Fig. 1 Grand concept

* Automobile R&D Center

The name Café Racer originated with the Ace Café in the UK, where motorbike aficionados get together. “Café Racer” is intended to convey the desire for an urban sports car that people could boast about to their friends.

In order to create the new value of a small sports car for a new era, development was carried out with the following items identified as main topics:

- (1) Advanced sporty form
- (2) Balance of totally new acceleration and fuel efficiency
- (3) Quick and agile handling
- (4) Comfort in daily use

3. Advanced Sporty Form

3.1. Exterior Design

3.1.1. Design concept

“Advanced Sensual Bullet” was termed for the exterior design concept, which expresses the “massiveness” of highly concentrated power and the “dynamic feeling” of the chassis that thrusts up out of that massiveness. A large grill is positioned low down at the front, conveying the notion of the car’s low center of gravity. The blacked out front pillars and the highly curved front window form a clear, unified glass area that realizes advanced quality and good visibility. The deeply pared back front and rear fenders produce a dynamic feeling. The rear extra window, which forms a continuous line with the fenders, and the rear combination lights give a sense of breadth and powerful steadiness. The finished design yields a premium sports car with a stylish presence, which possesses the appeal of a sports car together with the advanced nature of a hybrid system and satisfies adult sensibilities (Fig. 2).

3.1.2. Form with low total height and short overhang

In order to realize the low total height that is a necessary condition for a sports car, there was an issue to be faced: how to satisfy the requirement for pedestrian protection performance while somehow lowering the engine hood height.

Removing the “torque up” resonator as well as altering the structure of the intake manifold and air cleaner reduced the engine height by 14 mm relative to that of the 2008 model year FIT, which was the base. The use of simulation to optimize the hood sheet thickness, optimize design surfaces and collision areas, as well as modify the connecting structure between the upper members and the damper base as shown in Fig. 3, enabled the rear edge of the hood to be lowered by 23 mm relative to the 2009 model year INSIGHT. As a result of these measures, the height of the car roof was reduced by 75 mm to 1350 mm compared to the 2009 model year INSIGHT (overall height including antenna: 1395 mm).

Optimization of the stiffener shape in the rear frame structure and the addition of cross members made the rear panel into an energy-absorbing structure. This

allowed the car to clear U.S. Federal Motor Vehicle Safety Standard (FMVSS) 301 concerning rear impacts while also making the rear overhang 225 mm shorter, with an overall length of 4080 mm, than in the 2009 model year INSIGHT (Fig. 4).



Fig. 2 Exterior design

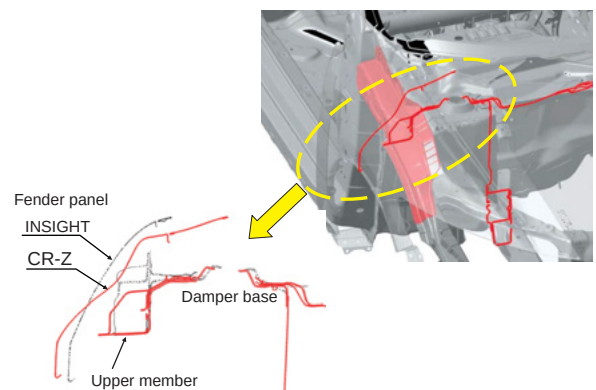


Fig. 3 Upper member

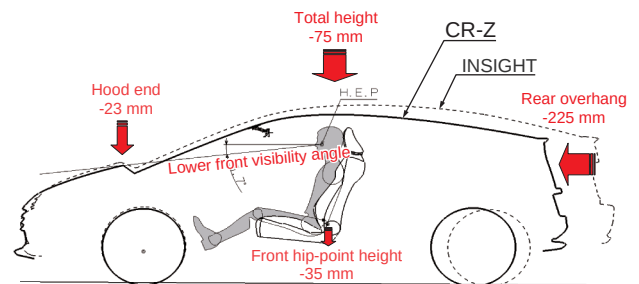


Fig. 4 Package design

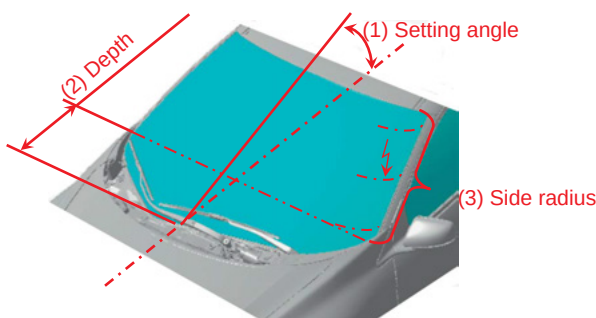
3.1.3. High curvature front window

It was necessary for the front window glass to have a high curvature in order to realize the cornering visibility and advanced form appropriate for a sports car.

