MAZDA

NEXT-GENERATION SKYACTIV-VEHICLE ARCHITECTURE AND KODO DESIGN

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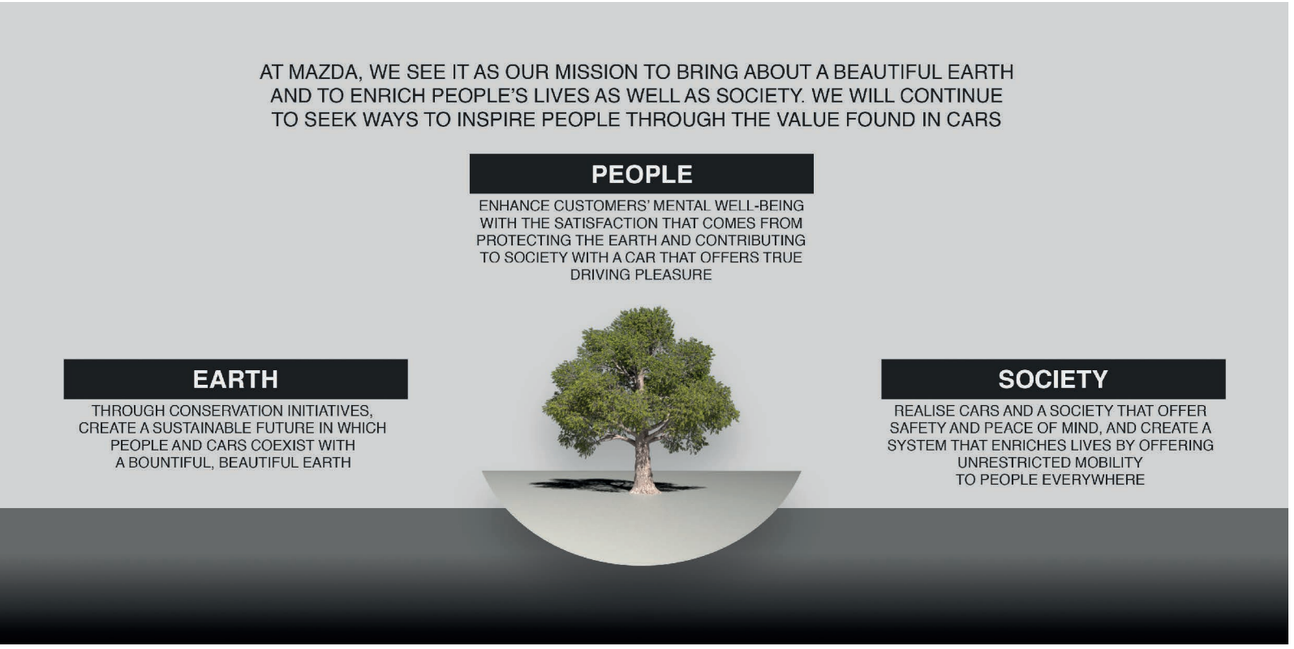


In 2007 Mazda announced a long-term technology development vision called Sustainable Zoom-Zoom, dedicated to creating cars people wanted to drive, whilst also taking into consideration the needs of the planet.

On August 8th 2017, recognising that stronger ecological measures are needed to lower CO2 emissions, drastically reduce greenhouse gases and safeguard the planet, Mazda announced a new long-term strategy - Sustainable Zoom-Zoom 2030.

Sustainable Zoom-Zoom 2030 has three principle points of focus:

The Earth: 'Creating a sustainable future in which people and cars coexist with a bountiful, beautiful Earth'. More specifically, reducing Mazda's corporate average 'Well-to-Wheel' CO2 emissions to 50% of 2010 levels by 2030, and by 90% by 2050.

Our Society at Large: 'Through cars and society that provide safety and peace of mind, create a system that enriches people's lives by offering unrestricted mobility to people everywhere'. This means standardising the brand's i-Activsense safety features, and expanding testing into autonomous vehicles and connectivity technology.

People that Drive Mazdas: 'Enhance customers' mental well-being with the satisfaction that comes from protecting the Earth and contributing to society with a car that offers true driving pleasure'. This builds on the first two points, whilst pursuing Mazda's philosophies of Jinba Ittai - the close connection between driver and car, and 'breathing life into the car' with Kodo exterior design.

These three key tenets - allied to a commitment to the principal of the right solution at the right time - inform every aspect of Mazda's approach to design, engineering and technological development today.

THE RIGHT SOLUTION AT THE RIGHT TIME

Moving beyond current 'Tank-to-Wheel' CO2 evaluations - which consider only emissions whilst driving, to a 'Well-to-Wheel' method - which also considers fuel extraction, manufacturing and shipping, allows Mazda to make a more accurate assessment of the appropriate powertrain development paths to pursue in the immediate future.

In this 'Well-to-Wheel' context, Mazda has reconsidered the merits of Electric Vehicles (EVs). With two thirds of global electricity production currently relying on the use of fossil fuels, the company believes regulations placing the emissions of an EV at 0g/km to be disingenuous...

A mid-sized electric car consumes around 20 kilowatt-hours of electricity per 100km. Production of this power with coal translates into CO2 emissions of 200g/km; with petroleum, 156g/km; and with Liquefied Natural Gas (LNG) 100g/km.

