SKYACTIV® TECHNOLOGY

Press Kit

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1. At-A-Glance: Defy convention

Engines, transmissions, body and chassis: Mazda's all-new range of SKYACTIV® technologies are designed to improve the efficiency and sustainability of the company's new generation of vehicles while at the same time further enhancing safety and driving dynamics.

Innovation is at the heart of SKYACTIV TECHNOLOGY, which is focused on optimized internal combustion and lightweight engineering. These technologies will be implemented into all future models — not just expensive "green" variants — in order to benefit all Mazda customers.

SKYACTIV-G 2.0-liter gasoline engine: The quest for the ideal combustion engine
A range of entirely new technologies has gone into the highly-efficient direct injection SKYACTIV-G gasoline engine. Exceptionally strong yet remarkably efficient, it takes compression to an all-new level, solving all the issues that until now have prevented this approach from being feasible. Such unconventional methodology is typical of Mazda's unique way of engineering.

Highlights:

- Exceptionally high 13:1 compression ratio in North America (14:1 in other markets due to a higher fuel octane)
- Extraordinary compression ratio made possible thanks to a 4-2-1 exhaust system, redesigned piston cavity, new multi-port injectors as well as other innovations to avoid abnormal combustion ("knocking")
- Continuously variable sequential valve timing (dual S-VT) on the intake and exhaust minimizes pumping losses
- Internal engine friction reduced by 30 percent
- Overall weight reduced by 10 percent
- Approximately 15 percent lower fuel consumption and CO_2 emissions than the current Mazda 2.0-liter MZR gasoline engine
- Approximately 15 percent more torque at lower and mid-range rpms

SKYACTIV-D 2.2-liter diesel engine: More torque, cleaner combustion

Clean, high-revving, responsive and more fun than ever, Mazda has raised the bar for diesel power with SKYACTIV-D. The engine's low compression ratio plays a central role here, too, as internal processes were again completely re-examined. The result: efficient power engineered to achieve the highest environmental standards without the need for special and expensive aftertreatment systems.

Highlights:

- Approx. 20 percent less fuel consumption (compared to the current 2.2-liter MZR-CD diesel) thanks to an extraordinarily low 14:1 compression ratio and subsequently greater expansion phase after combustion
- Variable valve lift for exhaust valves enables internal exhaust recirculation, immediately stabilizing combustion after a cold start
- New two-stage turbocharging delivers strong and steady responsiveness across the engine range (max. 5,200 rpms)
- Highly efficient active ceramic diesel particle filter (DPF)
- Fulfills Euro 6, Tier II BIN 5 (North America) and Japan's Post New Long-Term Emission Regulations without expensive NO_x aftertreatment
- Weight reduced by 10 percent
- Internal engine friction reduced by 20 percent

SKYACTIV-Drive six-speed automatic transmission

A smooth, responsive and fun yet fuel-saving automatic transmission, Mazda's SKYACTIV-Drive is engineered to deliver the best of all worlds in automatic performance and efficiency – even for a high-torque diesel engine.

Highlights:

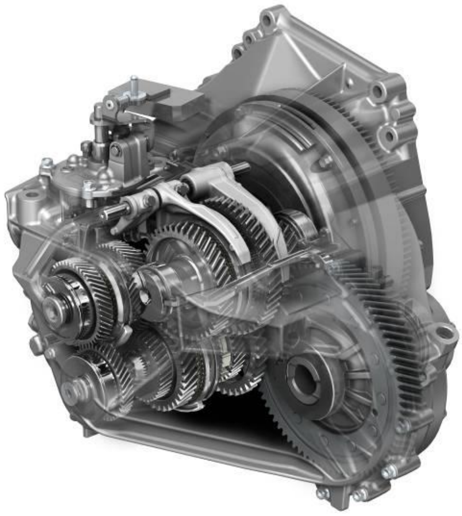
- Unique technology combines the advantages of continuously variable (CVT), dual clutch and conventional automatic transmissions
- Full range direct drive (torque converter with a full range lock-up clutch) delivers a direct manual gearbox-like feel
- Improved fuel economy by up to 7 percent
- Fast and smooth shift response thanks to new mechatronics module
- Powerful, steady acceleration from a standstill
- Available for both SKYACTIV-G and SKYACTIV-D engines

SKYACTIV-MT six-speed manual transmission

Lighter, smaller, more efficient, Mazda built the innovative new SKYACTIV-MT six-speed manual transmission to improve fuel economy, but without compromising on enjoyment. The benchmark was the swift and precise shifting feel of Mazda's legendary MX-5 Miata roadster.

Highlights:

- Optimized for front-engine, front-wheel-drive vehicles with easy and tight shifting
- Re-engineered with a considerably smaller and lighter design
- Compactness enables efficient packaging
- Better fuel economy thanks to reduced internal friction



SKYACTIV-Body

Lighter, stronger and safer, Mazda's developers went back to the drawing board to design SKYACTIV-Body, which integrates lightweight engineering, increased material strength and more efficient structures.

Highlights:

- Weight reduced by 8 percent using a newly-developed body structure, new production processes (bonding methods) and a larger proportion of high-tensile steels
- Enhanced driving dynamics owing to 30 percent more rigidity with the "straight structure" and "continuous framework" (ring structure) concepts for frame components
- Enhanced passive safety performance by re-engineering crash zones using multi-load paths

SKYACTIV-Chassis

Mazda has developed a chassis that combines nimble handling with ride comfort and stability when pushing the vehicle to its limits. The SKYACTIV-Chassis also achieves superior rigidity from a lightweight design. The driver will feel at one with the car.

Highlights:

- A “Jinba Ittai”-like feeling of oneness between car and driver inspired by the MX-5’s exceptional handling and ride comfort
- Improved driving quality at all speeds (low- and mid-range agility as well as high-speed stability) following a complete re-engineering of rear suspension mountings, trailing arm position, steering components and set-ups (among other things)
- Superior rigidity along with a 14 percent reduction in chassis weight thanks to newly developed suspension with front struts and a multi-link rear axle

2. Introduction

***"The sky's the limit"*: This phrase stands for an all-new generation of Mazda technologies and symbolizes a new era for the company. Distinct among manufacturers, Mazda's unique way of engineering has always included one key element: the joy of driving. The principal goal of Mazda's engineers when developing its SKYACTIV technologies was to dramatically increase vehicle efficiency for all next-generation vehicles by improving fuel economy and reducing CO_2 emissions while, at the same time, further enhancing safety and driving fun. And, they have managed to successfully reconcile these, at times, conflicting objectives with the completely new SKYACTIV range of engines, transmissions, body architecture and chassis that will go into Mazda's next generation of models beginning in 2012.**

Internal combustion engines will still power more than 80 percent of vehicles in 2020. Today's versions operate at only 30 percent efficiency, however, so there is much room for improvement. Defying conventional wisdom, Mazda's engineers focused on one objective: achieving ideal combustion. Therein lays the basis for Mazda's SKYACTIV-G gasoline and SKYACTIV-D diesel engines in all next-generation models – and not just pricey "green" models. This underscores the company's uncompromising commitment to improving environmental sustainability, vehicle safety and driving dynamics.

One of Mazda's core business objectives is to make personal mobility environmentally friendly and affordable for a broad section of the population. This is why Mazda has made it a priority to increase the efficiency of its internal combustion engines. The company's R&D staff in Hiroshima sought the best means of achieving a significant optimization of processes within this basic engine architecture, steadily and broadly reducing fossil fuel consumption.

Internal combustion: Still the basis for mobility in 2020

Many carmakers plan to concentrate on hybrid propulsion over the medium term and fully electric drives in the long term. Mazda is no different in this respect, having already spent more than 20 years working on hybrid and fully-electric vehicles. In fact, an electric version of the Mazda2 will be offered in very limited numbers in 2012 in Japan as part of a leasing program. This electric vehicle project should deliver valuable new insight into electric drive technology as well as how electric vehicles are used. But even if optimistic assumptions prove accurate – that around 12 percent of all passenger cars in North America and 23 percent in Europe will be powered by electricity by 2020 – the vast majority of people will be driving vehicles with internal combustion engines.

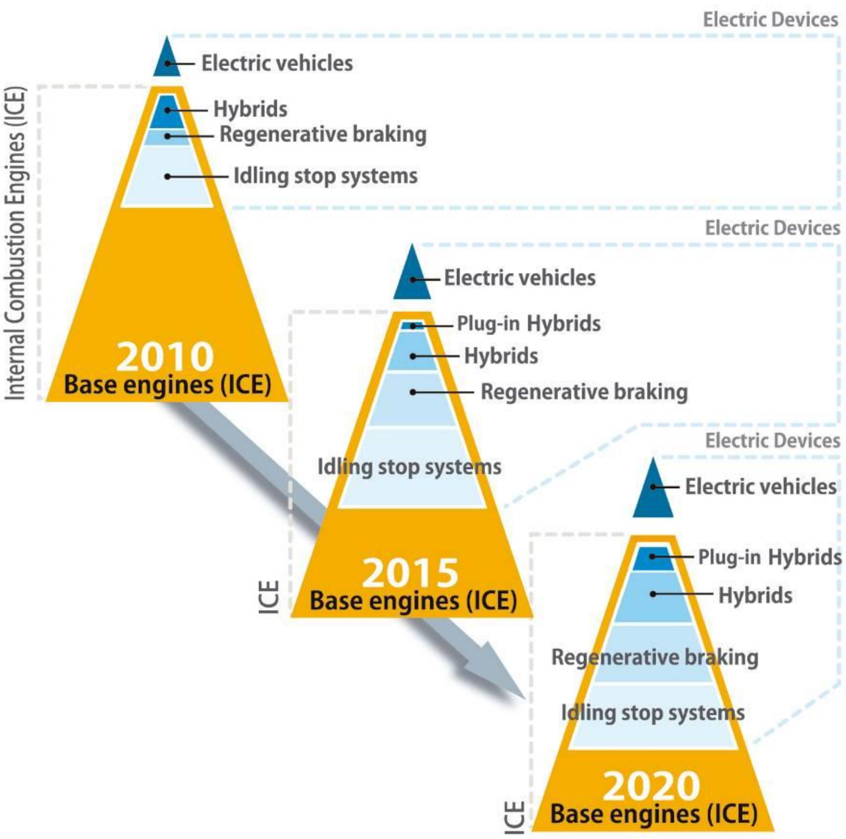


Fig.1-2 Anticipated expansion in adoption of environmental technologies

According to TrueCar Inc., an automotive solutions provider and publisher of new car transaction data, by 2020, hybrid vehicles will have an 8 percent market share in North America with purely electric cars garnering 4 percent of the market. Estimates are slightly higher in Europe. According to a 2010 EUROTAX study, electric only-powered vehicles will comprise 10 percent of the market. Sales of hybrid vehicles are also estimated at an additional 10 percent.

Whether low or high on the sales estimates spectrum, 10 years from now, vehicles powered exclusively by gasoline and diesel engines will still make up for 80 to 88 percent of the market. And the CO_2 footprint of internal combustion engines will remain lower than electric drives as long as their electricity comes from non-renewable sources.

3. “Sustainable Zoom-Zoom”: A Building Block Strategy

In 2007, Mazda devised its “Sustainable Zoom-Zoom” strategy, which calls for a staggering 30 percent increase in fuel efficiency (compared to 2008 levels) for all Mazda vehicles offered worldwide by 2015. This corresponds to a 23 percent reduction in fuel consumption and, therefore, CO_2 output.

