

Development of New Intelligent Tourer

2004 Model INSPIRE

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ABSTRACT

The new model, INSPIRE was developed based on the concept of a “New Intelligent Tourer.” The aim was to produce a new luxury sedan offering users a high degree of satisfaction through the achievement of superior luxury sedan performance while maximizing the advances and sportiness for which Honda is known.

The vehicle’s refined design gives it a tremendous sense of presence, individuality and quality, and a superbly quiet ride. Numerous new technologies are employed to fully realize the “New Intelligent Tourer” development concept.

The following give the INSPIRE a level of advancement and sportiness that is Honda-unique: (1) a balance between incredible driving performance and high fuel economy offered by the V6 3.0L i-VTEC variable cylinder system engine; (2) a body and suspension designed for a superbly comfortable ride belying the power of the vehicle; and (3) the employment of HiDS to offer stress-free high-speed cruising and an advanced safety support system that includes collision mitigation braking (a world first) and E-pretensioners.

The new luxury sedan is aptly named “INSPIRE,” offering as it does a level of driving appeal that competitors’ vehicles cannot match.

1. Introduction

Since the first-generation INSPIRE went on the market in 1989, it was well received as a Honda specialty - the four-door model. The vehicle evolved through similarly well-received second- and third-generation models. However, in recent years the market for sedans in Japan shrank and the severe decline in sales of high-class small sedans like the INSPIRE continues.

In the development of the fourth-generation INSPIRE,

the target was to achieve the level of advancement and sportiness worthy of the Honda name, with the sense of quality offered by a luxury four-door sedan. These goals were to be realized in a user-centered package. Target users covered a broad range: intellectually curious individuals from ages 30 to 60 who retain a feeling of being “young at heart.” The concept for this vehicle is established based on repeated group interviews and dealer surveys primarily focused on exactly what type of sedan the target users desire.

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2. Concept and Development Targets

Characteristics of the ways in which target users employ their vehicles were clarified through numerous user surveys. It was discovered that they frequently covered medium to long distances on the highways not only in their daily lives but also in their business activities. Knowing this enabled the fixing of a concept for the new INSPIRE that offers an overwhelming appeal to consumers - the “New Intelligent Tourer,” which employs the most advanced technology and which displays performance at the top of its class in city driving and ahead of its class on the highway.

The following three targets were set to realize the design concept:

- (1) Achievement of top-class basic performance
 - Design offering a sense of presence and classiness
 - Clean, precise lines for a high-quality feeling
 - Top-class smoothness of ride and quietness for a high-class sedan
 - Highest standard of collision safety performance in its class
- (2) Achievement of a level of advancement worthy of the Honda name

The target for the engine was a fuel economy of 11.6 km/l, equivalent to that of a 2.5L direct-injection engine, and the achieving of a Japanese three-star Ultra-Low Emission Vehicle certification, to comply with “Green Tax” regulations. A cylinder on demand system would be employed to achieve this. An additional target was the achievement of NV performance equivalent to that displayed by a standard V6 vehicle, through the use of active NV control technology.

To help provide safe and comfortable cruising, a collision mitigation system (CMS) and E-pretensioners were developed and employed. These are part of an advanced safety support system to help prevent or reduce the effects of rear-end collisions.

- (3) The target for engine power was set at 250 ps to achieve the sportiness worthy of a Honda vehicle.

High standards, beyond those normally associated with a high-class sedan, were set to achieve a smoothness of ride belying the power of the vehicle and a stability of steering and high-speed performance.

3. Design

3.1. Package

The Accord model marketed in North America was used as the base vehicle in designing the packaging of the new INSPIRE. 3D moving outlines of test subjects entering and exiting the vehicle were analyzed. This resulted in a number of changes (including increases to the angle of the front pillar and the size of the rear door opening around the rear pillar) to give the vehicle a greater feeling of spaciousness and to increase the ease with which users can get in and out. The rear window has been pulled towards the back and the roof lengthened to style a long, spacious cabin. This also is a benefit because it reduces the amount of direct sunlight shining on passengers in the rear seat. By not merely changing the dimensions but also increasing the quality of the cabin space in this way, the designers succeeded in creating a welcoming space that is both classier and easier to use, and that is compatible with a dynamic and powerful exterior design.

3.2. Styling

The exterior design of the new INSPIRE is also based on the North American Accord, and centered around a “Classy and Aggressive” design concept (Figs. 1 and 2). The front of the vehicle, with an advanced milli wave radar unit built in, sweeps back from the Honda logo to the hood, emphasizing the sense of V6 power. From the side the spacious long cabin and sporty high deck styling are visible. At the rear, crystalline high-mounted lights and integrated dual exhaust finishers contribute to the aerodynamics of the vehicle, and are suggestive of speed with style. Every part of the vehicle brings classiness and aggressiveness together in a superb balance. As a result, the vehicle not only possesses the sense of quality and refinement expected of a sedan in its class, but its individual styling gives it a presence that makes it stand out among other sedans.



