Special Feature 2

Offering New Clean Diesel Engines with Significantly Enhanced Environmental Performance to Customers around the World

Sustainable growth of the global automobile market is expected to continue primarily in emerging countries. At the same time, environmental regulations are increasingly becoming more stringent in both developed and emerging countries. In response, there is a growing demand for diesel engines that feature superior fuel efficiency and emit less CO_2. Amid such conditions, Toyota Industries' Engine Division has worked closely with Toyota Motor Corporation (TMC) in the diesel engine business in various areas, including development, production engineering and production.

In this special feature, we introduce the initiatives undertaken for the development and production of a new diesel engine, which simultaneously realizes superior power performance and environmental performance, as well as a turbocharger (hereafter, turbo) that plays a significant role in the enhancement of these performances.

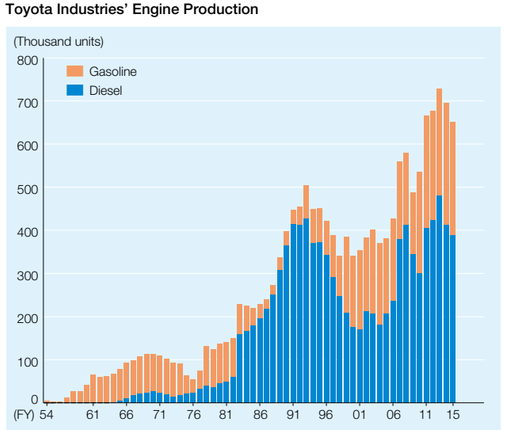
Participating in the Launch of TMC's New Environment-Conscious Diesel Engines from the Development Stage

Leveraging long-accumulated diesel engine technologies, we participated in the development of the GD diesel engines (1GD-FTV and 2GD-FTV), successor models of TMC's mainstay KD engine. In June 2015, our Higashichita Plant in Aichi Prefecture commenced production of the 1GD-FTV, a 2.8L direct-injection turbo diesel engine fitted on the Land Cruiser Prado and the Hilux that are marketed in Japan and Thailand, respectively.

The GD diesel engine, together with the 2GD-FTV 2.4L direct-injection turbo diesel engine, is fitted on approximately 70% of TMC's diesel-powered vehicles, and was developed in response to needs for cleaner engines both in developed countries where more stringent emissions standards are being enforced and in emerging countries where emissions standards are expected to be strengthened. The newly developed GD diesel engine adopted next-generation advanced thermal insulation diesel combustion that uses Thermo Swing Wall Insulation Technology (TSWIN)*1 for the first time in the world as well as the turbo for which we participated in the development. Together, these two features enable maximum thermal efficiency of 44%, one of the highest in the world. Compared with the KD diesel engine, the GD model offers significantly enhanced environmental performance, such as an approximately 15% reduction in CO_2 emissions at maximum. In terms of power performance, the starting torque and acceleration response have been dramatically improved. Further, the adoption of the urea Selective Catalytic Reduction (SCR)*2 system, a TMC first, and other features clear Euro 6, the world's most stringent emissions standard, as well as Japan's 2010 emissions standards and other regulations.

*1: Combustion improvement technology to reduce cooling losses during combustion
*2: Technology to neutralize nitrogen oxides in emission gases using urea

Toyota Industries' Engine Production



*Including lift truck engines and excluding CKD

Toyota Industries' Engine Business Possessing a History of Innovation and Challenges

Toyota Industries entered the Engine Business in 1953. Production expanded from automotive gasoline engines to automotive diesel engines and subsequently to engines for industrial use, including lift trucks, by applying the technologies for automotive engines. We have thus steadily broadened our scope of the Engine Business.

At present, we produce such automotive engines as KD diesel engines, which are fitted in TMC's Innovative International Multi-purpose Vehicle (IMV) series; VD diesel engines adopted in the Land Cruiser and other vehicles; and AR gasoline engines installed in the RAV4 and other vehicles. For industrial use, we also produce Toyota 1KD diesel engines, Y gas/gasoline engines and other engines and fit them in our lift trucks and other industrial vehicles.

