Diesel Engines

1 Introduction

In 2014, 1.205 million diesel engines for four-wheeled vehicles were produced in Japan, up 10.1% from 2013. In terms of engine types, 428,000 diesel engines were produced for passenger vehicles (up 14.1% from 2013), 685,000 for trucks (up 8.0%), and 92,000 for buses (up 8.2%).

In Japan, there were few newly announced and launched engines in 2014 although several years have passed since the launch of vehicles compliant with the Post New Long Term Regulations. However, the engines that were launched included a number of so-called "clean diesel" 1.5-liter engines for passenger vehicles. Vehicles installed with these engines are regarded as environmentally friendly vehicles similar to hybrid vehicles. Several of the commercial diesel engines launched in 2014 also featured refinements to improve fuel efficiency.

In Europe, the Euro 6 emissions standards for passenger vehicles came into force, prompting the announcement and launch of a number of new engines. Diesel engines are regarded as an important means of helping to reduce greenhouse gas emissions and addressing the issue of energy security on a global scale. For these reasons, various engines were unveiled and launched in all regions and vehicle classes in 2014 with the aim of reducing CO_2 emissions through improvements to combustion efficiency and weight reduction.

2 Engine Trends in Japan

2. 1. Summary

2. 1. 1. Diesel engines for passenger vehicles

Mazda Motor Corporation unveiled a new 1.5-liter engine for the Demio that went on sale in 2014.

2. 1. 2. Diesel engines for commercial vehicles

With a primary focus on improving fuel efficiency, Isuzu Motors Limited launched the 4JJ1 engine for the Elf truck and Mitsubishi Fuso Truck and Bus Corporation launched the 6R10 engine for large buses. Both these engines are refinements of existing engines.

2. 2. New engine characteristics (Table 1)

2. 2. 1. Mazda S5-DPTS engine (Fig. 2)

This engine is a 1.5-liter version of the 2.2-liter SH-VPTS engine that went on sale in 2013, featuring innovative technologies such as a lower compression ratio. This engine also incorporates various technologies to further boost fuel efficiency, such as improved heat insulation and lower mechanical loss to restrict increases in cooling loss.

2. 2. 2. Isuzu 4JJ1 engine (Fig. 3)

This engine achieves higher fuel efficiency by adopting a lower compression ratio and new higher pressure injectors.

2. 2. 3. Mitsubishi Fuso 6R10 engine (Fig. 4)

This engine features an asymmetric turbocharger and achieves efficient engine cooling through an electronically controlled variable flow water pump, thereby reducing pump drive loss and improving fuel efficiency.

3 Engine Trends outside Japan

3. 1. Summary

3. 1. 1. Diesel engines for passenger vehicles

Euro 6 emissions standards for passenger vehicles came into force, prompting the announcement and release of new engines from BMW, Volkswagen (VW),

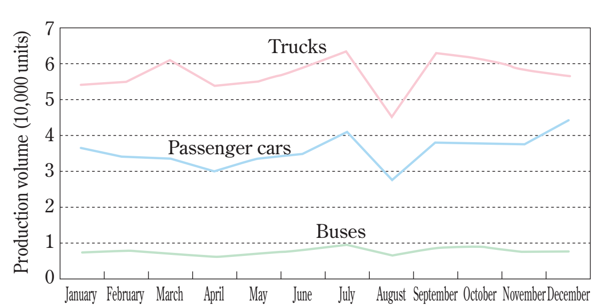

Fig. 1 Diesel engine production in Japan in 2014

Table 1 Specifications of new engines in 2014

Application	Manufacturer	Engine model	Cylinder arrangement	Bore × stroke (mm)	Displacement (cc)	Compression ratio	Maximum power (kW/rpm)	Maximum torque (Nm/rpm)	Characteristics
Passenger vehicles	Mazda	S5-DPTS	Inline 4	76.0×82.6	1 498	14.8	77/4 000	250/1500 −2 500	Low compression ratio, high-dispersion spray injectors, stepped egg-shaped pistons, high- and low-pressure EGR system, VGT, improved heat insulation, lower mechanical resistance
Commercial vehicles	Isuzu	4JJ1	Inline 4	95.4×104.9	2 999	15.8	110/2 800	375/140−2 800	Low compression ratio, new high-pressure injectors
	Mitsubishi Fuso Truck and Bus	6R10	Inline 6	132.0×156.0	12 808	17.3	257−309/1 800	1 810/1 200	Asymmetric turbocharger, electronically controlled variable capacity water pump

Fig. 2 Mazda S5-DPTS engine

Fig. 3 Isuzu 4JJI engine

and Volvo. These engines comply with these standards through innovations such as high-pressure injection, 2-stage turbochargers, and variable geometry (VG) turbocharging. These engines also feature fuel efficiency improvement technologies to lower fuel economy and CO_2. Other noticeable trends include modular design methods such as sharing materials and auxiliary equipment layouts with gasoline engines installed in the same model and other diesel engines. However, no new passenger vehicle engines were announced in North America.

