

# 2011 Odyssey Fuel Economy Improvement

Ryan CHAPMAN \*  
 Spyridon BLATSEAS \*  
 Dennis PLANK \*  
 Brandon OLLANKETO \*

Paul DeHART \*  
 Chase LIN \*  
 Evan MARTIN \*

Patrick SHAFER \*  
 Chris HARTWIG \*  
 Scott PAUL \*

## ABSTRACT

The 2011 Odyssey development team targeted achieving the “Best Family Vehicle” in terms of functionality, safety, and efficiency. In the area of efficiency, the overall goal was set to achieve “best-in-class” fuel economy. This goal was achieved through a total vehicle approach that involved efficiency gains in the following areas: engine operation, engine accessories and accessory belt drive system, chassis running resistance, and aerodynamics. In addition to hardware efficiency gains, aggressive weight reduction activities were conducted across all vehicle areas that contributed to the overall fuel economy improvement while meeting the functionality and performance targets.

## 1. Introduction

For the 2011 Odyssey, the development team was tasked with increasing fuel economy while maintaining and refining the minivan characteristics that consistently made it a top seller. During the planning stages, the need to increase fuel economy and maintain Odyssey’s marketability was apparent as fuel prices increased to record levels and consumers began seeking smaller vehicles. In addition, the Odyssey’s improved fuel economy was necessary to help meet increasing CAFE requirements. To maintain overall marketability and achieve CAFE, the development team targeted “best-in-class” fuel economy while providing minivan functionality with V6 passenger car level fuel economy.

As shown in Fig. 1, label fuel economy targets were set at 18/27 miles per gallon on 5-speed

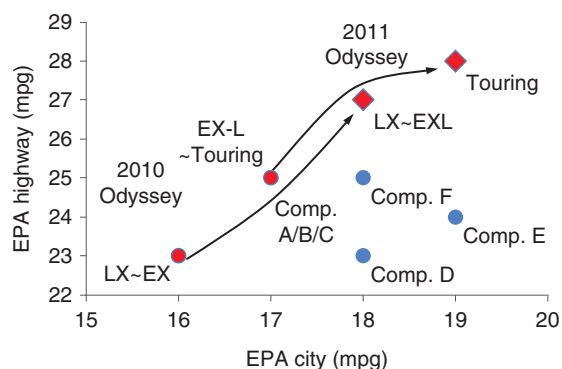


Fig. 1 Fuel economy competitiveness – EPA city versus EPA highway (mpg)

\* HONDA R&D AMERICAS, INC.

automatic transmission (5AT) models (LX~EX-L) and 19/28 miles per gallon on 6-speed automatic transmission (6AT) models (Touring and Touring Elite). Achieving the label and CAFE fuel economy targets required a total vehicle effort that encompassed the engine, transmission, chassis, and body-related areas as shown in Fig. 2.

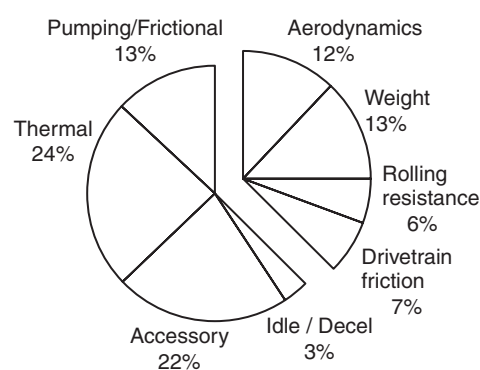


Fig. 2 Fuel economy improvement breakdown – Touring model highway mode

## 2. Engine

The power train development focused on “Smart Efficiency.” Based on this concept, the targets were set for “best-in-class” fuel economy and “best drivability.” Best drivability was retained by increasing power and mid-range torque. Fuel economy improvements started with applying the 3.5L V6 engine with Variable Cylinder Management (VCM) on all grades<sup>(1)</sup>. Engine improvements were made in the following

areas: engine pumping loss reduction, internal friction reduction, thermal efficiency, accessory load reduction, and idle/deceleration losses.

### 2.1. Pumping Loss Reduction

To minimize pumping losses, the Odyssey uses Honda's VCM technology, which allows for dynamic downsizing by deactivating two or three cylinders to allow the engine to run on three or four cylinders instead of six as shown in Fig. 3. As displacement decreases, throttling is reduced to achieve the same torque, which reduces pumping losses.

The VCM operation area was expanded through enhancements to Honda's Active Control Engine Mount (ACM)<sup>(2)</sup> and Active Noise Cancellation systems (ANC)<sup>(3)</sup>.

When the engine operates in 3- and 4-cylinder VCM modes, the engine mount system must inhibit vibration transfer to the chassis in addition to normal 6-cylinder mode. The ACM system compensates for operation on reduced cylinders by adding movement back into the engine to create a balance similar to 6-cylinder mode. The engine mount displacement has been increased by as much as 20%, which allows for higher torque operation in 3- and 4-cylinder modes.

For the 2011 Odyssey, the subwoofer size was increased and the low frequency performance (gain and phase) of the ANC microphone improved as shown in Fig. 4. Making these changes improved cancellation of the low frequency noise and enabled expansion of 3- and 4-cylinder VCM operation at lower engine speeds.

In addition to producing more torque and expanding low engine speed operation in 3- and 4-cylinder modes, engine losses and vehicle running resistance were reduced. These changes reduce the

gross engine power required to move the vehicle. Due to the reduced power requirements, the 2011 Odyssey is able to operate in the 3- and 4-cylinder VCM modes approximately 50% more often. Overall, VCM (as enabled by all the other reductions in losses) is the single largest contributor to the Odyssey's improved fuel economy and key to balancing performance and fuel economy.