Fig. 1 Exterior styling image



Fig. 2 Exterior styling



Fig. 3 Interior image

To design the interior of the new INSPIRE, the interior design of the US Accord was revamped based on a concept of “Clean and Emotional” styling (Fig. 3). The instrument panel and the door linings form a smooth curve in a wrap-around interior accented with metal ornamentation. This gives the sense of being surrounded by personal space and the luxury distinctive to sedans. The features designed to give the cabin as a whole a clean and emotional atmosphere include the minimization of the lines of the door linings, and the use of luminous meters and blue illumination.

4. Engine

4.1. Engine Development Goals

The concept for the power plant of the new INSPIRE is the achieving of a level of fuel economy and environmental performance that is beyond the vehicle's class. To achieve this, the engine employed in the US Accord was used as a base. A cylinder on demand system (cylinder stop mechanism)⁽¹⁾ was added, and the following basic performance targets, difficult to achieve in a direct-injection engine, were established:

- (1) Equivalent fuel economy performance to competitors' direct-injection engines (2000 regulation values +10%)
- (2) Low emissions (Achievement of ULEV certification)
- (3) Top-class running performance



Fig. 4 View of V6 i-VTEC Engine

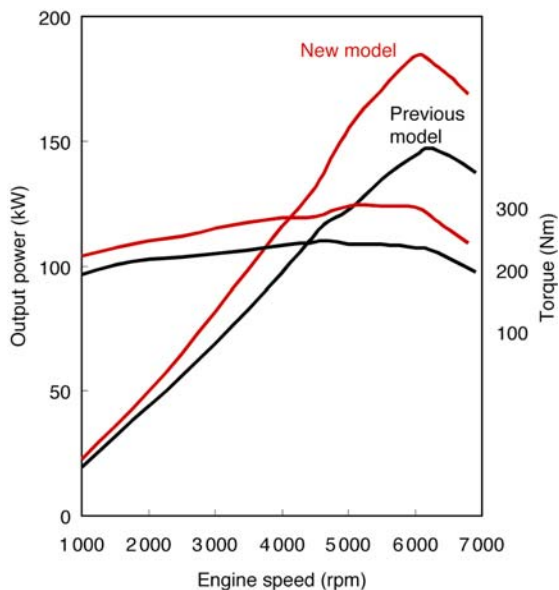


Fig. 5 Output performance

Table 1 Main engine specifications

	Previous model	New model
Engine type	60°V-6 SOHC VTEC	60°V-6 SOHC i-VTEC
Displacement	2495cc	2997cc
Compression ratio	10.5	10.5
Fuel	Premium	Regular
Max.power (kw/rpm)	147/6200	184/6000
Max.torque (N·m/rpm)	240/5000	296/5000
Transmission	5AT	5AT
Fuel economy (10-15 Mode)	10.2	11.6
Emissions level	J-LEV ★★	J-ULEV ★★★

4.2. Overview of Engine and Main Specifications

Figure 4 shows a view of the V6 i-VTEC engine employed in the new INSPIRE. Figure 5 shows the power characteristic of the engine, and Table 1 provides the main specifications.

In this engine, excellent dynamic performance has been balanced with fuel economy through the employment of a mechanism to stop the operation of the intake or exhaust valves of one bank (rear bank) of three cylinders as required. This enables the actual volume of exhaust to be varied.

4.3. Increasing Fuel Economy

In attempting to increase fuel economy, individual targets as shown in Fig. 6, were set for the contributions to be realized by engine, AT and body technologies. As a result, while the displacement of the engine has been increased to 3.0L, it displays a 14% improvement in fuel economy over the 2.5L engine employed in the previous INSPIRE 25V model, recording a fuel consumption of 11.6 km/l in Japanese 10-15 mode. The fuel economy of the improved engine equals that of a 2.5L direct-injection engine.