3. 1. 2. Diesel engines for commercial vehicles

Following the same trends as passenger vehicle engines, new and refined commercial vehicle engines were announced and launched by MAN, Scania, and Volvo Trucks in Europe to comply with emissions standards and improve fuel efficiency. Most of these are equipped with VG turbochargers, high-pressure injection systems, and intake inter-cooling. Some of these engines also include a low-pressure exhaust gas recirculation (EGR) system or a 2-stage EGR cooler. In contrast, Scania also unveiled a simplified engine system without EGR or a VG turbocharger with the aim of improving fuel efficiency focusing on commercial vehicle customers in the long-distance transportation field. In North America, both Cummins and Fiat Chrysler Automobiles (FCA) launched new engines. These featured high-pressure fuel injection and VG turbochargers, as well as compacted graphite iron (CGI) cylinder blocks for high-efficiency combustion and reduced weight to improve fuel efficiency.

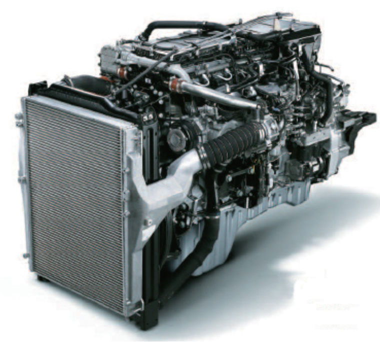

Fig. 4 Mitsubishi Fuso 6R10 engine

3. 2. New engine characteristics (Table 2)

3. 2. 1. BMW B37/B47 engines

BMW are switching over to new engines to comply with the Euro 6 standards. These engines feature the same bore/stroke ratio and have been installed in compact Mini and BMW brand vehicles in 3-cylinder 1.5-liter (B37) and 4-cylinder 2.0-liter (B47) formats. The engines were developed following a modular design approach with enhanced flexibility for development and produc-

Table 2 Specifications of new engines in 2014

Application	Manufacturer	Engine model	Cylinder arrangement	Bore × stroke (mm)	Displacement (cc)	Compression ratio	Maximum power (kW/rpm)	Maximum torque (Nm/rpm)	Characteristics
Passenger vehicles	BMW	B37	Inline 3	84.0×90.0	1 496	16.5	85/4 000	270/1 750 −2 000	Common modular design approach for cylinders, auxiliary equipment layout, and crankcase material of gasoline and diesel engines, VG turbocharger with low-resistance shaft bearings, 2,000 bar solenoid-type injectors
		B47	Inline 4	84.0×90.0	1 995	16.5	140/4 000	400/1 750 −2 750	
	Volkswagen	TDI BiTurbo	Inline 4	81.0×95.5	1 968	15.5	176/4 000	500/1 750 −2 500	Common modular design approach for 1.4- to 2.0-liter diesel engines, 2,500 bar piezo injectors, low-swirl cylinder heads, electric water pump, 2-stage turbocharger (high-pressure side: VGT), low- and high-pressure EGR, aftertreatment system directly attached to engine (SCR-coated particulate filter)
	Volvo Cars	D5	Inline 4	82.0×93.2	1 969	15.8	170/4 250	480/1 750 −2 250	Commonization between gasoline and diesel engines, high-pressure aluminum die-cast block, high-strength aluminum heads, 2,500 bar i-ART injectors, 2-stage turbocharger (high-pressure side: VGT)
Commercial vehicles	FCA	L630	V6	83.0×91.4	2 987	16.5	179/4 000	570/1 800	CGI block, aluminum heads, electronically controlled VGT, 2,000 bar injection system, cooled EGR
	Cummins	ISV5.0	V8	94.0×90.0	4 997		149−205/1 600	705−759/3 200	Latest high-pressure fuel injection system, VG turbocharger, CGI block, high-strength aluminum heads
	MAN	D38	Inline 6	138.0×170.0	15 256	18.0	382−471/1 800	2 500−3 000 /930−1 350	Top-down cooling, 2-stage turbocharger, 2-stage intake cooling, domed intake and exhaust valves, fire rings at the top of the cylinder, 2,500 bar injection pressure, 2-stage EGR cooler, steel pistons
	Scania	DC16	V8	130×154	16 353	17.4	382−427/1 900	2 700−3 500 /1 000−1 400	VG turbocharger, cooled EGR
		DC13	Inline 6	130×160	12 742	17.3	336/1 900	2 350 /1 000 −1 300	No EGR
	Volvo Trucks	D16K	Inline 6	144×165	16 123	16.0	405−552 /1 350−1 900	2 800−3 550 /900−1 450	2-stage turbocharger, intake inter-cooling, cooled EGR