When window glass is given a high curvature, distortion occurs at both ends of the glass. Moreover, the glass is set at an oblique angle, making this the most demanding shape with regard to distortion among all Honda vehicles to date (Fig. 5). Rather than gravity casting, therefore, the glass was manufactured instead using a stamping process that tends to cause less distortion to be generated. This was combined with repeated verification that the formability of the window was matched with its design conducted through molding simulations. As a result, a high curvature was achieved in the front window.

Garnish was also used on the front pillars in order to produce an impression that the front glass and side glass are unified. In order to enhance the unified impression of the front glass and the pillar garnish and to reduce wind noise, a flush surface front pillar that is integrated with the glass was adopted. This forms a water drainage channel by the combination of the edges of the glass at the ends with the front pillar garnish, and it achieves a balance of water drainage performance and wind noise reduction (Fig. 6).

Through the adoption of a high-curvature front window, good cornering visibility suitable for a sport car is obtained. Figure 7 shows front pillar visibility indices, with cornering evaluation points for visibility in a far-away direction on the vertical axis, intersection evaluation points for the scarcity of “blind spots” around the front pillar on the horizontal axis.



Model	(1) Setting angle	(2) Depth (mm)	(3) Side radius (mm)
INSIGHT	23.1°	66.3	1100 – 1600
CIVIC 2D	21.9°	60.0	1100 – 2150
ELYSION	27.0°	145.0	880 – 1140
FIT	26.0°	56.6	3000 – 4600
NSX	24.2°	176.0	800 – 1030
CR-Z	22.3°	143.4	600 – 1000

Fig. 5 Front window glass

3.1.4. Light-emitting diode daytime running lights (LED DRL)

In order to anticipate the EU DRL regulations that will be going into effect in 2012, and to enhance product appeal, a thin format, low power consuming DRL that uses white LEDs was developed. Figure 8 shows the light in an illuminated state. This high-density headlight, which incorporates a DRL function into a form factor no different from that of conventional headlights, is one major instance of the advanced design that characterizes the CR-Z.

Figure 9 shows the sectional structure of the DRL reflector. LEDs are highly directional, and taking advantage of this characteristic of LEDs, the reflector was made small. While possessing light distribution

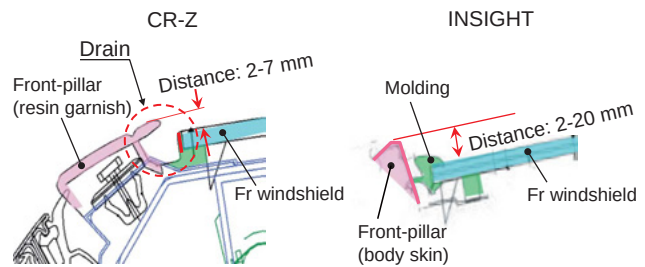


Fig. 6 Front pillar section

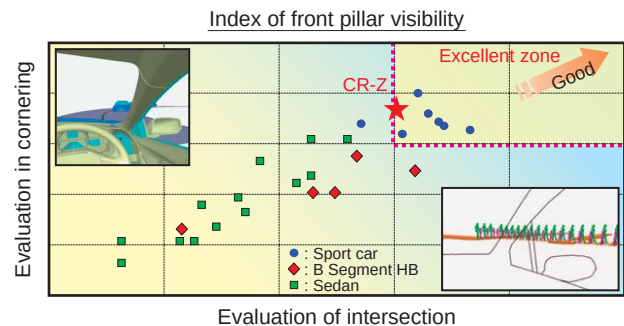


Fig. 7 Index of front pillar visibility



Fig. 8 LED DRL

performance on a par with conventional bulbs, LEDs have a greater service life, at 6000 hours, and consume approximately half the power, at 24 W.