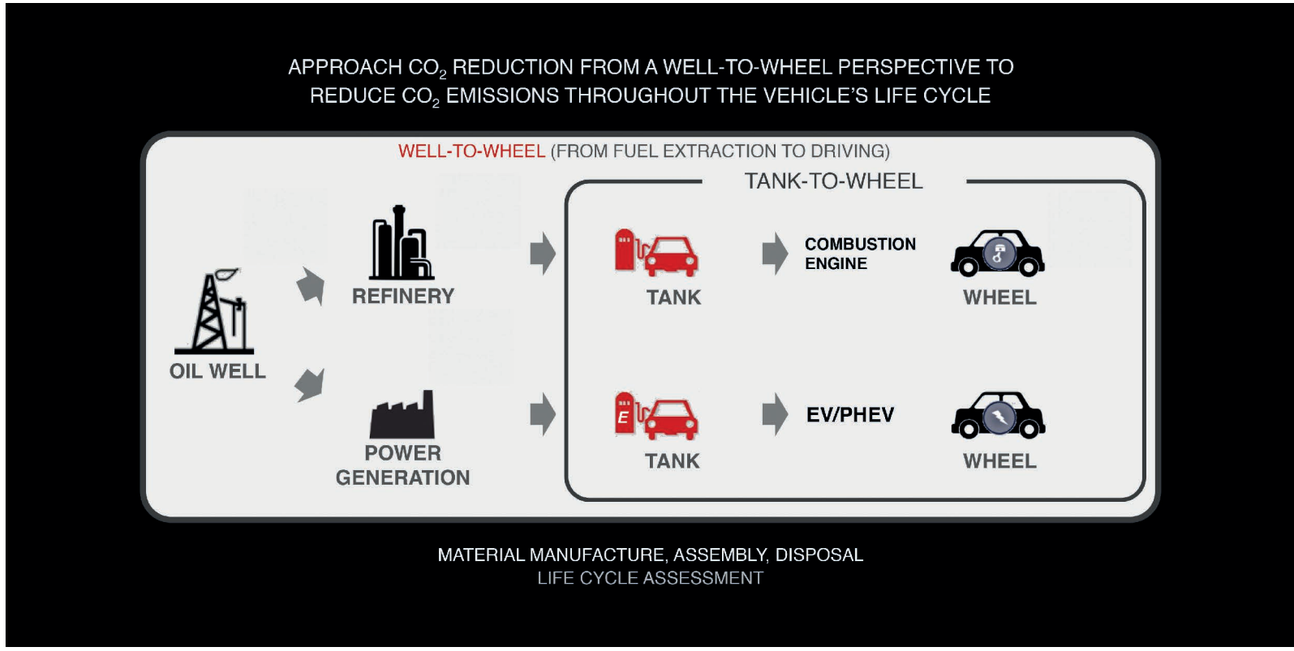
When converted to a 'Well-to-Wheel' figure, then, the average global CO2 emissions of an EV are some 128g/km, whilst Mazda's Skyactiv-G and -D engine range averages 142g/km. This means that with as little as a 10% improvement in efficiency, Skyactiv powertrains will be on a par with EV vehicles.

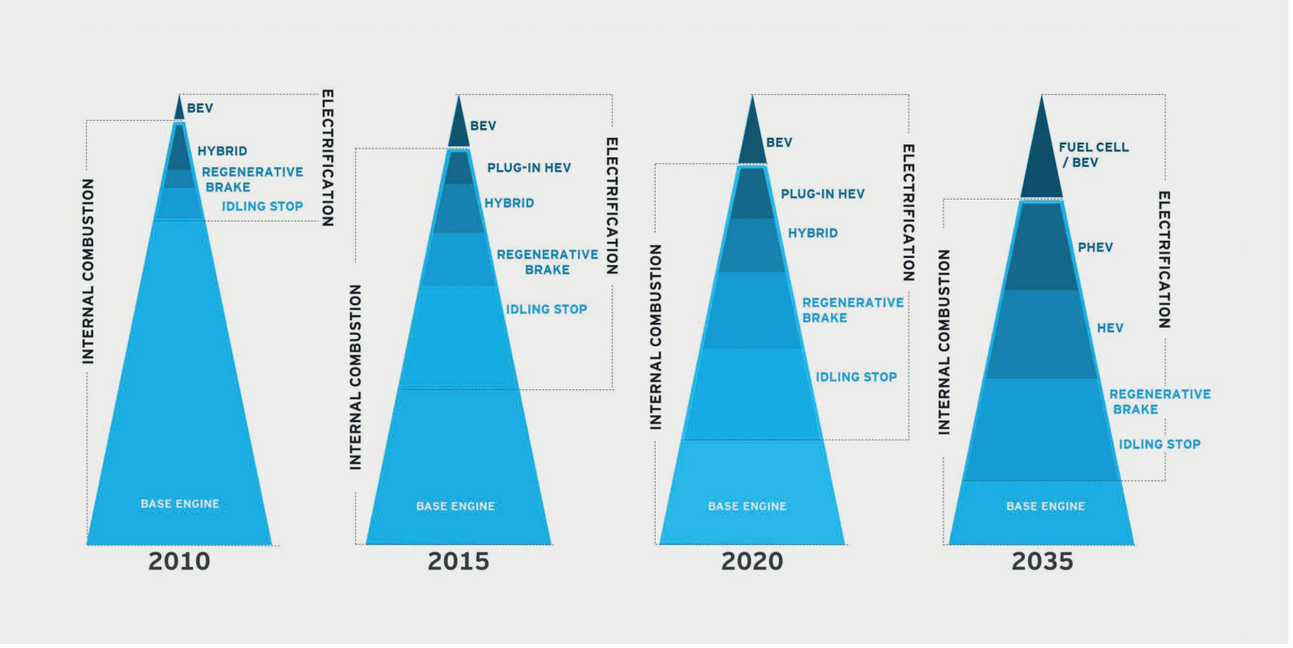
In fact, Skyactiv produces less CO2 than EVs whose electricity is generated by coal or petroleum. And whilst EVs using LNG-produced electricity have 30% lower emissions, Mazda believes it can improve the internal combustion engine sufficiently to match that level.

This is not to suggest that Mazda is turning its back on the development of the electric powertrain. The company has already introduced mild hybrid technology - or microhybridisation. This will be followed by models with built-in batteries in 2020, and the brand's first plug-in hybrid shortly thereafter.

Mazda will produce two Electric vehicles (EVs): one, launched in 2020, powered solely by battery; the other, at a later date, pairing a battery with a newly-developed range-extender powered by a small, lightweight and exceptionally quiet rotary engine.

To that end, Mazda has recently formed a new alliance with Toyota, Subaru, Suzuki, Daihatsu, Hino and battery manufacturer Denso to explore joint technologies for the combination of the ideal internal combustion engine with effective electrification technology, and for the development of EVs.





Mazda has, however, concluded that until more renewable energy sources replace dirtier forms of fossil fuel such as brown coal, and until charging times, the charging infrastructure and battery standards have dramatically improved, electric powertrains do not currently satisfy society's wish for a drastic reduction in greenhouse gas emissions.

So the company expects the internal combustion engine to still be playing a major role by 2030, helping to power the majority of vehicles on the world stage for many years, and making the largest contribution to CO2 reduction.