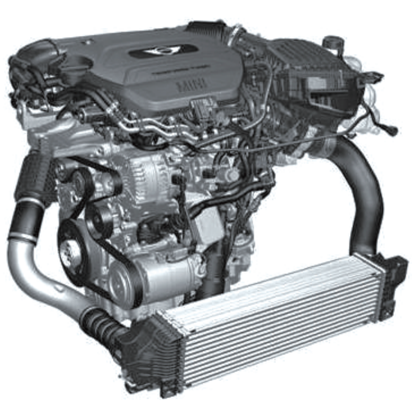

Fig. 5 BMW B37 engine

Fig. 6 BMW B47 engine

tion. Under this approach, the engines share the same auxiliary equipment layout as the gasoline engines installed in the same models, as well as the same crank case materials. The B47 has a VG turbocharger with a low-resistance shaft bearing to improve intake pressure transient response. It also features new solenoid-type injectors that achieve an injection pressure of 2,000 bar.

3. 2. 2. VW 2.0-liter TDI BiTurbo engine (Fig. 7)

This high-power engine was developed following the same modular design approach as VW's 1.4 to 2.0-liter

Fig. 7 VW 2.0-liter TDI BiTurbo engine

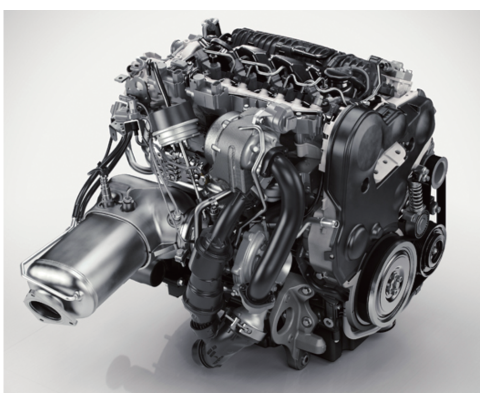

Fig. 8 Volvo D5 engine

Fig. 9 FCA L630 engine

Fig. 10 Cummins ISV5.0 engine

diesel engines, and installed in the Passat. To comply with Euro 6 while achieving both high power and fuel efficiency, this engine uses 2,500 bar piezo injectors, 2-stage turbocharging with a VG turbocharger on the high-pressure side, water-cooled compressor housing, as well as low- and high-pressure EGR. The aftertreatment system is partly incorporated into the housing immediately below engine in consideration of lower exhaust resistance. Other innovations include low swirl cylinder heads as a measure to boost power, stronger moving parts to ensure toughness, durability, and reliability, as well as a lower compression ratio.

3. 2. 3. Volvo D5 engine (Fig. 8)

Both the high-power diesel and gasoline engines for the XC90 were designed through a shared modular approach. In addition to measures to boost power, such as a high-pressure aluminum die-cast cylinder block and high-strength aluminum cylinder heads, the D5 engine also meets the requirements of Euro 6 through 2,500 bar injectors (developed using the Intelligent Accuracy Refinement Technology (i-ART) concept), and 2-stage turbocharging with a VG turbocharger on the high-pressure side.

3. 2. 4. FCA L630 engine (Fig. 9)

The L630 engine is installed in the Ram 1500 full-size pick-up truck and Grand Cherokee SUV. It was designed for compliance with the Tier 2 Bin 5/LEV II standards. This engine was manufactured by VM Motori under the FCA group umbrella and features an electronically controlled VG turbocharger and a common rail system with an injection pressure of 2,000 bar. The main engine unit uses a CGI block and aluminum heads.

3. 2. 5. Cummins ISV5.0 engine (Fig. 10)

This new engine was developed for pick-up trucks, recreational vehicles (RVs), and vehicles mainly driven on the highway. It features a VG turbocharger, the latest high-pressure fuel injection system, a CGI block, and high-strength aluminum heads. It was designed for compliance with the US10 emissions standards.