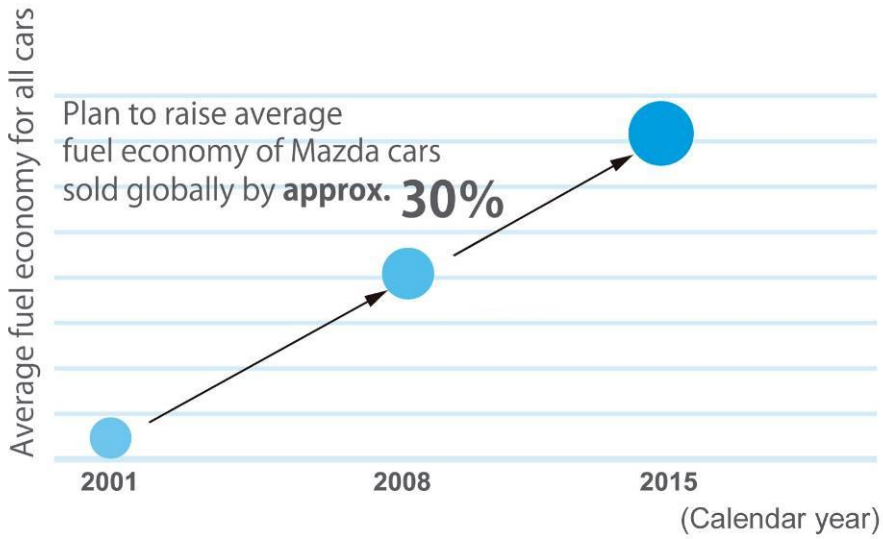


Fig.1-1 Target of average fuel consumption

This ambitious objective will be implemented using Mazda’s building block strategy, meaning the step-by-step introduction of auxiliary electrical systems to SKYACTIV internal combustion engines.

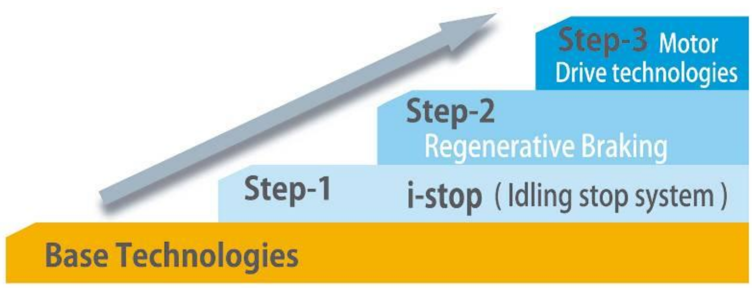


Fig.1-3 Building Block Strategy

Mazda's own "i-stop" (stop-start system) technology, introduced in 2009 in some markets, represents one step on the path to the comprehensive optimization of this underlying technology. Additional electrical components will follow. One example currently under development at Mazda is a regenerative braking system designed to recover energy during deceleration. As far as hybrids are concerned, Mazda has formed a partnership with Toyota to combine its hybrid technology with SKYACTIV engines (see box). The reductions to fuel consumption and CO_2 anticipated by 2015 would only be otherwise possible if half of all new Mazda passenger cars were hybrids or almost one quarter purely electric.

"Monotsukuri Innovation": Innovative processes, innovative manufacturing

In 2007, even before SKYACTIV TECHNOLOGY was previewed, Mazda began reforming all the processes involved in making cars, from R&D to manufacturing. This company-wide approach, called Monotsukuri Innovation, is organized around a common architecture concept and a flexible manufacturing concept based on Bundled Product Planning. Monotsukuri has led to breakthroughs in diversification (to meet varying customer needs) as well as standardization of architectures and systems for increased efficiency, thus enabling Mazda to deploy high-grade, high-performance technologies over a wider range of vehicle models as well as respond more quickly to changes in customer demands. Monotsukuri Innovation enables a high level of cost-efficiency that ultimately benefits the customer.

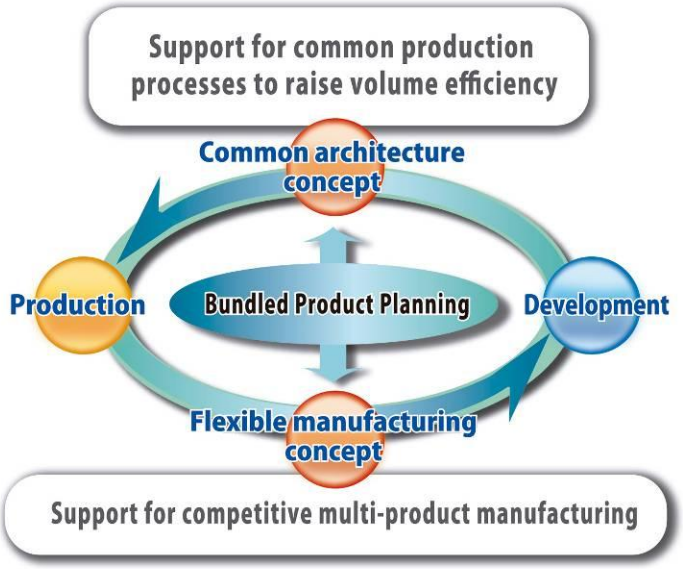


Fig.1-5 Monotsukuri Innovation

Mazda hybrid system technology in cooperation with Toyota

Toyota Motor Corporation and Mazda Motor Corporation reached an agreement in 2010 on the supply of the hybrid technology components, upon which the Toyota Prius is based. Mazda plans to combine this hybrid system with its next-generation SKYACTIV technologies to develop and introduce a hybrid vehicle in Japan, starting in 2013.

Advanced internal combustion for an efficient Zoom-Zoom hybrid

Mazda plans to offer hybrid vehicles in the medium term. However, it has chosen a different development focus than its competitors. Again, enhanced SKYACTIV internal combustion engines form the basis.

The fuel efficiency of today's engines decreases significantly from medium to low loads at low engine speeds. Why hybrid vehicles deliver such good fuel economy is because the internal combustion engine is used at its most fuel-efficient range to generate electricity, which (together with regenerated energy) powers the vehicle at lower loads. But the wider the internal combustion engine's inefficient lower load range is, the larger a hybrid's electric motor and battery need to be to compensate for it.

Therefore, thanks to its efficiency over a wide operating range, the combination of a SKYACTIV internal combustion power plant and an electric drive enhances overall hybrid effectiveness while achieving a Zoom-Zoom hybrid with a lighter electric motor and battery. Regenerative braking can thus serve as the predominant source of power to charge the battery.

4. SKYACTIV TECHNOLOGY

SKYACTIV TECHNOLOGY will be launched in North America in an all-new generation of models with new engines, transmissions, bodies and chassis. Along the way, Mazda followed what is known as the "breakthrough" approach. It calls for the resolution of technical conflicts – like enhancing safety, driving dynamics and fuel economy all at the same time – to continually improve the underlying automotive technology in new product generations.

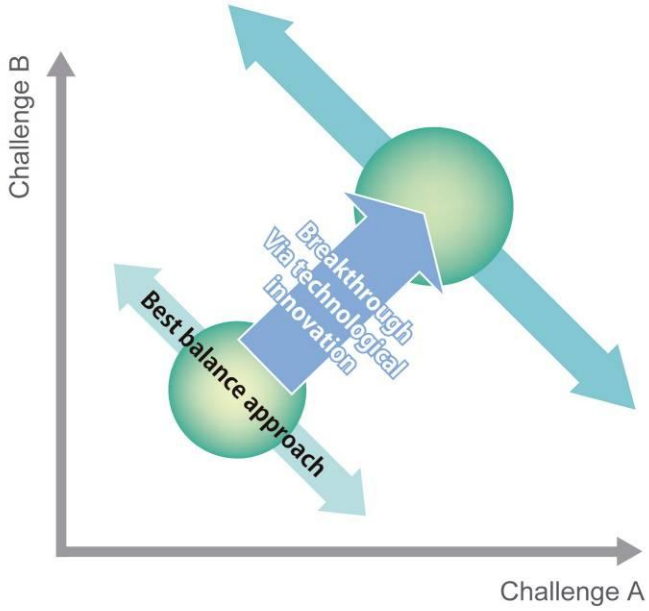


Fig.1-4 Breakthrough

Engineering the ideal internal combustion engine

Mazda is blazing its own trail based on the long tradition of ingenuity at its in-house engine R&D center. Even after 120 years of non-stop development the internal combustion engine still fails to utilize 70 to 90 percent of the energy contained in the fuel. Since this energy loss is primarily thermal in nature and can be attributed to the exhaust, cooling system, and engine and transmission surfaces, the R&D team's central focus was on improving the engine's thermal efficiency. Beyond that, Mazda has also been busy working to reduce internal engine friction as well as engine weight.

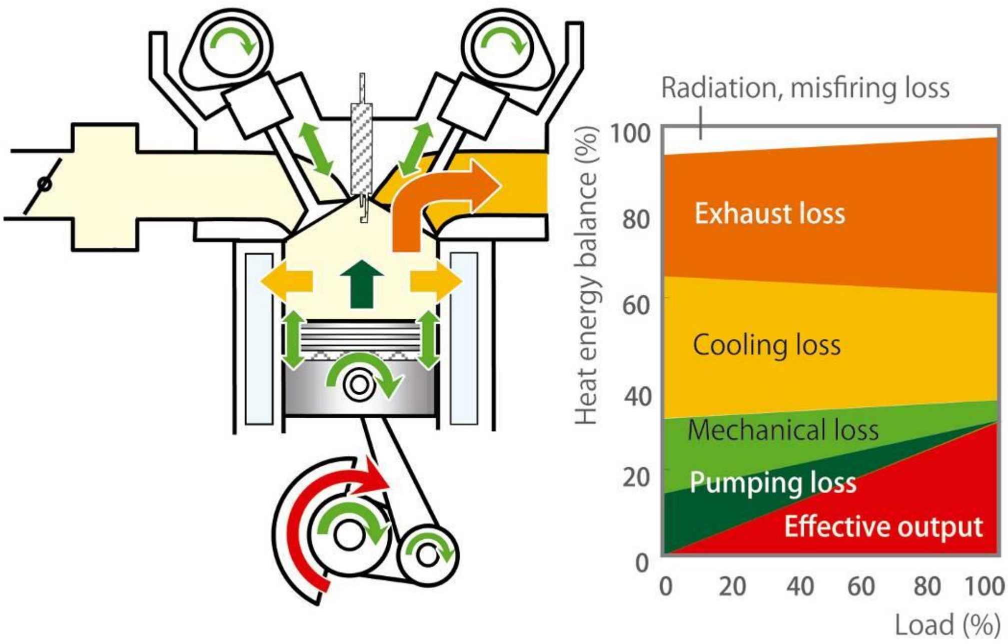


Fig.2-1 Energy balance in an ICE

The six controllable factors at the heart of this approach are:

- compression ratio
- air-to-fuel ratio
- combustion duration
- combustion timing
- pumping loss
- mechanical friction loss

The goal was to optimize these factors, making them function as optimally as possible and taking decisive steps towards creating the ideal internal combustion engine. Ultimately, the compression ratio would end up playing a central role among these factors in both gasoline and diesel engines.

