

Development of GLOBAL Hybrid Car Aimed at Popularization

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ABSTRACT

Amidst rising worldwide concern for the environment and the need to conserve energy, a special hybrid model, aimed at popularization, has been developed.

This model features a newly developed Ecological Drive Assist System that enhances fuel economy, an advanced exterior design that takes into account aerodynamics, an emotional interior design, and a package with greater utility achieved by a lightweight and compact hybrid system.

This hybrid car enhances fuel economy, provides refreshing everyday driving performance, and realizes a top level of safety performance, making it a car that can delight customers around the world.

1. Introduction

The world currently faces the issues of global warming and increases in oil prices, and the reduction of CO₂ in particular is an important issue. Cars with even better fuel economy and lower CO₂ emissions are therefore desirable. However, not only are electric vehicles and fuel cell vehicles still expensive, but infrastructure issues still exist for those vehicles, so the era of the hybrid car is predicted to continue for some time. This means that to reduce CO₂, it is important to make hybrid cars available at easier-to-afford prices, so more customers will be able to purchase them.

Therefore, efforts were made to develop a GLOBAL hybrid car aimed at popularization, namely the new model INSIGHT, which can contribute to the global environment by reducing CO₂ emissions.

In addition, this paper also introduces an assist system that enhances fuel economy, one that has newly been developed to enhance fuel economy as much as possible.

2. Development Concept

When establishing the development concept, the intention was to create a next-generation hybrid car that would serve as a benchmark for 10 years. With that in

mind, the grand concept was set as “Next Era Transportation (A Small Car Standard for a New Era)”.

To achieve this, development was promoted based on the following four items:

- (1) Clean and Green (Environmentally friendlier)
Good fuel economy, low exhaust emissions
- (2) Usable
Wide cabin and trunk space for a compact class vehicle
- (3) Fun
Exhilarating everyday performance, exclusive hybrid body
- (4) Affordable

3. Environmentally Friendlier Technology

3.1. Development Goals for Ecological Drive Assist System

Fuel economy is affected by traffic conditions and various driving operations by users. An assist system that can help enhance fuel economy (Ecological Drive Assist System) was developed to reduce the effects of traffic conditions and user driving operations, and to enable users to deepen their understanding about fuel-efficient driving.

3.2. System Overview

The Ecological Drive Assist System (Eco Assist) is comprised of two elements: ECON control that

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automatically controls the power train and air conditioning system with a priority on fuel economy, and a coaching system that informs users of fuel-efficient driving conditions and deepens understanding of driving that enhances fuel economy.

Figure 1 shows an overview of the hardware configuration.

- (1) ECON switch
- (2) Ambient meter
- (3) Eco guide (displayed on the multi information display)
- (4) Eco guide (displayed on the NAVI screen with Japanese specifications)

3.3. ECON Control

When the ECON switch is ON, control of the engine, motor, CVT, and air conditioning system switches to fuel economy priority mode, and the effects of traffic conditions and user driving operations on fuel economy

are reduced.

An overview of control when the ECON switch is ON is as follows.

- (1) Lowering the target value of the torque for the accelerator pedal pressing amount
- (2) Limiting the throttle valve opening
- (3) Limiting the CVT gear ratio change response
- (4) Increasing the amount of regeneration during deceleration
- (5) Saving energy consumption of the air conditioning system

3.4. Coaching System

The coaching system has a three-step configuration consisting of coaching that informs users of the fuel economy condition in real time, feedback that informs of the resulting eco-driving rate, and teaching that advises each user on points for enhancing fuel economy.

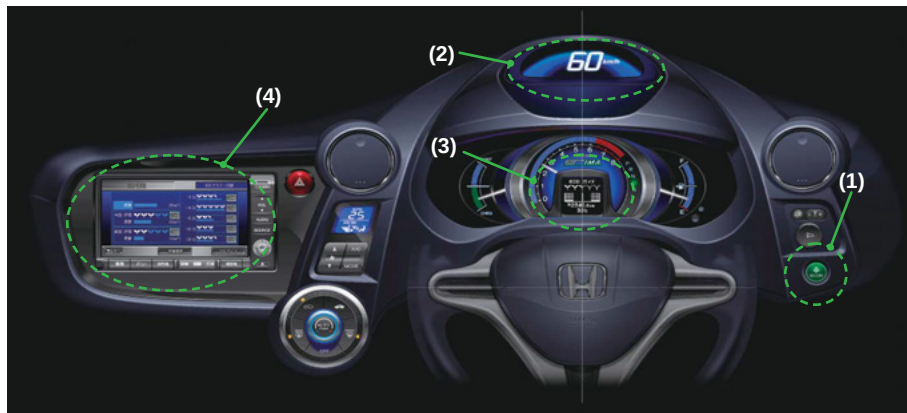


Fig. 1 Overview of ecological drive assist system

Driving condition	Coaching display	
	eco GUIDE (in multi-info. display)	Ambient meter
Efficient cruising Optimal environmental driving		
Optimal environmental deceleration		
Moderate acceleration		
Moderate deceleration		
Aggressive acceleration		
Quick deceleration		

Fig. 2 Ambient meter

(1) Coaching

This function enables users to easily understand the fuel efficiency at any given time by changing the speedometer background color (ambient meter) in three steps (blue, blue-green, green) according to the eco-driving rate of accelerator and brake operations. In addition, an eco guide display is provided as a multi information display screen, and shows the eco-driving rate of accelerator and brake operations by eco drive bar (Fig. 2).

