DIESEL ENGINES

1 Introduction

In Japan, there were few newly announced and launched engines in 2015 since most companies had already introduced vehicles compliant with the new 2015 heavy-duty vehicle fuel economy standards. Therefore it doesn't see a lot but a number of new and refined engine models were announced or launched in 2015 for commercial vehicles. These were supplemented by a range of new engines for passenger vehicles to meet rising customer expectations for better fuel consumption and environmental performance.

Outside Japan, European automakers continued to launch passenger vehicles installed with engines compliant with the Euro 6 emissions standards. The year 2015 also saw a number of refined Euro 6-compliant commercial vehicle engines with further improved fuel economy. In contrast, the Environmental Protection Agency in the U.S. pointed out illegal emissions software some models from European automakers, causing a social outcry and stimulating initiatives to measure real-world emissions.

Although competition to develop technology to lower fuel consumption and emissions is growing more and more fierce, regaining the trust of customers is likely to be a key issue for the future in the field of diesel engines.

2 Engine Trends in Japan

2. 1. Summary

2. 1. 1. Diesel engines for passenger vehicles

In the diesel passenger vehicle segment in Japan, Toyota Motor Corporation launched a new 2.8-liter engine for the Land Cruiser Prado. The distinguishing characteristic of this engine is its Thermo Swing Wall Insulation Technology (TSWIN), a next-generation heat management technology for diesel combustion.

2. 1. 2. Diesel engines for commercial vehicles

The following two fuel-efficient diesel engines were unveiled in 2015: Hino Motors Ltd. launched a new 5.1-liter engine for the Ranger series and Isuzu Motors launched a refined 9.8-liter engine for the Giga heavy-duty truck. These engines feature new technologies to reduce both emissions and fuel consumption, including higher fuel injection pressures to improve consumption and new minimized leakage injector that reduce supplied flow of the high-pressure fuel pump.

2. 2. New engine characteristics (Table 1)

2. 2. 1. Toyota 1GD-FTV engine (Fig. 1)

This new engine is a downsized successor to the KD engine series with higher torque. The next-generation TSWIN heat management technology helps to increase maximum thermal efficiency to 44%, thereby substantially improving fuel economy by adopting a tapered lip combustion chamber and an ultra-high-pressure fuel injection system. The engine also features a urea selective catalyst reduction (SCR) aftertreatment system and satisfies both the Japanese post-new long-term and Euro 6 emissions regulations. Toyota also launched the 2.4-liter 2GD-FTV engine for markets outside Japan at the same time[1].

2. 2. 2. Hino A05C engine (Fig. 2)

This new engine is the variant of the A09C engine for heavy-duty trucks and was developed for the medium-duty Ranger truck series. The new engine carries over the basic structural framework and moving parts within an optimized 4-cylinder design compatible with high fuel pressures and heat loads. As a result, the A05C has a smaller displacement than the previous engine. The engine achieves better fuel consumption through the adoption of dimple-textured cylinder liners to minimize the friction loss in power cylinder, a two-stage turbocharger, and an ultra-high-pressure fuel injection system. This engine also features an HC SCR exhaust aftertreatment system for greater user convenience. The A05C is also installed on route buses in combination with a hybrid system[2-4].

Table 1 Specifications of new engines launched in Japan in 2015.

Application	Manufacturers	Engine model	Cylinder arrangement	Bore × stroke (mm)	Displacement (cc)	Compression ratio	Max. output (kW/rpm)	Max. torque (Nm/rpm)	Characteristics
Passenger vehicle	Toyota	1GD	Inline 4	92 × 103.6	2 754	15.6	130 /3 400	450 /1 600 −2 400	Low compression ratio, TSWIN, tapered lip combustion chamber, higher injection pressure, new injectors
		2GD	Inline 4	92 × 90	2 393	15.6	110 /3 400	400 /1 600 −2 000	
Commercial vehicles	Hino	A05C	Inline 4	112 × 130	5 123	17.0	184 /2 300	834 /1 400	Dimple-textured cylinder liners, two-stage turbocharger, higher injection pressure, new injectors, compression release engine brake
	Hino	6UZ1	Inline 6	120 × 145	9 839	16.2	279 /1 800	1 814 /1 000 −1 200	Larger intercooler and radiator, more efficient EGR cooler, higher injection pressure, new injectors

Fig. 1 Toyota 1GD engine.