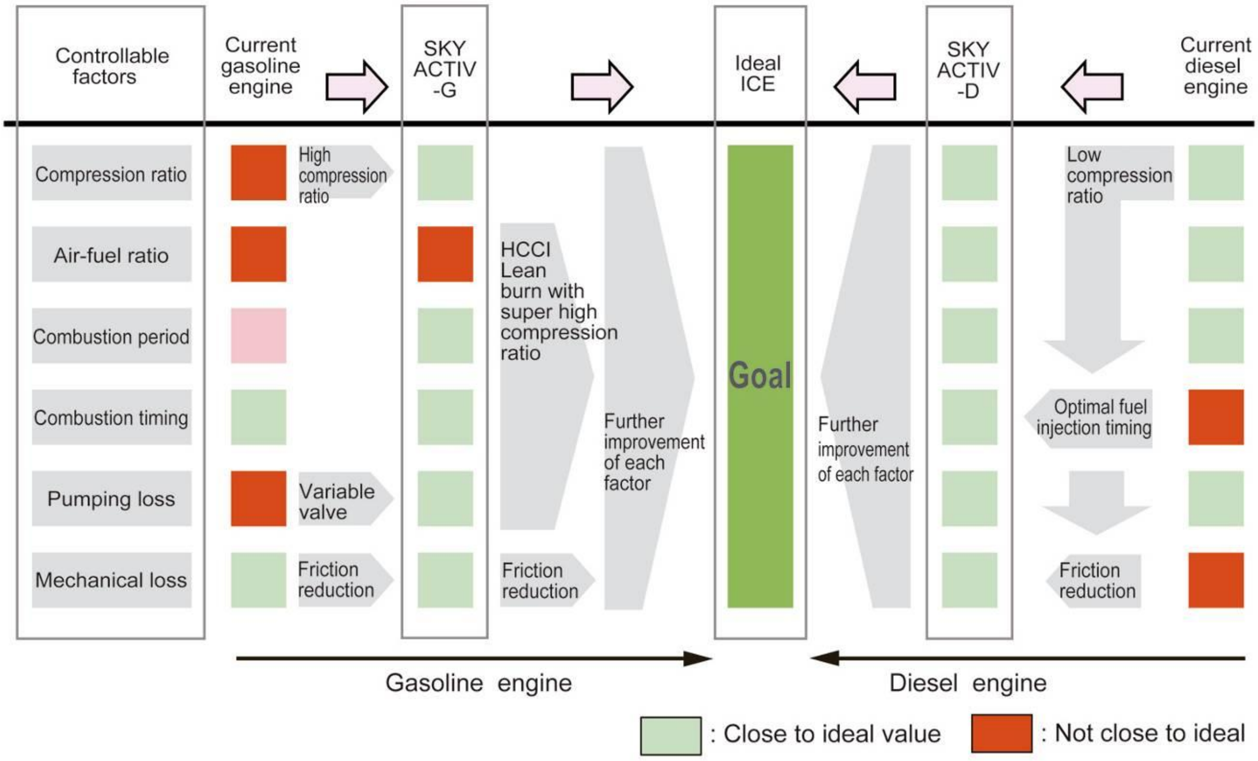


Fig.2-3 Roadmap toward the ideal ICE

One of Mazda's strengths is its willingness to defy conventional wisdom and approach challenges in new and innovative ways. An example is Mazda's unique rotary engine, which powered the legendary 787B – the only rotary to ever win the 24 Hours of Le Mans (in 1991). Yet another is the MX-5 Miata, a car that revived the market for roadsters worldwide. Innovative SKYACTIV technologies will mark Mazda's latest milestone in automotive history. Developed using characteristic Mazda processes, they demonstrate once again how Mazda is the master of its own technological destiny.

The new SKYACTIV engines, for example, were not developed independently in separate departments. Instead, a relatively small group of highly specialized engineers first developed the best possible individual engine architectures. These then served as the basis for all new engines, regardless of the number of cylinders or type of fuel.

"Our mass production development division worked together to engineer the best possible architecture with incredible efficiency, dramatic performance and the best quality we've ever had," said Seita Kanai, executive vice president, Mazda Motor Corporation. "We could then, for example, make the cylinder larger, smaller, multiply it by three, four, six, etc. create a range of engines for any future application."

Extreme compression ratio rather than downsizing

Some automakers are looking to improve the average fuel economy of their internal combustion engines by reducing displacement. Called "downsizing," the loss of power and torque is offset by forcing air into the combustion chambers using turbochargers or superchargers.

Although this is an effective approach, Mazda has chosen another route. As mentioned earlier, striving for the ideal internal combustion engine is an important basis of Mazda's building block strategy. According to Mazda's roadmap for the ideal engine, the most effective next step was to optimize the compression ratio.

5. SKYACTIV-G Gasoline Engine

The advantages of the unique direct-injection SKYACTIV-G gasoline engine are the result of Mazda's unique "breakthrough" engineering approach. By thoroughly analyzing and rethinking common thermodynamic principles, engineers succeeded in building an engine with an extraordinarily high 13:1 compression ratio. This is a level only seen thus far in high-performance race car engines not intended for everyday use. Mazda has overcome these barriers.

13:1 – an extremely high compression ratio

Any discussion about the compression ratio needs to examine the advantages and challenges of high compression. Raising the compression ratio in a gasoline engine increases its thermal efficiency, thus improving fuel economy. However, high compression in conventional engines leads to unwanted abnormal combustion (known as "knocking") and an associated reduction in torque. A richer mixture and delayed ignition timing are used to avoid knocking, but these also come at the expense of fuel economy and torque. So how were these issues overcome?

High compression without knocking

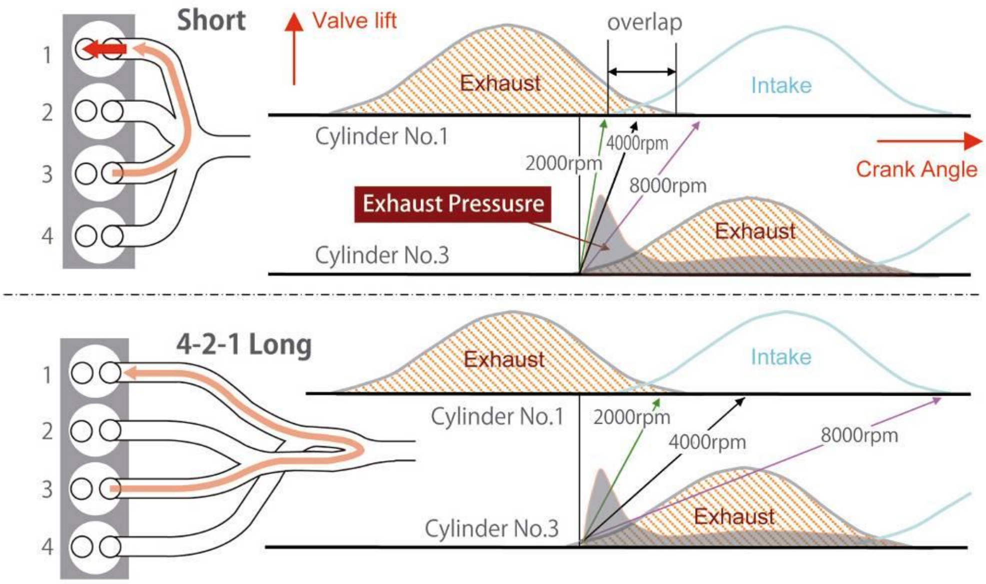


Fig.2-9 Residual gas reduction by 4-2-1 exhaust system

Knocking takes place when the air-fuel mixture ignites prematurely because the temperature and pressure are too high. This can be countered by reducing the quantity and pressure of hot residual gases in the combustion chamber. Mazda, in response, developed a special 4-2-1 exhaust manifold, which, due to its relatively long structure, prevents the exhaust gas that has just moved out of the cylinder from being forced back into the combustion chamber. The resulting reduction in compression temperature inhibits knocking.

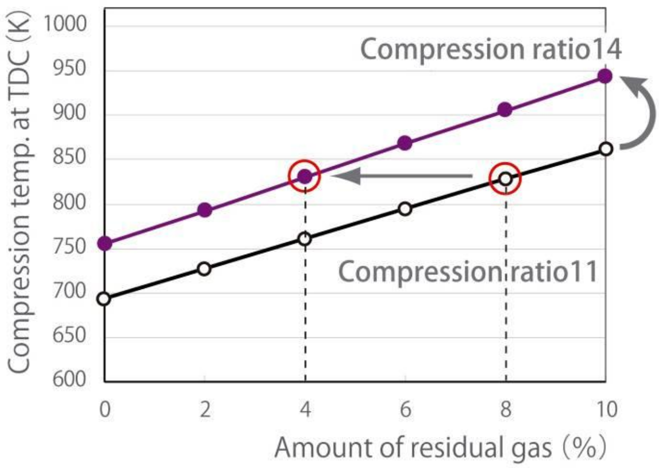


Fig.2-8 Effect of residual gas reduction

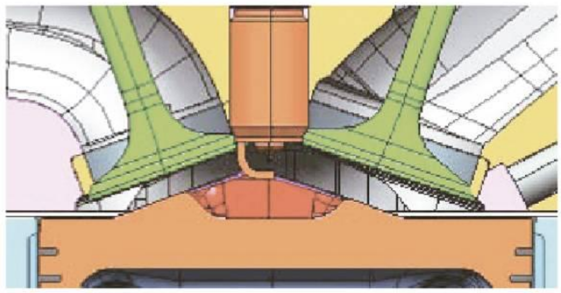
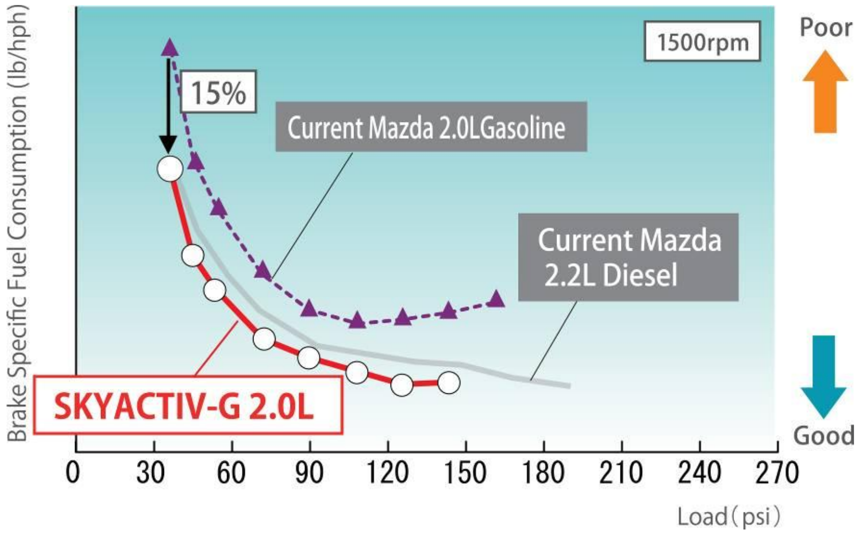


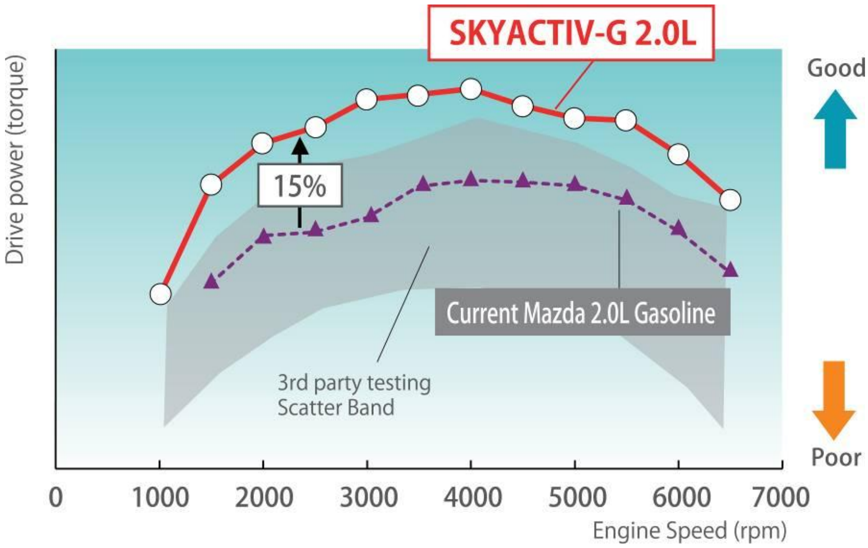
Fig.2-10 Piston cavity (1)

The combustion duration was also reduced. Faster combustion shortens the time the unburned air-fuel mixture is exposed to high temperatures, which enables normal combustion to conclude before knocking occurs.

