Innovative Combustion Technology from Japan; the Trump Card to Save the Global Environment

Cars provide indispensable support to industry, society, and our personal lives, getting us from place to place quickly and comfortably. At the same time, the impact of vehicles on global warming calls for improvements in drivability, safety, and greater environmental performance.
Innovations in combustion technology (The Plan for the Rising Sun Engine Initiative to Save the World) aim to improve internal combustion thermal efficiency up to a maximum of 50 percent, reducing the impact of combustion engines on the environment. This cooperative development project between industry, academy, and government will contribute to the development of Japan's practical engineering capacity and the nation's ability to compete.

Innovative Combustion Technology

The Plan for the Rising Sun Engine Initiative to Save the World

Program Director

Masanori Sugiyama

Field General Manager, Engine Engineering Field
Toyota Motor Corporation

Profile

Mr. Sugiyama joined Toyota Motor in 1984. He took over as project manager for new V6 engine development in 2002, and was subsequently named project general manager for renovation promotion of engine development in 2003. In 2007, Mr. Sugiyama took over as General Manager, New Engine Development Division. Mr. Sugiyama was named Executive General Manager, Field General Manager of Engine Engineering Field in 2013.

Masanori Sugiyama

Internal Combustion: The Force that Propels Vehicles Forward

Today, most vehicles around us operate using gasoline- or diesel-powered internal combustion engines. While, we are beginning to see the spread of electric vehicles powered by rechargeable batteries or a combination of fuel cell and motor, the ratio of such vehicles is still a very small part of the overall market. According to the Energy Technology Perspectives of the International Energy Agency, even a best-case scenario of electric vehicle adoption would have more than half of vehicles around the world over the next 30 years still powered by internal combustion, accounting for nearly 50 percent of petroleum energy consumption.

The car has been the subject of many dramatic technological advancements in safety, operation, and environmental performance. However, as concerns rise related to global warming and the depletion of oil resources, reducing vehicle fuel consumption continues to be a pressing issue. The intent of this program is to develop innovative combustion technology, aiming to produce dramatic efficiency gains in internal combustion for vehicles. As the program director, Mr. Masanori Sugiyama shared his thoughts on the program's research and development goals.

"Combustion technologies can be found across a diverse range of applications in energy and other fields. However, we have decided to focus solely on internal combustion for vehicles. Our goal is to increase combustion efficiency up to 50 percent, while making significant reductions in CO_2 output. We understand that these are extremely challenging goals, but considering the number of vehicles used around the world, our success could have an enormous impact."

Aiming for Lofty Goals through Industry-Academy-Government Cooperation

To achieve these ambitious goals, the program created a research and development structure tying together industry, academia, and government. The universities participating from around Japan have been divided into four teams: (1) Gasoline Engine; (2) Diesel Engine; (3) Controls; and (4) Loss Reduction. Each team conducts research under a Leader University. The program has also separately accepted the participation of research based on disruptive approaches, selecting six such promising approaches as of November 2014. The program intends to continue to call for the participation of research from a variety of fields.