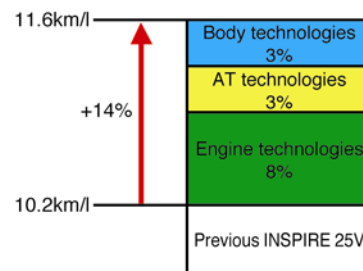


Fig. 6 Ratio of contribution to improvement of 10-15 mode fuel economy

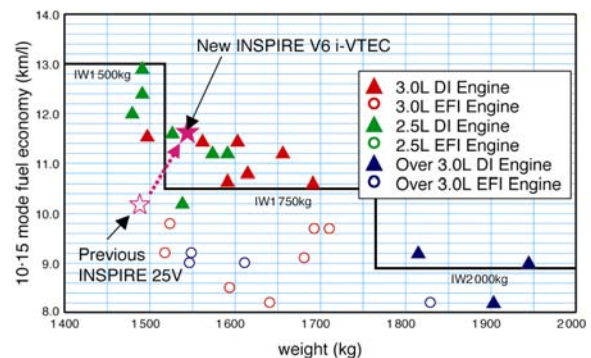


Fig. 7 10-15 mode fuel economy

4.4. Environmental Performance

Figure 8 shows a diagram of the system employed to reduce emissions in the new engine. The system enables independent reduction of exhaust gases in both banks of the V6 i-VTEC engine.

The employment of highly-accurate A/F ratio control in combination with the emission control system has enabled the achievement of a high level of environmental performance in the engine. As Fig. 9 shows, the system has recorded a low fuel consumption figure of 11.6 km/l in Japanese 10-15 mode. It complies with the Japanese three-star Ultra-Low Emissions standards. And, it has emissions figures that are only 25% of those stipulated in 2005 domestic standards, giving it a Japanese four-star rating.

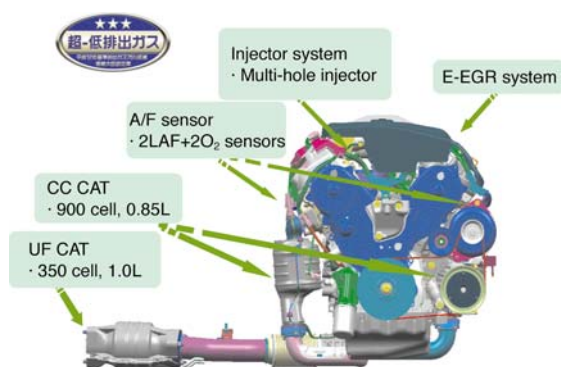


Fig. 8 Emission control system

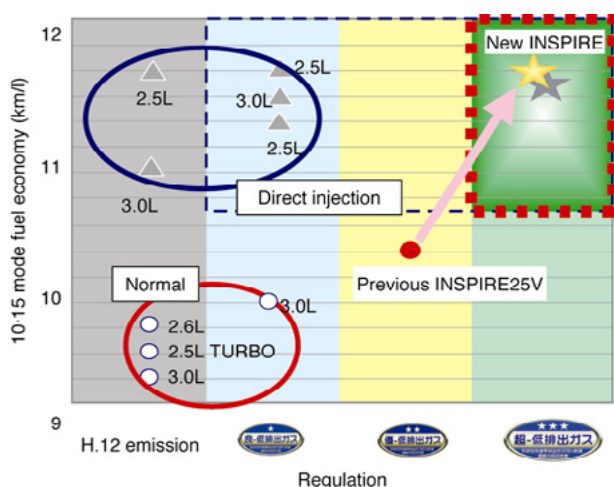


Fig. 9 Achievement of clean emissions and compliance with 2010 fuel economy standards

5. Transmission

To further increase the fuel economy of the variable cylinder engine, cooperative control with a cylinder stop mechanism has been employed in the AT. At the same time, a long torsion damper has been used in the lockup clutch to increase commercial appeal through improving NV performance during three-cylinder operation (Fig. 10).

As Fig. 11 shows, the damping (with a one-dimensional spring with a low spring constant up to the maximum torque produced during three-cylinder operation) has enabled fluctuations in the rotation of the main shaft to be maintained

at the same level as the level occurring during six-cylinder operation. This is equivalent to a reduction of 5 dB in drive system vibration and 3 dB throughout the cabin.