The Japan specification uses one half of LEDs as position lamps.

3.1.5. Low profile antenna

A stylish AM/FM antenna with sufficient reception performance was developed as a decorative item on the roof in this advanced design (Fig. 10).

Conventional AM/FM micro antennas had an antenna element rod (with windings inside) approximately 180 mm in length. The rod type antenna would receive signals by resonating at one-sixteenth the wavelength l ($l/16$) in the FM band while the low profile antenna (LPA) would receive signals by resonating at approximately one-fiftieth of that ($l/50$).

When a wire wound antenna element is used as it is to resonate at a wavelength of $l/50$, the reception band will become narrower and the usefulness of the antenna will be lost. The LPA has the antenna element in a plane form to enable wideband reception. A miniature AM/FM antenna with this structure that has been made practical to use is a world first.

The antenna element of the LPA is made up of a metal element and a coil in order to broaden the reception band. In combination with a low noise high gain amplifier, with which matching is a challenge, it realizes reception performance on a par with or better than a micro antenna.

Figure 11 shows a comparison of reception performance by the LPA and the micro antenna.

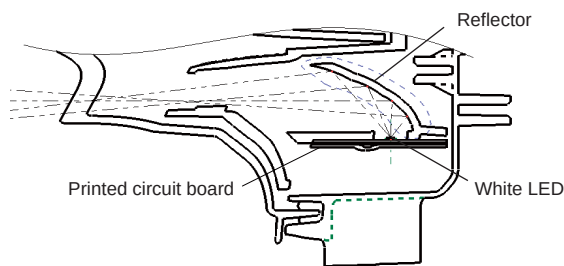


Fig. 9 Sectional structure of DRL



Fig. 10 Low profile antenna

3.2. Interior Design

3.2.1. Design concept

“Smart Cockpit” was the design concept for the interior (Fig. 12). The themes were a sporty cockpit, the kind of advanced feeling one would expect of an IMA car, and the highest level of functionality for a 2+2 package.

The instrument panel was configured with a “floating upper pad” that achieves a balance of a tight, sporty feeling and an exhilarating feel together with an “advanced and sports meter” (gauge cluster) that has a concentrated focus on the functions required when driving. The seats were made “smart sport seats” that achieve a balance of holding performance and safety functionality.

3.2.2. Sporty and high quality

A “soft feel” was adopted for the upper part of the instrument panel in order to further highlight the design and to enhance quality. This was the first “soft feel instrument panel upper” to be used by Honda. A “high shine metal film garnish” was adopted for the garnish connecting the instrument panel and the console and for the grip portion of the door lining. This was the first such garnish used in the automobile (interior) industry.

The “soft feel instrument panel upper” is fabricated by setting the already formed instrument panel in a die, injecting two types of liquid into the die, and producing a surface film of urethane by the resulting chemical reaction. Because the surface film is produced inside a die,

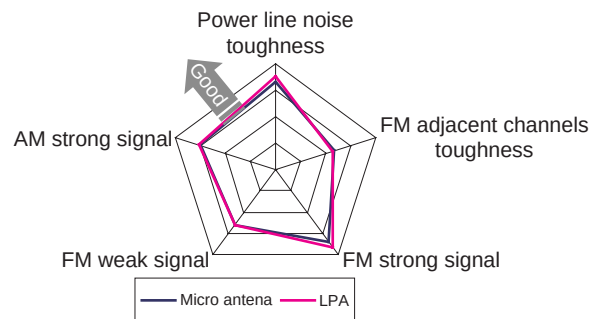


Fig. 11 Local compatibility



Fig. 12 Interior design

it has high transferability of grain and it readily allows adjustment of the gloss, thereby yielding a high-quality appearance. The surface film produced by this approach is only 1 mm thick and therefore cannot yield enough to actually feel soft to the touch, but it does convey an extremely high-quality impression.

The “high shine metal film garnish” is formed by using compressed air vacuum forming wherein the film structure shown in Fig. 13 is applied onto a base material that has been formed in advance. The first layer of the film has tin applied by deposition, after which a layer (genuine metal layer) that has had a glossy surface process applied to it is inserted. This approach yields an appearance that is on par with plating.