With that in mind, Mazda has concentrated on developing its combustion engine technology to the very highest standards - its innovative Skyactiv programme already realising three ground-breaking achievements which radically advance the technology of both petrol and diesel engines.

Skyactiv-G overcomes one of the most fundamental limitations in petrol engine design, that high compression ratios increase performance and fuel economy, but are restricted by the onset of knock beyond 10-12:1. Mazda has created an engine with a compression ratio of 14:1, which yields more torque and converts more of the fuel's energy to power whilst effecting a 20-30% improvement in fuel economy.

Skyactiv-D challenges the need for super-high compression ratios in diesels and runs at 14:1 instead of 16:1 or more. The result is a reduction in losses caused by high compression and the internal friction created by larger bearing surfaces which diesels have. The SKYACTIV-D is smaller and lighter with less internal friction, and boasts a 20% improvement in fuel economy.

Skyactiv-X is the next step on from the Skyactiv-G and features Mazda's own unique combustion method - Spark Controlled Compression Ignition (SPCCI) - to create a revolutionary engine which combines the benefits of both a spark ignition and compression ignition unit.

SKYACTIV-X WITH SPARK CONTROLLED COMPRESSION IGNITION (SPCCI)

- **10% more torque than 2018 Skyactiv-G 165 PS, depending on rpm**
- **Up to 20% better fuel economy than Skyactiv-G, depending on driving style**
- **Superior initial response and free revving to high rpm for enhanced driving pleasure**

Mazda's new 2.0 litre SKYACTIV-X engine is the world's first production petrol unit to exploit the benefits of diesel-like compression ignition.

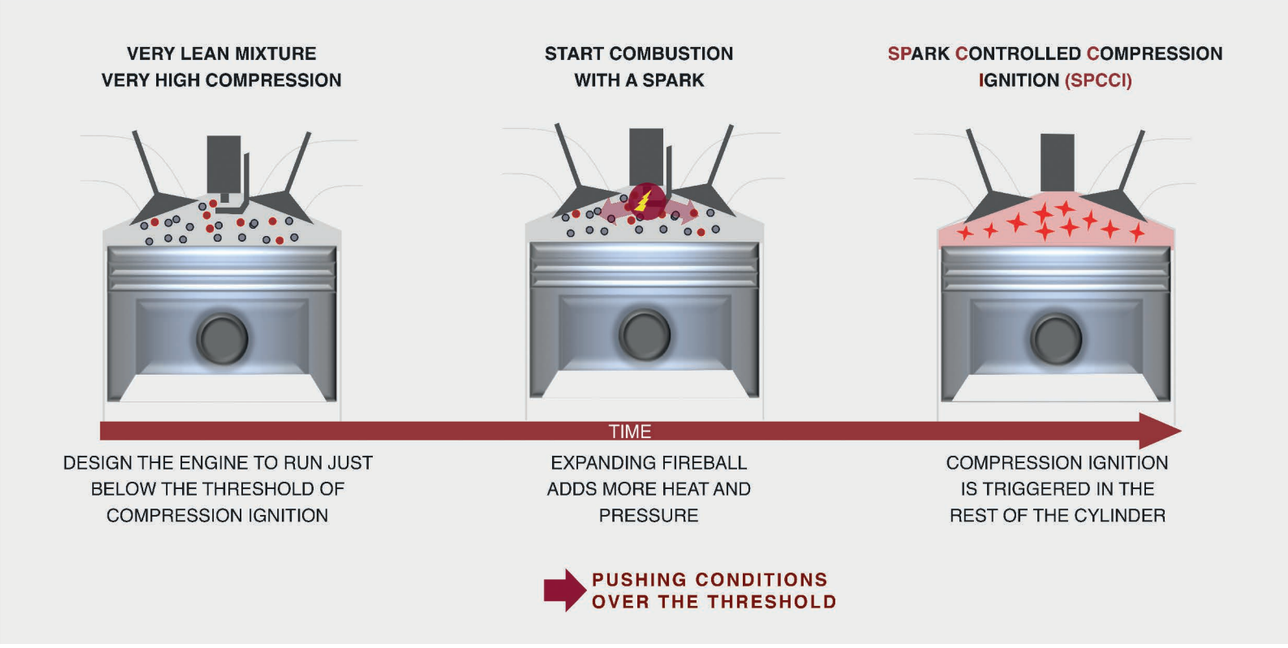
Key to its operation is the use of a highly lean, fuel- and emissions-efficient mixture of air and fuel: 2-3 times leaner than in today's conventional engines. This mixture has so little fuel in the air that a normal engine with spark plugs cannot fire it.

Mazda already uses uniquely high compression ratios on its current Skyactiv petrol engines to reduce fuel consumption. This lead to the idea of increasing the compression ratio even further and igniting the fuel simply by compression, as is the norm in modern diesel engines.

This concept has been tried before by several manufacturers with Homogeneous Charge Compression Ignition (HCCI), but none has been able to expand the area of lean compression ignition across a wide range of engine operation.

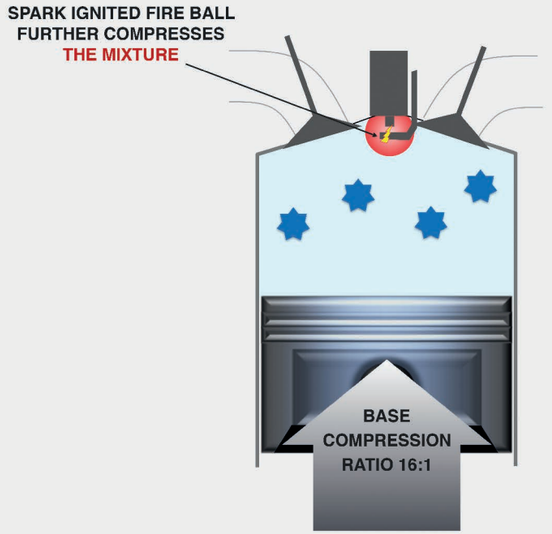
Mazda's unique solution to the problem is Spark Controlled Compression Ignition (SPCCI), which allows the engine to switch seamlessly between conventional combustion and compression ignition by using a spark to trigger both types of combustion in different ways.

HCCI prototype engines would turn the spark off altogether in compression ignition mode, causing unpredictable results and unstable combustion. In contrast, SKYACTIV-X uses a spark continuously like a conventional engine.



