Automotive ENGINEER

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Target setting

The new architecture that will help Jaguar compete in the D-segment

Suzuki refines its SUV for the road › **Delphi's challenge in China**

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Modern architecture

Designing an executive sedan from the ground up has allowed engineers to improve ride and handling, emissions and connectivity. The D-segment is now a lot more competitive

By James Scoltock

When Jaguar's engineers began developing the XE executive sedan in 2010, the focus was on competing with, and bettering, the vehicles that were already in the market.

The BMW 3 Series, Mercedes-Benz C-Class and Audi A4 have dominated the D-segment for many years – look on any road across Europe and there is sure to be a vehicle with one of the three marques' badges on the hood in close proximity. So in order to achieve its goals, Jaguar needed to adopt a new approach.

It's rare that engineers get to work on a vehicle that has no predecessor, starting from a blank sheet of paper, but this is what the XE's development team were given.

The result was a completely new architecture that gave engineers the freedom to pick and choose the technologies that would allow the XE to be competitive.

The XE's vehicle programme director, Nick Miller, says: "The idea behind wanting to come into this market segment was a key driver for the architecture. We knew that to make a compelling proposition we had to have certain attributes, so we had to come up with something new."

At the core of the XE is Jaguar's new

aluminium-intensive architecture – an architecture that will be used in future vehicles too – helping the body shell to weigh 251kg. The vehicle as a whole weighs from 1,474kg.

Aluminium content stands at more than 75% with steel added to the mix, and Jaguar has developed new alloys, including RC5754, during the car's development. Apart from a small amount of new metal that is needed to get to the correct grade, RC5754 can be produced almost entirely from recycled raw material.

"The material mix comes about because of various reasons. Weight distribution, with the engine at the front and rear-wheel drive, putting the steel low down at the back, allows us to get a 50:50 balance with an I4 engine," says Miller.

The architecture has been developed with four-cylinder engines in mind, although there is the bandwidth available to house vee engines too. The most powerful variant of the XE at the moment uses a 3-litre V6 gasoline unit that produces 250kW/450Nm. Although it may be a riot to drive, especially on the meandering mountain roads of northern Spain where the vehicle was launched, the CO_2 emissions of 194g/km are too high for most.

The key target for the development team was to bring carbon emissions down below 100g/km.

"We knew very quickly that, with the pressures on emissions, putting V8s and V6s in wasn't going to be the right answer, so an I4-centric architecture was very quickly one of the elements we fixed down," says Miller.

As well as a new body-in-white structure, Jaguar has also developed the first of its Ingenium family of engines. The 120kW/380Nm four-cylinder diesel unit uses both low-pressure and high-pressure exhaust gas recirculation (EGR) with thermal efficiency of over 40% to help the XE emit only 99g/km CO_2 when mated to a six-speed manual transmission. (Emissions rise to 104g/km when the engine is linked to the ZF-supplied eight-speed automatic.)

A selective catalytic reduction (SCR) system has been integrated to cope with NOx emissions.

"Defining the weight of the car, the characteristics of the powertrain and the aerodynamics are three of the key enablers to delivering that 99g/km, and very early on those were cast in stone and we had to deliver them," says Miller.

Jaguar's decision to push emissions as low as possible to gain an edge over its rivals in the segment didn't go unnoticed. Both BMW and Mercedes have developed powertrains that will push CO_2 emissions below 99g/km, and Audi isn't far from bringing the next-generation A4 to market, so will surely match that figure.

Efficiency gains: The 2-litre diesel decreases friction by 17% compared with the older 2.2-litre unit

But Jaguar can take it further – the firm has a lot of experience with electrification and it's an avenue that Miller says they could take in the future.

"We've got that portfolio of technology to draw on in the future," he says. "We've just at this point in time a super-efficient diesel engine delivering 99g/km which is a great place to be in this market segment. It doesn't mean that it'll be the same answer in five years' time, but at this point it was the right answer."

The pressure to reduce emissions is huge, but so too is the need to improve safety. Bodies such as Euro NCAP and the National Highway Traffic Safety Administration of the US have helped to push the adoption of safety technologies, and this had a big impact on the XE programme.

The sedan has a pop-up hood to increase the distance between it and the engine, helping to meet pedestrian safety requirements. The pyrotechnic system uses a piston in the hinge area.

Engineers also introduced a stereo camera to the vehicle to enable autonomous emergency braking.

"Just having that technology allows you to deploy all sorts of ADAS features going forward that we are working on and will feed in as Euro NCAP guidance changes in the future," says Miller.