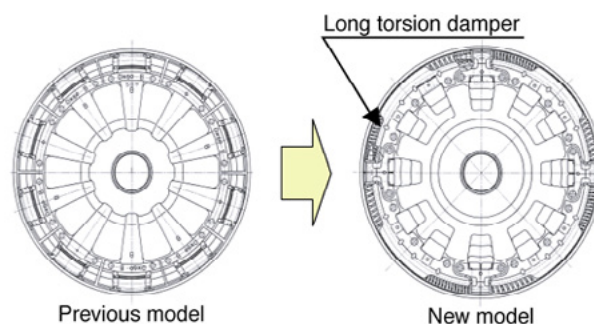


Fig. 10 Optimization of torsion damper characteristic for lock-up clutch

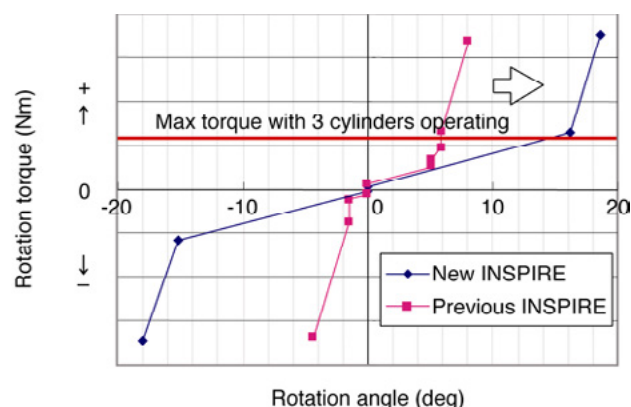


Fig. 11 Damper characteristics

6. Noise and Vibration

A cylinder on demand system has been employed in the engine of the new INSPIRE to achieve a balance between running performance and fuel economy. Because the number of cylinders in which combustion is occurring is reduced when one bank of cylinders is stopped, the frequency of vibration is reduced and the combustion pressure in each active cylinder increases. This significantly increases the amplitude of vibrations, the level of intake and exhaust noise, and torque fluctuations. This leads to a serious concern that NV performance and, hence, market appeal would decline. Two new technologies have been employed to prevent this: Active control engine mount (ACM) technology⁽²⁾ and active noise control technology (ANC)⁽³⁾. Conventionally, these are both high-cost systems. However, costs were reduced in the case of the new INSPIRE through the development of a new control logic and by employing existing vehicle systems, enabling both technologies to be offered as standard features. Once again the US Accord was used as the base vehicle in design relating to NV performance. By using additional soundproofing materials and by changing the materials employed, road noise performance is improved in line with the expectations consumers have of a domestic high-class sedan.

6.1. Active Control Engine Mount Technology

ACMs have been employed to counter the increased engine vibrations generated when one bank of cylinders is

stopped (Fig. 12). Two ACMs are used, at the front and the rear of the engine. The ACM ECU is located in the cabin, and is connected to the engine ECU.

This system uses the crank pulse signal (an existing engine control signal) to detect variations in crank rotation produced by combustion. The system employs the cylinder pulse as a standard for phase in the application of control. This enables the system to estimate the size and phase of engine vibrations, and to use those estimates in driving the excitation plate located in the hydraulic mount section of the ACM by means of an actuator. This control system eliminates the need for extraneous equipment such as special load sensors - enabling significant cost reductions in comparison to conventional systems employed by competitors. The actuator was specially designed for use in this system. It is a linear solenoid-type that generates a low level of heat. In terms of packaging, the positioning of an air release diaphragm in the top section improves heat resistance, and a reduction in total height ensures commonality with standard mounts. The use of this system reduces the transmission of engine vibrations with one bank of cylinders stopped by approximately 10 dB, making it possible to significantly reduce booming noise and body vibrations.

6.2. Active Noise Control Technology

Figure 13 shows the configuration of the ANC system. The control unit for this system is located on the top of the audio unit, and features a built-in microphone for compensation in the front seats. The microphone for compensation in the rear seats is located in the center of the rear tray. Adaptive feedforward control is applied to minimize the square of the noise signals from the two



Fig. 12 Cutaway view of ACM

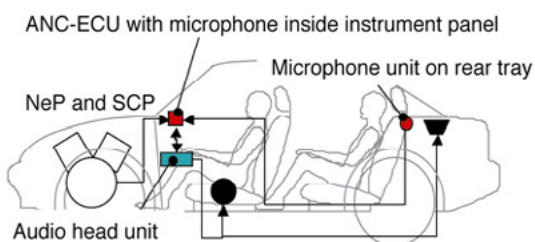


Fig. 13 On-board system configuration of ANC

microphones. A filtered-reference SAN algorithm was developed for the system to enable low-priced microchips to be used in place of high-priced DSP. This results in a significant reduction in the amount of calculation required. The existing audio system is used for output. Integration of the output of sound to cancel noise and the normal audio functions has made high performance compatible with low cost. The system reduces booming noises in the front and rear seats originating in the exhaust and drive systems by approximately 10 dB and, in combination with the ACM, it enables the achievement of a level of NV performance that makes cylinder stop undetectable.

6.3. Improvement of Road Noise Performance

Taking the high-rigidity body framework and the suspension system used in the US Accord as a base, additional soundproofing materials are employed, and the quality of the materials themselves are improved. Specifically, soundproofing materials are newly applied to the middle floor, felt materials are replaced by Thinsulate™, and the density of the backing of the carpeting on the floor is increased, resulting in the achievement of top-class road noise performance for a high-class small sedan (Fig. 14).

