Areas of use for diesel engines

No other internal-combustion engine is as widely used as the diesel engine[1]. This is due primarily to its high degree of efficiency and the resulting fuel economy.

The chief areas of use for diesel engines are
- Fixed-installation engines
- Cars and light commercial vehicles
- Heavy goods vehicles
- Construction and agricultural machinery
- Railway locomotives and
- Ships

Diesel engines are produced as inline or V-configuration units. They are ideally suited to turbocharger or supercharger aspiration as – unlike the gasoline engine – they are not susceptible to knocking (refer to the chapter "Cylinder-charge control systems").

[1]) Named after Rudolf Diesel (1858 to 1913) who first applied for a patent for his "New rational thermal engines" in 1892. A lot more development work was required, however, before the first functional diesel engine was produced at MAN in Augsburg in 1897.

Suitability criteria

The following features and characteristics are significant for diesel-engine applications (examples):
- Engine power
- Specific power output
- Operational safety
- Production costs
- Economy of operation
- Reliability
- Environmental compatibility
- User-friendliness
- Convenience (e.g. engine-compartment design)

The relative importance of these characteristics affect engine design and vary according to the type of application.

Applications

Fixed-installation engines

Fixed-installation engines (e.g. for driving power generators) are often run at a fixed speed. Consequently, the engine and fuel-injection system can be optimized specifically

1 Car diesel engine with unit injector system (example)

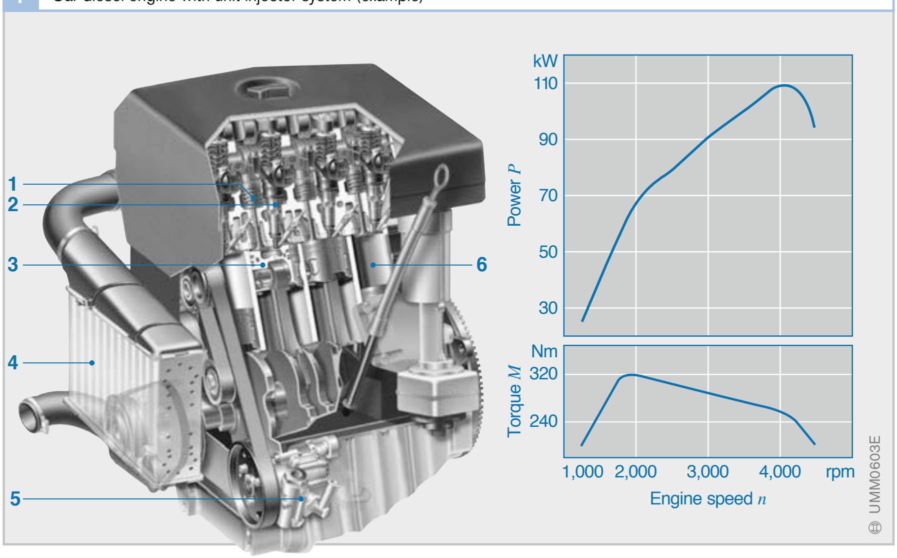

Fig. 1
1 Valve gear
2 Injector
3 Piston with gudgeon pin and conrod
4 Intercooler
5 Coolant pump
6 Cylinder

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for operation at that speed. An engine governor adjusts the quantity of fuel injected dependent on engine load. For this type of application, mechanically governed fuel-injection systems are still used.

Car and commercial-vehicle engines can also be used as fixed-installation engines. However, the engine-control system may have to be modified to suit the different conditions.

Cars and light commercial vehicles

Car engines (Fig. 1) in particular are expected to produce high torque and run smoothly. Great progress has been made in these areas by refinements in engine design and the development of new fuel-injection with Electronic Diesel Control (EDC). These advances have paved the way for substantial improvements in the power output and torque characteristics of diesel engines since the early 1990s. And as a result, the diesel engine has forced its way into the executive and luxury-car markets.

Cars use fast-running diesel engines capable of speeds up to 5,500 rpm. The range of sizes extends from 10-cylinder 5-liter units used in large saloons to 3-cylinder 800-cc models for small subcompacts.

In Europe, all new diesel engines are now Direct-Injection (DI) designs as they offer fuel consumption reductions of 15 to 20% in comparison with indirect-injection engines. Such engines, now almost exclusively fitted with turbochargers, offer considerably better torque characteristics than comparable gasoline engines. The maximum torque available to a vehicle is generally determined not by the engine but by the power-transmission system.

The ever more stringent emission limits imposed and continually increasing power demands require fuel-injection systems with extremely high injection pressures. Improving emission characteristics will continue to be a major challenge for diesel-engine developers in the future. Consequently, further innovations can be expected in the area of exhaust-gas treatment in years to come.