Another major improvement for the Odyssey's reduction in pumping losses is an increase in Exhaust Gas Recirculation (EGR). While EGR is often considered an emissions control device, it can have a considerable effect on fuel economy. By allowing exhaust gas recirculation back into the cylinder, pumping losses can be reduced in two ways. First, since the exhaust gas bypasses the throttle and flows directly into the intake manifold from the high pressure exhaust side, the flow is not throttled and pumping is not required. Second, in order to maintain torque, more fresh air must be admitted into the cylinder to compensate for air that was displaced by the exhaust gas. This means that the throttling must be reduced, which reduces pumping losses.

For the new Odyssey, the mass ratio of EGR to fresh air was increased by up to 10%, which reduced pumping losses and improved fuel economy. The primary enabler for this increase was the application of Dual-Finite-Electrode spark plugs (Fig. 5). The dual finite electrodes guarantee a strong, clean spark, allowing an increased EGR ratio without introducing combustion stability concerns.

Overall, efforts taken to reduce pumping losses through enhancements to the VCM (engine, transmission, ACM, ANC) and EGR systems netted over 7% of the Odyssey's highway fuel economy improvement.

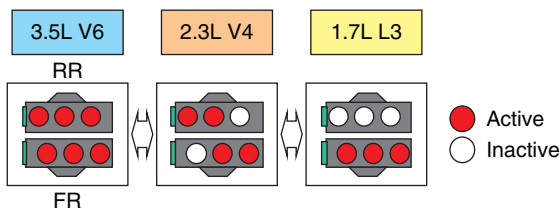


Fig. 3 VCM system operation: 3-4-6 cylinder modes

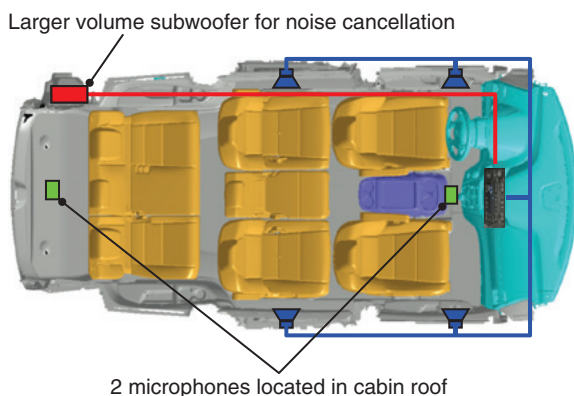


Fig. 4 Active Noise Cancellation (ANC) system

### 2.2. Internal Friction Reductions

Reducing engine internal friction was another strategy for improving fuel economy. This was accomplished by reducing piston sliding force and using 0W-20 engine oil.

To reduce piston sliding force, the two main piston sliding interfaces were analyzed and improved. These interfaces are the piston ring-to-cylinder liner and the piston skirt-to-cylinder liner.

The sliding friction in the piston ring-to-cylinder liner interface was reduced by changing the piston ring coating and the cylinder liner honing process. To achieve a smooth sliding surface, an ion plating hardening treatment was applied to the piston oil ring to help maintain the ring's smoothness and reduce

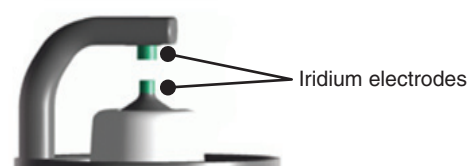


Fig. 5 Dual finite electrode spark plug

wear. To reduce cylinder wall friction, a secondary honing process was added to remove any high peaks from the initial honing process, which creates “plateaus” with valleys in-between (Fig. 6). The plateaus maintain a smooth sliding surface while the valleys hold oil to lubricate the rings as they slide by.

Figure 7 shows modifications made to the piston skirt-to-cylinder wall interface for reduced friction by removing small “dots” of molybdenum coating from the piston’s thrust surfaces on the skirt. These “dots” hold oil, helping to distribute the oil up and down the cylinder wall to further lower the friction between the molybdenum coating and cylinder wall.

Changing the piston sliding friction reduced engine friction by 4% and improved fuel economy by over 5% in both city and highway modes. To reduce friction under cold conditions, the engine oil was switched from 5W-20 to 0W-20 viscosity. This change contributed to over 10% of the engine’s fuel economy improvement in the city mode.

### 2.3. Thermal Loss Reduction

In addition to reducing pumping losses and internal friction, changes were made to reduce thermal losses in the engine. As shown in Fig. 8, the first change addressed the air entering the engine by applying a cold air intake system, which reduced intake air temperature by 21°C during the highway fuel economy test mode. Application of the cold air intake system improved highway mode fuel economy by 16%.

Second, EGR lowered combustion temperatures by displacing some of the oxygen in the cylinder with inert exhaust gas and netted an 8% increase in highway fuel economy. Overall, both of these changes advanced ignition timing, which converts more of the combustion energy into moving the piston versus escaping as heat through the exhaust gas.