HOW SPCCI WORKS

1. AIR AND FUEL ARE COMPRESSED TO NEAR COMPRESSION IGNITION CONDITIONS
2. THE SPARK PLUG INITIATES A SMALL FIREBALL
3. THE FIREBALL EXPANDS TO INCREASE TEMPERATURE AND PRESSURE UNTIL COMPRESSION IGNITION CONDITIONS ARE MET
4. THE MAJORITY OF AIR AND FUEL IN THE CYLINDER IS COMBUSTED THROUGH COMPRESSION IGNITION
5. THE TIMING OF THE SPARK IGNITION CONTROLS WHEN COMPRESSION IGNITION WILL HAPPEN



Here's how it works. In SPCCI mode, a split injection process creates separate zones of fuel-air mixture inside the combustion chamber.

First, a very lean fuel to air mixture is injected into the combustion chamber during the intake stroke, then a zone of atomised fuel is precisely injected directly around the spark plug during the compression stroke. Imagine a cherry on a cupcake, where the cherry is the richer zone, and the cake is the lean mixture.

Because of the high 16.3:1 compression ratio of Skyactiv petrol technology, the first charge is on the verge of spontaneously combusting anyway. To ignite the mixture at the right time, a small injection of atomised fuel directly around the spark plug builds a richer core. When the spark fires, it ignites the local zone of fuel and air. This increases pressure in the combustion chamber to the point where the main volume of the lean mixture rapidly combusts.

A super-high pressure fuel injection system atomises the fuel instantly, simultaneously creating powerful turbulence to ensure even, stable combustion. It works at very high speed too, injecting the two zones of fuel very quickly in conjunction with a new piston design.

The advantage of this method is that the compression ignition combustion phase is stable and the switch between conventional combustion and SPCCI is predictable and reliable. In-cylinder pressure sensors allow the engine management system to watch over the process and intercept any signs of abnormal combustion.

Improving fuel economy, SPCCI works in almost all ranges of engine operation except during cold starts, initial warm-up phases and at very high load. Under these circumstances, the engine seamlessly switches to normal operation, igniting a conventional 'stoichiometric' fuel and air mixture of 14.7:1.

Through control by the spark plug, the issues of knocking and instable combustion can be avoided, achieving a seamless transition between compression ignition and spark ignition. When the engine is running in compression ignition mode, it uses less fuel and produces less CO2.

Moreover, because SPCCI is so stable whereas HCCI wasn't, it can be used more frequently in the engine's operating range, which means the engine can run for a higher percentage of the time in a very efficient mode.

As a result, torque output is approximately 10% greater than that of the Skyactiv-G 165 PS, and the zone of good fuel economy is dramatically expanded over that of the same unit - by up to 20% depending on driving conditions.

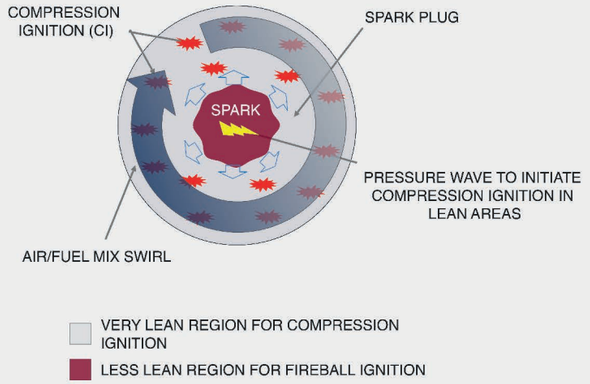
With improvements being especially great in the light engine load range, Skyactiv-X improves fuel economy, and reduces CO2 and NOx emissions, challenging the commonly-held belief that medium-sized petrol engines have poor fuel economy in cities.

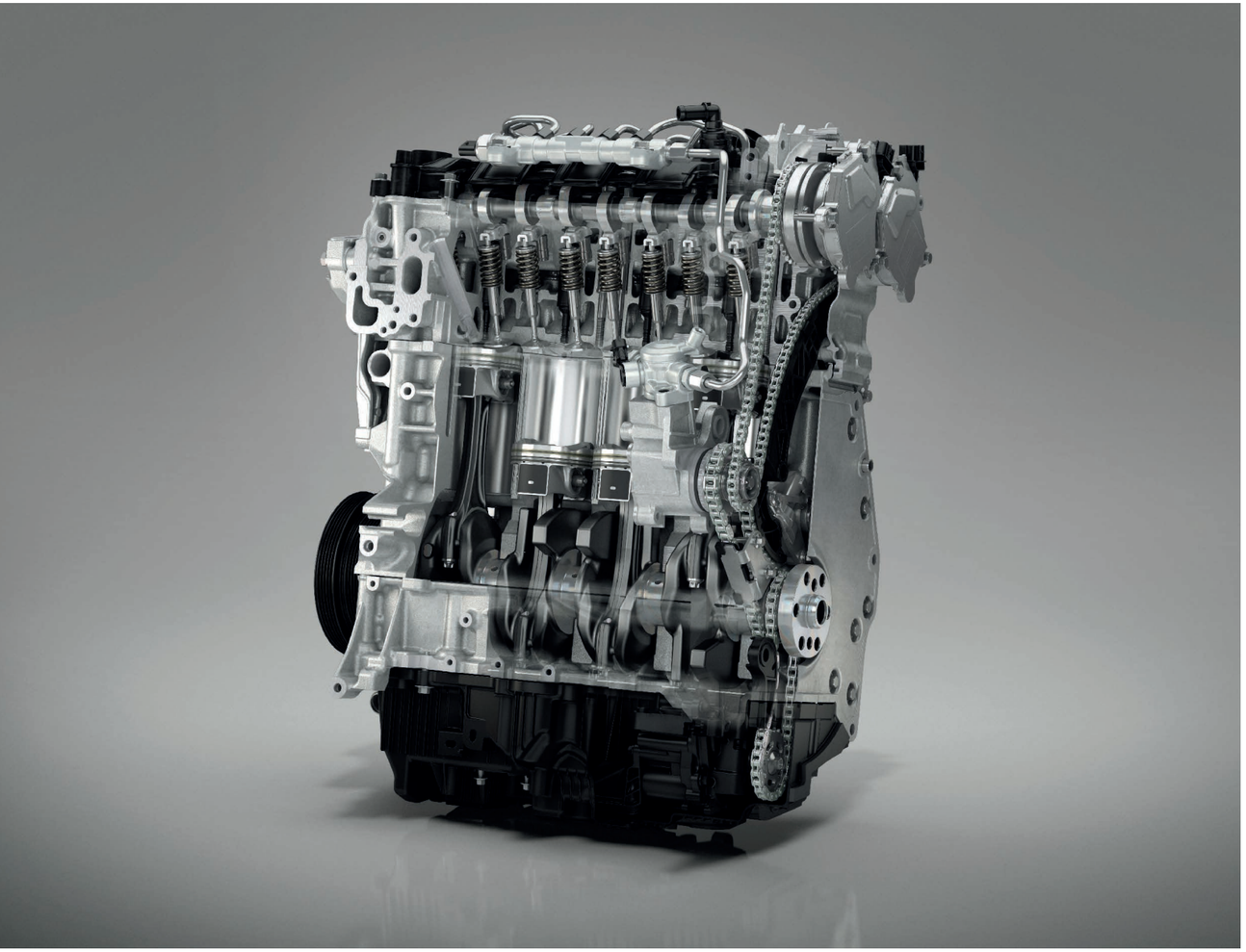
Combining the advantages of both petrol and diesel engines, SPCCI offers outstanding power, acceleration and environmental performance, making SKYACTIV-X a great alternative for those who prefer petrol engines, with the benefits of diesel.

