Feature Story 1

SKYACTIV-X Next-Generation Gasoline Engine: Our Contribution to the Earth, People, and Society

At Mazda, our goal is to protect the earth by reducing carbon dioxide emissions in real-world driving as much as possible. Since the internal combustion engine is expected to power the majority of vehicles for many years to come, we believe that perfecting it is the greatest contribution we can make to cutting carbon dioxide emissions.

The SKYACTIV-X next-generation gasoline engine, announced in August 2017, brings us one step closer to realizing our dream engine. Combining the advantages of both gasoline and diesel engines, the SKYACTIV-X was born of Mazda's mission to bring about a beautiful earth, to enrich people's lives as well as society, and to seek ways to inspire people through the value found in cars.

Eiji Nakai
General Manager
Powertrain Development Division

Interview with the lead engineer of the SKYACTIV-X next-generation engine

Pursuit of the ultimate engine

Q: What is the SKYACTIV-X and how is it different from previous engines?

A: Simply put, the SKYACTIV-X is a gasoline engine that combines the advantages of gasoline and diesel engines in a manner befitting the title "next-generation." It helps the earth and people by offering unprecedented environmental performance and responsive driving. For example, it improves fuel efficiency up to 20-30 percent over Mazda's current gasoline engine and also increases torque*1 10-30 percent. Basically, it offers the driving performance of

*1 A measure of the rotational or driving force generated by an engine. It affects acceleration from a steady speed.

a 2-liter gasoline engine sports car (MX-5) with the carbon dioxide emissions of a 1.5-liter diesel compact car (Mazda2).

Features of the next-generation gasoline engine

Value for customers	Gasoline engine	Next-generation gasoline engine	Diesel engine
Fuel economy	▲	◎	◎
Torque	▲	◎	◎
Responsiveness	▲	◎	◎
Output (smooth acceleration)	◎	◎	▲
Heat generation	◎	◎	▲
Exhaust cleanliness	◎	◎	▲

Q: Of all available technologies, such as electricity and hydrogen, why have you focused on the internal combustion engine?

A: While it's true that various technologies are being developed and brought to market, each has its issues. Energy infrastructure varies between countries and regions. The operating environment – road conditions and driving styles – also varies between customers. Given that, we considered what kind of environmental technology was best. The point was to reduce carbon dioxide emissions on a well-to-wheel basis – from the point of fuel extraction to driving the vehicle – and to do that in actual driving on a global level.

Our research pointed to the internal combustion engine. We realized that making existing engines more efficient would drive reductions in carbon dioxide emissions globally and in real-world driving.

The future prospects of the internal combustion engine have been demonstrated by external organizations. An International Energy Agency report projects that internal combustion engine vehicles will represent around 84 percent of all vehicles in 2035. Of course, we are also developing other technologies so we can deploy them to markets where they are suitable. Our electric vehicle scheduled for launch in 2019 is one example.

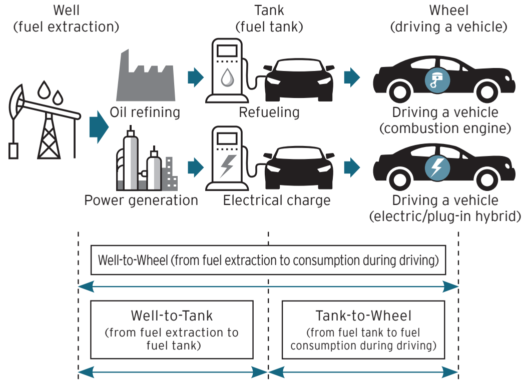
We are also researching ways to reduce overall emissions more efficiently by adding compact electrification technologies for driving speeds at which the efficiency of the combustion engine suffers.

Q: Does the internal combustion engine have that much potential for improvement?

A: We're constantly working to develop the ideal engine, so we know there's still plenty of room for improvement. There has been a lot of research on the potential – and technical difficulty – of improving the internal combustion engine's efficiency. When Mazda developed its existing engines (SKYACTIV-G and SKYACTIV-D), it demonstrated that potential and attracted attention from the science community. This helped to breathe new life into combustion engine research and development. That accomplishment followed major challenges: pushing the boundaries of abnormal combustion (knocking) under high-temperature, high-pressure conditions in gasoline engines (SKYACTIV-G) and pushing the boundaries of ignition performance (misfiring) under low-temperature, low-pressure conditions in diesel engines (SKYACTIV-D).