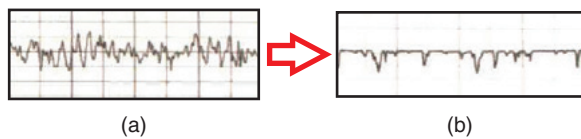


Fig. 6 Cylinder honing showing normal hone (a) and plateau hone (b)



Fig. 7 “Moly-Dot” piston skirt coating

### 2.4. Accessory Drive System Reduction

The accessory drive system was another focus area for reducing engine pumping losses. Reducing losses in each of the engine’s accessories allowed for an overall reduction in accessory belt tension. As shown in Fig. 9, the first and most fundamental change was made to the alternating current generator (ACG) by adding an Override ACG Decoupler (OAD). This device replaces the standard ACG drive pulley with one that incorporates a spring to absorb engine torque fluctuations, which yields a smoother operation and more consistent speed. As a result, the overall tension of the accessory drive belt was reduced by approximately 50%. Together, the OAD and reduced

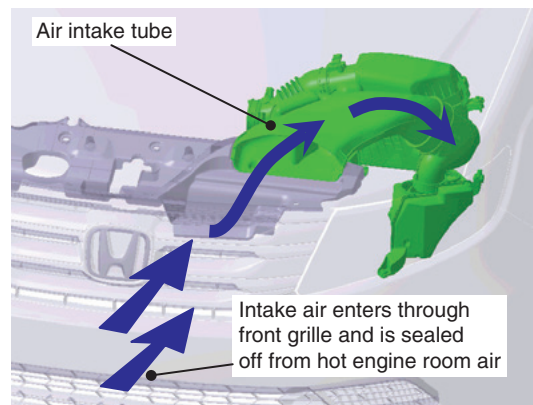


Fig. 8 Cold air intake system

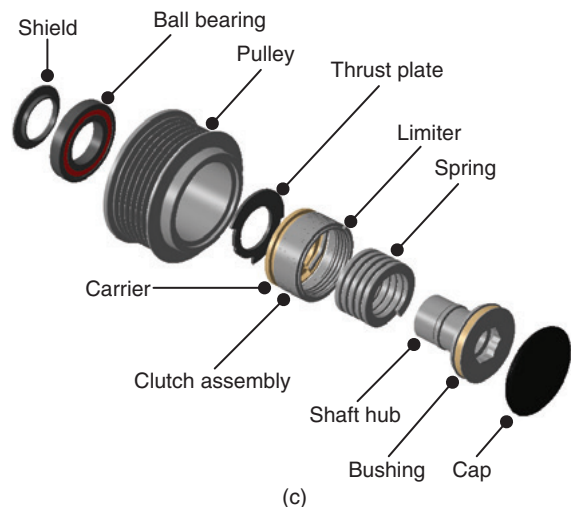
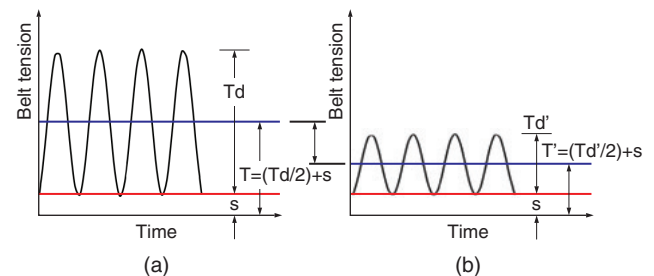


Fig. 9 Accessory belt tension and fluctuation shown without OAD (a), with OAD (b), and OAD components (c)

belt tension yielded a 9% improvement in highway mode fuel economy.

The largest benefit to the accessory drive system reductions came from changes made to the power steering pump. While Electric Power Steering (EPS) was investigated, applying a Variable Displacement power steering Pump (VDP) emerged as a solution<sup>(4)</sup>. The VDP system came at no additional cost from the previous Odyssey's power steering pump and provided most of the fuel economy benefit of an EPS system. This VDP contains an internal cam ring around the central vane pump. This cam ring is balanced by a spring and the pump pressure. When flow is reduced, the internal pressure shifts the cam ring closer to the centerline of the pump, thereby reducing the fluid displaced. By reducing the pump displacement, pump torque is decreased, thereby lowering engine parasitic losses. Overall, the VDP accounted for a 13% highway mode fuel economy improvement. As an added weight reduction benefit, a power steering cooler was not required on the towing package due to lower power steering fluid temperatures.

The final accessory on the belt drive system is the Air Conditioning (AC) Compressor. While the compressor remained essentially common to the outgoing model, changes were made in the AC control logic to reduce load on the compressor and hence the engine. This control system monitors a variety of parameters, such as humidity, and controls the evaporator temperature, air recirculation, and condenser fan speed for optimal performance and reduced compressor run time. This system yields fuel economy benefits of up to 5% in real-world driving.

### 2.5. Idle and Deceleration Reduction

The final area addressed in the engine was idle and deceleration losses. When the engine is idling and the vehicle is not moving, fuel economy is zero mpg. Conversely, when decelerating, if the vehicle is moving and fuel is shut-off to the cylinders, fuel economy is infinite. By reducing the idle speed, the impact of zero mpg operation was reduced, and optimizing the Deceleration Fuel Cut system, increased the time of operation at infinite mpg. During deceleration fuel cut, the Odyssey further applies a regenerative charging and cooling system to make use of the energy produced during deceleration to charge the battery and cool the engine. These changes netted a 9% increase in city mode fuel economy and a 3% increase in highway mode fuel economy.

## 3. Transmission

In addition to the already optimized 5AT, the application of the 6AT further improved fuel economy in multiple aspects<sup>(5)</sup>. The 6AT improves city mode fuel economy by over 4% and highway mode fuel economy by over 1% through reduced drivetrain losses.

### 3.1. Close Gear Ratio

Figure 10 compares the 5AT and 6AT gear ratios. Applying 6AT allowed for closer ratio gaps between gears, which resulted in better use of the engine's power during acceleration in city driving by keeping the engine speed in an optimum operating range. As a result, 3-cylinder VCM operation in the city fuel economy mode was dramatically increased.