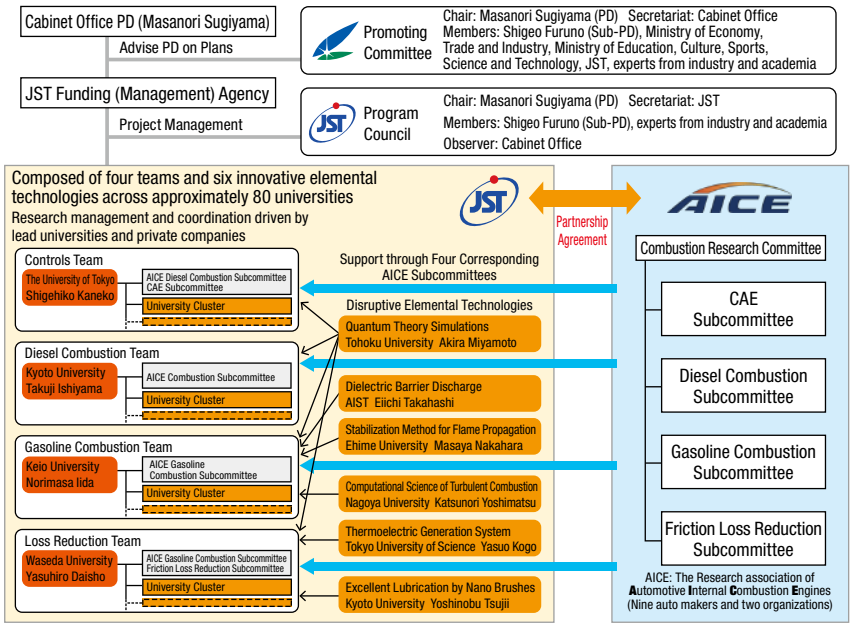
"While most of the world may consider internal combustion for vehicles to be a mature technology, there are still many things about the combustion mechanism that have yet to be explained by science," says Mr. Sugiyama. "Technological innovation requires the ability of academia." Sugiyama also states, "To achieve a 50 percent efficiency in combustion will require the coordination of different elemental technologies and the integration of expertise. This means we need to create bridges among several research fields. Each team in our program enjoys the support of corporate research and development departments that have long experience in these types of collaborations, as well as the overall direction of the Japan Science and Technology Agency, which is an expert in research management."

With the participation of numerous universities, this research program was up and running in just a few short months. One of the biggest contributing factors to this speed was the role played by the Research Association of Automotive Internal Combustion Engines, which is made up of nine Japanese auto makers and two industry organizations. This is a new, greater challenge to improve the environmental performance of internal combustion using first-of-its-kind technologies from Japan; the determination of an industry to call for academic cooperation in contributing to make a better world.

Contributing to Japan's Practical Engineering Capacity

The goals of this program will have implications beyond simply improving internal combustion efficiency.

Historically, technologies resulting from university research had been responsible for much of Japan's practical automotive engineering capacity. As Japanese manufacturers become more capable, they took over the major role in research and development. More recently, however, rapid globalization

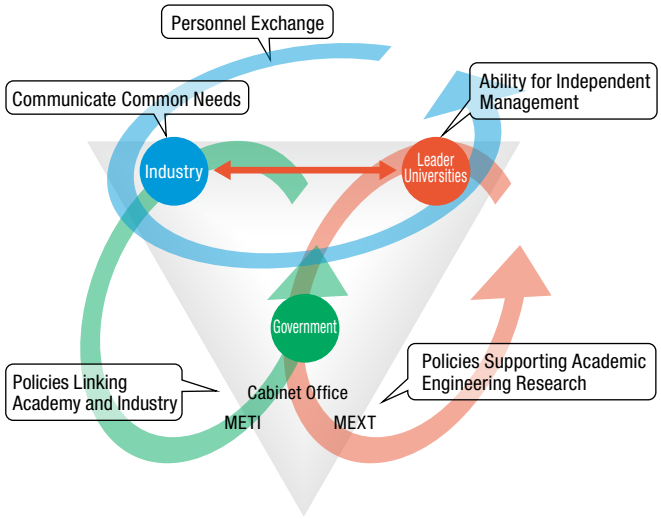


Implementation Structure

Masanori Sugiyama

World-best 38.9% thermal efficiency as of December 2014.
(Source: Honda R&D Co., Ltd.)

●SPORT HYBRID i-MMD 2.0L DOHC i-VTEC



●Future Structure of Industry-Academy-Government Cooperation

has increased the demand for faster corporate research and development, resulting in fewer resources allocated to basic research. This development is a cause of concern about Japan's decline in practical engineering.

