Development of a New Generation Clean Diesel Engine (2.2L) which Achieves both Driving Pleasure and Environmental Performance -Realization of a concept for ultra-low compression ratio of 14.0

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1. Overview

CO2 reduction by use of hybrid vehicles (HEVs) or electric vehicles has attracted attention in recent years. On the other hand, however, many vehicles are thought to have an internal combustion engine (ICE) even in 2030. This prediction has increased the significance of improving ICE efficiency more than ever. Therefore, Mazda started to focus on pursuing ideal ICEs for both gasoline and diesel engines and has developed a next-generation diesel engine, SKYACTIV-D (2.2L). The engine is characterized by the world's lowest compression ratio for a mass-produced diesel passenger car and high-efficiency boosting, which became breakthrough technologies to realize its high performance. This engine has been mounted on CX-5 (SUV) and ATENZA (sedan/wagon) and realized smooth acceleration, embodiment of driving pleasure, low fuel consumption at the top level in its class as well as clean emissions conformable to the latest emission regulations without using NOx after treatments..

2. Technology Details

Compared to other ICEs, diesel engines have high efficiency. Despite of the advantage, however, domestic share of diesel passenger cars grew at a sluggish pace due to the following problems: - Difficulty to realize ideal combustion timing and duration due to NOx and PM restrictions (Diesel knocking noise is included in this problem.) - Increase in mechanical friction due to robust engine structure required to endure its high peak firing pressure. - Cost increase due to use of NOx after treatments to conform to strict emissions regulations

To break through these problems, we focused on the realization of the SKYACTIV-D technical concept shown in Fig.1, in which an ultra-low compression ratio of 14.0 (the previous model for European market had 16.3) and high-efficiency boosting were combined.

As shown in Fig.2, deterioration in auto-ignitability at cold conditions, which was an obstacle to lowering the engine's compression ratio, was prevented by reducing ignition delay to the level of the previous model. To realize this, we designed the engine to start boosting from an extremely low-load region using the smaller one of two turbochargers, increase in-cylinder temperatures by re-opening exhaust valves in intake stroke and form local rich mixtures by conducting small-quantity and multi-stage injection.

As Fig.3 shows, lowering the compression ratio made it possible to lower the peak firing pressure while maintaining the engine power. This enabled us to design lighter weight and lower rigidity reciprocating/rotational parts. As a result, a large reduction in mechanical friction was achieved. To realize ideal combustion timing and duration as well as clean emissions at the same time, we put premixed compression ignition combustion to practical use by controlling ignition timing based on model-based prediction of ignition delay in the low compression ratio engine.

As shown in Fig.4, we also developed an egg-shaped combustion chamber using a CFD analysis with accuracy increased by integration with fuel spray measurements. As this chamber can suppress momentum loss and form a strong vertical vortex, we were able to realize both a reduction in combustion duration and clean emissions in diffusive combustion in a high-load region. By use of these techniques for improving combustion, our new diesel engine has conformed to Japan's Post New Long Term and Euro 6 Emissions Regulations without expensive NOx after treatments and achieved low fuel consumption (reduced by 15 to 20% compared to the previous model for European market) at the top level in its class including HEVs. In addition, wide-range boosting performed by small-size and large-size turbochargers and use of lighter weight reciprocating/rotational parts helped to realize driving pleasure with smooth acceleration soaring up to high engine revolutions. Thanks to the realization of the technologies above, the vehicles with SKYACTIV-D have gained product competitiveness not only in Europe but also in the Japanese market.

3. Summary

An original technical concept to combine an ultra-low compression ratio of 14.0 and high-efficiency boosting, which would overturn the notion of diesel engines, arose from our approach to the ideal ICE. By realizing the concept, we were able to balance drivability, fuel consumption, emissions and cost at a high level. Over one year after the release of the new diesel engine, we have seen certain prospects for the contribution to CO_2 reduction which is derived from the popularization of diesel passenger cars leading to high thermal efficiency and the promotion of diesel fuel consumption in Japan.

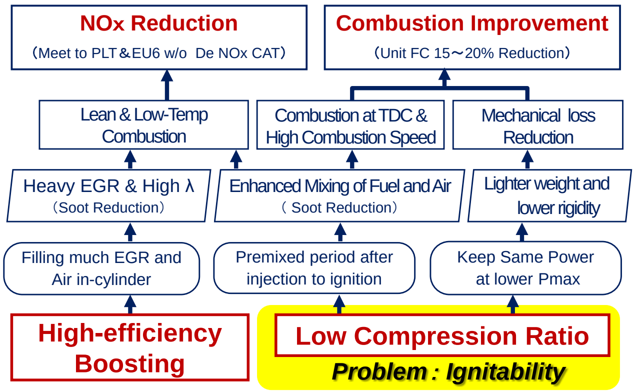


Fig.1 SKYACTIV-D Technology Concept

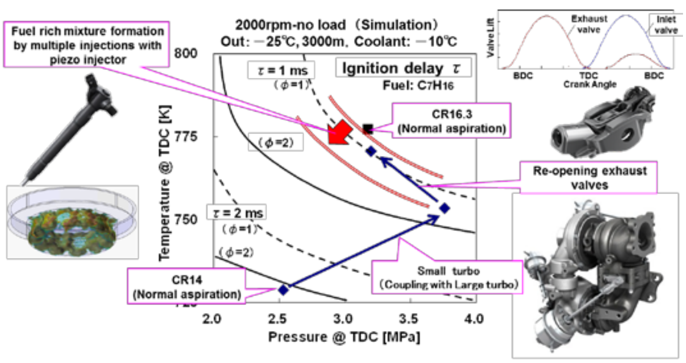
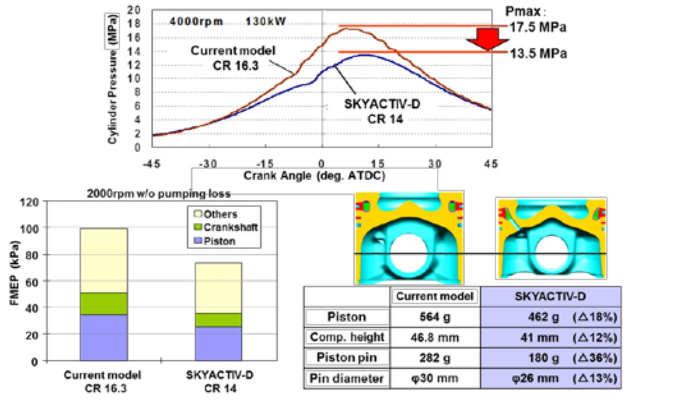


Fig.2 Ignitability improvement techniques for lowering compression ratio



	Current model	SKYACTIV-D
Piston	564 g	462 g (Δ18%)
Comp. height	46.8 mm	41 mm (Δ12%)
Piston pin	282 g	180 g (Δ36%)
Pin diameter	φ30 mm	φ26 mm (Δ13%)

Fig.3 Lower the peak firing pressure to design lighter weight and lower rigidity parts

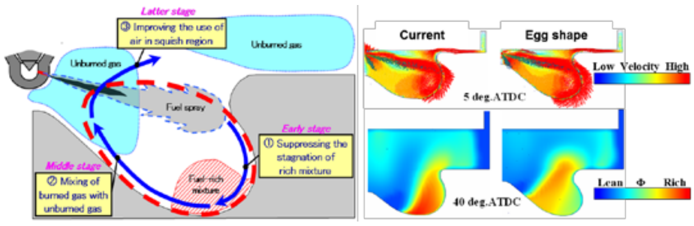


Fig.4 Egg-shaped combustion chamber concept and its CFD analysis result