For the 6AT, the 6<sup>th</sup> gear ratio is higher than the 5AT's 5<sup>th</sup> gear; however, due to increased mid range torque, there is ample driving force during the highway mode to allow for 3-cylinder VCM operation while lowering the engine speed to reduce overall friction.

### 3.2. Multi-Disk Lock-Up Converter

Figure 11 shows the higher capacity Multi-Disk Lock-Up Converter (LC), which allowed for expanding the LC feedback control area. This expansion reduced unnecessary torque converter (TC) slip; which was not

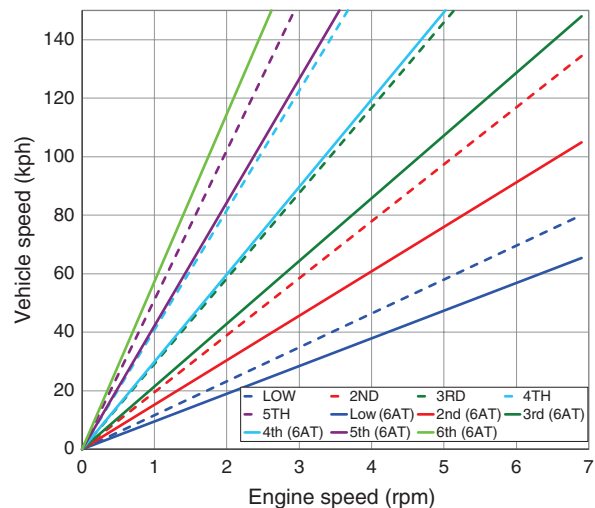


Fig. 10 5AT and 6AT gear ratio comparison

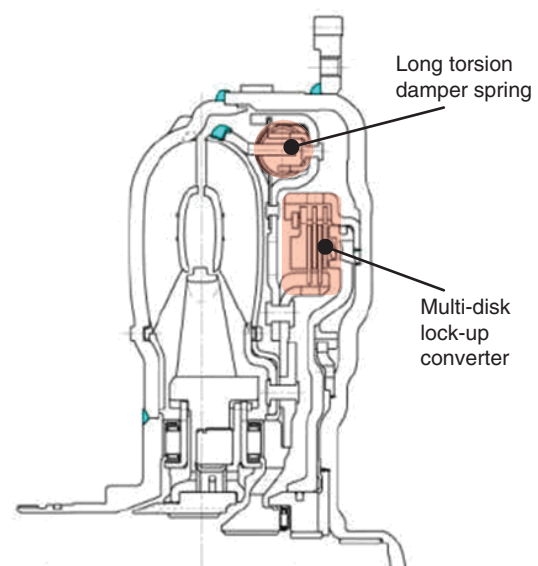


Fig. 11 Multi-disk lock-up torque converter

possible with the 5AT single plate LC. The expanded LC area reduced wasted energy and provided the majority of the city fuel economy increase and enhanced dynamic driving feel.

### 3.3. Long Torsion Damper Spring

Figure 11 shows the special torsion damper springs inside the TC that was selected to increase vibration absorption during VCM operation. This allowed for further expansion of VCM areas without compromising overall vehicle quality in terms of noise, vibration, and harshness (NVH) and improves fuel economy through reduced pumping losses.

### 3.4. Low-Viscosity Automatic Transmission Fluid

Applying low-viscosity automatic transmission fluid (ATF) reduced fluid friction during the critical warm-up phase, which in turn improved overall efficiency.

### 3.5. Transmission Calibration

Transmission calibration focused on more aggressive transient tip-in control to decrease unnecessary TC slippage. Shiftmap tuning was also optimized to maximize VCM operation before and after shifts. Continuous fuel cut (F/C) during natural deceleration downshifts also contributed to overall fuel economy by increasing F/C time.

## 4. Aerodynamics

Aerodynamic drag ( $C_dA$ ) is a function of the vehicle's coefficient of drag ( $C_d$ ) and frontal area ( $A$ ) and has a direct impact on highway fuel economy. Reduced running resistance through reduced aerodynamic drag lessens the required engine torque to maintain highway speeds. The 2011 Odyssey's overall  $C_dA$  was reduced by 5% compared to the previous model and contributed to 12% of the Touring model's highway fuel economy benefit.

Enhancing the functionality and usability of the interior packaging increased the vehicle's frontal area, even with a lowered roof profile. The main contributor to the increase was reduced tumblehome to increase head clearance for the second row seat's wide mode position. Also, adding turn signals to the side mirrors on Touring grades increased frontal area. To overcome the frontal area increase, the entire vehicle exterior was considered for reducing the coefficient of drag ( $C_d$ ).

To improve engine room and underbody flow, air guide plates were added to increase the airflow efficiency to the cooling system. The cooling open area was then strategically minimized to reduce drag while maintaining cooling and heat resistance performance as shown in Fig. 12. To control the exit flow from the engine room, the front inner fender side wall was optimized by extending rearward.

Under the vehicle, the front lip spoiler and front inner fender strakes were designed to work in concert. As shown in Fig. 12, the lip spoiler and strake position and shape were optimized using computational

fluid dynamics simulation. The airflow was diverted lower and toward the inside of the vehicle. This airflow change reduced the high pressure zone on the front tires. A rear undercover was added on the left side to reduce the drag of the rear fascia.

As shown in Fig. 13, the upper cabin and tail lights were shaped through extensive wind tunnel testing to control the airflow separation. The tailgate spoiler and side spoilers were shaped specifically for aerodynamic drag reduction. The Touring grade side sill garnish shape was styled to push air out and around the rear wheels.

