Innovative Combustion Technology

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

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 the global environment calls for improvements in drivability, safety and greater environmental performance. Innovative combustion technology (The Plan for the Rising Sun Engine Initiative to Save the World) aims to dramatically improve internal combustion thermal efficiency up to a maximum of 50 percent, reducing the impact of combustion engines on the environment. This cooperative research and development project between industry, academia and government will also contribute to the development of Japan's practical engineering capacity and the nation's ability to compete.

Program Director

Masanori Sugiyama

Toyota Motor Corporation
Advanced Development
Power Train Company
General Manager,
Higashifuji Technical Center
Executive General Manager

Profile

Mr. Sugiyama joined Toyota Motors 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, Engine Engineering Field in 2013 and, in 2016, he was named Executive General Manager for Power Train Company and Field General Manager for Advanced Power Train Engineering Field. In 2017, he was appointed to his present position.

Research and Development Topics

1. Research to improve gasoline engine thermal efficiency

Work towards elemental technologies for super lean burn, high boosted combustion, as well as combustion under high EGR volume, 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

Develop elemental technologies such as fast and quiet combustion and clean low temperature combustion that lead to thermal efficiency of up to 50 percent in comparison to today's maximum of 43 percent.

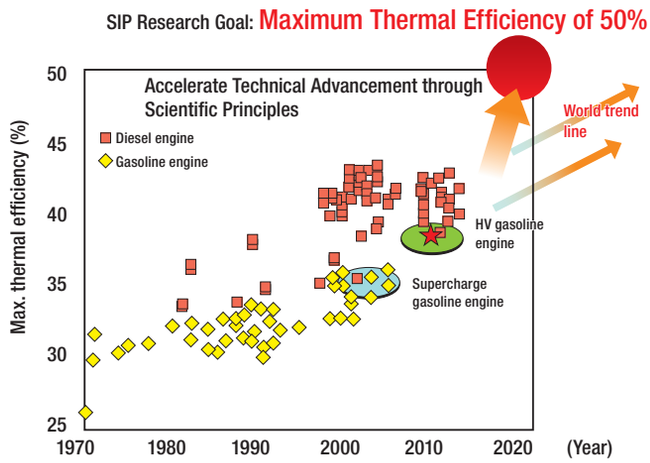
3. Shared research for gasoline and diesel engines

Develop foundational technologies shared between gasoline and diesel engines, including modeling and control technologies for combustion, research into combustion analysis tools, and research into various types of loss reduction.

•SPORT HYBRID i-MMD 2.0L DOHC i-VTEC

(Source: Honda R&D Co., Ltd.)

•Changes in the Thermal Efficiency of Automotive Internal Combustion Engines and SIP Goals



Exit Strategies

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

Offer fundamental technologies and development tools to society that 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.

☑ Create a structure for sustainable multi-industry, multi-academic collaboration

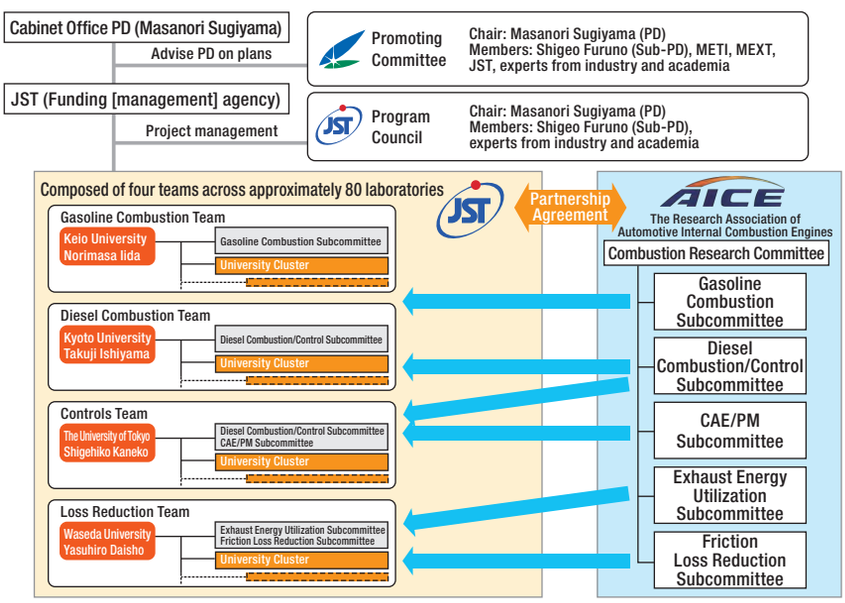
A successful industry-academia cooperative research relationship will communicate common needs from industry, facilitate personnel exchange between industry and academia, grow the management capabilities of leader universities, and create new industries originating in university research. This new cooperative scheme will serve as a model to other industries, leading to a new development process that will contribute to a stronger Japan. Japan's Ministry of Economy, Trade and Industry (METI) and Ministry of Education, Culture, Sports, Science and Technology (MEXT) work together to study policies to create, over the next five years, a sustainable multi-industry, multi-academic cooperative research relationship that contributes to Japan's 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, aim for international deployment by vendors, etc., including de facto standards.