CONTROL FUEL DISTRIBUTION THROUGH CYLINDER SWIRL AND FUEL INJECTION TIMING

- SPCCI NEEDS DISTINCTLY DIFFERENT AIR FUEL RATIOS
- A SLIGHTLY LESS LEAN REGION NEAR THE SPARK PLUG
  → **ALLOWS THE FIREBALL TO IGNITE**
- THE MAJORITY OF THE MIXTURE INSIDE THE CYLINDER REMAINS VERY LEAN
  → **IT COMBUSTS WITH CI**
- SWIRLING THE AIR INSIDE THE CYLINDER AND GENERATING A VORTEX EFFECT
  → **KEEPS IT VERY LEAN**

TOP DOWN VIEW OF CYLINDER





M-HYBRID SYSTEM – ELECTRIFICATION FOR BETTER FUEL ECONOMY

- **Recovered energy recycling and electric motor assistance for improved fuel efficiency**
- **Motor torque boosts engine torque, using less fuel to match petrol engine acceleration**
- **Motor input quickly adjusts engine speed during upshifts for smoother gear changes**
- **System battery supports car battery for extended engine off periods**

Mazda's Skyactiv-G 2.0 and Skyactiv-X engines feature the company's intelligent Mazda M Hybrid system. Compact and highly efficient, the mild hybrid system features a belt-driven integrated starter generator (ISG) and a 24V lithium-ion battery with a capacity of 600kJ. It supports greater gains in fuel economy by recycling energy recovered during deceleration and powering the ISG, functioning as an electric motor, to assist the engine.

The ISG converts the recovered kinetic energy into electric power and stores it in the lithium-ion battery. The system then uses a DC-DC converter to transform that voltage to the appropriate level, and supplies it to the car's electrical equipment.

Adopting the belt-driven ISG also delivers a refined drive feel by enabling the system to provide drive assist and helping the engine restart more quickly and quietly after shutting down for idling stop. The lithium-ion battery is mounted between the wheels, minimising its impact on interior space, while helping to optimise weight distribution and contributing to collision safety.

The Mazda M Hybrid system's brake-by-wire technology smoothly and dynamically blends electric and friction brake forces to maximise both stopping power and energy recuperation efficiency. Not only does it offer shorter braking distances with high levels of vehicle stability, but also - through the transformation of electric brake force into useable energy - further reductions in CO2 emissions.

The electronically controlled brake-by-wire system is also designed to revert to entirely mechanical friction braking as a fail-safe in the event of an electrical system failure.

Jinba Ittai

Throughout the development of its revolutionary Skyactiv technologies, Mazda has consistently aimed to provide the joy of Jinba Ittai driving.

Jinba-Ittai - driver and car as one - is a concept which reflects the company's belief that car and driver should have a bond, similar to that between a horse and its rider. Based on this idea, Mazda continues to look at ways of integrating the driver ever more closely with the car, creating an intuitive interface between the two to offer its customers an entirely engaging driving experience.

With its next-generation Skyactiv-Vehicle Architecture, Mazda has focused on a fundamentally human-centred development process in which the basic functions of the company's Skyactiv technologies have been fine-tuned to ensure that occupants can make use of their natural ability to maintain their balance while the car is moving.

Over and above the development of individual components such as seats, body, chassis and tires, Mazda has focused on whole-vehicle coordination, re-allocating functions to create an architecture that works together as a coordinated whole.

Making full use of inherent human abilities allows Mazda to go beyond the traditional concept of a platform, offering more intimate communication between car and driver for the ultimate in Jinba Ittai driving - the car responding almost as though it were an extension of the driver's body, enhancing safety, peace of mind and driving enjoyment.

IDEAL STATE OF HUMAN WALK

PROGRESSION AXLE WHEN WALKING

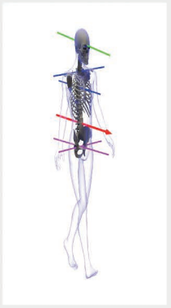
- LOW STRESS MOTION
- HEAD KEPT WIDELY STABLE AND PARALLEL TO GROUND
- COMPENSATION MOTION OF BODY
- BEST POSITION TO REACT SPONTANEOUSLY TO CHANGING ENVIRONMENT

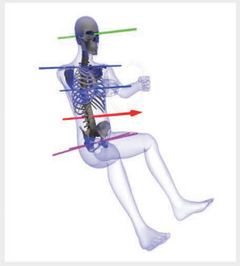
IDEAL CONDITION

- PELVIS IS UPRIGHT
- S-SHAPE OF SPINE

TRANSFER THIS PRINCIPLE TO DRIVING POSITION

- SELF-BALANCING PRINCIPLE





Human-Centred Development

When walking, we use the flexibility of our spine to move our pelvis and upper body in opposite directions around a ‘progression axis’ - our direction of travel.

We do this completely unconsciously, using minimal posture change or muscle force to keep our body balanced and head still, even when changing direction or climbing stairs.