The Touring grade's side mirror is larger than the base grades' side mirror due to adding an integrated side turn signal. Consequently, extensive wind tunnel testing was conducted to reduce drag induced by the mirror wake. Wind noise reduction was also completed in parallel during the testing.

Finally, the seals on the front and rear quarter windows were designed with a ramp shape to avoid separation and reduce wind noise.

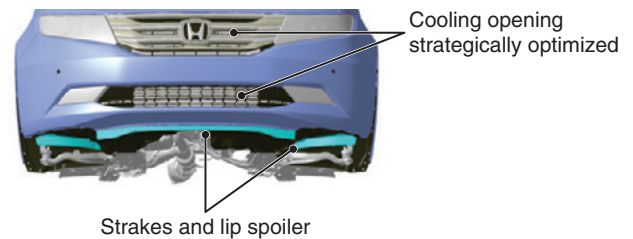


Fig. 12 Front aerodynamic components



Fig. 13 Wind tunnel development of rear flow separation

## 5. Drivetrain Friction Reduction

Traditionally, chassis-related efforts to improve fuel economy performance were limited to reducing tire rolling resistance. While the contribution to overall vehicle fuel consumption among chassis parts is clearly dominated by tire energy loss, every part's influence was considered during vehicle development.

### 5.1. Bearings

As total vehicle coast-down testing has improved, the bearing drag reduction benefit to fuel economy has been quantified. In an effort to improve fuel efficiency wherever possible, an effort was made to reduce bearing drag, even though its effect on fuel economy is on the order of 0.01 mpg. Two key design factors influencing bearing drag are sealing against water and the required preload needed to achieve bearing stiffness. In the past, improvements for sealing and preload have directly resulted in a drag increase. For the 2011 Odyssey, the chassis design team targeted an 18% drag reduction without affecting sealing or stiffness.

The front wheel bearing drag was reduced by changing the bearing type and optimizing the seal lip geometry. The front bearing was changed from a GEN1 to GEN3 structure, which reduced the bearing preload by eliminating the variation from the outer race-knuckle interface and the inner race-hub interface. Optimizing the seal lip involved changing the lip material and modifying the seal geometry to reduce contact pressure while ensuring equivalent sealing performance. These changes reduced front bearing drag by an average of 24% and increased bearing mass by 9.7%.

The rear wheel bearing drag was reduced by modifying the bearing layout and optimizing the seal lips. The bearing layout was changed from a symmetric GEN3 layout to an asymmetric GEN3. This change reduced the bearing weight and increased the geometrical stiffness, which allowed the preload to be reduced while maintaining overall bearing stiffness. Reducing the preload reduced the rolling element contribution to drag. The seal lip optimization strategy matched the front bearing approach and also reduced the overall bearing drag. These changes resulted in an average rear bearing drag reduction of 48% and a mass reduction of 6%.

From a total vehicle standpoint, wheel bearing drag was reduced by 37% with a nominal mass increase of only 2% and contributed to over 2% of the highway fuel economy increase.

### 5.2. Brake Drag Reduction

The 2011 Odyssey increased the brake package size from 16" to 17" to enhance brake feeling and performance without increasing mechanical drag. Several countermeasures were required to overcome the increase in effective radius. The target was achieved by changing pin A and B locations, applying V-springs to the pads, changing the pad retainer shape, and applying grease between the pad abutments and retainer.

Pin A and B positions were changed to better control the caliper body tilt angle. The 2010 Odyssey previously applied the tighter fit Pin A to the trailing side and the guide Pin B to the leading side. During the 2011 Odyssey testing, it was determined that due to the additional weight and center-of-gravity (CG)

location of the caliper body, the pins needed to be swapped to better control caliper body position during retraction as shown in Fig. 14. It was also decided that the body position could benefit from increasing the guide Pin B bushing volume.

Figure 15 shows the pad v-springs that were added to separate the pads from the disk during off brake to reduce parasitic drag. The v-spring set force was determined by checking the post durability vehicle test brake pad sliding force to determine the minimum force required to separate the pads from the disk. However, due to the application of the v-springs, it was determined that the pad rattle noise rating exceeded the development target.

To offset the rattle noise caused by adding v-springs and to maintain a good drag level, it was necessary to change the pad retainer shape. The pad retainer was changed from a P-type to a C-type as shown in Fig. 16. The P-type retainer was initially