Meeting safety criteria in North America has meant that the body structure will change slightly, mainly due to side-impact requirements, but Miller is relaxed as he says the architecture has been designed in such a way that it has the flexibility to meet differing and ever-changing demands.

The need to be adaptable is shown

Slick shifter: ZF supplies the eight-speed automatic

POWERTRAIN

Paul Whitwood
Chief engineer for engine programmes

"Efficiency means delivering lower friction and optimal combustion. So where we would normally have plain bearings in areas such as the camshafts and balancer shafts, we have needle roller bearings. We also avoid pumping oil or coolant around the engine unless we have to, so both coolant and oil pumps are variable control devices. We're only going to put sufficient oil pressure in the engine that we need at any point, and that might vary from 1bar all the way up to 5.5bar depending on engine speed, load and temperature.

"The crankshaft is offset by 12mm; if you offset the piston position you can reduce the side load on the piston and the friction.

"Overall there's about 17% lower friction than the outgoing engine – the 2.2-litre – which is a real enabler for 99g/km CO_2.

"We've maximised both peak engine performance and peak torque, but protected transient performance and low-speed torque. That's really important to make the car drive.

"We use a variable geometry nozzle turbo on the compressor side, to optimise the energy recovery from the exhaust and boost available pressure. That's important not only for peak performance but also this transient stepping of the throttle and getting the performance when you want it.

"We have a 1,800bar solenoid injector, commonrail system acoustically damped so you don't get injector tick. It delivers the right level of control pre- and post-pilot injection. The fuel injection equipment is by Bosch.

"The biggest emission control technology is probably the exhaust gas recirculation (EGR) system. We pipe in both low-pressure and high-pressure EGR. In an ideal world you would want to put in just low-pressure EGR because it's clean, taking the EGR from downstream of the diesel particulate filter so we can cool that gas much more. The problem with cooling dirty exhaust gas is that it's full of pollutants and then you start to get gumming and contamination problems. The high-pressure system takes EGR straight out of the exhaust manifold. The problem with that is that you can't cool that EGR gas as effectively.

"Selective catalytic reduction is the most effective way of dealing with NOx. You get conversion rates of up to 90%. It's part of the Euro 6 delivery on our Ingenium engines.

"We have variable timing on the exhaust cam that allows us to choose valve timings that suit the performance. It also allows us to get faster catalyst light-off."

INFOTAINMENT

Anish Kotecha
Infotainment engineer

"The InControl system is our first updatable platform. We wanted to deliver more tools, more features and more personalisation, which I think is key.

"The infotainment system comprises an eight-inch capacitive touchscreen and allows for gesture control. You can swipe between screens, it gives faster response and has an embedded navigation system. The InControl apps enable you to use your smartphone inside the car and use some of your favourite apps on the vehicle's touchscreen.

"It was launched last June and there are a wide variety of apps available. The key thing for us is that this app is available to our customers free of charge, and then we work with all of these different app developers to make more apps compatible for in-car use.

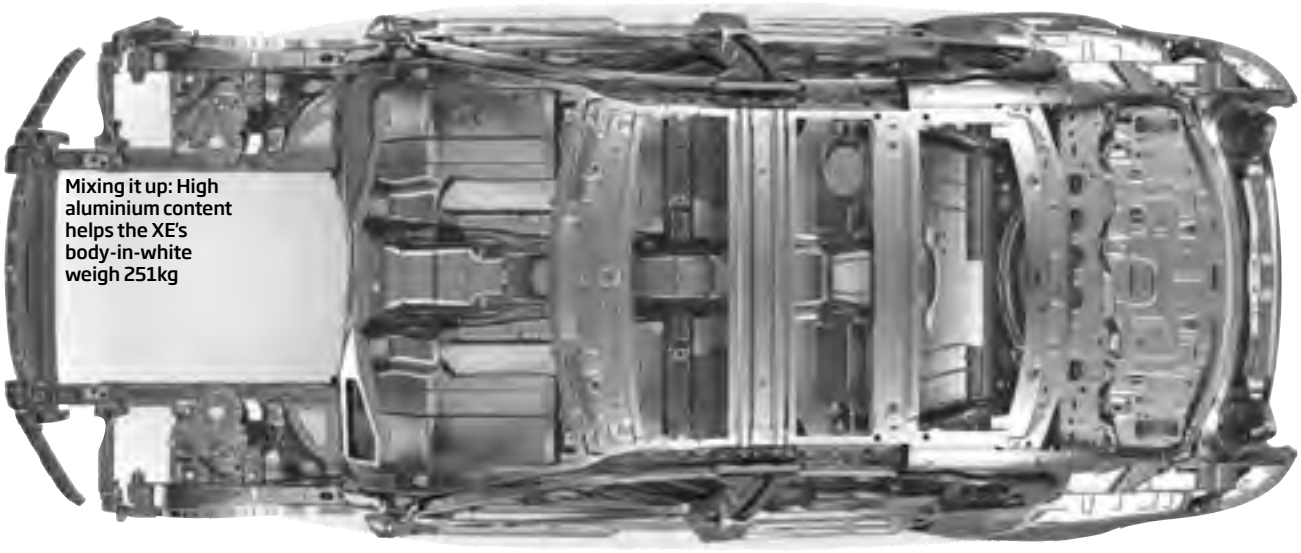
"The platform is owned by Bosch, but we're first to market with that platform and we'd encourage other OEMs to take it, encourage app developers to integrate our software development kit, so the apps are available for use by other OEMs.