Keeping the right body posture is essential to this instinctive balancing act. With our pelvis upright and our spine forming an ‘S’ shape, the reaction force from our footsteps is transferred to our pelvis via our lower legs, allowing it to move in a smooth, continuous pattern, and us to walk in comfort and with minimal fatigue.

Mazda has transferred this principle to the driving position. Occupants sit with the pelvis supporting the spinal column in an ‘S’ shape, while the reaction force from the car’s movement over the ground is smoothly transferred to the pelvis through the car body rather than through the person’s legs.

The smooth movement of the sprung mass - the car’s bodyshell - is fundamental to ensuring that occupants can use their natural balance ability to the full. And the seats must move in conjunction with the sprung mass without a delay, so that input energy is transmitted smoothly to the pelvis.

To develop a sprung mass capable of this kind of smooth, continuous movement, Mazda has focused on the following three points:

- Ensuring energy is transferred smoothly from the unsprung to the sprung mass
- Aligning the direction of forces
- Reducing rigidity variations between diagonally opposed bodyshell corners

Achieving these three aims ensures that the diagonally opposed corners move together, without a delay, as they send and receive energy.

Seats: Moving Together with the Sprung Mass

- **Pelvis supported in the correct, upright position and spine in a natural ‘S’ shape**
- **Allows occupants to fully benefit from the subconscious use of their innate balancing ability**
- **Improved comfort, less driver fatigue, better control of the vehicle and greater driving enjoyment**

Mazda’s next-generation Skyactiv-Vehicle Architecture uses the latest insights obtained from human biology research in the design of the car’s seats.

Ensuring that the occupant’s pelvis is properly supported so as to maintain the spine’s ‘S’ shaped curve enables them to make full use of their natural balancing ability.

So, the shape and firmness of the seat is designed not only to support the pelvis in the correct, upright position, but also to envelop the rib cage and the upper section of the spine, helping to maintain the natural ‘S’ shape of the spinal column.

In addition, the design of the seat base cushioning provides good support for the thigh bones, while its structure allows the occupant to move each thigh independently.

At the same time, Mazda has increased the rigidity of the seat’s internal structure and of its attachment points to the car’s bodyshell. This means that the seat moves together with the sprung mass with no delay, ensuring that input energy is transferred smoothly and instantaneously to the occupant’s pelvis.

The end result of this painstaking, human-centred design development is a seat which offers ideal pelvis and spine posture for occupants of widely varied physiques, allowing them to benefit from the entirely subconscious use of their innate balancing ability.

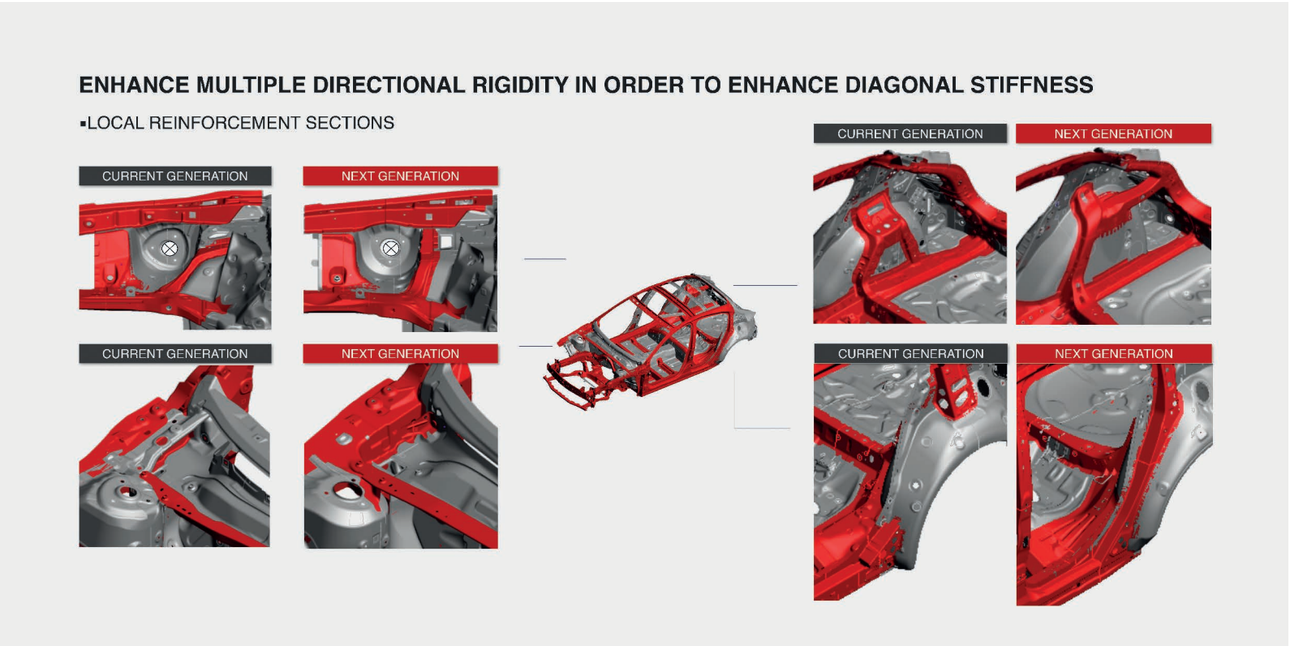
Those benefits include better and safer control of the vehicle, less driver fatigue and greater driving enjoyment.

DIRECT LOAD TRANSFER WITHOUT DELAY

REINFORCE FRAME STRUCTURE
- STIFFER MOUNTING POINTS TO BODY
- RIGHT ANGLE STRUCTURE
- STIFFER 4 BALL SLIDERS

BACKLASH ELIMINATED
- SEAT RECLINE JOINT
- SEAT RAIL

SUPPORT IDEAL POSITION OF PELVIS AND SPINE FOR WIDE RANGE OF OCCUPANT ERGONOMICS
- REDESIGN LOWER BACKREST & CUSHION-FRAME
- TILT FUNCTION FOR CUSHION
- OPTIMISE DAMPING / STROKE STRUCTURE CUSHION / BACKREST (HIGH DAMPING URETHANE FOAM)



Bodyshell: Transmitting Force without delay

- **Better body control for improved handing and driving enjoyment**
- **More rigid cabin structure for enhanced occupant crash protection**

Targeting the ideal path for transmitting input energy from the ground to the bodyshell, Mazda has taken the basic Skyactiv-Body model - based on the concept of a 'straight and continuous' framework - and fine-tuned it still further.