(2) Teaching

The user's eco-driving rate is scored centering on accelerator and brake operations, and the results are displayed as the number of "leaves" using a plant leaf motif in the above-mentioned eco guide display (Fig. 3). In addition, the system works to maintain and increase

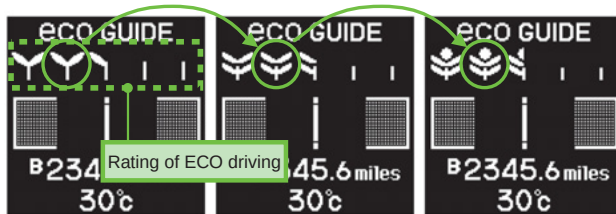


Fig. 3 ECO guide display

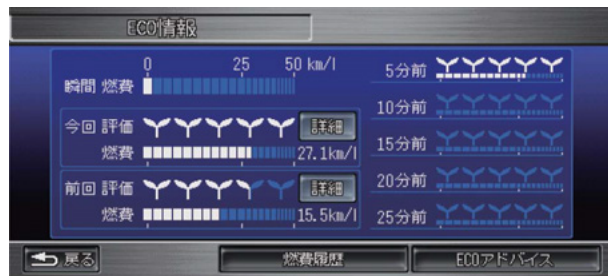


Fig. 4 NAVI display

Table 1 Mode fuel economy

Destination		Mode FE	Remarks
US	CITY	40 mpg	EPA label FE
	HWY	43 mpg	EPA label FE
EU		4.4 L/100km CO ₂ 101 g/km	
J	10 · 15	30 km/L	
	JC08	26 km/L	

motivation towards eco-driving by showing the leaves growing in three steps according to the eco-driving mastery level of the user.

(3) Teaching (Japan version only)

Detailed fuel economy information, a breakdown of the above-mentioned eco-driving rate score, and advice on driving methods that further enhance fuel economy are displayed using a NAVI screen available as a factory-installed option in order to deepen user understanding about driving that enhances fuel economy (Fig. 4).

In addition, a system was constructed that can provide similar information as the above, even to users without a NAVI screen installed, by using the link between the HDS (Honda Diagnostic System) terminal and a PC.

Various information is also provided on a web page via a link with the internavi system, such as fuel economy ranking, history of eco-driving rate mastery, and detailed advice on driving that enhances fuel economy, and the like. This creates an environment that lets users approach eco-driving while having fun.

3.5. Technology for Increasing Mode Fuel Economy

As seen in Honda's other hybrid models, this model is equipped with a simple, compact, and high efficiency IMA (Integrated Motor Assist) system, and efforts were made to enhance fuel economy compared to gasoline engine cars.

Table 1 shows the mode fuel economy for each destination.

The 1.3 L i-VTEC engine mounted in this model incorporates the following technologies for enhancing combustion and reducing both friction and knocking, while increasing standalone fuel economy performance by 2%:

(1) Combustion enhancing technologies

- Exhaust valve timing delay
- Highly ignitable double fine electrode spark plugs

These combustion enhancing technologies provided stable combustion, realized the introduction of high volume EGR (Exhaust Gas Recirculation), and reduced BSFC (Brake Specific Fuel Consumption).

(2) Friction reducing technologies

- Piston skirt MoS₂ pattern coating
- Optimized piston skirt shape

- Low-tension piston rings
- Main bearing MoS₂ shot peening
- Cylinder liner plateau honing
- Reduced cam chain width
- Reduced cam journal surface roughness
- Reduced cam journal contact area

These friction reducing technologies successfully reduced friction by 2% compared to the conventional IMA engine.

(3) Knocking reducing technologies

Compared to a conventional IMA engine, this model uses a main coolant flow circulation route that first flows in a single direction around the cylinder block, and then flows in a single direction inside the cylinder head. In addition, the heat transfer rate was increased by speeding up the coolant flow rate around the combustion chamber. These measures helped to suppress knocking compared to the conventional IMA engine.