Among these, we play a particularly major role in the development and production of TMC's diesel engines, contributing to their production of appealing diesel-powered vehicles by tapping our strengths in terms of development and production aspects such as the development of clean, fuel-efficient and high-performance engines as well as high-mix low-volume production through flexible production lines.

New Engine Meeting the Globally Rising Expectations for Clean Diesel Engines

While automobiles are becoming increasingly electrified, as exemplified by hybrid vehicles and electric vehicles, in Europe diesel-powered vehicles have long been highly appreciated for their effectiveness in countering global warming because they are fuel efficient and produce less CO_2 emissions compared with gasoline-powered vehicles. Also, in terms of power performance, diesel engines could be regarded as a power train that can meet the high standards required for installation in TMC's Land Cruiser and IMV vehicles.

For the development of the GD diesel engine, we drastically revolutionized the engine structure not only to respond to emissions standards in Europe, Japan, Asia, South America, Oceania and other regions but also to realize superior performance in such properties as fuel efficiency, low speed torque, quiet operation and reliability. As for the turbo fitted on the engine, respective members of the engine and turbo development projects shared targets and undertook tasks through close communication on each other's development status.

Primary concerns regarding diesel engines include noise and vibration as well as particulate matter (PM) and other substances of concern included in emissions. The GD diesel engine, however, not only offers a powerful driving experience representative of diesel-powered vehicles but also features improved environmental performance, and we expect this engine will demonstrate excellent competitiveness in the future global market.

Newly developed GD diesel engine

Applying Our Strengths Such as Technologies and Know-How Cultivated in the Compressor Business to the Development of the Turbo, a Key Component

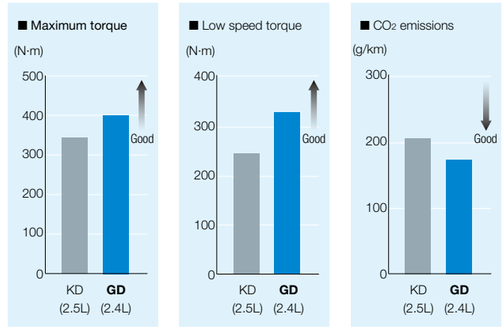
More often than not, an engine's power performance and environmental performance are determined by the capabilities of the turbo installed inside the engine. For this reason, improvements in turbos are indispensable as emissions standards become ever more stringent worldwide. Naturally, our endeavor to develop the world's best diesel engines entailed the development of the world's best turbo.

However, four leading turbo manufacturers already account for more than 80% of the global market, and it was considered that there was no room for new entrants. Undaunted by this disadvantage, we participated in TMC's project to develop diesel engine turbos for automobiles and successfully commenced production in February 2015.

For the launch of the turbo, we drew upon the strengths of each of our diverse businesses, including close cooperation with the GD diesel engine development team, know-how cultivated in the Car Air-Conditioning Compressor Business as well as the experience in 2013 to install a new internal-combustion lift truck with our first industrial turbo developed and produced in-house.

In the turbo development, a particular focus was placed on realizing lighter weight and a more compact size while achieving high efficiency at the same time. In order to efficiently reroute exhaust energy back into the engine, we reviewed the basic framework and materials, changed production methods and incorporated various ingenuities. In addition, since the pleasure of driving is an essential element

Comparison of GD Engine and KD Engine



Comments from Engine Developers

(Engineering Dept., Engine Div.)

Takeyuki Kato
Group manager

Taku Ishikawa
Working leader

We set a technically challenging goal for the development of the GD diesel engine in order to significantly improve performance, with all relevant departments such as development, quality assurance and production engineering working together as one team.

For example, we aimed to reduce the number of bolts to tighten one cylinder from six to four in order to realize the optimum design of the port, but that entailed the problem of inadequate sealing of the cylinder head. Also, improving engine performance gave rise to such issues as thermal load and stress on the cylinder head, requiring a review of the structure and materials as well.

With the difficultly of such challenges, all the related departments on the same floor gathered across boundaries and worked closely to surmount these issues, which gave us tremendous confidence in ourselves.