The film allows more freedom in design because of its high extensibility and can be applied even to deep-drawn shapes like the door grip. This film possesses a metallic gloss that cannot be reproduced through coating. On the other hand, this method also enables the film to be applied to complex shapes that cannot be formed from metal plate. Adoption of this technology therefore realized a high-quality appearance.

The “soft feel” instrument panel upper and the high shine metal film garnish enabled the creation of an interior one would not expect to find in a small car, with a level of finish typical of cars one class above it.

3.2.3. Advanced three-dimensional gauges

The gauges were created to communicate the feeling of the design concepts of “advanced” and “the future” at a single glance. There is a single round gauge with crystal accents placed in the center. The luminescence of the finely-worked dial markings with radial blue lines and the virtual image technology realized a three-dimensional view of the gauge that suggests an image from outer space. The main functions required when driving are concentrated in the central area, enabling enhanced readability (Fig. 14).

3.2.4. The smart sport seat

The front seats were developed with an emphasis on

the ability to cradle their occupants and provide solid support during sporty driving. A sporty bucket seat design was adopted and the headrest was also made a shock mitigation seat with safety functionality for the neck. In order to give the seats a unified appearance, garnish was applied to the portions connecting the headrest to the seat back.

Seat fabric that conveys the impression of being advanced was used on the main, side, and support portions (Fig. 15).

The seat’s ability to firmly cradle its occupants was realized by the following three items of technology:

- (1) The rising portions of the seat cushion and seat back were made into separate pieces and the urethane was made softer. These measures enabled the seat shape to provide support for people with smaller bodies while the shape of the seat reaching further outward from the seat could provide support for people with larger bodies. The seat is thus able to hold people regardless of their physique, so that, for example, it could eliminate the discomfort felt when steering operations cause a seated person’s body to lean in the direction opposite to the direction being steered.
- (2) Support wire was added to the side of the base seat frame to control the sideways movement of the seated person’s body during cornering.