Automobile engines generate energy by compressing air, exhaust gas, and fuel and igniting it to combust. Theoretically, the more air you put in and the more you compress it before combustion, the greater power you can obtain – but it doesn't work like that. High compression ratios in gasoline engines cause abnormal combustion, while low compression ratios in diesel engines cause misfiring. While tackling these challenges in both types of engines, Mazda's engineers honed their skills for developing our next-generation engine, the SKYACTIV-X.

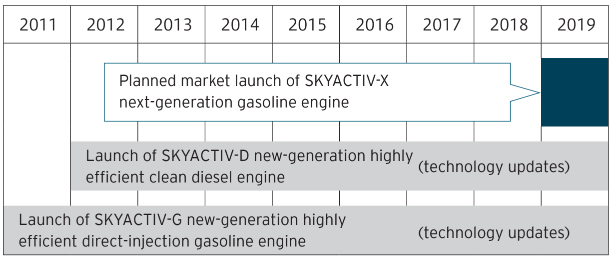
Conceptual diagram of Well-to-Wheel*



*Where fossil fuel is extracted and used to drive a vehicle.

Rollout of SKYACTIV Technology (gasoline/diesel engines)

SKYACTIV Technology: Collective term for Mazda innovative base technologies



Q: What technical innovations went into SKYACTIV-X?

A: The first is that we used the tendency for abnormal combustion to our advantage. The SKYACTIV-X generates a lot of energy by forcefully compressing a large volume of air-fuel mixture and igniting it with a spark plug, which then triggers multiple flames of combustion (compression ignition) throughout the cylinder.
The second is the balance of air to fuel (gasoline) inside the cylinder. A mixture of air, exhaust gas, and fuel is created inside the cylinder, and the more air relative to fuel, the better the fuel efficiency. With the SKYACTIV-X, we succeeded in increasing the air-fuel ratio significantly over that of conventional engines.

Q: You must have encountered difficulties in achieving those innovations. How did you overcome them?

A: Achieving our target combustion consistently in different user environments — air temperature, altitude, driving conditions, etc. — was a major hurdle. With compression ignition, gasoline burns vigorously only when the right temperature and pressure conditions are met. It's especially hard to combust when the air-fuel ratio is high. We had to create conditions for the combustion of a predetermined amount of fuel as planned in every combustion cycle and in various driving scenarios and operating conditions. It was like trying to find the perfect way to cook rice by adjusting the size of the flame every time.
To find that perfect flame, we decided to expand our computing resources. Designing a new and complex method of combustion requires an accurate simulation of the combustion chamber. This was computer model-based development, where we determined the ideal combustion by calculation and then worked to achieve it in the real world. In the past our work was a time-consuming process that involved creating lots of prototype vehicles or engines and testing them repeatedly. But that approach would have gotten us nowhere when developing the present engine, since there were countless possible combinations. Computer model-based development increased our work efficiency dramatically.
We have also cooperated with academia and government to develop the fundamental technologies. As we increased the accuracy of our simulations, we found the right "flame" that would allow gasoline to combust vigorously. We used the simulation results to create something like a recipe that we then programmed into an engine control unit.
That recipe is Spark Controlled Compression Ignition (SPCCI), which embodies compression ignition technologies pursued by successive generations of gasoline engine engineers. We have been able to package SPCCI as an engine system. We are refining it for maximum customer satisfaction when we launch it in 2019.

Q: What kind of engine do you want to develop next?

A: Our goal is to continue striving for the world's best engine: a responsive source of power that is more efficient and emits less carbon dioxide emissions in real-world driving scenarios according to the user's environment, and emits cleaner exhaust.
We have overcome a number of challenges in the process of developing the SKYACTIV-X. In fact, we were even able to clear the hurdle of abnormal combustion and make it to our advantage. Coffee tastes bitter when you are a child, but you come to appreciate it as an adult. Something like that has happened in my career as an engineer. The challenges we face now in our pursuit of the ideal combustion engine will inevitably become our strengths. That inspires us to continue pursuing the engine that will help bring about a beautiful earth and enrich people's lives and society.

Spark-Controlled Compression Ignition

Spark-Controlled Compression Ignition (SPCCI) is Mazda's proprietary combustion method that offers complete control of compression ignition combustion by way of spark ignition. Once ignited by the spark plug, the expanding spherical flame serves as a second piston (air piston), further compressing the air-fuel mixture in the combustion chamber and providing the necessary conditions for compression ignition. By controlling the timing of spark plug ignition, SPCCI expands the range of conditions under which compression ignition can take place.