New turbocharger

of passenger cars, we undertook development while seeking advice from the engine development team how to "spice up" the turbo, which enabled us to gain yet another invaluable experience and knowledge.

Our development team was responsible primarily for improving the variable nozzle vane, which significantly contributes to better performance of the turbo, and reviewing the aerodynamic design. These achievements made it possible to realize the world's top level in terms of compact size, high efficiency and wider flow range of the turbo. In the commercialization stage of the turbo, we launched a Company-wide project and leveraged our broad-ranging technologies and know-how, including those of the Engine Business as well as compression and machining technologies of the Car Air-Conditioning Compressor Business. In addition, we applied technologies accumulated by the Engine Business and completed an optimum turbo that provides superior cost performance for the GD diesel engine.

An even more meticulous machining precision is required for the production of turbos compared with engines. As such, we sought the cooperation of our Production Engineering Development Center to enable in-house production. The center has been responsible for the development of production equipment for car air-conditioning compressors, which requires extremely precise machining technologies, and the collaboration enabled mass production of high-quality, high-performance turbos.

Comments from Turbo Developers

(T Project, Engine Div.)

Manabu Ishikawa
Project leader

Hiromu Iwata
Working leader

We spent enormous efforts in the design of the variable nozzle, which affects the basic performance of the new turbo. The nozzle plays a major role in adjusting the flow of emissions to the rotating wing depending on the operating condition of the engine and in realizing high efficiency of the turbo. However, optimizing the nozzle for the engine itself was a big challenge. While changes in the turbo design would have an impact on the engine system, changes in the engine would affect the turbo structure. To address this issue, we exhaustively discussed matters by leveraging the advantage of developing both the engine and turbo, so we all had a great sense of accomplishment when we were able to come up with the best possible solution. Building on this experience and knowledge, we will aim for the development of next-generation turbos, including those for materials handling equipment.

Comments from Turbo Production Engineer

(Production Engineering Dept., Engine Div.)

Katsushige Takamatsu
Working leader

The most difficult challenge in the production of the new turbo was balancing high quality and low cost in addition downsizing. To provide products whose quality is competitive with leading turbo manufacturers, we established a production line by utilizing our manufacturing expertise and incorporating new ideas. Particularly crucial was the machining of the wing, for which members from such departments as development, production engineering, production and quality assurance worked as a team to achieve high machining precision. By leveraging our past experience in the production of lift truck turbos, we repeatedly discussed with members of the development department how to balance machining precision with production efficiency, thus successfully establishing a more efficient production line.

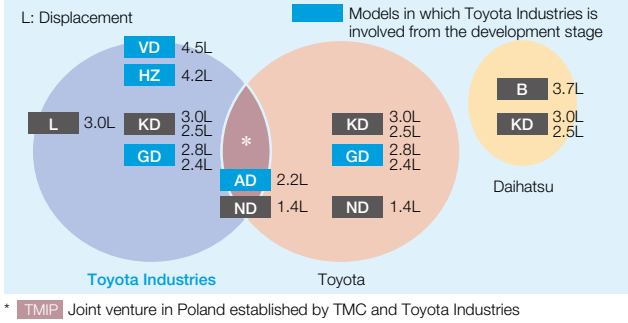
Creating a Structure to Deliver Appealing Diesel Engines to Customers around the World

In November 2014, we announced the agreement of the gradual integration of development and production of diesel engines, which have been carried out jointly with TMC. The aim was to efficiently strengthen the competitiveness of diesel engines by consolidating functions undertaken by both companies and optimally allocating resources.

We will strive to offer appealing automotive and industrial diesel engines that possess even more superior quality, including higher environmental performance, by promoting development efficiency, bolstering cost competitiveness, further enhancing specialization of the Engine Business and honing 3E (Energy, Environmental protection and Ecological thinking) technologies.

We will aim for the growth of our Engine Business by solidifying the development and production foundations built by the launch of new diesel engines and turbos, thereby contributing to the realization of an environmentally friendly society.

Assignment of Automotive Diesel Engine Production in the Toyota Group



* TMIP Joint venture in Poland established by TMC and Toyota Industries