Implementation Structure

As an expert in research management, the Japan Science and Technology Agency (JST) oversees the program as a whole. Approximately 80 participating laboratories and public research institutions have been divided into four teams covering the research fields of gasoline combustion, diesel combustion, control, and loss reduction, each led by a leader university. The Research Association of Automotive Internal Combustion Engines (AICE) has entered into a partnership agreement with JST to support each research team, creating a research and development framework that brings together industry, academia and government agencies.

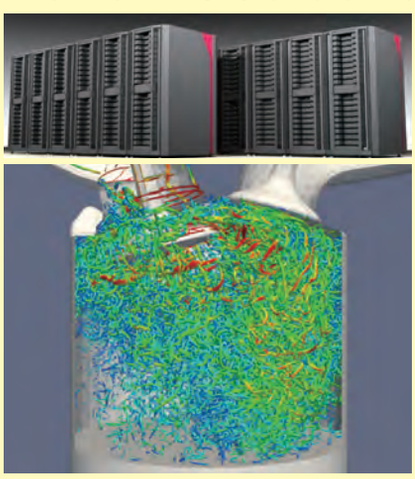


Progress to Date

Unveiling the HINOCA Rising Sun Software

Although automotive engines are widespread, surprisingly little is known about the many unresolved issues surrounding heat flow phenomena associated with combustion. It is the mission of HINOCA to unravel these issues and model them numerically to build highly versatile, Japanese-made 3D simulation code for engine combustion.
Starting from this fiscal year, HINOCA has also been released to engineers at automakers. Together with relevant researchers and with members of the CAE/PM Subcommittee at the Research Association of Automotive Internal Combustion Engines (AICE), collaborative efforts are being made to increase the accuracy of modeling by using super computers to represent actual engines. It is expected that this technology will be broadly adaptable, from basic research to development, including for elucidating the turbulent vortex structure generated inside engines.

● Visualization of turbulent vortex structure using Japan Aerospace Exploration Agency's (JAXA) supercomputer



Program Director **Masanori Sugiyama** Interview

Expectations for Deepened Multi-industry, Multi-Academic Collaborations and for Invigorated Automotive Engineering

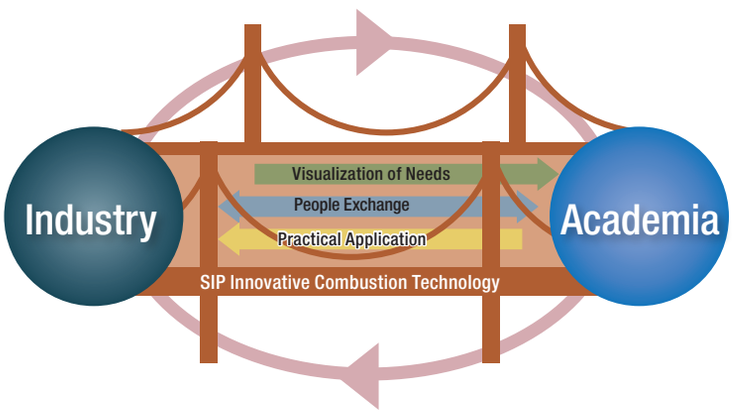
While electrification of the automobile continues, more than half of all vehicles are expected to still be using internal combustion engines 30 years from now. This program continues to make progress in improving the thermal efficiency of automotive internal combustion engines by combining specialized knowledge of control, combustion and loss reduction.

Sparking an Exchange of Knowledge Among Researchers

Three years have passed since we set an ambitious goal for achieving a thermal efficiency of 50 percent for gasoline and diesel engines under industry-academia-government collaborative research. With approximately 80 laboratories and public research institutions participating, the scale of this joint research is unparalleled. Program Director Masanori Sugiyama sees a positive outcome from the deepening cooperation. “In the first year, we were feeling our way around. Now, however, industry support of our academic research teams has resulted in mutual trust and smooth communications. Members from both the Japan Science and Technology Agency (JST) and Program Council managing the research and development have been visiting the universities frequently, offering advice and motivating teams to succeed.”

To achieve these program goals, it is essential now to form new scientific theories, rather than reasoning by analogy based on past engine development experience and results. To this end, program researchers are combining a number of research fields, including chemical reactivity and basic combustion. Based on these results, research teams then work together to build larger integrated models. Academic research tends to drill deep into a particular field, having limited interchange with other fields. Through this joint research, however, a number of research fields have been cross-linked and integrated, encouraging active exchange of researcher knowledge.