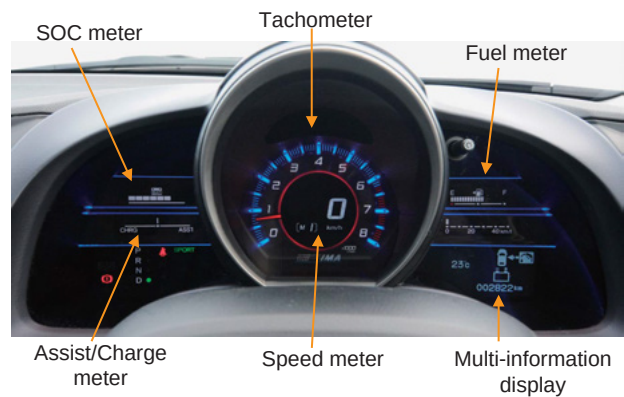


Fig. 14 Advanced 3D meter

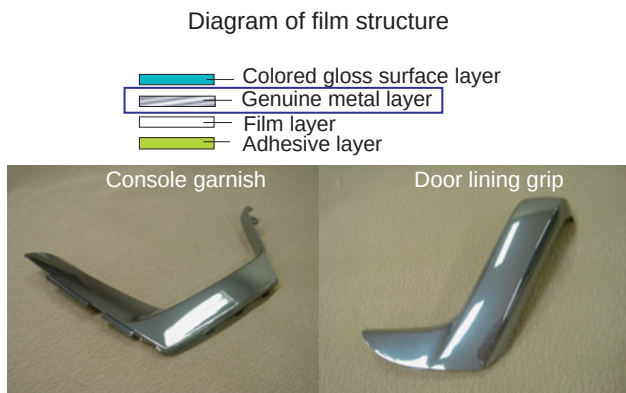


Fig. 13 Door grip and console garnish

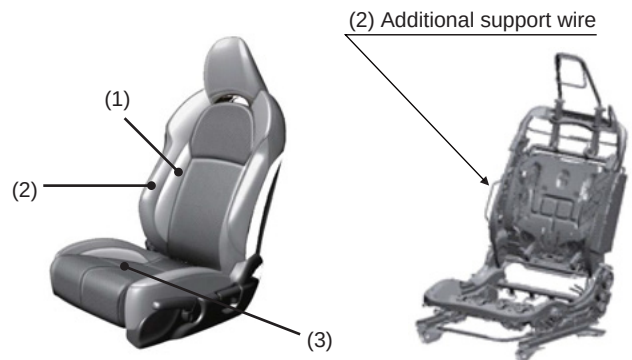


Fig. 15 Design and structure of front seat

- (3) The angle of the seat under the seated person's thighs was set so that the buttocks would be less likely to slide across the seat cushion during acceleration and deceleration. Attention was given not just to the angle but also to the coefficient of friction of the seat fabric, and fabric that would tend to keep the buttocks from shifting out of position was chosen.

The front seat was developed to achieve a high level of integration of design and functionality. The Honda team therefore feels certain that customers will be able to experience with their bodies how enjoyable it is to drive this car.

4. Balance of Totally New Acceleration and Fuel Efficiency

4.1. Power Train

4.1.1. Engine

The 1.5 L, 4-valve engine of the 2009 model year FIT was taken as the base engine, and some enhancements were made in order to mount the IMA. The engine was further modified to incorporate a variable valve timing and lift electronic control (VTEC) system with one-valve idling, which enhanced its environmental performance and brought it a California Air Resources Board (CARB) emissions rating as an Advanced Technology Partial-Credit Zero Emission Vehicle (AT-PZEV). Incorporating the IMA made up for the engine's reduced output in the high speed range due to its enhanced environmental performance, while the IMA motor also increased torque in the low speed range. As a result, the output curve became flatter with respect to engine speed, and both the power responsiveness at low to medium speeds and the ease of handling in practical use were enhanced (Fig. 16).

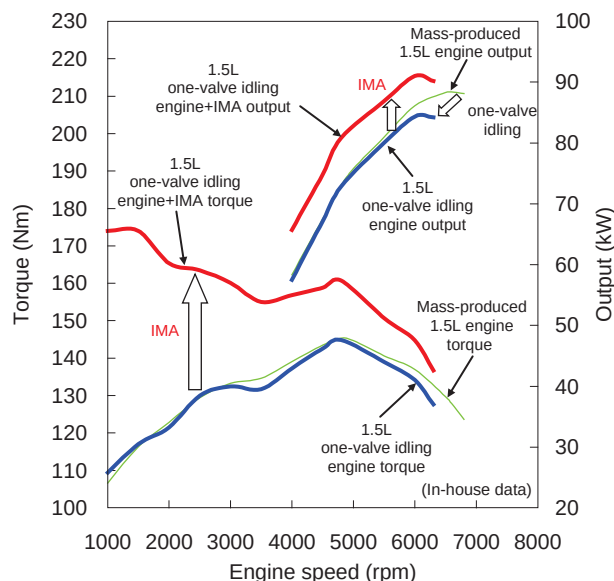


Fig. 16 Power train performance

4.1.2. Transmission

The world's first such combination of a hybrid engine and a six-speed manual transmission were developed for this car, and measures were taken to give it a sporty feel. The following changes were made to the base six-speed manual transmission in the course of transmission development:

- (1) For the purpose of incorporating the IMA, the mission case was changed, a neutral sensor switch was added, and a new clutch was developed especially for IMA use.
- (2) In order to enhance the car's sporty feel, the shift stroke was shortened (from 50 mm to 45 mm) and the operational load of shifting was reduced.
- (3) The transmission ratio was configured to pursue a balance between fuel efficiency and driving performance.

The Japanese- and American-specification cars were also configured with the same continuously variable transmission (CVT) as that of the 2009 model year INSIGHT.

4.1.3. Integrated Motor Assist (IMA)

The IMA motor, battery, and IPU (Intelligent Power Unit) were carried over from the INSIGHT specification. The cables and the intake and exhaust ducts were modified to fit the chassis shape. The combination of a 1.5-L engine, IMA, and six-speed transmission enabled the car to clear the AT-PZEV regulation values while also achieving a balance of fuel efficiency performance above the level for a car with 1.5-L displacement, and driving performance at or above the level for a car with 1.8-L displacement (Fig. 17).