3.6. Aerodynamics

Aerodynamic performance was enhanced to aim for an

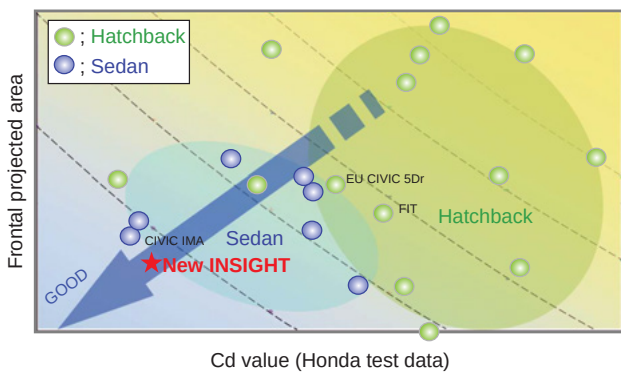


Fig. 5 Aerodynamic performance

environmentally friendlier car (good fuel economy, low exhaust emissions), and achieved an aerodynamic performance that is among the top class in the world (Fig. 5).

3.6.1. Exterior design

In keeping with the grand concept of an environmentally friendlier car (good fuel economy, low exhaust emissions), “Aero Athlete” was selected as the exterior design concept. The aim was to achieve an advanced style that organically integrates the aerodynamic performance developed through wind tunnel tests with a solid feeling sports car chassis (Fig. 6).

The front emphasizes the feeling of the hood extending outward in a single line from the cabin, and the flow from the bumper to the lower parts presents an advanced facial form unique to Honda.

The sides flow directly from hood to rear in an elegant yet strong mono-form that, together with a solid and speedy lower body, presents a sports car chassis with a powerful, solid feeling.

The rear also expresses a sports car chassis with a



Fig. 6 Exterior design concept

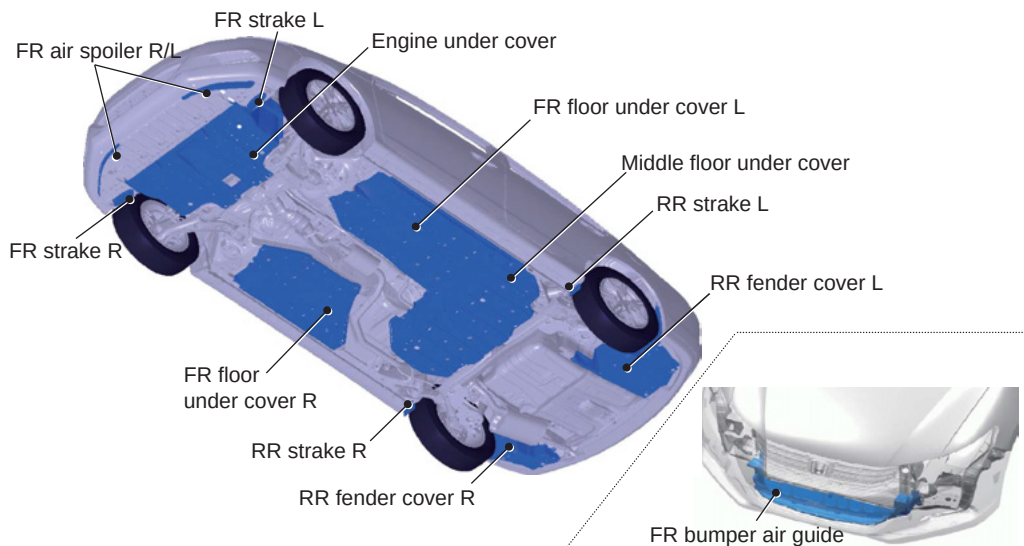


Fig. 7 Aerodynamic parts

narrowed cabin and a wide lower body, and the rear end of the cabin, door mirrors, and bumper lower edge have also been optimized through wind tunnel tests to realize high aerodynamic performance.

3.6.2. Aerodynamic devices

A front chin spoiler and front and rear strakes are used as aerodynamic devices to enhance the straightening effect of the underbody. In addition, the area from the engine room bottom to the floor, fuel tank bottom, and rear bumper is almost fully covered and flattened. Air guides are also set to enhance the straightening effect from the front bumper opening to the radiator (Fig. 7).

3.7. Air Cooling System

Dual layer AC pipes are used inside the engine room for the first time in any Honda car to enhance fuel economy. The dual layer structure uses an inner pipe with a spiral groove, and exchanging heat between the high pressure liquid and low pressure gas pipes increases the cycle efficiency by 4% (Fig. 8).