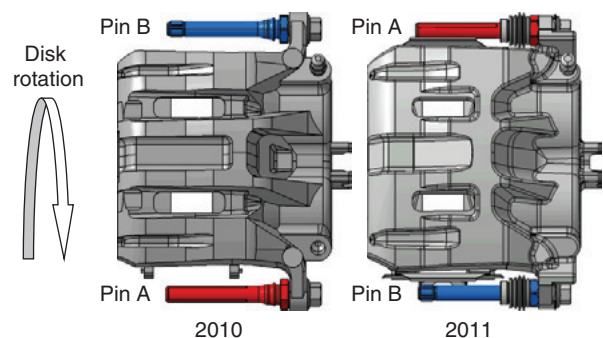


Fig. 14 2010 and 2011 Odyssey pin A and B locations

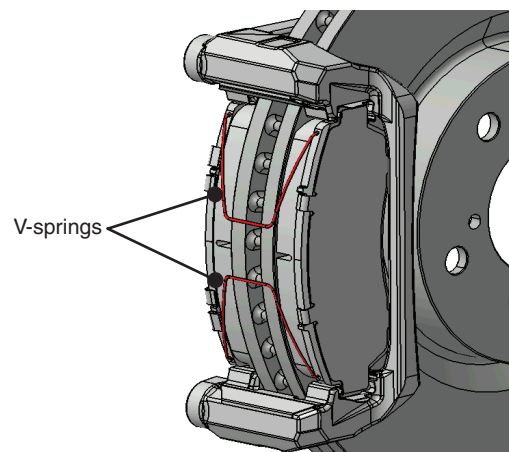


Fig. 15 2011 Odyssey V-springs

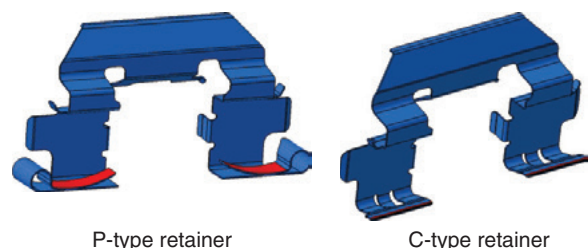


Fig. 16 2010 Odyssey P-type and 2011 C-type retainers

applied due to its ability to aid in pad retraction; however, it was not able to meet the pad rattle target. To meet the pad rattle target, the C-type retainer was implemented to maintain enough spring force on the pad to reduce pad rattle while reducing pad sliding force by approximately 32%. Pad sliding force was reduced by limiting the contact surface area between the retainer and pad interfaces. In addition, Molycoat M77 grease was applied between the pad and retainer interfaces to reduce the frictional forces and further reduce the pad sliding force.

After applying the aforementioned brake drag reduction items, the vehicle met the brake drag target. At 55 mph, the vehicle has an average 5% reduction in brake drag allowing enhanced brake feeling and performance without sacrificing fuel economy.

## 6. Rolling Resistance

The 2011 Odyssey uses 17" and 18" wheel fitments, which are one-inch larger over the previous model's wheel sizes. The 2010 Touring grade P235/60R17 tire was chosen as a reference tire for 2011 model tire development. The target was to reduce rolling resistance 6% versus the reference tire without degrading important performance areas, such as braking and snow performance.

For the 2011 Odyssey, the LX through EX-L grades applied P235/65R17 tires while the Touring grades applied P235/60R18 tires. An iterative approach was used to develop each tire's cavity shape, tread pattern, compounds, and materials to optimize the tire performance.

Compared to the reference tire, each tire improved rolling resistance by 7 to 8%, which contributed to 6% of the Touring model's highway fuel economy increase. In addition, each tire developed for the 2011 Odyssey achieved all dry braking, wet braking, and subjective performance targets.

## 7. Weight Reduction

For US Environmental Protection Agency (EPA) Fuel Economy, vehicle weight is critical in determining vehicle running resistance and EPA test conditions. Vehicle weight is categorized into equivalent inertia weight ranks (IWR) based on vehicle curb weight. Furthermore, the certification inertia weight rank is set based on power train and the model grade comprising the majority of vehicle sales. The certification IWR for the 2010 Odyssey was based on the EX-L grade, which allowed all variations to fall within the 4750 IWR.

The 2011 Odyssey required a separate weight certification based on 5AT application on LX through EX-L grades and 6AT application on Touring grades. Achieving the targeted fuel economy required all grades to fall within the 4750 IWR. This was especially important on the high feature content Touring grades. Overall, the vehicle weight was

reduced by 47 kg and the 4750 IWR was achieved for all certification models offsetting a 13% reduction in highway mode fuel economy.

### 7.1. Engine Weight Reduction

Engine weight was reduced by 5.5 kg while reducing cost, increasing horsepower, and contributing to improved fuel economy. The main design changes responsible for this weight reduction involved converting to lightweight materials, such as magnesium and plastic; optimizing material thickness and size for stamped, cast, and molded parts; and improving system efficiency.

Intake system weight reduced by 2 kg through structural optimization and system efficiency improvements while improving performance and fuel economy. The overall number of parts in the intake system was reduced by integrating parts between the air cleaner case and intake tube and between the resonator and cold air intake tube.

By applying a lightweight radiator package, the overall cooling system weight was reduced by 1.4 kg while increasing cooling performance. This was achieved by combining a new thin radiator core design with dual ring fans and changing the sub shroud material from steel to lightweight nylon.

### 7.2. White Body Weight Reduction

The 2011 Odyssey body is a conventional steel body with targeted use of advanced high strength steels (AHSS). It is 12.5 kg lighter than its predecessor and has increased body rigidity and collision performance.

Each component of the body was reviewed during development with material grades and thicknesses chosen to meet the functional requirements within each body system. A collaborative approach between design and manufacturing groups was used to refine the white body design. Each structural change was evaluated through extensive use of CAE tools. Crash simulations, body rigidity, and spot weld durability simulations were conducted to help ensure structural changes met all of the functional requirements. Part thickness and grade changes were cross-checked by all simulation groups.

Another challenge was to enhance collision performance by reducing side impact intrusion and increasing roof strength. Both required structural changes from the previous design. A typical approach would be to increase the size of the body sections to increase strength; however, this can reduce passenger space. The team chose not to increase the overall section sizes and looked for opportunities to use AHSS grades and enhance the section efficiency.