3. 2. 6. MAN D38 engine (Fig. 11)

This is the largest displacement engine developed by MAN for installation in heavy-duty vehicles. Compliant with Euro VI, the D38 engine also features a 2-stage tur-

Fig. 11 MAN D38 engine

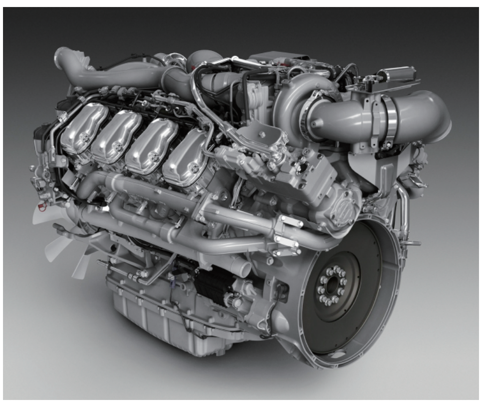

Fig. 12 Scania DC16 engine

Fig. 13 Scania DC13 engine

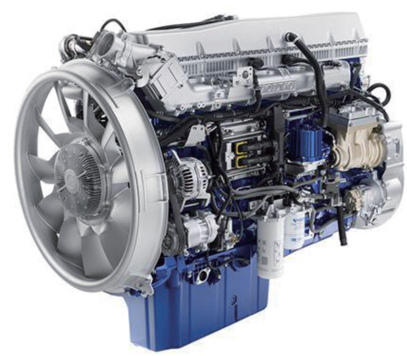

Fig. 14 Volvo D16K engine

bocharger, 2-stage intake air cooling system, and 2,500 bar fuel injection system for highly efficient combustion. Other distinguishing characteristics of this engine include a so-called top-down cooling system that flows coolant from the high-temperature heads to the cylinder block, domed intake and exhaust valves, fire rings inserted at the top of the cylinder bore to prevent carbon deposits, as well as steel pistons to improve toughness, durability and reliability.

3. 2. 7. Scania DC16 engine (Fig. 12)

This is the largest displacement engine developed by Scania for installation in heavy-duty vehicles. It features a VG turbocharger and cooled EGR for compliance with Euro VI. It is the only V8 engine in its class.

3. 2. 8. Scania DC13 engine (Fig. 13)

Scania unveiled and launched the Euro VI-compliant DC13 engine in 2011. However, it has been re-designed without either EGR or a VG turbocharger with an emphasis on improved fuel efficiency particularly for long-distance fleet users, while retaining Euro VI compliance. The higher NOx emissions caused by removing the EGR system are countered by a higher consumption of AdBlue in the urea injection system. To accommodate this change, the AdBlue tank capacity was increased.

3. 2. 9. 3 Volvo Trucks D16K engine (Fig. 14)

This is the largest displacement engine developed by Volvo for installation in heavy-duty vehicles. It is compliant with Euro VI and features a 2-stage turbocharger, an intake inter-cooling system, and cooled EGR.

4 Research and Development Trends

In recent years, automakers have focused on developing technology for compliance with stringent emissions standards such as Japan's Post New Long Term Regulations, and Euro 6/VI. In addition to emissions compliance, other developed technologies aim to reduce mechanical engine losses and optimize cooling to improve combustion characteristics for lower CO_2 emissions or higher fuel efficiency.

Recent technological approaches to comply with emissions standards include developing technology to lower engine-out emissions, after treatment systems, and integrated control technologies. Key future trends are likely to include a growing emphasis on research and development into basic technologies to reduce CO_2 emissions and improve fuel efficiency, as well as into optimized "product" technologies incorporating these basic technologies with emissions standards compliance technologies and hardware- and software-based technologies to improve control accuracy. Manufacturers of expensive and complex diesel engines adopting these necessary new technologies to comply with emissions regulations (particularly commercial vehicle engines) will have to select which systems to use based on these optimization technologies to reduce costs and provide improved usability for customers.

In contrast, most mass-production passenger vehicles will continue to offer gasoline engines and multiple diesel engine choices for the same model. Therefore, from the standpoints of development and production efficiency, passenger vehicle diesel engines will adopt efficient packaging that use common parts and layouts with other engines for the same model, and that also incorporate the aftertreatment system. These engine packages will have to satisfy the restrictions inherent in vehicle installation. Therefore, in addition to the development of technology for compliance with emissions standards and improving combustion characteristics, research and development into separating and consolidating structures and functions in engines with complex configurations will continue growing in importance to achieve engine packages that satisfy these restrictions.

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