4.2. 3-Mode Drive System

4.2.1. System aims

In order to allow drivers greater enjoyment of the distinctive characteristics of a hybrid sports car, the drive system was configured with three modes: SPORT, NORMAL, and ECON. In NORMAL mode, a balance of agile handling and fuel efficiency by means of smooth

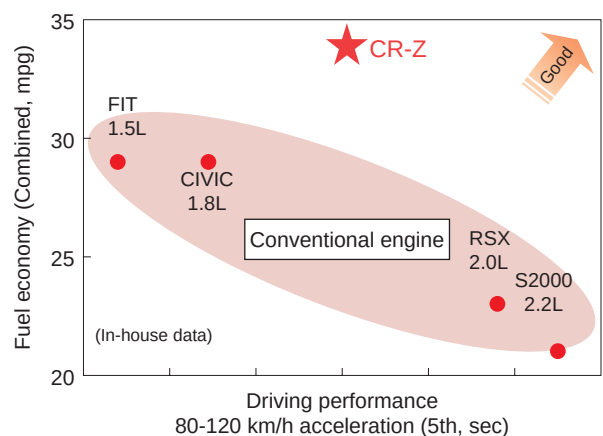


Fig. 17 Driving performance and F/E

driving is achieved at a high level. SPORT mode enables enjoyment of an exciting feeling by means of driving performance characterized by high response and power and firm handling. In ECON mode, support for ecological driving provides the vivid experience of enhanced fuel efficiency (enhanced from 5% to 10% at most). The enjoyment of working these modes to suit the driving situation was also part of the aim.

4.2.2. System configuration and settings

Figure 18 shows a conceptual image of the 3-mode system and its settings. Each mode switches to its steering effort, engine response, motor assist, and air conditioner settings. When the engine starts, the car is in NORMAL mode, and after that it can easily be switched to either of the other modes by pressing a button. The color of the ambient meter also changes with the mode. NORMAL and ECON modes are blue when the car is being driven. That changes to green when the car goes to fuel efficient driving, and it stays constantly red in SPORT mode, producing a sportier quality.

This 3-mode drive system has realized three different kinds of driving performance, something that could only be found in a hybrid vehicle.

4.3. Quick and Agile Handling

4.3.1. Chassis

The suspension was carried over from the 2009 model year INSIGHT specification. The front tread was enlarged by 20 mm. The rear tread was enlarged by 27 mm, with a change from 1° to 1.5° in the camber angle in light of tire wear performance as well as a modification to the shape of the reinforcement inside the trailing arm. Special dedicated settings were also used for the springs, damper characteristics, and high-efficiency brushless EPS characteristics, thus realizing a ride feel that achieves a high-level balance of driving stability that is sporty yet quick and highly stable with ride comfort that has flexibility (Fig. 19).

Large-diameter 195/55R16 tires, a size widely distributed on the market, were used. Tires were

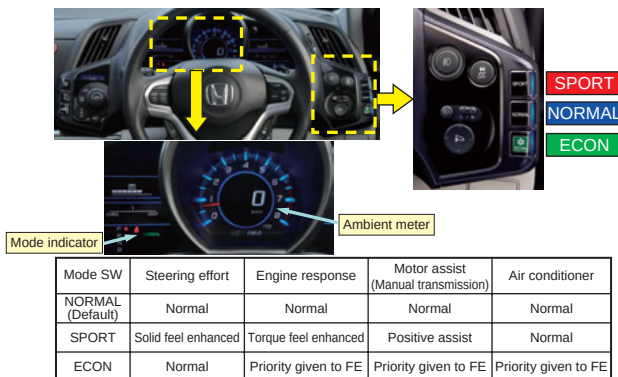


Fig. 18 3-mode drive system

developed exclusively for summer season use and all-season use. This achieved a high-level balance of driving stability that was also fuel efficient with ride comfort.

The mount system supporting the power train employed a system with three principal axes of inertia with a torque rod similar to that in the 2009 model year INSIGHT, and the mount characteristics were given special settings. These measures contributed to the enhancement of driving stability and ride comfort.

Aluminum-forged front suspension lower arms and aluminum wheels designed for lighter weight were also used. These measures contributed to a reduction in the vehicle weight and enhancement in driving stability and ride comfort.