"What we want to do is keep the apps DNA, so the way they look on your phone is how they look on the touchscreen, to keep the familiarity.

"Everything is run off the phone which means that this is updatable whenever we like. Whenever we want to add new features or new apps all we have to do is send an update to your phone, and you download your app just like you would with anything else.

"The InControl remote gives you the ability to control the vehicle from your smartphone anywhere in the world. It allows you to check on the car's status, for example its location. I can beep and flash the headlights to find the car and unlock it quicker. We also have the ability for remote engine start, to pre-heat or cool the cabin to a set temperature."

"The InControl remote gives you the ability to control the vehicle from your smartphone anywhere in the world"



Mixing it up: High aluminium content helps the XE's body-in-white weigh 251kg

clearly in the infotainment and connectivity arena. Here, consumer demands change each month, and keeping pace can be challenging. The issue was highlighted for Miller on a trip to China: "All the questions were about the infotainment technology – they almost took the driveability of the car as read," he says.

The XE shares its InControl infotainment system with the Land Rover Discovery Sport. It allows users to plug-in their smart devices and run content and features from them on the vehicle's eight-inch touchscreen. But there is the bandwidth to upgrade if necessary, and in the future the XE could share the same Ethernet-based system that will be used in the next-generation XF sedan.

"The InControl Pro system will come to the XE eventually and it requires some electrical changes to do this, but if you're going into global markets you've got to cater for different nuances and demands," says Miller.

The executive sedan market has been dominated by three OEMs for many years, and each has managed to progress the segment with each generation of vehicle. But Jaguar's clean-sheet approach will make it even more competitive, and should bring even more technologies to the arena too, whether they are materials, powertrain, safety or infotainment. ■

Connected space: Smartphones keep the infotainment system up to date

CHASSIS

Paul Atkins
Vehicle integration manager

"We wanted to deliver a car that gives you that correct balance of ride and handling, so the integral link allows us to separate the forces going into the suspension. Lateral forces go through the lower arm. The longitudinal control of the wheel, where you want comfort and plushness, those forces go through the upper arm.

"It's a proven technology but it's something that is normally found in the segment above. It's a little heavier, but we've deployed lightweight technology in the body, so we've traded some of that and said save weight there, and we're going to deploy it here.

"We started at a customer level, broke down all the targets, and then from the vehicle target broke that down to a component target, and that drove the technology we deployed. It's given us the breadth of capability to deploy active chassis technology on top of it – you just extend it.

"The damping technology allows us to play with that comfort and 'connected to the road' feeling. Equally the electric power steering technology allows us to give you light loads in the steering at parking efforts, but then build as you increase the speed range and make sure the car isn't twitchy and overly responsive when you're on the autobahn.

"At the front there are a lot of people in the segment that use a more simple system. Again, double wishbones are something you find on the segment above, so when you look at us against the segment competitors we are delivering more.

"We've got more camber control to give that precision steering, but without sacrificing comfort.

"We're coming into a segment with a brand-new car. It's an architecture that is going to deliver our future products as well.

"Things were made simpler because of the clean-sheet design. Others have tried to deploy similar technologies to our rear axle, but they are compromised because they are fitting it into an existing platform."

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Born in the USA

How Kia's North American testing facilities are shaping its vehicles

Fiat takes the A-segment off-road › **Why Toyota isn't charging in**

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THE HEAT IS ON

North America is Kia's most important market. *Automotive Engineer* was given unprecedented access to the firm's giant 4,300-acre US engineering facility to find out how it maintains its position

By James Scoltock

The Mojave desert in California is a sweltering place. Temperatures regularly exceed 40°C, and the baking sun makes the tarmac crack as if there's been seismic activity. Step out of an air-conditioned car and it's like breathing in hot air from a fire.