3.8. Low Emissions Technology

A high level of low emissions performance for each destination (Table 2) is realized by adopting various technologies such as a cylinder head with an integrated exhaust manifold, quick catalyst activation using a close-coupled catalytic converter, a UEGO (Universal Exhaust Gas Oxygen) sensor located in front of the close-coupled

Table 2 Mode emission

Destination		EM rating
US	KL	AT-PZEV
	KA	US BIN 3
EU		EURO 5
J		75% lower than 2005 standards

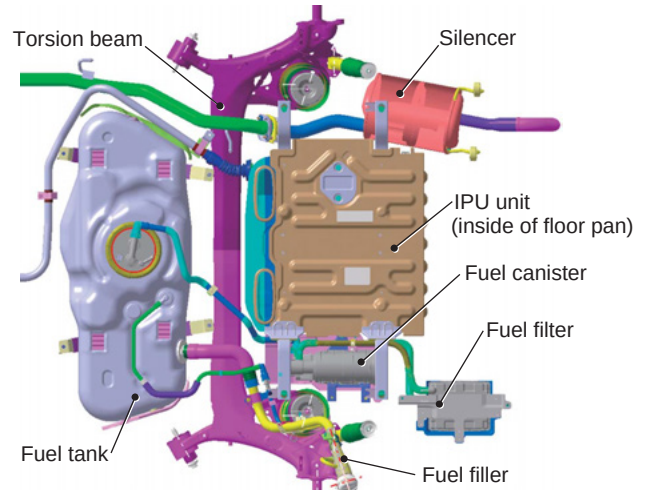


Fig. 9 Layout of fuel system

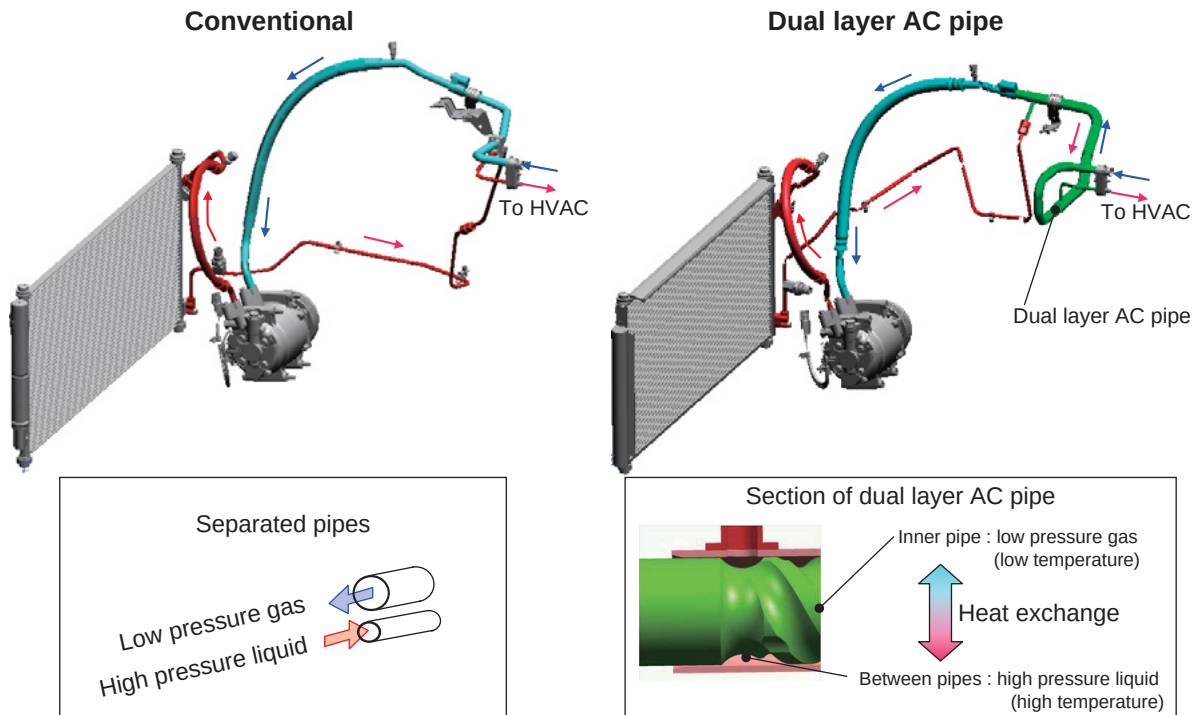


Fig. 8 Dual layer AC pipe

catalytic converter, a HEGO (Heated Exhaust Gas Oxygen) sensor located in front of the under-floor catalytic converter, precision adaptive control of the air-fuel ratio using DBW (Drive By Wire) and an AFM (Air Flow Meter).

3.9. ZERO-EVAP Fuel System

The fuel tank uses a resin tank that has a high degree of shape freedom and contributes to reducing weight. A lower overall height is realized by locating the fuel tank under the rear seat. In addition, a 40 L capacity combined with good fuel economy performance provides a cruising range that establishes the advantage of hybrid vehicles.

A large-sized fuel canister has been developed for the fuel system to meet the AT-PZEV standards in the U.S. A compact layout for the fuel tank, fuel canister, and fuel filler contributes to rear-end crash safety performance. At the same time, using a parallel layout, in which the IPU (Intelligent Power Unit) is located inside the floor pan, silencer and fuel canister under the floor, enables a flat trunk compartment. This contributes to increasing the product appeal of the trunk compartment (Fig. 9).