Fig. 2 Hino A05C engine.

2. 2. 3. Isuzu 6UZ1 engine (Fig. 3)

The heavy-duty Giga truck series is installed with the 6UZ1 engine, which features refinements from the previous engine including a larger intercooler and radiator, more efficient exhaust gas recirculation (EGR) cooler, an ultra-high-pressure fuel injection system, and new injectors. These measures increase torque at medium and low engine speeds and improve fuel economy[5].

2. 2. 4. Isuzu 6NX1 engine

This is a lightweight and compact heavy-duty truck

Fig. 3 Isuzu 6UZ1 engine.

engine featuring a two-stage turbocharger. It was unveiled by Isuzu at the Tokyo Motor Show. It is reported to have a displacement of 7.79 liters and achieves power of 250 kW at 2,000 rpm and torque of 1,422 Nm at 1,300 rpm[6].

3 Engine Trends outside Japan

3. 1. Summary

3. 1. 1. Diesel engines for passenger vehicles

In Europe, automakers continued to launch vehicles installed with Euro 6-compliant engines. Another major trend is modular design that share parts with engines with different power characteristics and gasoline engines. Development is focusing on downsizing and increasing brake mean effective pressure (BMEP) to improve fuel economy. Manufacturers are also focusing on developing engines for different markets.

3. 1. 2. Diesel engines for commercial vehicles

The following two fuel-efficient diesel engines were unveiled in 2015: Mercedes-Benz launched a 12.8-liter engine for the Actros heavy-duty truck and Iveco launched a 4.5-liter engine for the Eurocargo truck. These are both refined versions of engines that were already compliant

Table 2 Specifications of new engines launched outside Japan in 2015.

Application	Manufacturers	Engine model	Cylinder arrangement	Bore × stroke (mm)	Displacement (cc)	Compression ratio	Max. output (kW/rpm)	Max. torque (Nm/rpm)	Characteristics
Passenger vehicle	Suzuki	E08A	Inline 2	77 × 85.1	793	15.1	35 /3 500	125 /2 000	Smaller and lighter, low-rotational variation 2-cylinders, compact high-pressure fuel pump, low compression ratio
	Nissan	YS23	Inline 4	85 × 101.3	2 298	15.4	140 /3 750	450 /1 500 −2 500	Two-stage turbocharger, variable capacity oil pump
	Mercedes	OM626	Inline 4	80 × 79.5	1 598	15.4	100 /3 800	320 /1 500 −2 600	Steel pistons, variable capacity oil pump, fuel filter with electrical heater, high- and low-pressure loops EGR
		OM654	Inline 4	82 × 92.3	1 950	15.5	140 /3 500 −4 100	400 /1 600 −2 800	Steel pistons, step-recess combustion chamber, crankshaft offset, electric priming pump, fuel filter with electrical heater, high- and low-pressure loops EGR
	BMW	B57	Inline 6	84 × 90	2 993	16.5	235 /4 400 195 /4 000	620−680 / 1 800−2 400	High injection pressure, tri-turbo
	Subaru	EE20	Boxer 4	86 × 86	1 998	15.2	110 /3 600	350 /1 600 −2 800	Low compression ratio, new injectors, high- and low-pressure loops EGR
Commercial vehicles	Mercedes	OM471	Inline 6	132 × 156	12 809	18.3	310−390 / 1 600	2 100−2 600 /1 100	Twin overhead camshafts, higher compression ratio, new combustion chamber geometry, X-Pulse fuel injection system, asymmetric turbocharger, EGR flap valve
	Iveco	Tector 5	Inline 6	104 × 132	4 485	18.0	118−137 / 2 200	680−700 / 1 100−1 600	No EGR, higher compression ratio, new combustion chamber geometry, new wastegate turbocharger, Hi-SCR system

Fig. 4 Suzuki E08A engine.