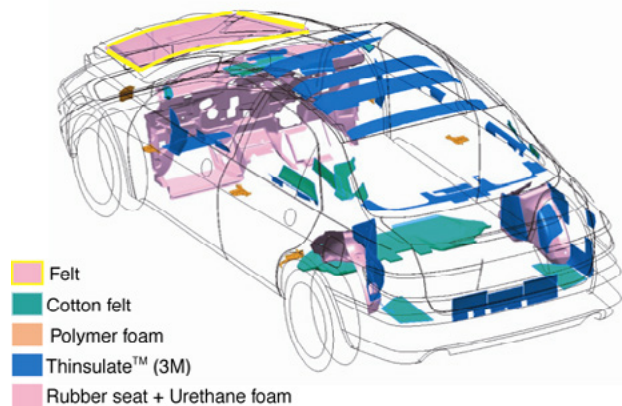


Fig. 14 Placement of soundproofing/sound absorbing materials

7. Chassis

The target in the design of the chassis is the achievement of excellent running performance, with the emphasis on superb handling and stability (especially during high-speed driving) and to offer the comfortable ride expected of a high-class sedan. The world's first collision mitigation system (CMS)⁽⁴⁾ is employed in the vehicle as an original Honda pre-crash safety technology.

7.1. Suspension

The well-received US Accord was once again taken as a base, and the double wishbone suspension employed in the vehicle is further advanced and matured to continue to help enable both steering stability and ride comfort (Table 2).

The front suspension in the US Accord employs an A-type lower arm and a high-capacity compliance bush, with optimized geometry and mounting points. In the new INSPIRE, the settings of the springs and damper mounts are

Table 2 Suspension dimensions

		New INSPIRE	US Accord
Front	Spring	5.5	5.6
	Stabilizer	$\phi 25.4 \times 4.5t$	$\phi 25.4 \times 4.5t$
	Damper Mt.	77.5kgf/mm	100kgf/mm
Rear	Spring	2.9	3.1
	Stabilizer	$\phi 15$	$\phi 13$
	Damper Mt.	100kgf/mm	100kgf/mm

altered to increase the comfort of the ride. Optimizing the balance between front and rear, and increasing the rigidity of the body and dampers ensure steering stability.

A five-link double wishbone system with optimized geometry and a higher-capacity and optimized bush was employed in the US Accord to increase stability and smoothness of ride. This system is used as the base for the rear suspension of the new INSPIRE. In addition to softening the springs and dampers to provide a smoother ride, the diameter of the stabilizer and the rigidity of the body is increased to ensure an even higher level of stability (Fig. 15).

205/60R16 size tires are employed in the new INSPIRE. To balance a smooth, comfortable ride with a powerful grip, the height and the hardness of the bead filler sections are adjusted.

The innovations described above result in a drive feel that is not merely softer but also possesses excellent convergence and a level of steering stability offering users a relaxed driving experience.

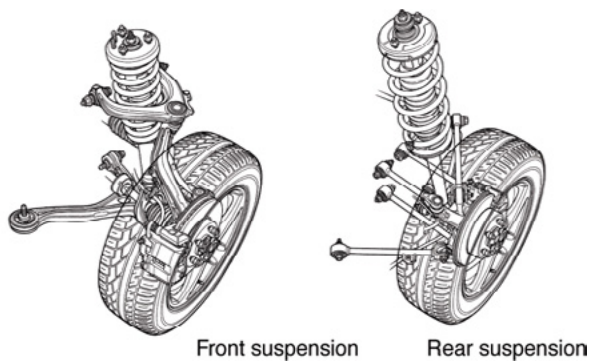


Fig. 15 View of suspension

7.2. Steering

Electronic power steering (EPS) is employed in the new INSPIRE to contribute to the achieving of excellent low-speed handling and high-speed stability and superb fuel economy, in addition to the enabling of HiDS⁽⁵⁾ to be used in the vehicle.

The increase in the power of the motor to match the V6 engine, the reduced inertial mass and increased rigidity of the mounts results a stable and precise steering characteristic. Tuning with particular attention to the region around the center offers both a smooth steer feeling and superb responsiveness (Fig. 16).