4. Aiming for Greater Utility

4.1. Package

The aim was to simultaneously achieve a low overall height with a reduced frontal projected area for enhanced fuel economy, and a spacious cabin interior in which adults can sit comfortably.

The platform is newly designed based on the 2008 model year FIT, and has a similar low floor structure to the FIT. However, the fuel tank location is changed from under the front seat to under the rear seat, which enables the seat position to be lowered, thereby securing sufficient headroom and providing a sporty driving position (Fig. 10).

4.2. IPU Package

The IPU is comprised of a battery and the PCU (Power Control Unit), and the overall size and weight have been

reduced by 19% and 28%, respectively, compared to the conventional unit. This enabled the IPU to be mounted under the trunk compartment floor, which achieved a hybrid car with low center of gravity and large trunk compartment equal to that of a normal passenger car.

In order to reduce the IPU size, the nickel-metal-hydride battery⁽¹⁾ performance is enhanced to secure the required output power, and the number of batteries is reduced for a smaller battery box size. The inverter and DC-DC converter of the PCU are positioned immediately next to each other, and the size is reduced so that all parts including the ECU can fit into a single case (Fig. 11).

4.3. Interior

4.3.1. Design

“Emotional Hybrid Interior” was selected as the interior concept to express an advanced feeling as “Next Era Transportation” in line with the development concepts of greater utility (Fig. 12).

The heater controls and other controls use a layout centered on the driver to increase driving pleasure.

The meters use a two-layer arrangement as seen in the 2006 model year CIVIC to present an advanced feeling,

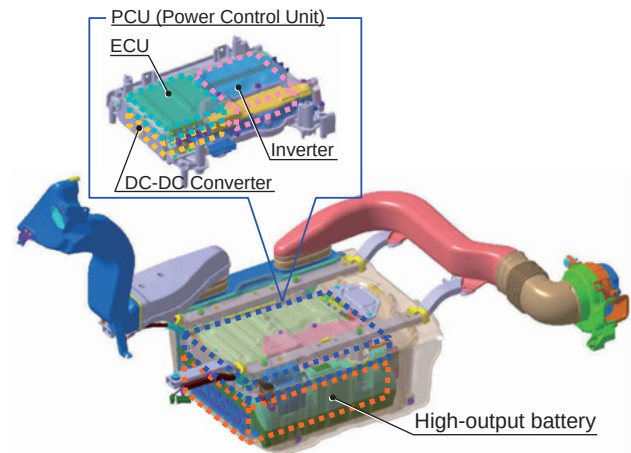


Fig. 11 Overview of IPU assy

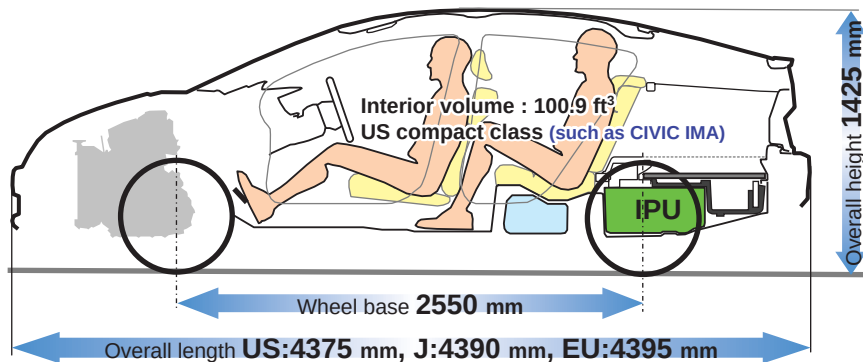


Fig. 10 Package design



Fig. 12 Interior design concept



Fig. 13 Rear seat

and visibility is enhanced by division into an area with information that is particularly important while driving (e.g., speed) and an area with other information. Cost was reduced by integrating the meter circuit board and case, which were separate in the CIVIC, into a single unit.

The instrument panel has a converse round shape with the center bulging outward towards the driver. This provides an expansive and refreshing feeling in addition to an advanced feeling.

The interior uses a bright and clean two-tone color scheme in the image of the environment.

4.3.2. Seats

The front seat shape and use of different hardness pads gives high holding performance, and a combination of stretchable covering and highly flexible seat surface due to deeper surface anchor positions provides softer seating comfort.

The rear seat can be folded down to create a flat and gap-free floor with the trunk compartment. In addition, the embedded headrests and built-in center 3-point seatbelts help maximize rearward visibility (Fig. 13).

4.3.3. Trunk compartment

To further emphasize the development concept of a “useful” wide trunk compartment, versatility is added to the instant mobility flat tire repair system (IMS) specifications. The trunk floor can be moved up and down in two levels to expand the height, as was favorably received in the European CIVIC. In addition, a box with lid is added and other measures are taken to help prevent small items from rolling around (Fig. 14).

For specifications with a spare tire, the under-floor storage is used as a storage space for small items (Fig. 15).