The new engine also received special piston cavities, which allow the initial combustion flames to propagate without interference, and new multi-hole injectors, which enhance fuel spray characteristics. Together with the 4-2-1 exhaust manifold, these innovations resulted in a substantial 15 percent increase in torque over Mazda’s current 2.0-liter MZR gasoline engine.

Everyday drivers will love the SKYACTIV-G’s noticeably higher torque over a wide range of rpms as well as its 15 percent improved fuel economy.





Minimizing pumping loss

To improve engine efficiency, it is also necessary to reduce the “pumping loss” that occurs at lower engine loads when the piston draws in air while moving downward during the intake stroke. Generally, the amount of air going inside the cylinder is controlled by the throttle located upstream of the intake pipe. At lower engine loads, only a small amount of air is necessary. The throttle is nearly closed, causing the pressure inside the intake pipe and cylinder to be lower than the atmospheric pressure. As a result, the piston has to overcome a strong vacuum. This is known as pumping loss, which negatively affects efficiency.

Mazda managed to minimize pumping loss with a continuously variable dual S-VT (sequential valve timing) on the intake and exhaust valves. This changes the opening and closing timing of the valves, enabling the air intake quantity to be controlled by the valves rather than the throttle. During the intake stroke, the throttle and intake valves are kept wide open while the cylinder moves downward. The intake stroke finishes when the piston reaches the cylinder bottom (bottom dead center or BDC). But if the intake valves close here, there is too much air inside the cylinder when only a small amount of air is needed at lower engine loads. In order to push out the excess air, the intake S-VT keeps the intake valves open when the piston starts to move upward during the compression stroke. The intake valves then close when all unnecessary air is pushed out. This is how an S-VT minimizes pumping loss, making the overall combustion process more efficient.

A drawback to this process is destabilized combustion. Since the intake valves are kept open even when the compression stroke starts, the pressure inside the cylinder decreases, making it difficult for the air-fuel mixture to combust. This is not a problem for the SKYACTIV-G, however, thanks to its 13:1 compression ratio. The high compression ratio increases combustion chamber temperature and pressure, so the combustion process remains stable — despite reduced pumping loss — and the engine is more fuel efficient.

Reducing weight and internal engine friction

Reduced weight

Reduced friction

A vehicle's overall responsiveness can be enhanced by decreasing the size and weight of its components. And a complete engine redevelopment project presents the opportunity to forge new paths when it comes to lightweight design. With 20 percent lighter pistons, 15 percent lighter connecting rods and a 30 percent reduction to internal engine friction compared to the current 2.0-liter MZR engine, the new SKYACTIV-G power plant is gleefully free-revving, adapts faster to load changes and thus bolsters the sporty character of the Mazda it powers. With less energy expended in the process, fuel economy is improved by 15 percent compared to the current engine.

6. SKYACTIV-D Diesel Engine

The other member of Mazda's new generation of innovative engines is a diesel: the all-new common rail SKYACTIV-D. At 14:1 SKYACTIV-D is the lowest-compression diesel engine in the world. SKYACTIV-D is also one of the first diesels to comply with strict Tier II BIN 5 North American emission regulations without needing expensive selective catalytic reduction (SCR) aftertreatments or a lean NO_x trap catalytic converter (LNT).

Diesel engines do not require spark plugs. The injected fuel mixture ignites on its own at high pressure and the resulting high compression temperature near the "top dead center" (TDC), or when the top of the piston is closest to the cylinder head. To ensure reliable cold starting and stable combustion during the warm-up phase, conventional diesel engines have high compression ratios of 16:1 to 18:1. But not Mazda's unique SKYACTIV-D.

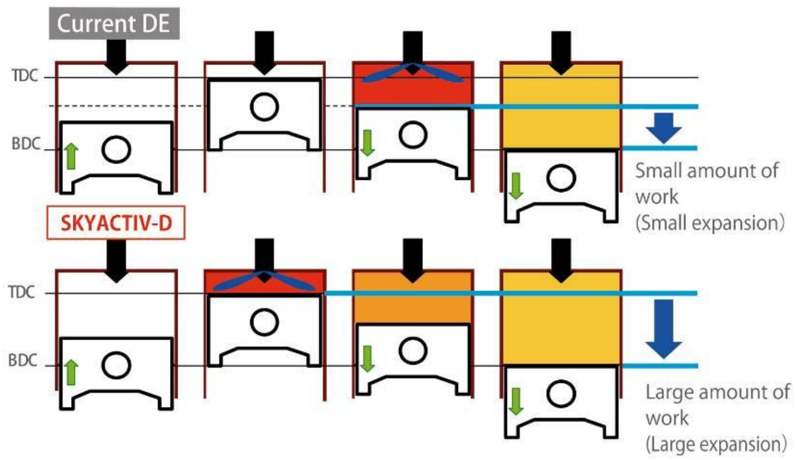
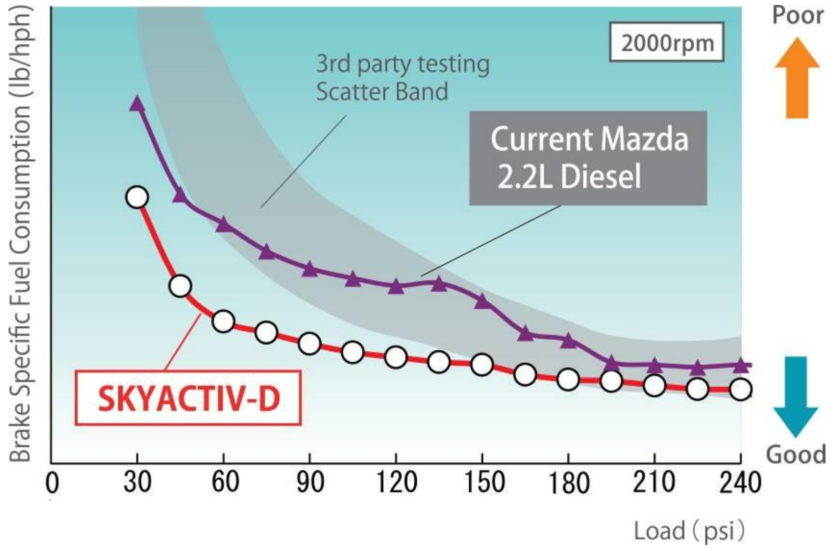
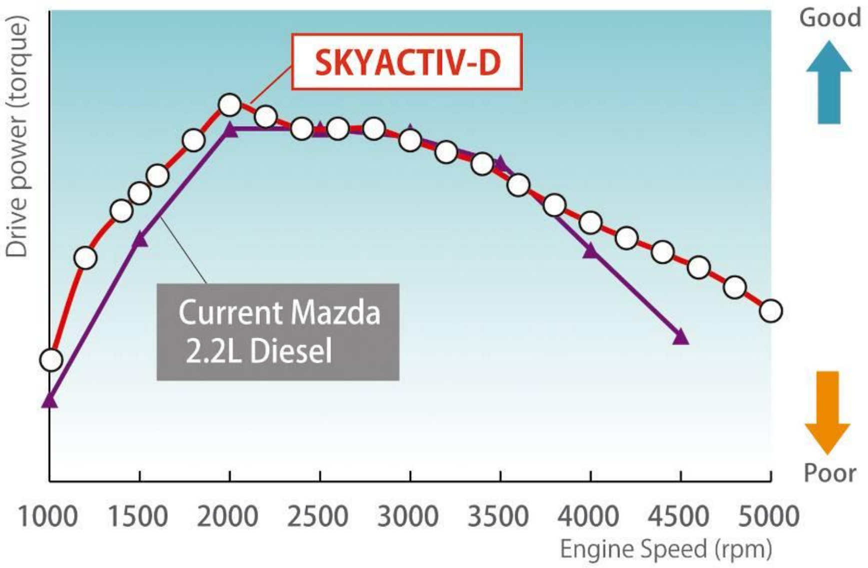


Fig.2-17 Higher expansion ratio due to lower compression ratio

Its low 14:1 compression ratio enables combustion timing to be optimized. When the compression ratio is lowered, compression temperature and pressure at TDC decrease. Consequently, ignition takes longer even when fuel is injected near TDC, enabling a better mixture of air and fuel. The formation of NO_x and soot is alleviated since combustion becomes more uniform without localized high-temperature areas and oxygen insufficiencies. Furthermore, injection and combustion close to TDC make a diesel engine highly efficient. The expansion ratio (or amount of actual work done) is greater than in a high-compression diesel engine. Simply put, optimized combustion timing means the SKYACTIV-D diesel engine makes better use of the energy contained in the fuel. And that is how a 20 percent reduction in fuel consumption was achieved.





Tier II BIN 5 without NO_x aftertreatment

Thanks to its low compression the SKYACTIV-D diesel engine also burns cleaner, discharging far fewer nitrous oxides while producing virtually no soot. It can thus do without NO_x aftertreatments and still meet tough emissions standards the world over.

The fact that Mazda's SKYACTIV-D is still considered a pilot development today – no other manufacturer has attempted to emulate it thus far – can be attributed to the system-related drawbacks of low compression. For example, the compression-ignition temperature for cold starts and during cold operation is normally too low in a diesel engine with a compression ratio of only 14:1. It would run rough, particularly in winter conditions, misfiring during the warm-up phase. And at extremely low temperatures, the engine might not start at all.