4.3.2. Body rigidity

Driving stability performance that is quick requires high body rigidity. However, the CR-Z is a two-door hatchback coupe, which means that its design includes doors with larger openings and a tailgate opening. Consequently, gussets were added in the corner areas of the upper front bulkhead and patches were efficiently placed between the front damper and the dashboard upper

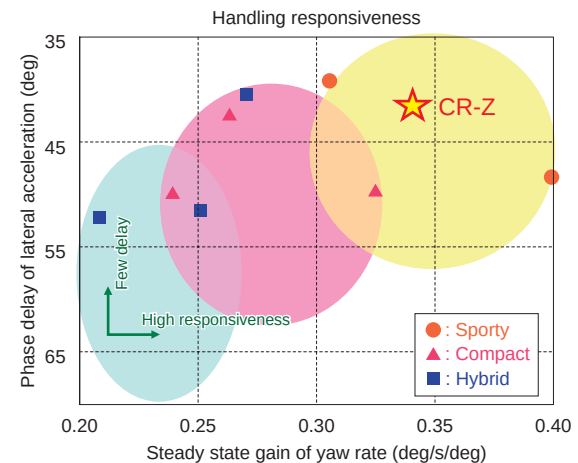


Fig. 19 Chassis dynamics

member. The structure between the center pillar and the roof rail was straightened and a closed section member was used all around the periphery of the tailgate opening. These measures were taken to increase the body rigidity (Fig. 20).

In addition, the trailing arm attachment points in the rear suspension employed H-shaped performance rods. This contributed to enhancement of driving stability performance.

4.3.3. Sporty sound

Measures were also taken with regard to the car's sound in order to underscore the development concept of the "hybrid sports car."

The results of sensory evaluation showed that mid-frequency sound during acceleration produces a sporty impression. Therefore the focus was turned to engine acceleration sounds and exhaust sounds, and this led to optimization of the characteristics of the mounts, which are parts that transfer the engine vibration. The exhaust system, which was limited as to layout because of the short overhang, was designed specially to produce a powerful impression in cars with manual transmission and a clean impression in cars with CVT.

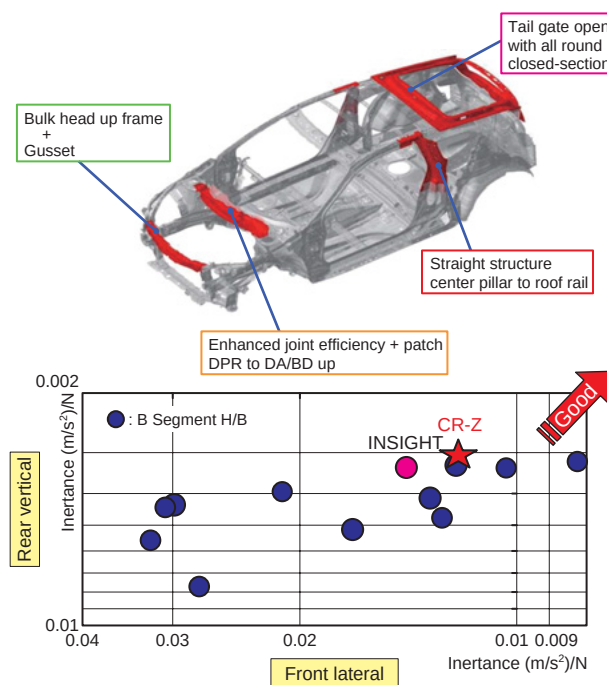


Fig. 20 Body structure and rigidity

5. Comfort in Daily Use

5.1. One-Touch Fold-Down Seats

In order to achieve a balance of sporty design that has all excess pared away and luggage space functionality for daily use, a luggage space with a simple structure was developed.

The luggage space can hold two small suitcases (655 x 480 x 255 mm) or one large suitcase (750 x 540 x 280 mm) even with the rear seats in their upright position. The luggage space accommodates an optional tonneau cover and can be used in three modes, giving it good everyday usability.

The rear seat backs form a single unit that can be folded over easily by the one-touch release of a locking knob at the center. This expands the luggage space to a flush area that is all on a single level and is spacious enough to hold two popular 9.5-inch golf bags (Fig. 21).