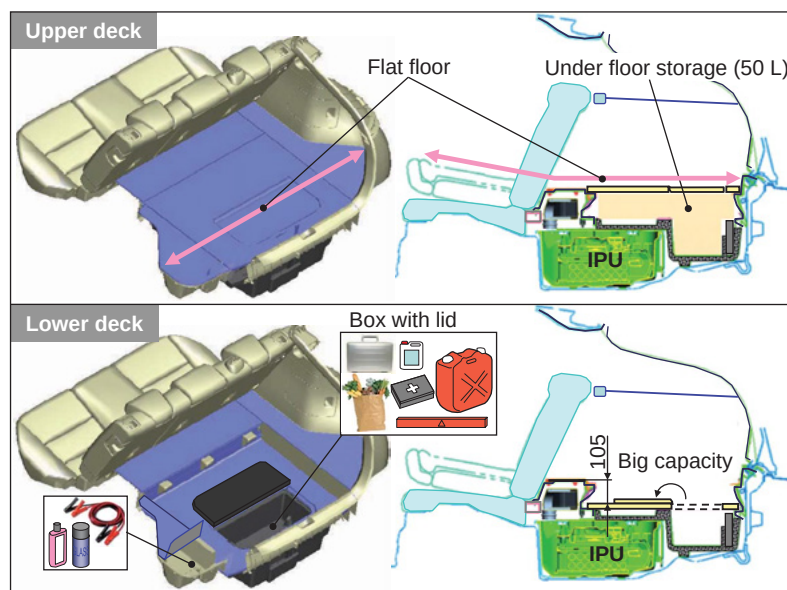


Fig. 14 Trunk with IMS

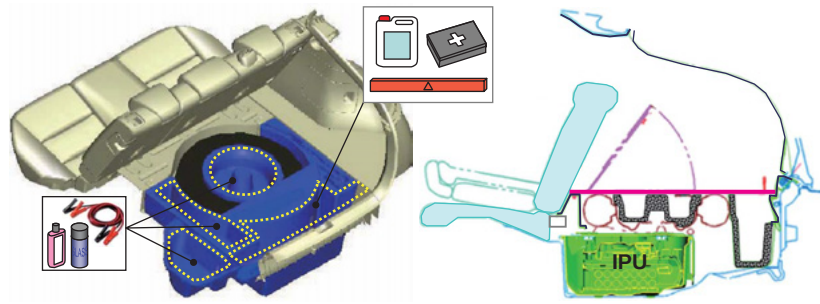


Fig. 15 Trunk with spare tire

5. Fun

5.1. Power Train Drivability

The power train of this model utilizes the high response that is a feature of the IMA system and the direct feeling of the starting clutch type CVT. In addition, the starting clutch contact timing control has been refined by collaboration between the engine, the IMA motor, and the CVT, thus realizing both fuel economy and brisk acceleration performance.

5.2. Chassis

5.2.1. Riding comfort

The front suspension uses a strut type, and the rear suspension uses an H-shaped torsion beam type. Stabilizers are used for both the front and rear suspension. The spring and damper characteristics use special settings, and the steering uses a high efficiency EPS and special settings. This achieved an organic balance between nimble and highly stable handling, smooth riding comfort, and a refreshing steering feel, and realized a pleasantly exhilarating riding feel in everyday driving.

The mount system that supports the power train uses the 3-point principal axis of inertial method with torque rods. Special engine mount and torque rod characteristics are set to optimize the mounting balance due to the use of the IMA system. In particular, a fluid sealing type trans-mount has been developed, which contributes to enhanced riding comfort.

5.2.2. Brakes

The brakes use negative pressure type boosters, and the pedal stroke and pressing force are optimized, realizing a pleasant and linear braking feel. As for the CAS (Creep Aid System), instead of a conventional separate CAS unit, software is added to the VSA unit to provide CAS functions, which reduces cost and weight (Fig. 16).

5.3. Body

5.3.1. Body rigidity

Body rigidity is an important factor that supports fun driving. Simulations were used to increase connection rigidity, which realized a lightweight and highly rigid

structure. Regarding the large cross section tailgate opening, the rear panel is enlarged and connected to the frame end to achieve a big tailgate opening design with good torsional rigidity. Regarding the rear damper mounts, the rear pillar damper stiffener and rear end gusset sizes are increased, which increases the connection efficiency of the opening cross section and the rear frame. In addition, regarding the rear compliance bush mounts, V-shape braces are applied to achieve both higher lateral rigidity of the compliance bush mounting points and the fuel tank layout (Fig. 17). Only the main items are noted