Exhaust Variable Valve Lift (VVL)

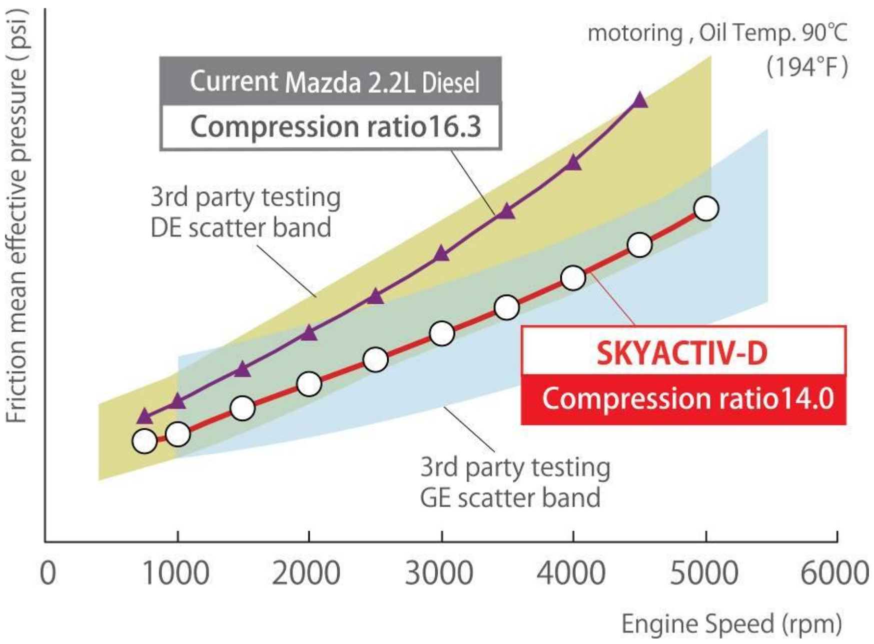
To improve cold starting and cold running, SKYACTIV-D diesel engines are furnished with ceramic glow plugs as well as exhaust variable valve lifts (VVL). The role of the latter is to allow the internal recirculation of hot exhaust gas into the combustion chamber. How it works is a glow plug is used to carry out the first combustion cycle, which is enough to raise the exhaust gas to a sufficient temperature. After the engine starts, the exhaust valve does not close as usual during the intake stroke. Instead, it remains slightly open to allow some exhaust gas to re-enter. This increases the air temperature in the combustion chamber, which in turn facilitates the subsequent ignition of the air-fuel mixture and prevents misfiring.

Reducing weight and internal engine friction

Reduced weight

Reduced friction

SKYACTIV-D's lower compression ratio means lower maximum pressure and less strain on engine components than in conventional diesels. This allows room for structural modifications to further reduce weight: cylinder heads with thinner walls and an integrated exhaust manifold are 6.6 pounds (3 kilograms) lighter while the new aluminum-made cylinder block saves another 55.1 pounds (25 kilograms).



Add another 25 percent decrease in the weight of the pistons and crankshafts, and Mazda has managed to reduce overall internal engine friction by 20 percent in the SKYACTIV-D diesel engine relative to the current MZR-CD diesel. For the driver, this translates into superior responsiveness, more pulling power and better fuel economy.

Two-stage turbocharger

Turbochargers not only help diesel engines deliver more torque but also improve fuel economy while reducing harmful emissions. SKYACTIV-D utilizes two-stage turbocharging.

One small and one large turbocharger are featured, which are selectively operated according to driving conditions. The small, quick-responding turbo feeds air to the combustion chambers at low engine speeds to provide low-speed torque and eliminate "turbo lag," which is characterized by abnormally low torque and poor throttle response caused by a lack of exhaust pressure to rotate the turbocharger's turbine up to a speed necessary to supply boost pressure.

A two-stage turbocharger ensures increased torque and responsiveness at low engine speeds and more power even at unusually high rpms, enabling SKYACTIV-D to easily reach its 5,200-rpm redline. There is no compromise to power, driving dynamics or driving enjoyment, despite the engine's extraordinary efficiency. And the synergetic effect of the two-stage turbocharging and low compression ratio enables optimal timing for combustion. Since there is a sufficient supply of air (oxygen), NO_x and soot emissions are kept to a minimum.

7. SKYACTIV-Drive Automatic Transmission

Striving for the ideal automatic transmission, Mazda focused on the following:

- **Improving fuel economy**
- **Ensuring a direct gas pedal response**
- **Shifting gears smoothly**
- **Delivering comfortable acceleration**

SKYACTIV-Drive was designed to do all this and more.

Technology		CVT	Dual Clutch	Step AT	SKYACTIV - Drive
Good Fuel Economy	FE at low speed	+	+	o	+
	FE at high speed	−	+	+	+
Easy start up (Launch feel)		+	−	+	+
Easy start up on hill (Creep)		+	−	+	+
Direct feel		−	+	o	+
Smooth shifting (Shifting Quality)		+	o	o	+
		Important in Japanese market	Important in European market	Important in NA market	Ideal for global market

+ : Better
o : Average
− : Worse

Fig.2-22 Advantages of each transmission type

The all-new SKYACTIV-Drive six-speed automatic transmission combines the benefits of conventional automatics with those offered by continuously variable (CVT) and dual clutch transmissions. It shifts quickly and smoothly, reacts dynamically to changes in the engine load right from the get-go and raises the bar when it comes to fuel economy. The heart of SKYACTIV-Drive is a newly-developed six-speed torque converter with a full range lock-up clutch for all six gears called full range direct drive. The lock-up clutch ratio has been raised from 64 percent from the current five-speed automatic to 88 percent during vehicle operation.

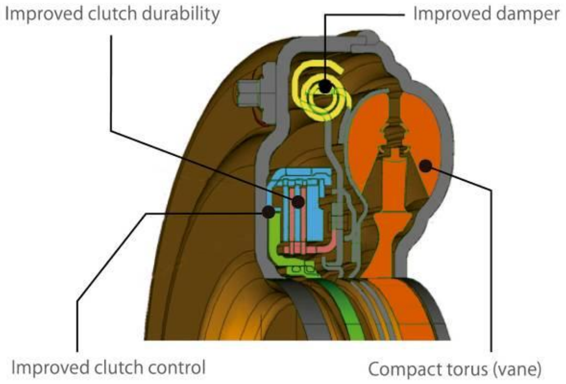
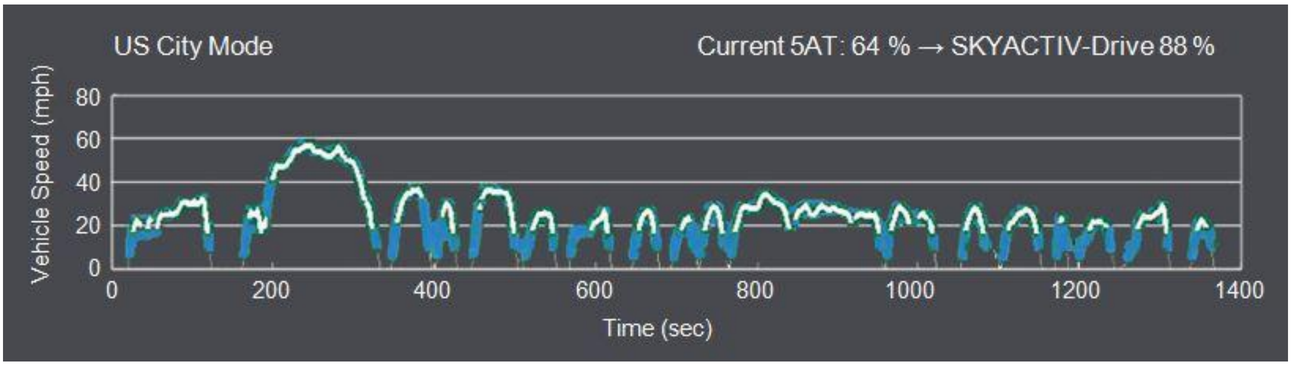


FIg.2-24 Full range direct drive



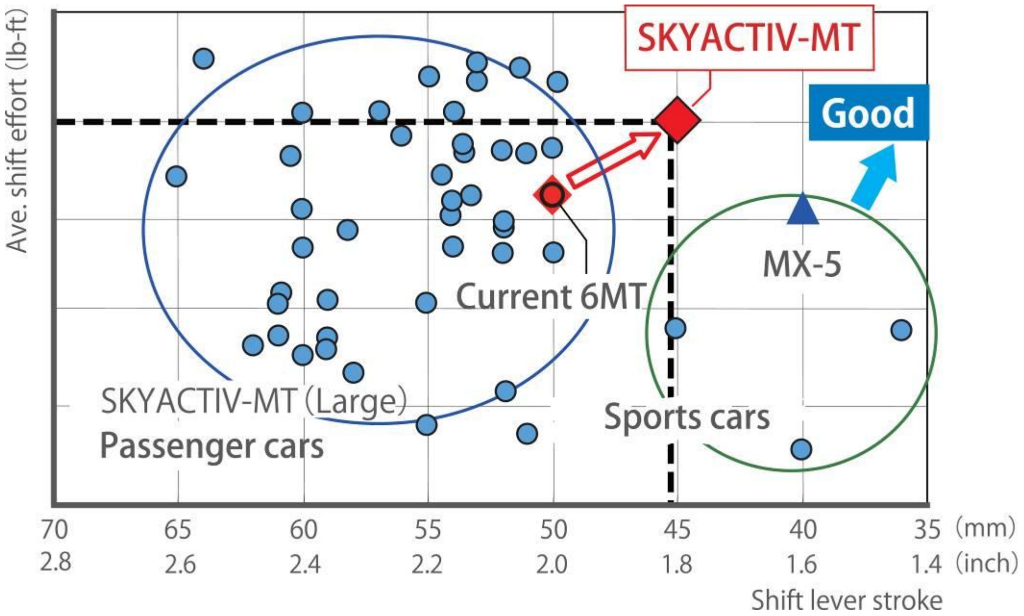
The early lock-up between engine and transmission by the torque converter (which enables engine output to be sent directly to the drive wheels) inhibits the characteristic loss of power during acceleration, delivering a more direct driving feel. Preventing engine output loss also improves fuel economy. High-precision hydraulics are essential to such a design. In order to make the necessarily fast and accurate oil pressure modulation possible in the first place and improve reliability, Mazda furnished SKYACTIV-Drive with a mechatronics module.

While maximizing the lock-up range is necessary to improve the driving feel and fuel economy, a negative effect is an increase in NVH (noise, vibration and harshness) because there is nothing to absorb the difference in the rotational speeds of the engine and transmission. A new torque converter was adapted to resolve this conflict. The expanded lock-up meant the role of the torus piece was confined to very low speeds. Therefore, it became smaller and thus creating space for an improved damper as well as a multi-disk lock-up clutch and its piston, which improve clutch durability and control.

SKYACTIV-Drive is available in two versions, making the automatic transmission compatible with both SKYACTIV gasoline and diesel engines.

8. SKYACTIV-MT Manual Transmission

Mazda came up with a redeveloped, high-precision six-speed gearbox. With a remarkably compact and lightweight design along with diminished internal friction resistance, SKYACTIV-MT represents yet another contribution to economical resource usage.



Like its automatic transmission sibling, the SKYACTIV-MT six-speed manual transmission will be launched in two versions to meet different engine torque requirements. The goal was to reduce weight by between 7 to 16 percent (depending on the model) relative to the current manual transmissions. A completely new approach was needed to generate something truly innovative since today's manuals have a relatively simple architecture. Every single component was paid attention to in order to gauge its functionality. With a new architecture featuring a shortened countershaft and no separate shaft for reverse gear in the larger model, SKYACTIV-MT is a testimony to Mazda's innovative power.