The Rear Roof Rail is one example of section optimization. The rail spans across the vehicle from D-Pillar to D-Pillar and forms the top of the tailgate ring. This part has functional requirements for body rigidity and safety performance as well as providing the structural base for the Tailgate Hinges. As shown

in Fig. 17, the previous design rotated the tailgate into the section during opening. For the 2011 Odyssey, the Tailgate Hinge design rotates the tailgate above the roof as shown in Fig. 18. This allowed the Rear Roof Rail section to be smaller and more efficient. The third row seat packaging was improved and the more compact design reduced the weight by over 0.35 kg.

The enhanced strength of AHSS allowed for body system construction changes that further reduced weight. As shown in Fig. 19, 59% of the Odyssey's

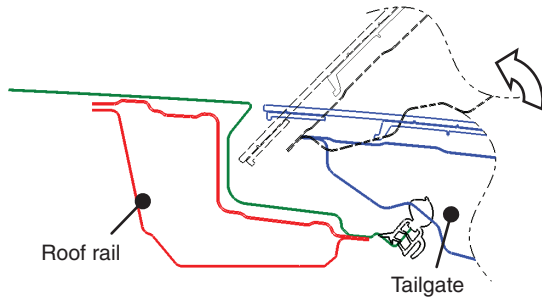


Fig. 17 2010 Odyssey rear roof rail section – tailgate closed and open positions

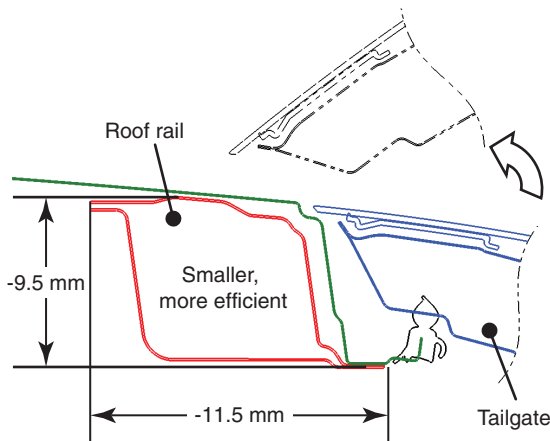


Fig. 18 2011 Odyssey rear roof rail section – tailgate closed and open positions

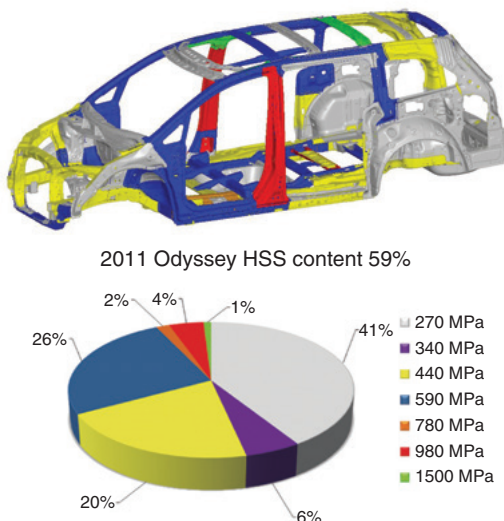


Fig. 19 2011 Odyssey high strength steel usage

Table 1 Seat assembly weight comparison

| Seat assembly weight comparison (EX-L)<br>(Excludes level-1 plastics and bolts) |        |        |                 |
|---------------------------------------------------------------------------------|--------|--------|-----------------|
| EX-L                                                                            | 10M    | 11M    | Difference (kg) |
| FR RH                                                                           | 35.85  | 28.58  | -7.27           |
| FR LH                                                                           | 33.65  | 30.39  | -3.26           |
| Mid RH                                                                          | 28.50  | 25.10  | -3.40           |
| Mid LH                                                                          | 27.00  | 25.10  | -1.90           |
| Mid CTR                                                                         | 15.10  | 18.60  | 3.50            |
| RR 40%                                                                          | 24.40  | 22.68  | -1.72           |
| RR 60%                                                                          | 36.60  | 31.98  | -4.62           |
| Total                                                                           | 201.10 | 182.43 | -18.67          |

white body structure is composed of steels with tensile strength over 340 MPa, which is a 68.5% increase in AHSS usage. Building upon Honda's previously-developed models, 780 MPa, 980 MPa, and 1500 MPa AHSS grades were used for the first time on the Odyssey platform. Examples of AHSS usage to reduce weight on the 2011 Odyssey include the front floor frame (-1.3 kg), second row seat mounting crossmember (-0.86 kg), and the roof side rail (-0.75 kg).

### 7.3. Interior Weight Reduction

The majority of interior weight can be attributed to the seating system. Seats in the 2010 Odyssey EX-L accounted for approximately 60% of the interior parts' total weight. Customers' desire for versatile eight-passenger seating arrangements along with higher seat performance targets can result in higher seat design complexity and additional weight. The challenge for the 2011 Odyssey development was to find ways to reduce the seat system weight, enhance the seating arrangement flexibility, and exceed existing functionality. With this in mind, the focus was to optimize the previous seat design and maintain a high degree of functionality and performance.

As shown in Table 1, regarding the complete seat set, the seat weight was reduced by approximately 18.7 kg compared to the previous design. Considering the addition of new features and regulation changes, the weight savings is actually higher when compared to an equivalent design specification. For example, the 2011 Odyssey mid center seat adds a comfort slide adjustment, ISOFIX child seat attachment, and a dynamic damper, resulting in a weight increase of 3.5 kg. Mid row outboard seats added 1.66 kg due to dynamic dampers. The rear seat weight increased by 3.22 kg due to upgrading the outer headrests to comply with FMVSS 202a, adding an ISOFIX location to the 40% seat, and adding new cargo load floor flaps.