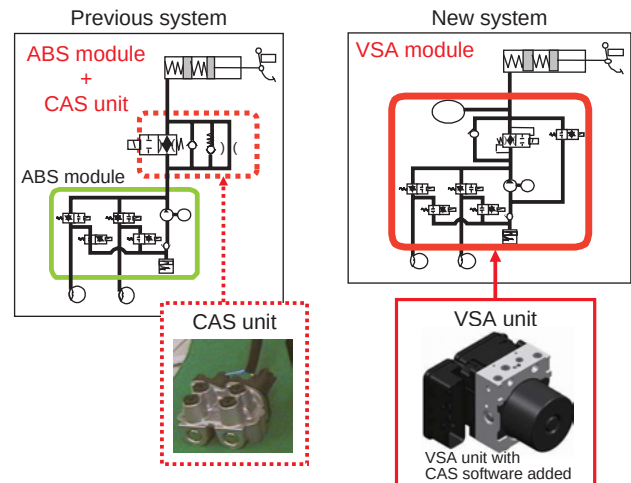


Fig. 16 CAS system

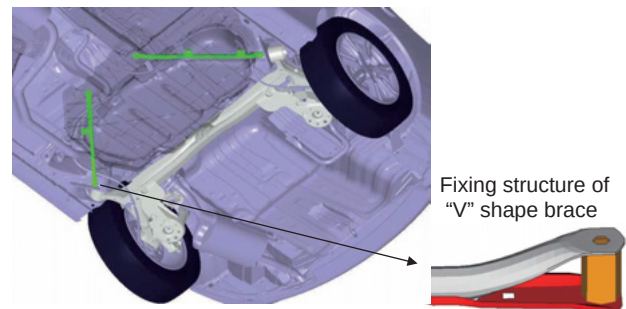


Fig. 17 Reinforcement of rear compliance

above, but as the result of these and other measures, the rigidity of the body mounting points shown in Fig. 18 is realized.

5.3.2. Sound insulation and IR cut

The combination of sound insulation and IR (Infrared Rays) cut glass is used for the first time in the world in a compact car (Fig. 19). Sound insulation and heat shielding functions are added to the intermediate film of the front windshield laminated glass. Thus, sound insulation effects of approximately -3.0 dB for high frequency sound of 1 kHz or higher are obtained. In addition, heat shielding effects equivalent to an increase in fuel economy of approximately 0.3 km/L (10-15 mode driving, outside air temperature 40°C, solar radiation

conditions 930 W/m²) when using the air conditioning during the daytime are obtained.

5.3.3. Lightweight soundproof package

Car body quietness is enhanced and weight is reduced by reviewing the layered structure of the conventional sound insulation materials, and by applying materials with good sound absorption performance. In addition, sound penetration is reduced by adding separators containing foamed filler to the base of each pillar on the bottom of the car body (Fig. 20).

5.3.4. Crash safety performance

Crash safety performance that is among the highest in its class is achieved for a frontal offset deformable barrier crash at 64 km/h, frontal flat barrier crash at 55 km/h, and side crash at 55 km/h with respect to the New Car Assessment Program (NCAP) of each country, including Japan's J-NCAP.

A compatibility support body⁽²⁾ is used for the front of the car to help reduce vertical or lateral misalignment of vehicle structures in a car-to-car crash.