MX-5 Miata sets the standard

A sporty shifting feel was at the top of the specifications list, with the MX-5 Miata roadster's extraordinarily precise and agile manual gearbox serving as the inspiration. With the shift knob having only a 1.8-inch (4.57-centimeter) stroke from neutral to the in-gear position, the SKYACTIV-MT's tight-shifting is reminiscent of the MX-5. Gear changes feel crisp yet with minimal effort. Simply put, SKYACTIV-MT radiates its Zoom-Zoom DNA.

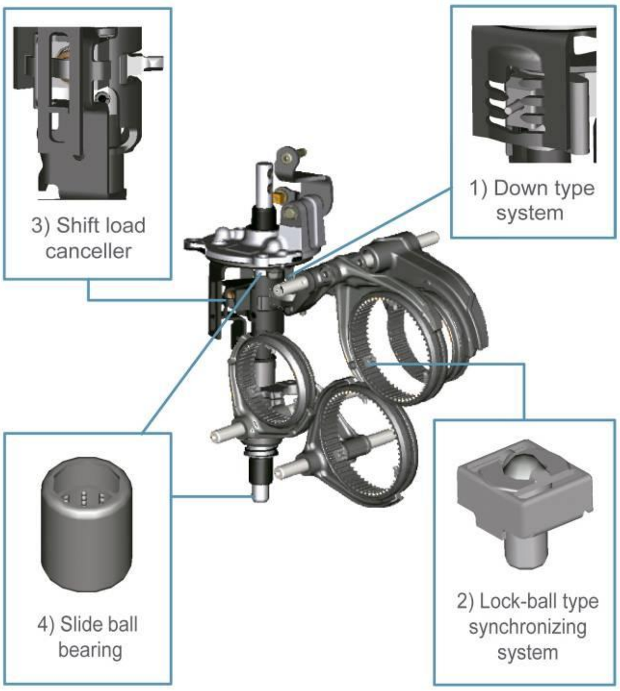
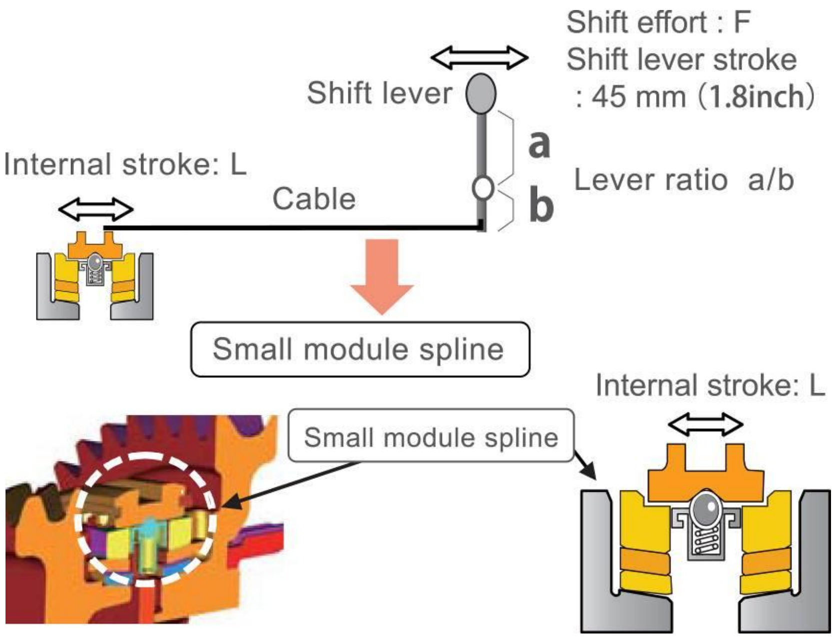


Fig.2-30 Newly introduced technologies

Mazda used a sophisticated mechanism to realize this desired shift precision and crisp feeling. The ideal operating characteristics were carefully considered based on benchmarking the MX-5 and its competitors. SKYACTIV-MT was given a continuous and lighter shifting feel with less resistance. To add precision and crispness, the shifter was designed to feel moderately heavy at the start of a gear shift and gradually became lighter, as if simply sliding into the next gear.



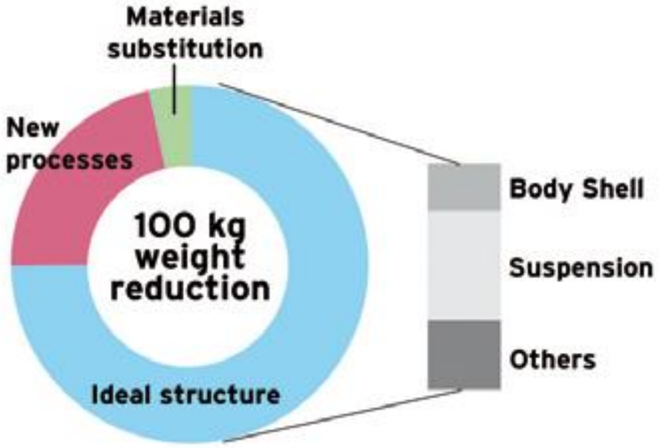
9. SKYACTIV-Body & SKYACTIV-Chassis

“Sustainable Zoom-Zoom” stands for efficiency without compromising driving pleasure. Implementing such a strategy meant no getting around the weight factor.

Lightweight engineering: A Mazda expertise

With a racing heritage such as Mazda’s, engineers are always looking to slim vehicles down. After all, lighter vehicles are not only more efficient but also more fun to drive. With better fuel economy their lightness amplifies vehicle performance, whether by acceleration, handling or braking. More weight, in contrast, breeds even more weight and resources, since a heavier body requires a heavier engine, which in turn necessitates a bigger fuel tank and so on.

Again using the MX-5 Miata as an example, the nimble and performance-oriented roadster is a market-changing model whose low weight makes it such a joy to drive. Its crisp steering, perfect front-rear balance and low center of gravity are all that much more pronounced because of the car’s weight, or rather lack thereof.

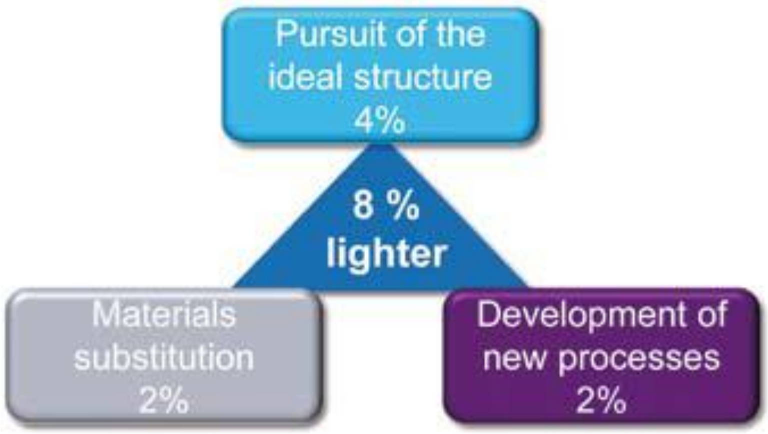


Another more recent example of lightweight engineering is the Mazda2, which was launched in North America as a 2011 model. Bucking the trend towards bigger and heavier cars, the subcompact was designed to be far more economical and perform better while also being safer.

Unique approach to cost-effective optimization

This tradition continues with SKYACTIV-Body and SKYACTIV-Chassis. Rather than concentrating on individual (and often expensive) materials like carbon fiber or aluminum, Mazda takes a unique approach to lightweight engineering. This holistic and customer-friendly process has three elements: optimizing body structure and design, adopting new production processes and substituting materials to produce lighter, stronger and safer vehicles that deliver a “Jinba Ittai”-like driving feeling.

The results speak for themselves: The new SKYACTIV-Body weighs eight percent less than its predecessor while the SKYACTIV-Chassis is 14 percent lighter. In fact, Mazda has even set the goal of making all its next-generation models 220.5 pounds (100 kilograms) lighter than before. This, in turn, enhances the synergy effects with other SKYACTIV technologies and increases the performance potential of SKYACTIV engines.



SKYACTIV-Body

Mazda’s commitment to “Sustainable Zoom-Zoom” is what motivates the R&D departments to design environmentally-friendly cars that meet the highest internationally-recognized safety standards while delivering great driving dynamics.

At times the objectives for SKYACTIV-Body were again in conflict with one another. To reconcile these issues, engineers were forced back to the drawing board. The result was car bodies for a new generation of Mazda vehicles that set new standards in lightweight construction.

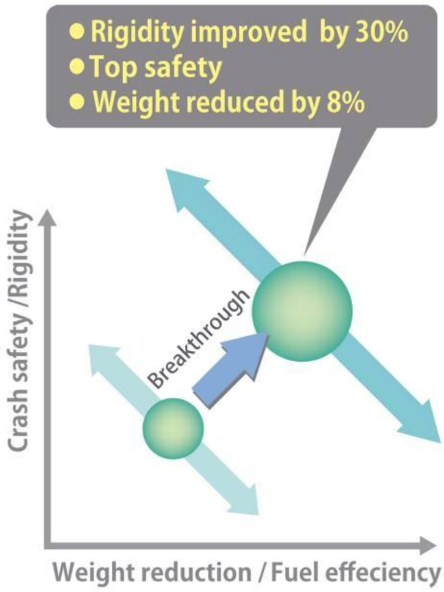


Fig.2-33 Aim of SKYACTIV-Body

Less weight, more rigidity

To efficiently transmit forces, a lightweight yet strong body structure requires as many straight sections as possible. The layout also needs to be optimized so that forces are dispersed throughout the structure and not concentrated at localized sections. Mazda engineers created a design featuring continuous straight lines from front to rear, and curves were removed from the underbody to as great an extent as possible.

Fig.2-34 Straightening of basic framework and continuous framework structure

The suspension mounting positions at the rear, for example, are bonded directly to the underbody framework as a “dual brace.” Additionally, the four vertically-positioned ring structures used for the upper body are bonded to the reinforcement area of the underbody, further enhancing overall rigidity. Meanwhile, redeveloped suspension cross members not only enhance body rigidity locally but also improve it overall since the body mount positions were optimized in the process.

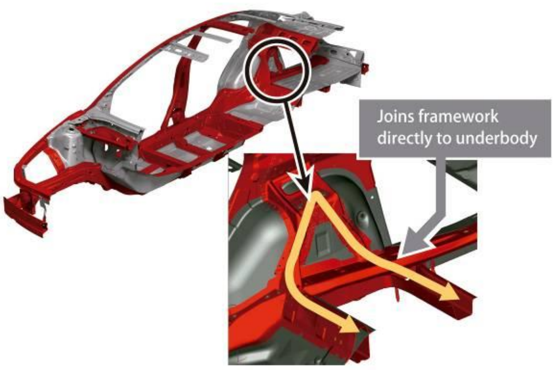


Fig.2-35 Dual brace

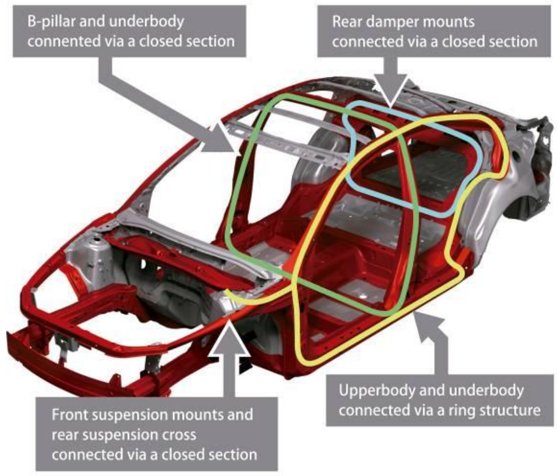


Fig.2-36 Ring structure

Multi-load path structure for optimum safety

One of Mazda’s brand principles is to continually improve passive safety in its cars. The company, therefore, developed the unique multi-load path structure for SKYACTIV-Body. This structure efficiently absorbs the load at the time of a collision by dispersing it into multiple directions. For example, during a frontal collision, crash energy is dispersed from the front (and thus absorbed) along three continuous routes or "paths" – upwards to the A-pillar, downwards through the underbody and via a middle path to the sides of the car body. The upper branch frame plays a multifunctional role. It not only diverts energy to the A-pillar but also works to counter any upward motion of the front frame since this would negatively affect the desired distribution of energy.