Although it's a location that most of us would rather avoid, for engineers testing the durability of vehicles, it's the perfect environment. Which is why Kia has invested over $60 million to construct its 4,300-acre proving ground there. It's footprint dwarfs the company's other facilities located in Namyang and Hwasung, South Korea, which only take up 408 acres and 203 acres respectively.

The size of the Mojave facility is proportionate to the importance of the North American market for the firm. It outstrips even Kia's domestic sales, so developing vehicles for American customers is incredibly important.

An added bonus of its location is its proximity to Edwards Air Force base, which means there is a no-fly zone in the area. That's a real benefit at the beginning of vehicle development programmes when secrecy is of the utmost importance.

Whether it's a new vehicle or one being adapted for the market, ensuring it can cope with the varied road surfaces and duty cycles that are specific to North America is a challenge. This is why the Mojave facility has 116km of roadways.

Matt Seare, the proving ground's manager, says: "We have the high-speed oval, an uphill area, vehicle dynamics area, winding roads, straight stability roads, special surfaces and off-road areas. We have 4,300m^2 of buildings – and we've recently added 1,530m^2. We also keep adding infrastructure for electric vehicles and in the future, fuel cells."

"It's specifically for weathering and exposing parts to UV radiation and trying to accelerate wear"

Matt Seare

The general target for engineers is to compress a whole vehicle's or component's life – 160,000km – into between 32,000km and 64,000km. The roadways have been specifically designed to replicate the conditions found on US freeways, which can be atrocious.

"We went out to the freeways and they let us shut down a lane for ¼ mile from midnight to 4am. Engineers measured distances and an exact profile of the roads and reproduced those profiles here in the proving ground," says Seare.

This means that everything from concrete road panels that have warped to sunken sections are replicated. "It's a great place to do suspension tuning," says Seare.

But the oppressive heat in the desert means that maintaining the roads so that tests are repeatable is a real challenge.

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Thermal limits: Temperatures in excess of 40°C help accelerate durability testing

"The thickness has a big bearing on how the asphalt copes with the heat. The thinner asphalt tends to shrivel like the mud in Death Valley, so you see a lot of public roads where cracks have started to show as all the oils evaporate," he says.

But the heat is an important ingredient of what happens at the proving ground. Walk around the facility and you are met with shelf after shelf of components, from windshields and headlights to parcel shelves and steering wheels, subjected to direct sunlight for months on end. "It's specifically for weathering and exposing parts to UV radiation and trying to accelerate wear," says Seare.

There are also vehicles left out to bake, not just Kia's, but other marques too – all hooked up to data acquisition systems.

Most of Kia's vehicles – even for a market as large as North America – are developed in South Korea, so making sure that they meet the durability requirements is important, but it isn't only the US that the proving ground serves.

HIGHT FLEXMAN

Manager, product development quality

"Our role is to be the voice of the North American customer. Our vehicles are global vehicles, but they have to be tuned for different markets, so we start looking at them from the clay model stage and decide what things aren't going to be right for North America.

"Once we get to the mule vehicle stage, we start doing ride and drives, looking at the features and functions of the vehicle and how well they actually operate in the car.

"We work very closely with our colleagues at the Hyundai-Kia Technical Centre to tune vehicles looking at the steering, suspension and noise, vibration and harshness issues.

"We really interact with the guys at the California proving ground because they have consistent surfaces, so we can look at every vehicle on the same surface and see how we're improving. We also use the facility to benchmark competitor vehicles.

"What we're trying to do is build DNA for Kia vehicles, so, whether you climb into a B-segment Rio or a K900 luxury sedan, there's a feature that lets you know it's a Kia product.

"Hot-weather testing takes place in Death Valley where temperatures reach 55°C. As well as that, we visit the coldest spot in the US – the International Falls in Minnesota on the Canadian border. The lake there is about 4km across and it runs for around 56km.

"We go up to that lake and do a lot of traction, ABS and electrical testing, as well as climate control analysis on the vehicles. A recent trip there was for cold-weather testing on electric vehicles. We also visit Colorado and travel to the tops of Pikes Peak and Mount Evans – at 14,000ft – to do brake testing."