Fig. 5 Nissan YS23 engine.

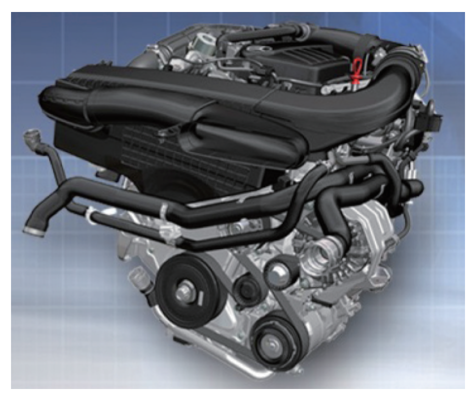

Fig. 6 Mercedes-Benz OM626 engine.

with Euro 6, and feature higher compression ratios. Although recent diesel engines for passenger vehicles have featured lower compression ratios due to shared modular designs with gasoline engines, technological development for commercial vehicle engines is moving in a different direction.

3. 2. New engine characteristics (Table 2)

3. 2. 1. Suzuki E08A engine (Fig. 4)

This is a lightweight and compact 0.8-liter 2-cylinder engine produced and sold by Suzuki Motor Corporation's Indian subsidiary Maruti Suzuki India Limited. The weight of the engine was reduced while maintaining strength and rigidity by adopting an open deck high-pressure aluminum die-cast cylinder block. This engine also features a crankshaft with a 360-degree phase and a primary balance shaft laid out directly to the side to damp rotational vibration. A compact high-pressure fuel pump design was adopted by separating it from the fuel regulating valve and a compact block for maintaining high pressure

Fig. 7 Mercedes-Benz OM654 engine.

Fig. 8 BMW B57 engine.

was adopted to eliminate a common rail[4][7][8].

3. 2. 2. Nissan YS23 engine (Fig. 5)

This new engine is available on the NP300 pick-up truck. This is a downsized version of the previous 2.5-liter engine with greater low-end torque due to a two-stage turbocharger and an injection pressure of 2,000 bar. Fuel economy was also improved by adopting a variable capacity oil pump and reducing the friction loss in power cylinder[9][10].

3. 2. 3. Mercedes-Benz OM626 engine (Fig. 6)

This entry-level diesel engine for the C-Class was jointly developed with Renault. It features a single-stage turbocharger and a 1,600 bar fuel injection system. Despite being positioned as an entry-level engine, excellent fuel consumption and low emissions were achieved by steel pistons, a variable capacity oil pump, an fuel filter with electrical heater, and both high- and low-pressure EGR loops[11][12].

3. 2. 4. Mercedes-Benz OM654 engine (Fig. 7)

This is the first engine developed and launched under the Mercedes Powertrain Architecture (MPA) modular design approach that covers both inline and V-configuration engines. This engine achieves improved combustion

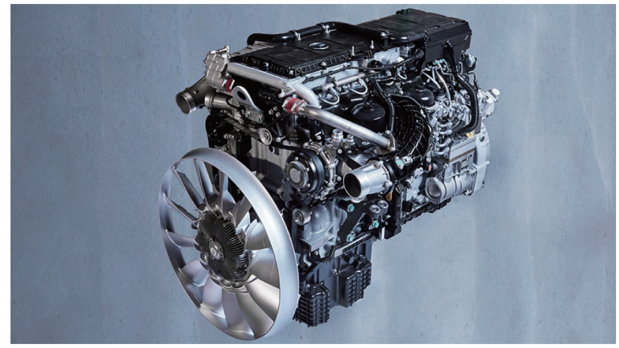

Fig. 9 Mercedes-Benz OM471 engine.