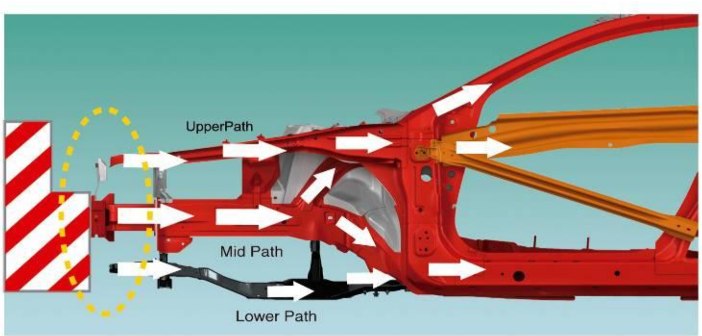


Fig.2-37 Multi-load path

Even the door on a SKYACTIV-Body works to absorb impacts. And the multi-load path structure applies to side impacts, too, greatly improving the overall safety of occupants.

Manufacturing – weld bonding and more spot welds

Weld bonding is used for the roof-rail section to create a circular "ring-like" reinforcing structure. Previously, the body assembly process meant that this structure was separate from the C-pillar section. Now, thanks to weld bonding, parts are attached in advance and sent to the assembly line as a unit. This same method was used in creating the wheel housing. The number of spot weld points also was greatly increased, contributing significantly to the body's excellent rigidity.

More high-tensile steels for greater strength, less weight

Additional advantages were generated by greatly increasing the use of high-tensile steels in the SKYACTIV-Body, and engineering efforts have paid off. Utilization of high-tensile steels has grown from 40 to 60 percent, thus reducing the weight of the car body while increasing its strength and rigidity at the same time.

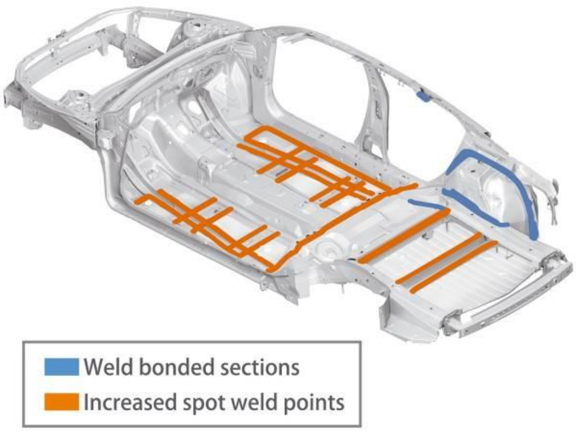
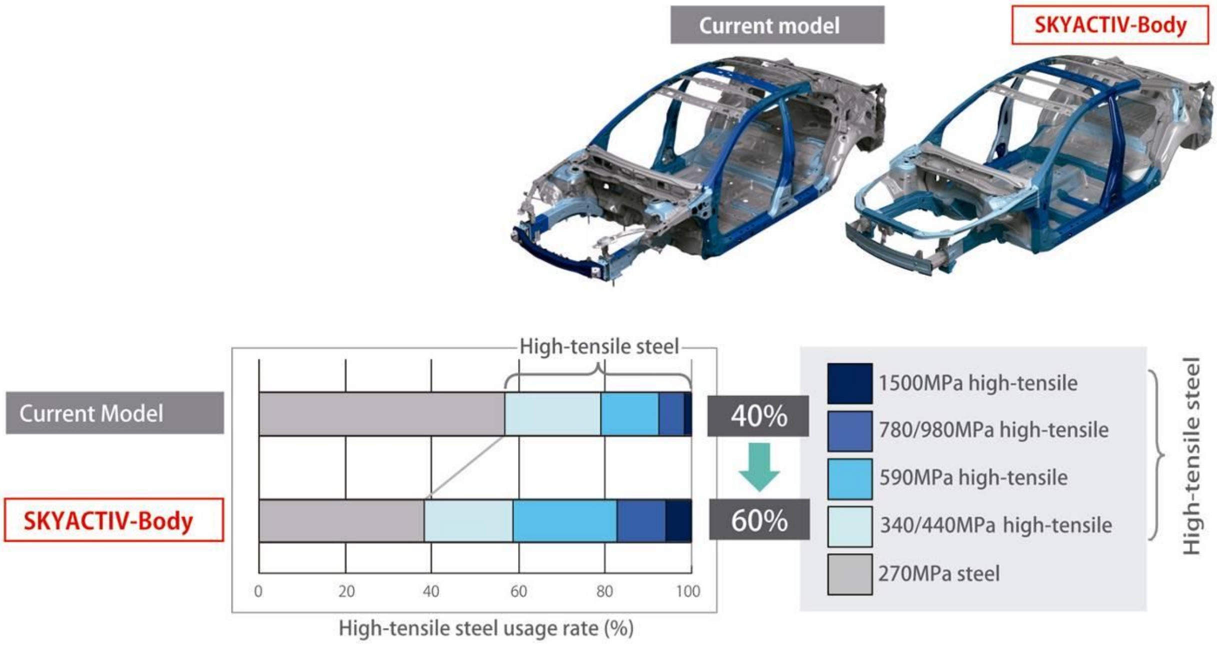


Fig.2-39 Weld bonding, increased spot welding



Fug.2-40 High-tensile steel usage rate

SKYACTIV-Chassis

Like with other SKYACTIV technologies, Mazda's chassis developers were also faced with conflicting goals: deliver extraordinary agility and a feeling of "oneness" between car and driver, ensure high-speed stability, and offer the best possible ride comfort. However, enhancing steering agility, especially at low- and mid-range speeds, can negatively affect high-speed handling and stability in general. And such agility and nimble responsiveness can get in the way of ride comfort. On top of all this, developers were looking to significantly reduce the weight of the chassis. Mazda engineers managed to achieve all these goals with its SKYACTIV-Chassis, taking a unique approach to resolve the conflicts.

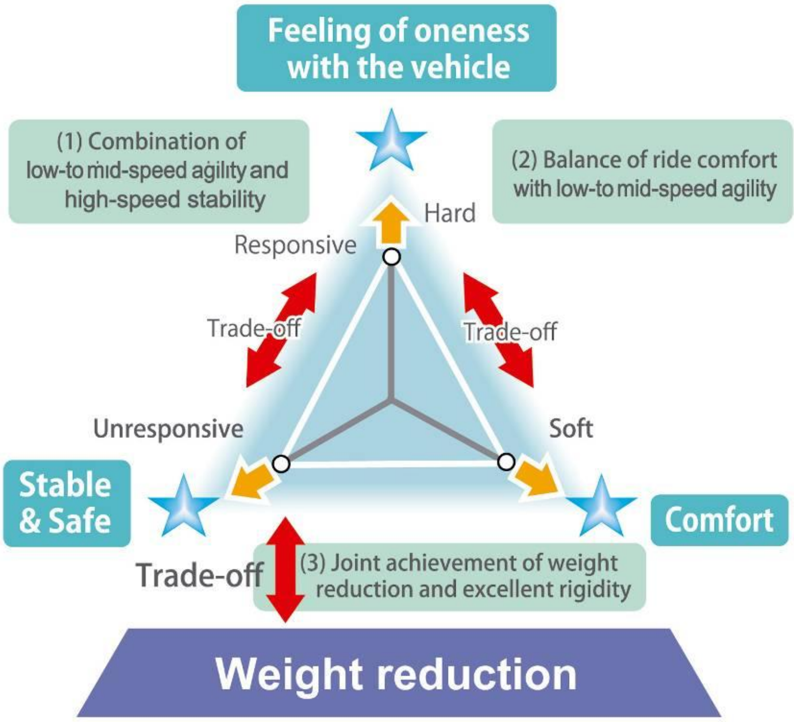


Fig.2-42 SKYACTIV-Chassis : Aims of technology

SKYACTIV-Chassis Aims of technology	New front suspension	New multi-link rear suspension	Lightweight, highly rigid cross member	Electric power steering
(1) Combination of light feel at low-mid range and stability at high speeds	●	●	—	●
(2) Balance of ride comfort with light feel at low-mid range	●	●	—	—
(3) Joint achievement of weight reduction and excellent rigidity	●	●	●	—

Fig.2-43 Main technologies used and their characteristics

Reconciling low- and medium-speed agility with high-speed stability

The first challenge was to ensure high-speed stability from a chassis that also delivered precise handling at low- and mid-range speeds. Mazda, therefore, developed a new electric power steering system that enhances the driving experience by providing an immediate response to the driver right from very low starting speeds. But such nimbleness could make the vehicle sensitively overreact at higher speeds. This is where the rear suspension's geometry was re-examined. Suspension links were optimized and rear-wheel grip enhanced to reduce yaw gain (or ease of turning). Meanwhile, a higher steering gear ratio (for more direct steering) was adopted, increasing yaw gain to maintain nimble steering at lower speeds. As a result, the vehicle is both agile and stable, with the driver enjoying the best of both worlds at any given speed.