Mr. Sugiyama emphasizes that he wants to put the brakes on this situation and create a culture that supports the development of domestic practical engineering. "I hope the research structure we have put together serves as a model not only in the internal combustion field, but for all future industry-academy-government cooperation and talent development for Japanese practical engineering," says Sugiyama.

Germany offers a model of industry-academy-government cooperation. Under an awareness that a recovery in the automobile industry would lead to a national recovery, Germany established an internal combustion research consortium in 1956 called FVV. Today, nearly 150 German automakers, suppliers, and universities make up the largest consortium related to internal combustion research, development, and manufacturing. This consortium supports the international competitiveness of Germany's auto industry.

One of the additional goals of this program is to rally Japan's industry and academy similar to the FVV model, casting a light on academic research and training in Japan's declining practical engineering field.

A Smile for One and All

Even with a strong, future-forward research and development structure, reaching a 50 percent thermal efficiency will be no easy task. Sugiyama says the following about the technological hurdles. "Simply stated, we are trying to convert the chemical energy of combustion into dynamic energy. During that conversion process, we lose energy through heat and other forces, which means it's important to be able to recover this energy. There is also another issue in the tradeoff between reducing fuel consumption and making cleaner exhaust. Control technology is the key to accomplishing both of these goals at the same time, which is another focus of our program."

As stated before, the mechanism of combustion includes many elements not yet fully explained by science. This inability calls for more foundational technologies to measure, analyze, and model the process. This program aims to accomplish its goals through new development processes and other approaches that integrate the capabilities of each team member. The first three years of the program have seen progress toward the development of innovative elemental technologies, with plans to conduct demonstration tests over the remaining two years.

"I have been involved in the development of mass-production engines for many years," says Program Director Sugiyama. "During all that time, my credo has been that no technology, no matter how impressive, can make a contribution to society if it cannot be mass produced." Under the direction of Mr. Sugiyama, this program is focused on delivering results for the benefit of society. Program team members have stated their desires to see the fruits of their work result in smiles on the faces of consumers, as they redouble their efforts to develop disruptive combustion technologies.

Research and Development Topics

1. Research to improve gasoline engine thermal efficiency

Realize elemental technologies for super lean burn, high boosted combustion, and the combustion under large amount of EGR, leading to thermal efficiency of up to 50 percent in comparison to today's maximum of 39 percent.

2. Research to improve diesel engine thermal efficiency

Realize elemental technologies for fast silent combustion, clean low temperature combustion, leading to thermal efficiency of up to 50 percent in comparison to today's maximum of 43 percent.

3. Research in common for gasoline and diesel engines

Realize foundational technologies for use in both gasoline and diesel engines, including modeling and control technologies for combustion, and research for various loss-reduction technologies.

Exit Strategies

☑ Create and popularize combustion technology that reduces CO_2 and strengthens Japan's competitive advantage

Offer society foundational technologies and development tools to reduce CO_2 by 30 percent (vs. 2011).
Leverage these results to improve fuel efficiency for the Japanese auto industry, strengthening the industry's competitive advantage, and contributing to lower global CO_2 levels.

☑ Establish a sustainable industry-academy-government research structure

A successful industry-academy-government cooperative research structure will communicate common needs from industry, facilitate personnel exchange between industry and academy, grow the management capabilities of leader universities, and create new industries originating in university research. This new cooperative scheme will serve as a model to other industries, leading to a new development process that will contribute to a stronger Japan.
Today, Japan's Ministry of Economy, Trade and Industry and Ministry of Education, Culture, Sports, Science and Technology work together to study policies to create, over the next five years, a sustainable industry-academy-government structure that supports industrial competitiveness.

☑ Create a strategy for a standard control model

Promote the standardization of control models and control/analysis software to reduce development costs and create new industries.
At the same time, create a de facto standard for international deployment.

A new wind is pushing Japan's practical engineering development, personnel training, and contribution to a better global environment.

Offer environmental technologies for a better world; create a model for industry-academy-government cooperation