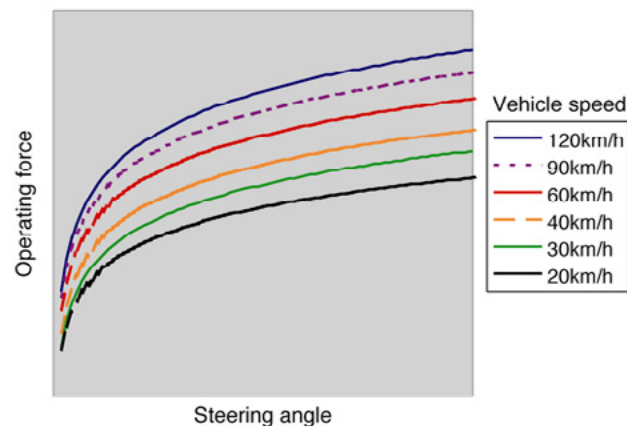
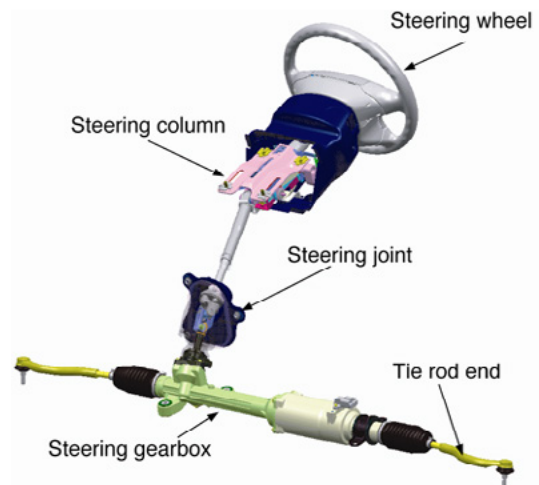


Fig. 16 View of steering system

7.3. Brake

Fuel consumption performance is further improved by reducing the drag resistance of the brakes to reduce rolling resistance. At the same time, the following are improvements to the calipers for both enhanced brake performance and feeling:

- (1) Altering the shape of grooves in the piston seals ensures clearance between the disc and the pad.
- (2) The shape of the retainer is altered to reduce the sliding load on the pad.

These changes reduce drag resistance by 75%, contributing to improved fuel economy (Fig. 17).

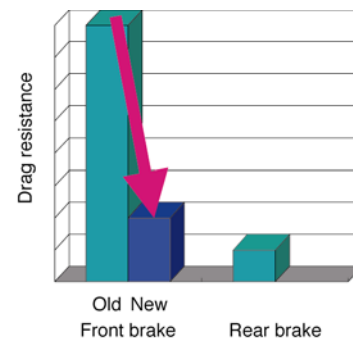


Fig. 17 Brake drag resistance

7.4. Improvement of Aerodynamics

Reducing aerodynamic resistance is generally effective in improving actual fuel economy at high speeds. Reducing aerodynamic resistance becomes even more effective when the range of three-cylinder operation is increased in the cylinder on-demand system. The following elements are established as contributing to a reduction of aerodynamic resistance on the basis of digital wind tunnel simulations and wind tunnel tests:

- (1) 3D round cabin (Fig. 18)
- (2) Flush surfaces
- (3) Aerodynamic under floor styling (Fig. 19)
- (4) Aerodynamic high-mounted stop lights integrated with the trunk
- (5) Aerodynamic door mirrors

These improvements allow the achievement of a coefficient of drag of 0.29. Increasing the range of three-cylinder operation also contributes to improved fuel economy.

8. Body

“Body with Confidence” – a body providing tremendous confidence and peace of mind – is the concept employed in developing a body befitting the expectations for a high-class sedan.

8.1. Body Rigidity

Dynamic rigidity was a particular focus in the development of the new INSPIRE - to achieve superior stability in all driving conditions, from city driving to high-speed driving. As a result of the improvements based on structural analysis and driving tests, the body displays both high dynamic rigidity and considerably improved static rigidity, increasing the vehicle's competitiveness in the market.