To help protect the fuel system and IPU in a rear-end

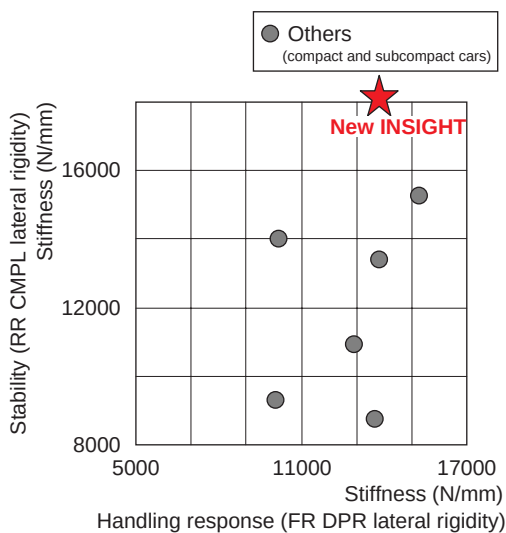


Fig. 18 Body rigidity for rear suspension

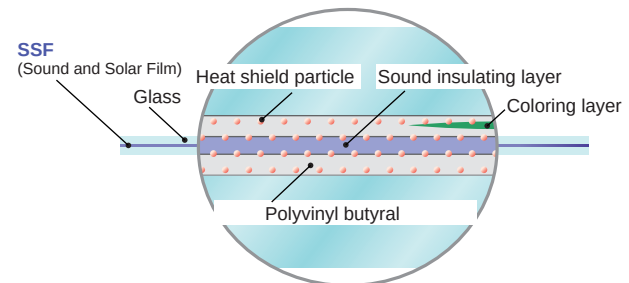


Fig. 19 Sound insulation and IR cut glass

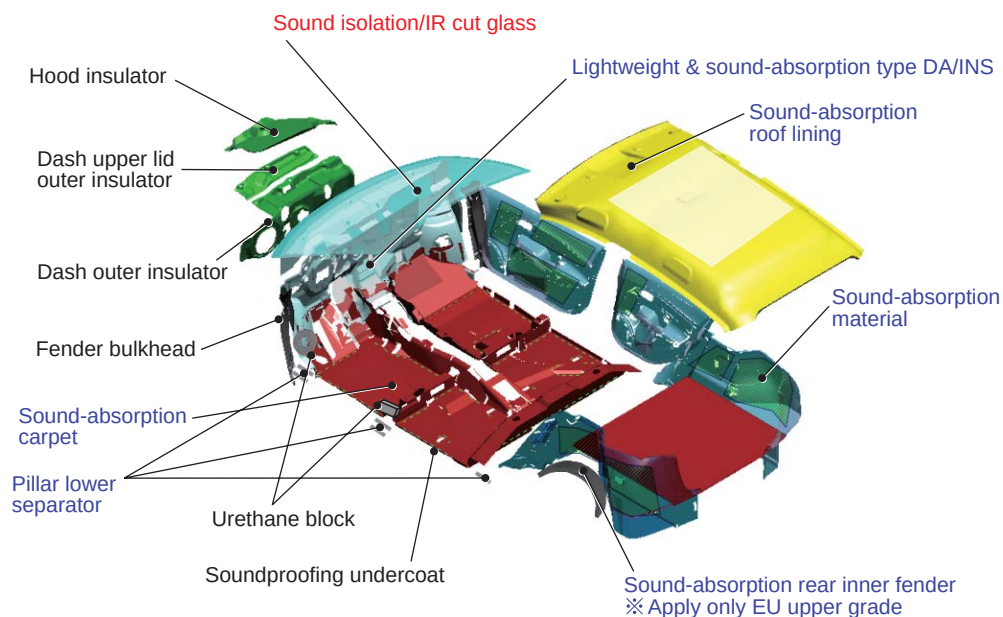


Fig. 20 Sound insulation materials

crash measures are taken to create a structure that can efficiently absorb the crash energy with a short crash stroke, including employing a rear frame with large cross section and adding a rigid cross section structure to the rear panel.

In addition, the front seats are equipped with active head restraints as a standard feature. This helps reduce the backward motion of the head in a rear-end crash, which mitigates the impact to the neck.

6. Affordable

6.1. Hybrid System

6.1.1. Technologies for reducing the IPU cost

In addition to the above-mentioned technologies for reducing the IPU size, the IPU cost has been reduced by measures such as using beam lead bonding for the inverter power module, reducing the number of fuses by optimizing the protective structure of the DC-DC converter circuit, and integrating the high voltage cable and DC-DC converter output cable wiring. This has achieved a cost reduction of approximately 42% compared to the conventional model.

6.1.2. Thin type motor

The motor uses the same basic structure as the conventional IMA motor, but the thickness and weight of the magnet parts have been reduced by 22% and 15%, respectively, by optimizing the output power relative to the vehicle weight. In addition to streamlining the manufacturing process, this has achieved a cost reduction of approximately 35% compared to the conventional model.

6.2. Chassis Commonality

The full use is made of the chassis platform of the 2008 model year FIT, which is well received by the market, and efforts have been made to promote commonality. However, in this new hybrid vehicle the fuel tank and exhaust system use different designs to realize a low overall height (Fig. 21).

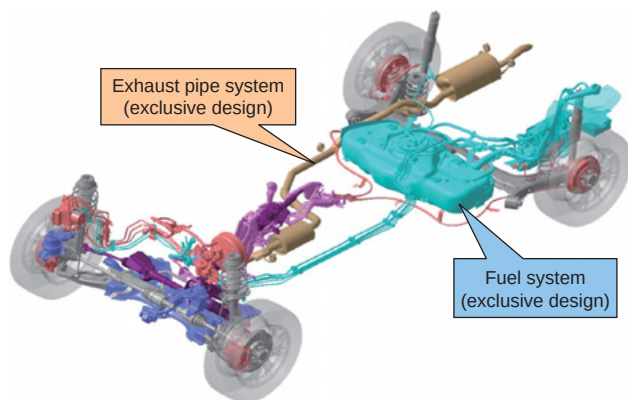


Fig. 21 Chassis platform

7. Conclusion

The first generation INSIGHT was the pioneer vehicle for hybrid technology in Europe and North America. Its naming included the meaning of a car that announced the arrival of a new era. As such, this new model was also named “INSIGHT” as the successor to that first generation INSIGHT.

The concept for the new INSIGHT is that of a popularization type that is easily affordable and will be driven by even more customers. Therefore, the name includes the meaning of a car that announces the arrival of the new era of the full-scale popularization of hybrid cars.

The authors are confident that this “GLOBAL Hybrid Car aimed at Popularization” will be driven by even more customers than previous Hybrid models.

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