Cars with the instant mobility flat tire repair system (IMS) specification have a large under-floor box for storage of items that people want to have in the car but that are only infrequently used (such as the car inspection certificate, triangular emergency sign, car washing implements, and so on). Cars with the spare tire specification have a smaller storage box.

Furthermore, cars for the North America market were made in a two-seater specification without rear seats (Fig. 22). A separator and trays were installed instead of seats. The bottom of the trays are lined with carpeting material so that objects placed in the trays will not rattle. A damper is built in to reduce the noise the separator would make hitting the trays when it is folded over, and this realizes a high-quality operational feel. A central locking knob was installed to allow the same usability as in the rear seat specification.

Efforts were made to design common parts in the two-seater development by carrying out the development with efficiency. For example, the frame of the separator carried over the frame of the rear seat, and the holes for the rear seat belts were used to install lights to illuminate the trays, resulting in the common use of the side lining. These measures allowed a balanced implementation of the two different packages.



Fig. 21 Luggage space

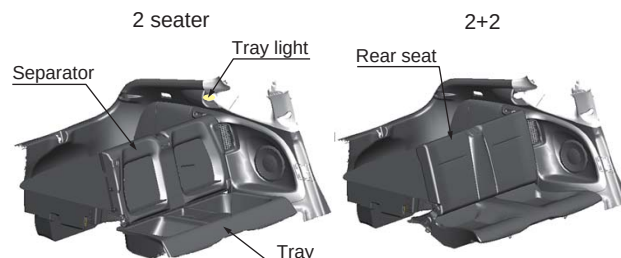


Fig. 22 Rear package

5.2. Rear Wide-Angle Camera

In order to further enhance the usability of the rear view camera, a wide-angle camera that increased view angle from conventional 130° to 180° was developed. Figure 23 shows an image from that camera.

Simply displaying a 180° image will result in extreme distortion of the kind found with fisheye lenses, making it difficult to recognize objects.

What was done, therefore, was to specify the physical size of vehicles to the rear of the car and vehicles 180° to either side that are displayed in the camera image. The view of the central area is then displayed in an image equal to that from a conventional camera, and the track of an object that is moving across the view from side to side is drawn so that it will appear as a straight line. This modification allows recognition of objects across a wide angle of view without a sense of strangeness or discomfort.

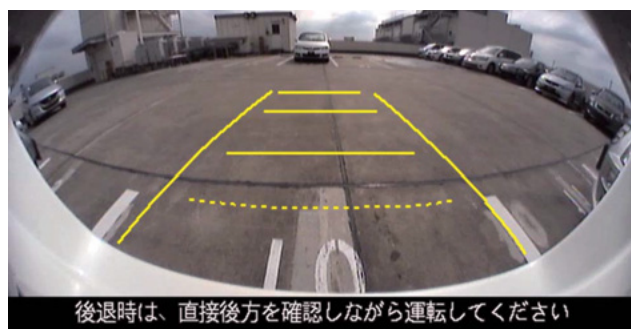


Fig. 23 Image from wide-angle camera

6. Conclusion

The CR-Z that was created in this development effort has low, sporty styling and quick, precisely maneuverable handling together with a new generation sporty sensation from a totally new acceleration based on the car's hybrid configuration, while the design also provides fuel efficiency that takes everyday usability into consideration. Therefore the CR-Z has been given new value, while offering sheer driving pleasure, as a car that can be used to suit ordinary days and extraordinary days, depending on how the driver feels at the time.

The CR-Z has been brought to a level of styling and performance sufficient to establish its own distinctive presence among them. It will have more than enough presence to give customers the joy that comes from driving a car as well as the joy that comes from owning one. The challenge was "to create new value in a small sports car," and the response of the development team is "the CR-Z." Honda is certain that this will make good sense to more and more customers.

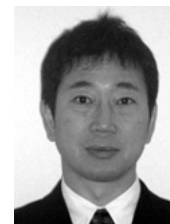
■ Author ■



Masahiro ISHIKAWA



Masaharu HOSODA



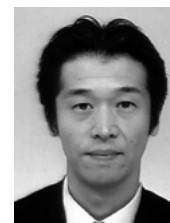
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