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Bigger is better: Kia's North American testing facilities cover 4,300 acres

ORTH HEDRICK

Vice-president of product planning

"We've introduced the Optima sedan hybrid and we're about to introduce the Soul EV. Both use the same battery technology, a lithium-polymer cell – it's more thermally stable, and the energy density produced is higher.

"For the Optima, it represents about 3-4% of our vehicle mix. It isn't a huge portion, but it allows us to field a green car and have that dialogue with the green buyer. We're very confident about the new EV.

"The issue with diesel is that there is a significant difference in emissions standards. I think by Euro 7 the US and the EU will converge and that will help us.

"We've studied the Germans and they've done very well with diesels, but there's also a giant subsidy that they've incurred, a cost that they haven't passed on to the consumer to get that new diesel technology fielded. But we're still hopeful, probably by 2017-18, that we'll have a better shot at bringing diesel technology to the market in a few years.

"We haven't announced anything yet on plug-in hybrids, but we'll have something in the near future. That's obviously the next step between a hybrid and a full electric vehicle. We've had a lot of interest in the technology and we're actively developing it.

"We're actively working on autonomous vehicles, but there are a lot of hurdles. I think one of the biggest is who assigns risk and liability in the event of an accident. It's a very litigious society in North America.

"But also when you move into a city where there's an intersection and you involve pedestrians, bicycles and random factors, if there's construction, where the road path differs from the map used by the vehicle, that's what throws the whole system off.

"Bringing these kinds of vehicles to market could take 10-15 years – we have all the technology in place, but we can't get everything stitched together yet."

"We do a lot of South American and European testing. We do a lot of the work that's used on European cars, but we don't really do autobahn testing," says Searle.

The maximum speed on the facility's 10km oval track is 250km/h, but European high-speed testing can be conducted at Kia's facilities in Rüsselsheim and on the Nürburgring. Interestingly, the Californian track's length, maximum 12% banking and radius mean that in theory, at a constant speed of 120km, you could track around it in the middle lane without needing to touch the steering wheel.

The emphasis is still on physically testing vehicles and components, but an increasing amount of testing done as computer simulation is impacting on the work that's carried out in the desert.

"I think computer simulation has changed the whole industry," says Seare. "It's taken a lot of the iterative processes out, so it makes it a lot easier for people such as the ride and handling guys to make the car handle better. But you still have to prove it out. It's undeniably useful as a tool and will continue to be so, but computer design hasn't quite got to the point where it can tell us everything."

Which is why engineers not only benefit from the facilities offered at Kia's Californian proving ground, but also take advantage of even higher temperatures in Death Valley and the freezing conditions in Alaska for cold-weather testing.

North America isn't likely to relinquish its crown as the most important market for Kia, so continued long-term investment in the proving ground will carry on for the foreseeable future, as will the number and variety of tests that engineers are able to perform there in its blistering heat. ■

Hot stuff: Weathering and UV radiation exposure are important test areas for engineers

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A different approach

Mazda hasn't followed the same path to downsized, turbocharged direct-injection engines as others, and, with higher compression ratios and homogeneous charge compression ignition, it may not have to

By James Scoltock

Back from the dead: Rotary technology could help boost powertrain efficiency

The drive by governments to reduce carbon emissions has put considerable pressure on OEMs to develop smaller-displacement, turbocharged, direct-injection gasoline engines. It's a trend that has shaped the industry, but not every firm is convinced by the move.

Mazda believes that naturally aspirated engines can achieve the efficiency and emissions levels required by both legislators and consumers in the real world. And changes to the official test cycle could further highlight the benefits of its position.

Takashi Suzuki, Mazda's general manager of engine performance development, says: "We believe that the naturally aspirated engine will provide better thermal efficiency than a downsized four-cylinder unit. Maybe there will be a bigger impact from changes to the driving cycle on downsized engines because real-world fuel economy is not focused on very light load acceleration."

But the need to continually improve the combustion process grows, especially as CO_2 limits edge further and further below 100g/km.

Mazda's initial approach with its SkyActiv gasoline technologies was to improve the combustion process by using naturally aspirated direct-injection units with a much higher compression ratio – the company's gasoline engines are now well known for using 14:1. And with adaptations to the pistons and a complex 4-2-1 exhaust manifold, the firm has helped to reduce carbon emissions and improve fuel efficiency.

But increasing thermal efficiency remains a key target, and the OEM is looking at ways to improve the second generation of its gasoline engines. Some of the technologies that it wants to introduce have never been able to clear the technological challenges that would allow for volume production. But Suzuki is optimistic that systems such as homogeneous charge compression ignition (HCCI) combined with a much higher compression ratio could bring gasoline thermal efficiency a step closer to 50%.