characteristics and fuel economy by adopting an aluminum cylinder block and head capable of in-cylinder pressures up to 205 bar, 2,050 bar piezo injectors, steel pistons with a step-recess combustion chamber, and a 12-mm offset crankshaft. Low emissions were achieved through a high- and low-pressure loops EGR system called Multiway EGR, and adopting a diesel oxidation catalyst (DOC), diesel particle filter with SCR coating (SDPF), and SCR on the engine side[13].

3. 2. 5. BMW B57 engine (Fig. 8)

Continuing from the 3-cylinder 1.5-liter B37 and 4-cylinder 2.0-liter B47 engines, the 6-cylinder 3.0-liter B57 engine is compliant with Euro 6 and has been launched as the successor to the N57 engine. The rate of parts commonization with these 3- and 4-cylinder engines was improved through a modular design that sets the per-cylinder displacement at 500 cc. This modular design approach also shares parts with gasoline engines, as well as block materials. The injection system produces 2,500 bar and the tri-turbo is carried over from the N57 engine[14].

3. 2. 6. Subaru EE20 engine

This Euro 6-compliant engine features a lower compression ratio, new injectors, and high- and low-pressure loops EGR system[15].

3. 2. 7. Mercedes-Benz OM471 engine (Fig. 9)

This is a refined second-generation version of the OM471 that was first launched in 2011 as a Euro 6-compliant engine. This engine features twin overhead camshafts, a higher compression ratio, new combustion chamber geometry, and the X-Pulse fuel injection system that increases the injection pressure to 2,700 bar. It carries over the asymmetric turbocharger, which was a distinguishing feature of the previous generation, and repositioned the EGR flap valve much further forwards in the exhaust manifold and turbocharger. This design enables more efficient use of the turbocharger even under operating conditions with low EGR rates[16].

3. 2. 8. Iveco Tector 5 engine

This engine continues the concept adopted by Iveco in 2013 for achieving Euro 6 compliance, with no EGR, a DPF with passive regeneration only, and a high-efficiency SCR system. This engine achieves higher fuel efficiency by adopting a higher compression ratio, new wastegate turbocharger and new higher-pressure injectors. This approach also creates higher low-end torque and makes downspeeding at rated engine speed.

4 Research and Development Trends

Research and development into diesel engines from the 1990s to the first decade of the twenty-first century focused on the treatment of emissions. Since then, this has been complemented by an additional focus on fuel economy to meet customer needs for fuel-efficient engines and to help suppress global warming with lower CO_2 emissions. Strong progress is being made in both of these fields. Initiatives to improve fuel economy by increasing indicated work and reducing losses include increasing fuel injection pressures, improving combustion chambers, adopting high efficiency and multi-stage turbocharging, downsizing engines and reducing engine speeds, as well as measures to reduce the mechanical loss of the engine and auxiliary equipment. Heat shielding technologies are also being researched and developed to help reduce cooling loss. New and refined engines have been announced and launched with these features in recent years. To help lower emissions, research and development is examining technologies to improve the conversion rates of aftertreatment systems, lower engine-out emissions, and construct controls to perform these functions more accurately. At the same time, development to lower emissions under real-world environments is also becoming more important. These research and development activities are likely to continue in the future.

In addition, since the adoption of technologies to lower fuel consumption and emissions is pushing up engine costs, research is also focusing on ways to hold costs down by optimizing the effect of each technology. One example is an extremely low cost engine that achieves high NOx conversion efficiency without EGR. Another example of low-cost technological development in the field of passenger vehicles is shared modular designs for both gasoline and diesel engines installed in the same model.

Research into low-cost technologies is likely to be a key theme in the future, alongside technologies for lower emissions and fuel consumption.

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