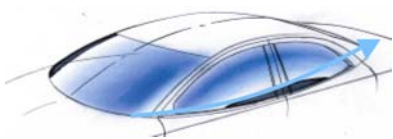


Fig. 18 3D round cabin

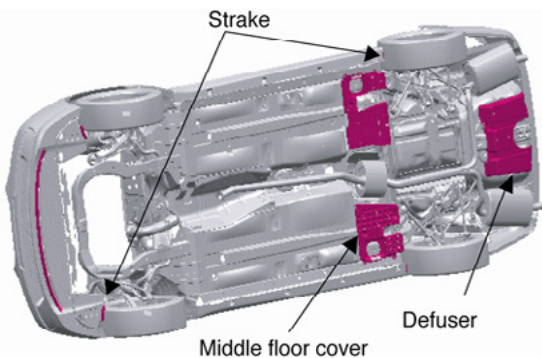


Fig. 19 Aerodynamic under floor styling

The right-left mode of front active rigidity is enhanced to improve responsiveness and to enable direct and supple cornering. A continuous closed cross-sectional structure is adopted in the front bulkhead. This highly efficient continuous structure enables control of displacement at the very front of the vehicle. In addition, the up-down mode of rear dynamic rigidity is enhanced to achieve stability and a level of comfort belying the power of the vehicle. A large stiffener is employed in the center of the rear pillar, and reinforcement is applied from the roof to the rear panel. The front of the vehicle is strongly reinforced as a collision safety measure. To ensure that the rear of the vehicle does not seem weak in comparison, major connecting sections are effectively reinforced to achieve an excellent balance of rigidity from front to rear (Fig. 20).

8.2. Collision Performance

The new INSPIRE is the first Honda vehicle to receive the highest rating (six stars for both seats) in the JNCAP collision safety performance evaluation. To achieve a six-star rating, it is necessary for a vehicle to receive high points in a 64 km/h offset collision, a 55 km/h flat barrier collision, and a 55 km/h side collision. This achievement is made possible in the new INSPIRE by reducing deformation of the body through side frame bending mode control, steering column stroke load control and under floor reinforcement. In addition, high-tensional materials have been used at many points in the body framework. Lightweight but strong, these materials improve both front and side collision performance. 48% of the framework consists of high-tensional materials, of which approximately 2/5 is the even more highly effective 590 MPa-grade (Fig. 21).

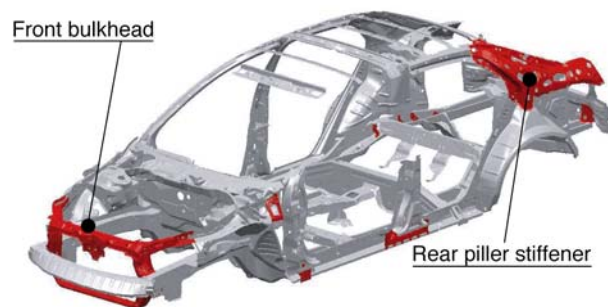


Fig. 20 Body construction

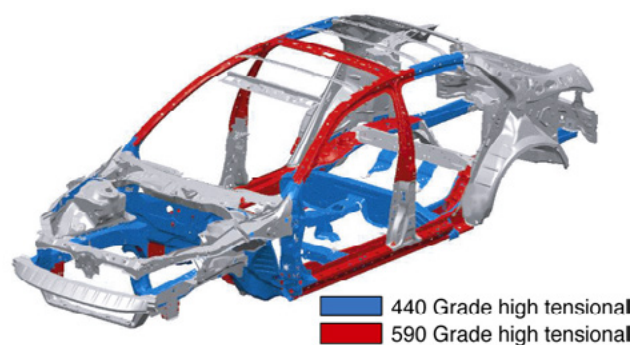


Fig. 21 High tensional strength

9. Interior

The interior design of the new INSPIRE is based on the concept of “Smart, Emotional, Clean.” The driver interface is improved, and is centered on a center module, while the instrument panel and the door trim achieve a wrap-around effect with a high-quality and “emotional” styling. The high-class impression generated by the vehicle is further enhanced by features such as seats having an all-new framework designed to reduce fatigue on long drives and electrically operated rear sunshades.

E-pretensioners have been employed in the seatbelt system of the new INSPIRE as yet another Honda pre-crash safety technology.

To reduce the environmental impact associated with the soft pads on the surfaces of the instrument panel and the door trims, the standard PVC skin has been changed to a spray urethane skin (Fig. 22). With PVC coatings, a slush is conventionally produced by heating and liquefying powdered PVC in a metal mold, after which rapid chilling forms a skin. In the spray method used for the new INSPIRE, in contrast, liquid urethane is sprayed onto a metal mold and the skin is formed by means of a chemical reaction. This enables the mold to be maintained at a fixed temperature, reducing the amount of energy expended in the production process.

The freedom of form offered by the spray method has been exploited to form a high-quality exterior surface. The design carefully eliminates breaks or joins between different components. To achieve this, the skin of the meter visor, the inside door handles, etc. are formed in one piece. The opening on the lid of the front passenger seat airbag is produced by a laser from the rear surface of the instrument panel, making the cut in the lid invisible. This laser operation is optimized based on a variety of conditions for airbag operation to help ensure the same high reliability in the new lid as is displayed by conventional lids.