He says: "Many engineers said HCCI could be a good solution for improving the internal combustion engine but no one could introduce the technology to the market, so you can imagine how high its technical difficulty is.

"But Mazda is investing a lot of resource into HCCI and with technologies such as CAE, where computer performance has improved a lot, potentially we could resolve the hurdles."

Not all are convinced by the merits of HCCI, as injecting fuel and burning it without a spark is a very complex technology to master, and for some the benefits are too small to warrant the investment.

Suzuki's research suggests, however, that a lean HCCI system with a shorter combustion period could bring improvement as much as 30% over current combustion systems, but it will also need to be mated with a significant reduction in pumping losses. And it will mean a change to the compression ratio, possibly to as high as 18:1.

"I wouldn't say that is the top limit, because if we can reduce the cooling loss further, such an optimal point could also move, and the higher compression ratio and leaner position could become the best point," says Suzuki. "And by moving in this direction the technical difficulty also increases a lot, so even though I say we are targeting this direction there might be a limit."

Mix up: HCCI and higher compression ratios are the way ahead

Charging up: Greater levels of electrification are a given in the future

Another area that concerns Suzuki is the particulate matter, which will grow in importance as regulations tighten in the next five years. Suzuki admits that it's an area that engineers struggle with, but solutions such as gasoline particulate filters aren't a cost-effective solution.

"Particulates are a very sensitive part of the combustion process because it's based on the level of deterioration or deposit levels, and is easily changed because of the spray pattern," he says.

Injector technology is adapting to the challenge but engineers will never be satisfied with the speed of development, especially when they are facing such large external pressures from legislators.

Suzuki says: "When the engine or fuel is cold the spray pattern will affect the particulate numbers a lot. To overcome that, improvement to the injectors is mandatory. But the level of change is a difficult question for us. If we request very high fuel pressure a lot of areas in the engine have to be changed – cylinder head, camshaft design, the fuel pump – so the impact is quite big. If the engineer says we need a 40MPa fuel pressure, it's easy to say, but the designers of the cylinder head will struggle to manage those requests."

Targeting greater efficiency in the combustion process and reducing emissions, whether they are carbon or particulates, will eventually require greater levels of electrification. It's something that Suzuki is open about, but by improving the combustion process he and his engineers want to limit the amount of electrification that is required and, in turn, the costs.

"Even though our focus is on the internal combustion engine, we will gradually apply electrical technology – that is mandatory for the automotive industry," he says. "But if we have a better internal combustion engine the electricity could be minimised; a big motor requires a huge battery, which would be very expensive."

"Mazda is investing a lot of resource into HCCI and with technologies such as CAE, where computer performance has improved a lot, potentially we could resolve the hurdles"

Takashi Suzuki

How far Mazda develops electrified powertrains will be decided by the restrictions placed on it by legislators. But the twist of increasing restrictions is that it could bring back combustion technologies that have disappeared due to the need to improve vehicle efficiency.

Mazda is well known for its development of the rotary engine for some of its sports cars in the past. Now the firm is also developing the technology as a range-extender for electric vehicles.

Suzuki says: "The California Air Resources Board forced OEMs to produce electric vehicles without knowing the real issues, one being driving range. In such cases an auxiliary charging device might be required."

The rotary engine's advantages include improved packaging and reduced noise. The single-rotor 22kW, 330cc concept engine that Mazda has developed can fit in a vehicle's trunk where the spare tyre would normally be housed. With this in mind, the system has been designed to rotate horizontally.

NVH is also better than with gasoline and diesel engines of similar output, according to Mazda. Sound levels of the rotary, gasoline and diesel units would be 87, 92 and 96dBA respectively.

Suzuki says: "The electric vehicle during acceleration is very quiet. If the range-extender is very noisy, its product value might become very low. But if it's a very quiet sound it will not harm the image of the electric vehicle. So that's why we developed this technology, and wanted to understand people's reactions."

Suzuki is at pains to emphasise that the rotary range-extender engine is purely a development concept and no decision has been made as to whether it'll be taken to volume production. But given the industry's move to greater levels of electrification, if the engine offers the right mix of efficiency, ease of packaging and quietness, it could well be used in a production vehicle.

Mazda's other developments might also see the OEM continue to follow a different path to others, forgoing turbocharged direct-injection units for high compression ratios and HCCI. It'll be fascinating to follow its progress. ■

Spray pattern: Improved injectors will help minimise particulates