•Creation of Sustainable “Multi-Industry, Multi-Academy” Collaboration



Industry ⇒ Academia: Visualize Common Needs in Industry
Academia ⇒ Industry: Provide Basic Knowledge
Academia ⇔ Industry: Sustained Exchanges in Human Resources/Needs/Seeds

Universities throughout Japan
Companies at the Edge of their Individual Potential
} United!

Progress Through Open Innovation

Under this program, open labs have been established at the four leader universities, equipped with state-of-the-art laboratory equipment and serving as forums for experiments, discussions and data-sharing among industry and academic researchers. The Keio University SIP Engine Laboratory in the Ono Sokki Technical Center was the first such open lab. This center is home to more than 100 registered researchers and student participants. Mr. Sugiyama spoke of his expectations for developing human resources, saying, “The experience of collaborative research with other laboratories and companies offers students a great learning opportunity. Seeing that your own research can lead to large results increases motivation as well.”

A research environment that promotes this kind of open innovation leads to steady results. As of this June, the program had delivered a success when the Gasoline Combustion Team and the Diesel Combustion Team achieved net thermal efficiencies of 44.4 percent and 46.4 percent (single cylinder engines). The Loss Reduction Team has developed a technology in which low-friction materials are used to form a hardened surface on the engine piston, while the Control Team and Gasoline Combustion Team are collaborating to develop HINOCA, software for the three-dimensional simulation of engine combustion. Another of the goals of this program is to develop standards from unique Japanese control models and analysis software, leading to future reductions in development costs.

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Innovating Practical Engineering Research

Thus far, this program has achieved its target efficiencies each year. However, from this point forward, the path to success steepens, and we will need to strengthen the cycle of exploring, pursuing and verifying new ideas.

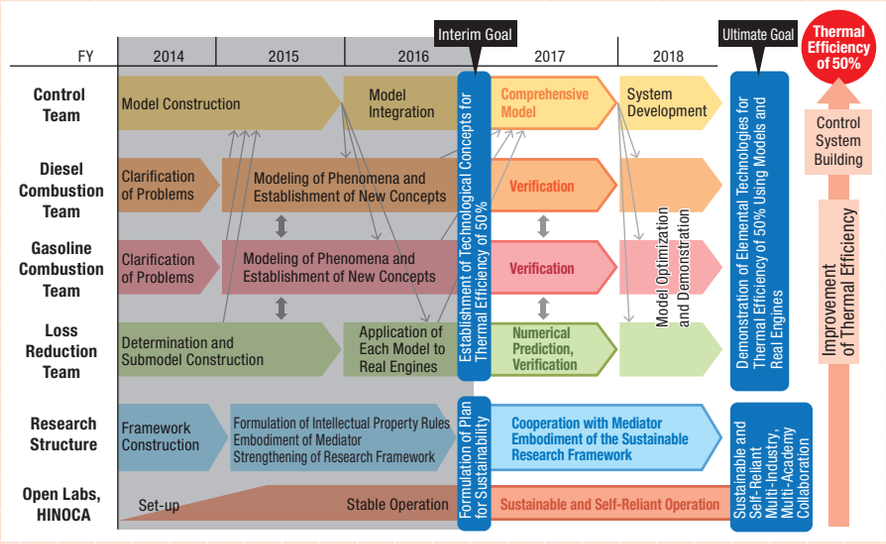
It took researchers 40 years of effort to finally raise the thermal efficiency of internal combustion engines from 30 percent to 40 percent. To gain another 10 percent in a span of five years is certainly a lofty goal.

To break through this wall, program participants are engaged in the scientific approach mentioned earlier. The ultimate goal is to elucidate the science behind combustion phenomena in theory. The next step is to turn this progress into general models, advancing development by motivating industry. This is an important element for achieving Society 5.0 as provided under the 5th Science and Technology Basic Plan, as well as an important initiative leading to highly competitive manufacturing for Japan.

"Model-based development will change approaches to automotive engineering in a significant way. As an SIP program, internal combustion engine research is gaining greater attention. We see an increase in the number of students aspiring to this field as well. Our aim is to incorporate new dynamics in the field to reinvigorate and innovate automotive engineering." (Sugiyama) We are accelerating open innovation to achieve ambitious goals.

Future Plans

This year, verify the technological concepts established for achieving thermal efficiency, and demonstrate those concepts using actual engines. Also, examine specific measures aimed at the sustained and self-reliant operation of open labs and HINOCA.



Our goal of increasing thermal efficiency to 50 percent is not merely a dream. It has become a very real possibility. Both automobile engines and automotive engineering will keep improving.