In the front row seating, weight was reduced by a total of 6.53 kg. This does not include a 4 kg weight transfer caused by replacing the passenger seat-mounted folding table with a body-mounted removable center console. The majority of the front

seat weight reduction, which is approximately 5.05 kg, was achieved by replacing the complex welded stamping seat riser assembly with a more efficient design. The new seat mounting concept consisted of a body-integrated rear mount structure and a taller 3-piece stamping for the device front mounting foot. These changes eliminated the need for a separate seat riser altogether (Fig. 20). An additional 0.88 kg savings was achieved by applying the latest generation passenger seat occupant detection system. The remaining amount of front row seat weight reduction was obtained by applying the latest generation anti-whiplash front seat back frame and an 8-way/4-way power device.

In the mid row, the outboard seat combined weight was reduced by 5.3 kg. The majority of this mid outboard weight savings resulted from applying a new low-effort slide adjuster device and an optimized recliner and walk-in mechanism. For the 2011 Odyssey, a dynamic damper was added to each mid outboard seat; however, approximately 95% of this weight increase was offset by deleting the inboard arm rests and their mounting brackets. To compensate the inner armrest feature loss, the larger 2011 mid center seat applied an integrated arm rest and cup-holder, which is accessible when the center seat back is folded down.

In the rear row seating, a total weight savings of 6.34 kg was achieved by optimizing the seat frame and mounting structure and reducing the lock quantity of the 60% foot comp to one using latest generation locks (Fig. 21).

For the 2011 Odyssey rear seat, the pivot mounting structure design was changed to reduce weight and simplify factory assembly (Fig. 22). For the center pivots, a lightweight welded steel stamping design was applied to replace the previous generation's bolt-on cast iron structure. For the outboard spring-loaded pivots, a lighter level-2 bolt-on design was applied, eliminating the need for the factory to install it to the body prior to the seat installation. Optimizing the rear seat pivot mounting structures reduced the rear seat weight by approximately 5.54 kg.

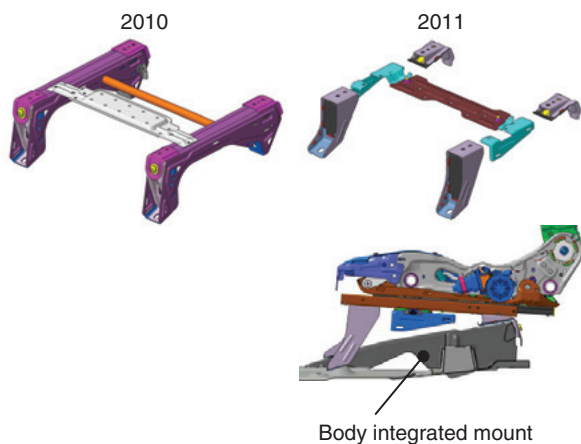


Fig. 20 2010 and 2011 front seat mounting system



Fig. 21 2011 Odyssey 3<sup>rd</sup> row seat structure and 60% foot comp single lock

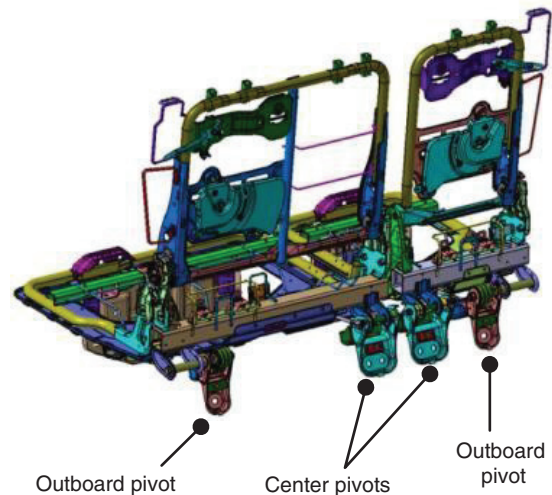


Fig. 22 2011 Odyssey rear seat integrated mounting pivot

## 8. Conclusion

The 2011 Odyssey's overall fuel economy achievement involved a total vehicle effort on a part-by-part and system-by-system basis that encompassed the engine, transmission, chassis, and body areas. Fuel economy improvements started with applying the 3.5L V6 engine with VCM to all grades. Changes to the engine design and calibration involved reduced pumping losses, increased EGR usage, air intake temperature management, reduced internal friction, reduced accessory drive losses, and reduced idle/deceleration losses. For the transmission, internal friction was reduced and gear ratios optimized for VCM usage. In addition, 6AT was applied to the Touring models to enhance drivability and further increase fuel economy. Changes to the chassis focused on reduced running resistance through tires, brakes, and bearings. Changes to the vehicle body focused on aerodynamics

and weight reduction with increased structural rigidity and enhanced safety performance. Total vehicle weight reduction was 47 kg.

Fuel economy on the 2011 Odyssey improved by +2/+4 mpg on the LX~EX models, +1/+2 mpg on the EX-L model, and +2/+3 mpg on the Touring models in EPA city and highway modes. Through these fuel economy improvements, the 2011 Odyssey achieved the 18/27 mpg label target on the LX~EX-L models and 19/28 mpg label target on the Touring models. In addition, vehicle development achieved the CAFE strategy and maintained Odyssey's overall marketability with "best-in-class" fuel economy by a margin of 3 to 4 mpg over competitors.

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## ■ 著 者 ■



Ryan CHAPMAN



Paul DeHART



Patrick SHAFER



Spyridon BLATSEAS



Chase LIN



Chris HARTWIG



Dennis PLANK



Evan MARTIN



Scott PAUL



Brandon OLLANKETO