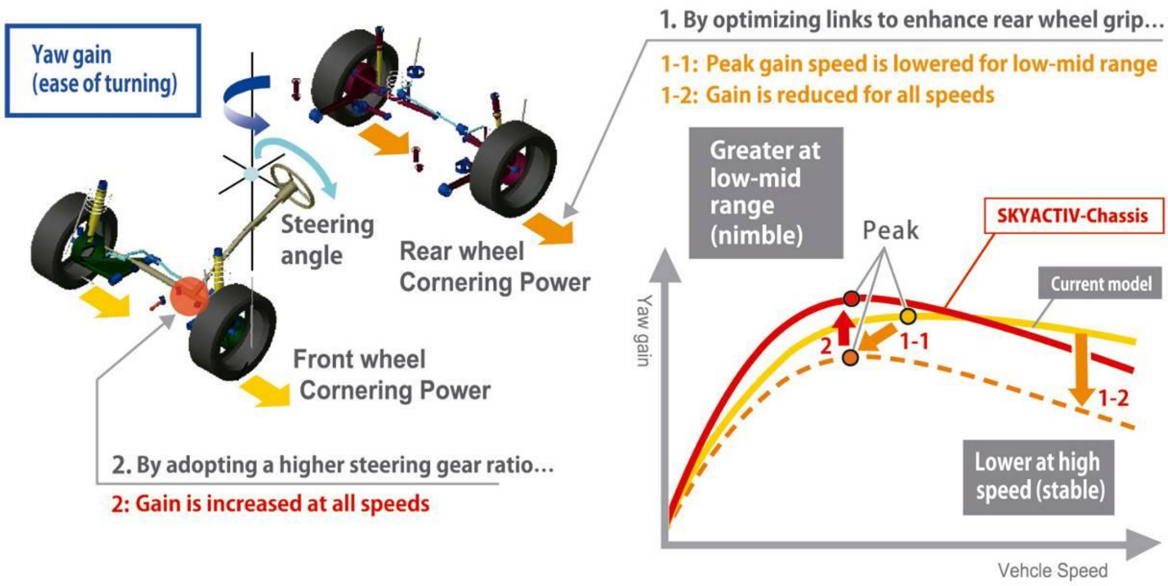


Fig.2-45 Vehicle movement changes in accordance with speed

The firmer high-speed steering feel was reinforced by increasing the caster angle — and subsequent caster trail — on the front wheels, which enhances the steering's self-aligning torque. Power steering assistance was then increased at lower speeds to ease steering and give it the desirably lighter feeling at such velocities. As a result, the new generation of Mazda vehicles steers smoothly and securely in all situations.

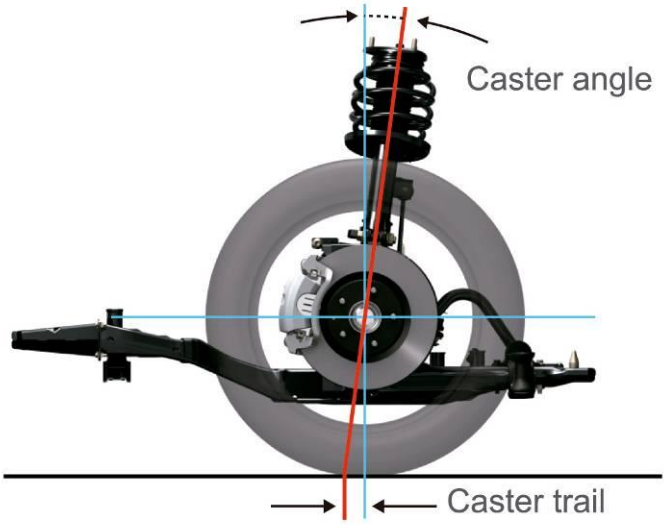
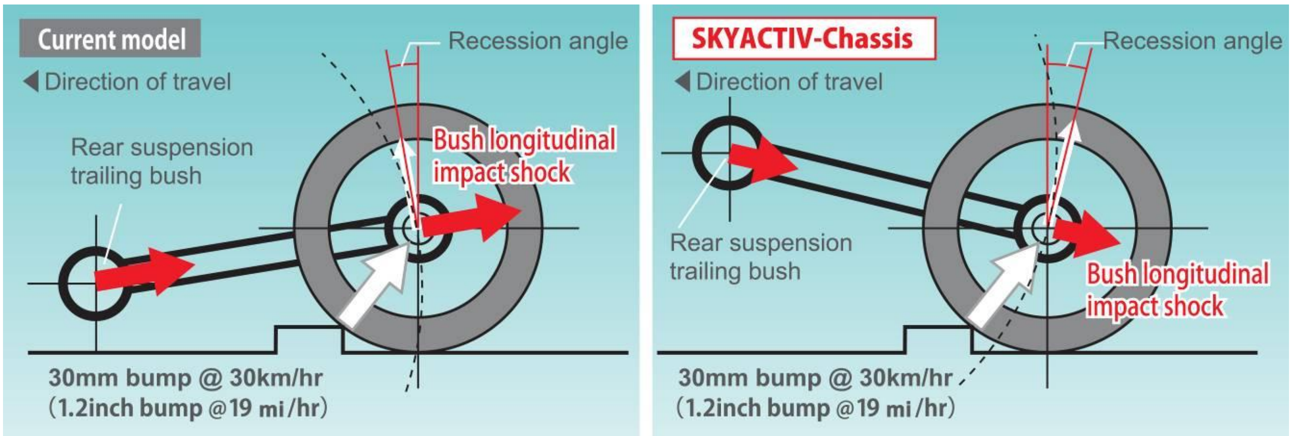


Fig.2-46 Increased caster trail

Reconciling low- and medium-speed agility with superior ride comfort

As the interface between the platform and the wheels, the suspension is essential to a vehicle's handling. The arrangement and structure of the suspension determine the precision with which a car steers. They also influence ride comfort. Therefore, the second greatest challenge for Mazda developers was to optimize this architecture. The rear suspension proved vital when trying to achieve the best possible balance between agility and ride comfort. The aim was to improve handling without stiffening springs or shock absorbers.



To enhance the operational efficiency of the dampers, the mounts were set at a position enabling a greater lever ratio. The damping force and rigidity of the top mount rubber were thus reinforced, reducing their impact on ride comfort. The position of the rear suspension trailing link attachment was also shifted upwards, thereby adjusting the direction of movement of the trailing links to more easily absorb longitudinal impact shocks from the road. This improves ride comfort while at the same time prevents the rear of the vehicle from rising. The result is increased stability when braking, which helps reduce stopping distance.

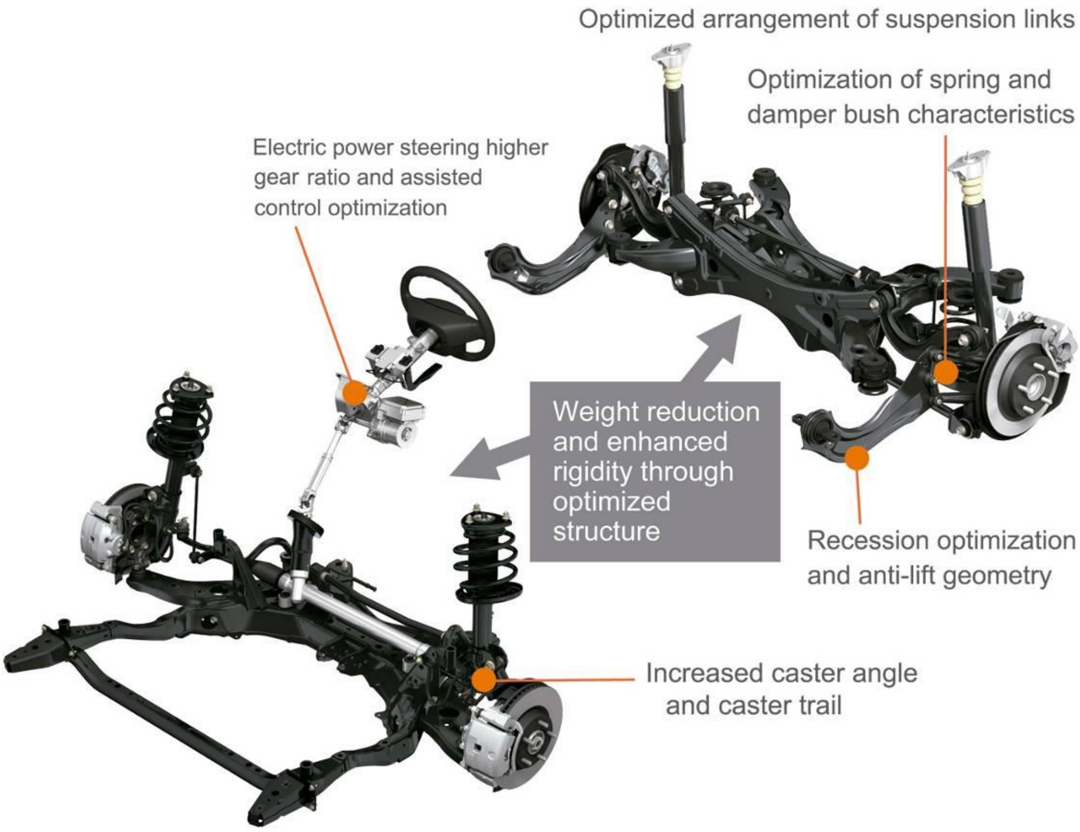


Fig.2-44 SKYACTIV-Chassis Breakthrough technologies

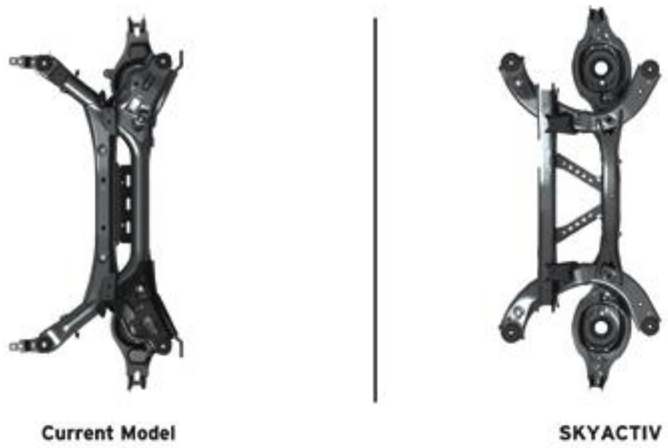
Reconciling reduced weight with increased rigidity

SKYACTIV-Chassis weighs 14 percent less than the current version, but is still more rigid. And that was chassis breakthrough number three.

Placing a special focus on the chassis cross members, engineers were able to achieve ambitious weight reduction objectives. After defining their functional requirements, computer-aided engineering (CAE) technology was used to design a conceptual model and coordinate the optimum structure into the overall vehicle package.

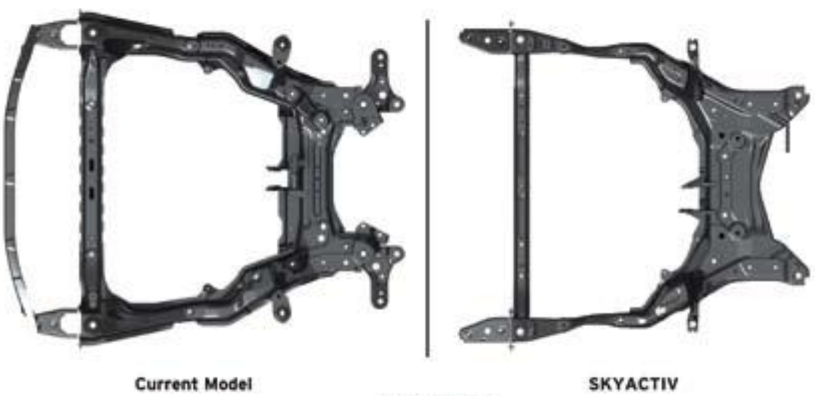
The center section in the front of the car was extended and the longitudinal offset of the lower arm attachment position was reduced. In the rear, meanwhile, the longitudinal span of the cross member was extended and the longitudinal offset of the lateral link attachment position reduced.

Welding flanges were also removed from the front and rear to enhance the coupling rigidity of the welded sections. All these measures considerably enhanced overall stiffness in a lighter chassis.



Rear Cross Member

Intelligent solutions led to numerous improvements that together make up the SKYACTIV-Chassis. Engineers have achieved what they set out to deliver, namely the driving fun, safety, ride comfort, agility and stability worthy of a new generation of Mazda vehicles.



Cross Member

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