To the ring structures that connect the framework vertically and laterally in previous bodyshell structures, Mazda has now added front-to-back connections, creating multi-directional ring structures that improve diagonal rigidity.

The front cowl side panel, front and rear damper attachments, and rear door opening have been positioned for maximum effectiveness, based on analysis of energy paths.

As a result of this new multi-directional ring structure, the delay in the transmission of input energy to the diagonals stretching from the front to the rear has been reduced by 30% compared to previous bodyshell structures, with forces now transmitted between all four diagonal corners almost instantaneously.

Chassis: Smoothing out input forces from the Unsprung Mass

- **New suspension geometry and softer tyre walls smooth out input energy from the road surface**
- **This optimises G-Vectoring Control operation to increase ride comfort and maximise tyre grip**

Input energy from the ground is communicated to the body via the suspension. Traditionally, vehicle architecture has been designed to reduce the magnitude of forces conveyed to the sprung mass.

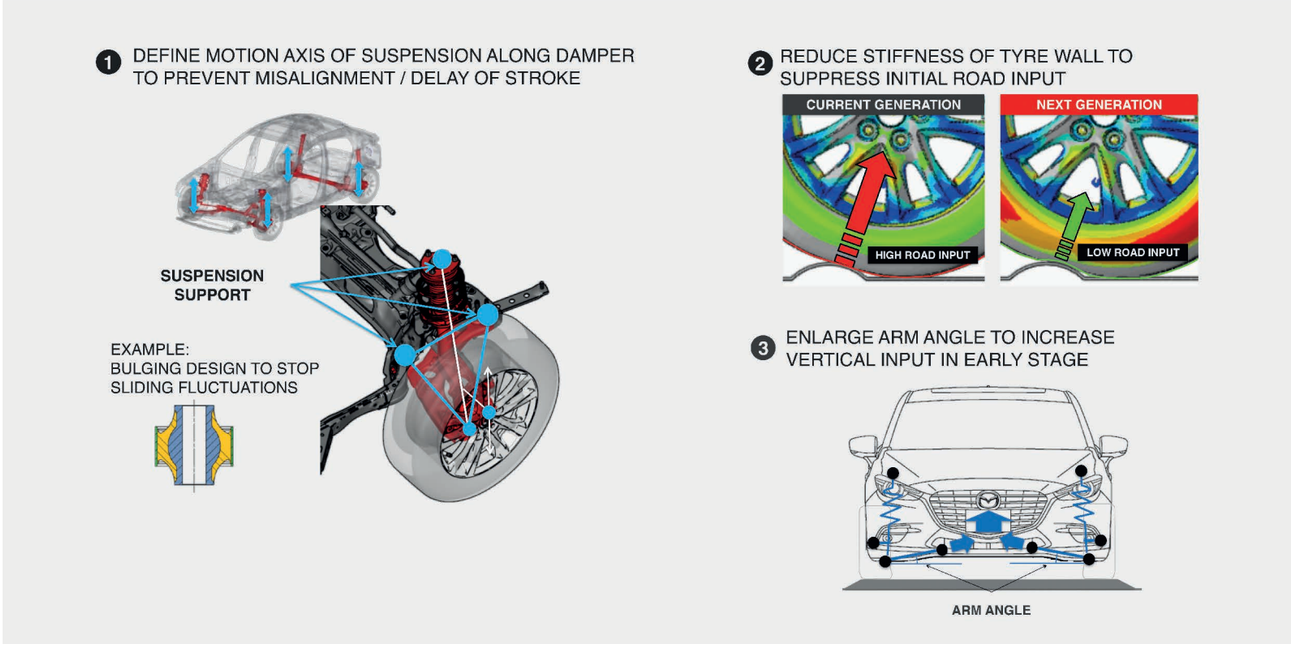
With Skyactiv-Vehicle Architecture, however, Mazda has added a new concept - smoothing out the forces conveyed to the unsprung mass over the time axis - and, based on this, has completely redesigned the allocation of functions among the various components.

While the suspension operates in a vertical direction, the suspension arm angle faces downward - in an inverted V shape - at all times, so that the inertial force of the sprung mass pushes the tyres down toward the ground. Meanwhile, the use of a spherical bush ensures that the transmission of energy is perfectly aligned with no slippage, making it easier for the attachment of the suspension arm and link to rotate smoothly.

A more efficient functional arrangement has also been adopted for the tyres. In a radical departure from Mazda's previous approach, which focused on increasing the vertical stiffness of the tyres, the company has softened the side walls and reduced stiffness.

Doing so has allowed Mazda to plan for the adoption of its unique vehicle dynamics control technology, G-Vectoring Control, right from the initial conceptual stage of platform development, resulting in a more effective functional allocation.

G-Vectoring Control adjusts engine torque in response to steering input in order to control lateral and longitudinal acceleration G-forces in a unified way and smoothly optimise the vertical loading of each tyre during cornering. As a result, the rubber of the tyres is able to maximise its vibration absorption and damping effects.



ENHANCING LINEARITY OF CHANGE OF NOISE PERCEPTION

STIFFNESS ENHANCEMENT BY:

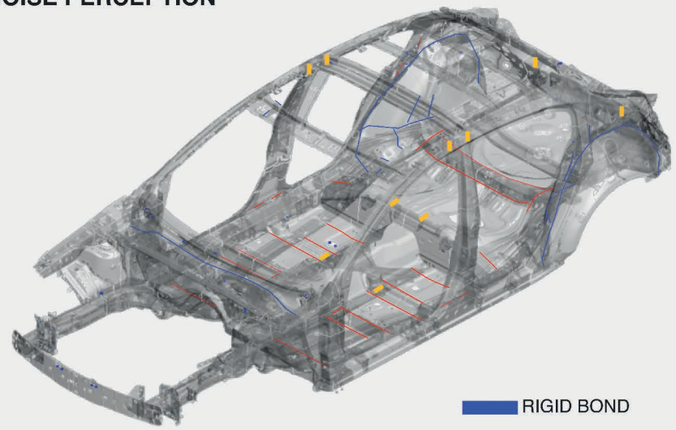
- REINFORCED BODY STRUCTURE (MODE CONTROL)
- SUS STIFFNESS STRUCTURE UP

STRUCTURAL DAMPING AT HIGH STRAIN AREAS

- DAMPING BOND
- DAMPING NODES

ENHANCED SOUND PACKAGE CONCEPT

- MULTI LAYER & SANDWICH CONCEPT
- FIRE WALL TRANSMISSION LOSS GROWTH
- UNDERFLOOR COVER



Improved Noise, Vibration and Harshness (NVH) Performance

- **Greater overall cabin quietness under normal driving conditions**
- **Smoothing out of sudden noise and vibrations entering the cabin for even greater perceived quietness**

Creating a quiet interior space is another important factor in ensuring that people can make maximum use of their natural abilities. Skyactiv-Vehicle Architecture represents a major step forward in NVH performance.