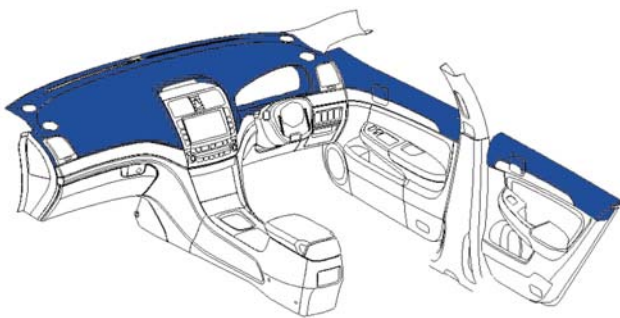


Fig. 22 Area of spray urethane application

10. Electrical Equipment

To realize the “Cruising Smart” concept established for the electrical equipment employed in the new INSPIRE, development proceeded with the following targets:

- (1) Reduced driving burden in highway cruising;
- (2) Making equipment designed for user comfort smarter.

Line beam headlights with a new reflector structure are employed to reduce the burden of night time driving. HiDS is employed to reduce driver load during highway driving and this further increases the safety of the vehicle in combination

with the CMS and E-pretensioner pre-crash safety technologies. Cylinder stop cooperative control has been added to cruise control, to improve fuel economy when cruising and to increase commercial appeal. On the instrument panel, a center module brings together displays and controls for vehicle operation. The large, luminescent displays make it easy for the driver to read a variety of information on vehicle status.

10.1. Line Beam Headlights

Low beam line beam headlights featuring reflectors are used in the new INSPIRE. The reflectors are capable of directing light in the upper part of the beam, which is normally ineffective for illumination, in a tight forward beam. This increases luminous flux intensity by approximately 50% and extends the beam cast by the lights for long distances without diminution of the range illuminated, including the area directly in front of the vehicle. As a result, visibility during night driving is increased helping to reduce the burden on the driver (Figs. 23 and 24).

10.2. HiDS Coordinated with CMS

To bolster the CMS, a high-resolution milliwave radar unit is installed to conduct mechanical scans and increase the ability of the system to detect targets (vehicles in front) (Fig. 25).

A deceleration control logic employing a VSA hydraulic unit was developed to establish a balance between the sudden responses of the automatic brake system and the deceleration feeling produced by the IHCC headway control - making a system designed for user safety and comfort even smarter.



Fig. 23 Line beam

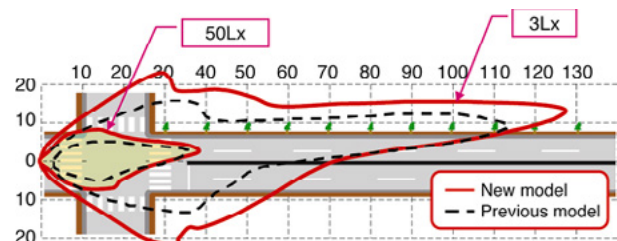


Fig. 24 Area of line beam illumination

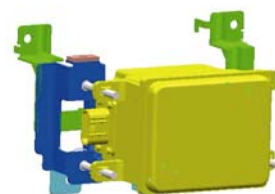


Fig. 25 Milli wave radar

10.3. Cruise Control – Cylinder Stop Cooperative Control

By limiting the changes in the degree of opening of the throttle when the vehicle is in cruise control mode to the extent that changes in vehicle speed are not apparent to vehicle users, the frequency of three-cylinder operation can be increased. This results in a roughly 3% improvement in fuel economy relative to fuel economy prior to the introduction of cooperative control.

10.4. Meters

Large, easy to read, luminescent meters are employed in the new INSPIRE (Fig. 26). A liquid crystal multi-information panel is located within the meter display, centralizing information on the vehicle and on running status. This makes accurate information easily available to the driver. Increasing visibility of the HiDS and CMS systems status, information on fuel consumption, and warning messages, raises the commercial appeal of the vehicle. Fig. 27 shows an example of the meter displays.



Fig. 26 Meter panel display



Fig. 27 Multi-information display

11. Conclusion

Numerous new devices and technologies are employed in the new INSPIRE. However, no matter how superb the technology developed, ultimately it must be functional for users, rather than simply drawing attention to its existence. Development of the technologies employed in the new vehicle was predicated on the fundamental concept that technologies should have the maximum possible effect, and that they should also offer their benefits effortlessly and without nuisance to users. Many new technologies employed in the new INSPIRE are merged and sublimated into the overall vehicle – the “New Intelligent Tourer.” As a result, the vehicle is the very embodiment of a high-class sedan with a new level of appeal not matched by competitors. As such, it is truly capable of “inspiring” its users.

This development reached fruition with the generous

assistance of many individuals, both on the Honda team and from other companies. The authors wish to take this opportunity to offer their sincere thanks to all who assisted in the project.

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