Through research into the human hearing mechanism, Mazda has discovered that people experience more discomfort when sounds and vibrations increase suddenly, or to a marked extent. In addition to suppressing the overall cabin volume under normal driving conditions, Mazda has focused on ensuring that noise and vibration from various sources changes with greater linearly over time to create a perception of superior cabin quietness.

The characteristics of vibration energy damping are important for controlling both the timing at which noise enters the cabin and the direction from which it arrives. To ensure effective control over vibration energy entering the body, Mazda has adopted a new, high-efficiency damping structure that includes damping nodes and damping bonds, depending on the characteristics of the points where energy tends to concentrate.

With traditional vehicle architecture, a sudden change in the road surface creates a change in noise levels over and above the actual change in vibration energy conveyed from the road.

By contrast, Mazda's Skyactive-Vehicle Architecture ensures that such a change is experienced by occupants as a more gradual and linear shift commensurate with the actual degree of change in the surface. The ultimate result is a quieter and more comfortable ride.

KODO DESIGN - SCULPTING WITH LIGHT

Introduced in 2010, Mazda's unique KODO design philosophy and its ability to breathe vitality into the car has been the driving force behind the multiple award-winning styling of the current Mazda range.

With the pleasure of ownership a key principal of Mazda's Sustainable Zoom-Zoom 2030 long term development vision, KODO design remains central to the company's desire to constantly improve the brand and push design quality to the level of art.

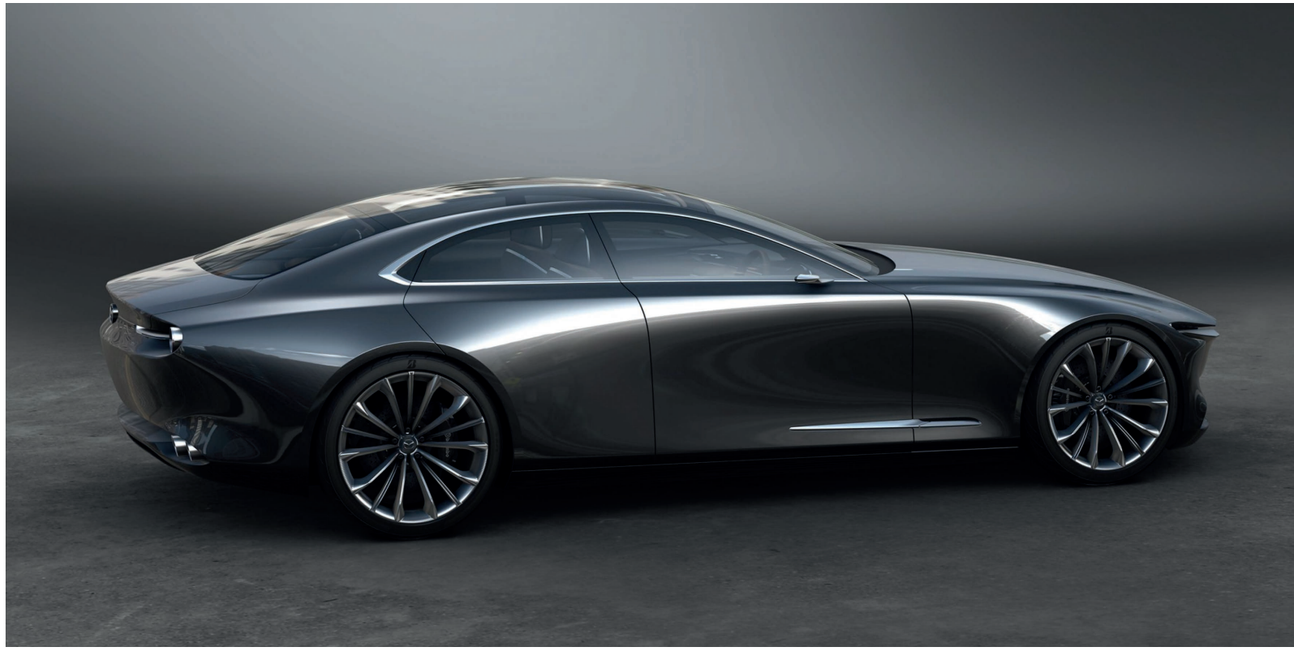
Building on this recent design success, the unveiling of the three latest Mazda concept vehicles showcases the unique elegance which encapsulates the next evolutionary stage of KODO design; the RX-Vision in 2015, and the 2017 Vision Coupe and Kai Concept compact hatchback - the latter a design study incorporating strong visual clues as to the styling of the new Mazda3.

This new vision retains the vitality of KODO design but now targets greater styling prestige through the elegance and purity of a minimalist aesthetic which removes all unnecessary elements.

Inspired by the purest traditions of Japanese art and the beauty of space between objects, the foundation of future Mazda elegance will be dynamic proportion, a classical silhouette and an artistic manipulation of light that relies on the uniquely hands-on approach of the company's designers and craftsmen.

Only through hundreds of hours of painstaking clay sculpting and painting work has it been possible to hone the perfect balance of tension, power and constantly changing reflections inherent in the muscular shoulders, elegant curves and sweeping, concave surfacing of the Vision Coupe concept.

Creating such controlled vitality - a form both beautiful and thoughtfully simple - requires immense degrees of time, discipline and craftsmanship. Yet it is fundamental to the uniquely Japanese elegance of Mazda's next generation design vision, in which the ownership experience is further enriched by the presentation of the car as art.



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