2 Commercial-vehicle diesel engine with common-rail fuel-injection system (example)

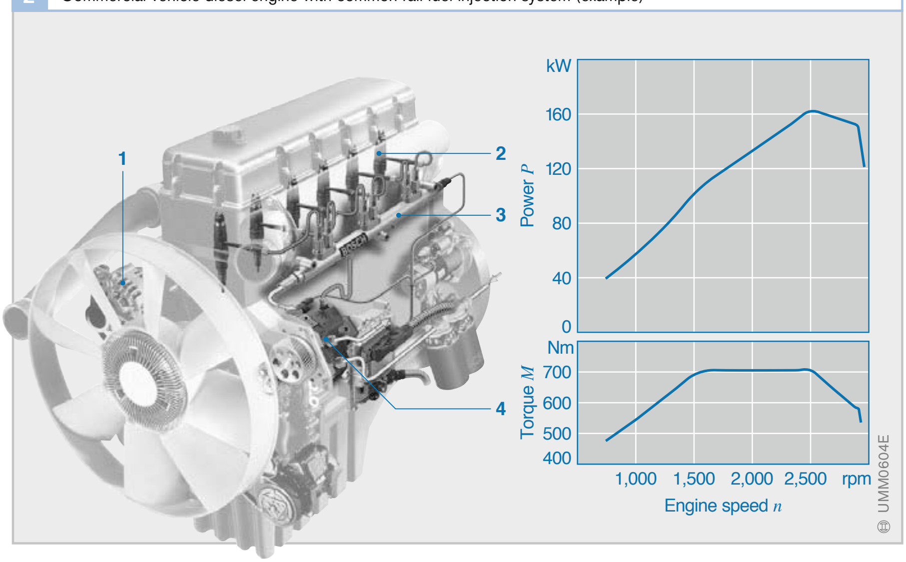

Fig. 2
1 Alternator
2 Injector
3 Fuel rail
4 High-pressure pump

Heavy goods vehicles
The prime requirement for engines for heavy goods vehicles (Fig. 2) is economy. That is why diesel engines for this type of application are exclusively direct-injection (DI) designs. They are generally medium-fast engines that run at speeds of up to 3,500 rpm.

For large commercial vehicles too, the emission limits are continually being lowered. That means exacting demands on the fuel-injection system used and a need to develop new emission-control systems.

Construction and agricultural machinery
Construction and agricultural machinery is the traditional domain of the diesel engine. The design of engines for such applications places particular emphasis not only on economy but also on durability, reliability and ease of maintenance. Maximizing power utilization and minimizing noise output are less important considerations than they would be for car engines, for example.
For this type of use, power outputs can range from around 3 kW to the equivalent of HGV engines.

Many engines used in construction-industry and agricultural machines still have mechanically governed fuel-injection systems. In contrast with all other areas of application, where water-cooled engines are the norm, the ruggedness and simplicity of the air-cooled engine remain important factors in the building and farming industries.

Railway locomotives
Locomotive engines, like heavy-duty marine diesel engines, are designed primarily with continuous-duty considerations in mind. In addition, they often have to cope with poorer quality diesel fuel. In terms of size, they range from the equivalent of a large truck engine to that of a medium-sized marine engine.

Ships
The demands placed on marine engines vary considerably according to the particular type of application. There are out-and-out high-performance engines for fast naval vessels or speedboats, for example. These tend to be 4-stroke medium-fast engines that run at speeds of 400...1,500 rpm and have up to 24 cylinders (Fig. 3). At the other end of

3 Marine diesel engine with single-plunger fuel-injection pumps (example)

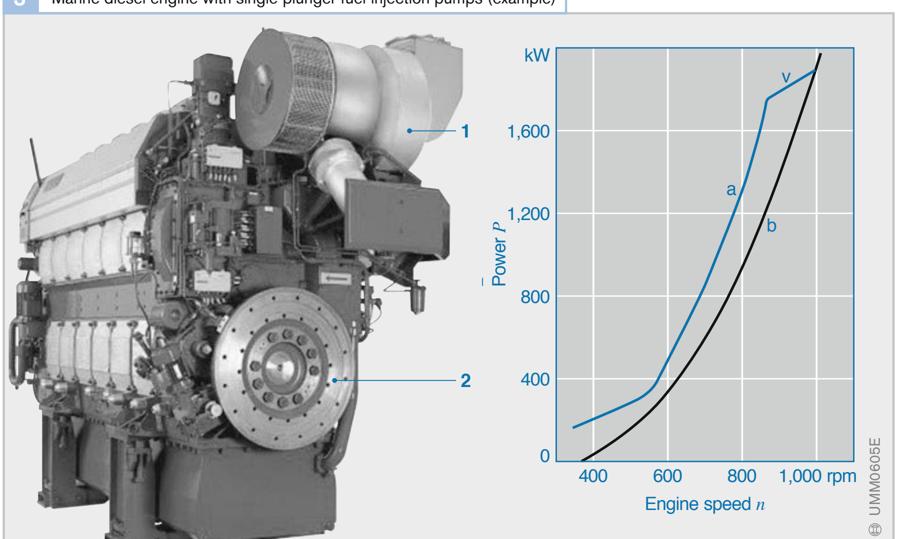

Fig. 3
1 Turbocharger
2 Flywheel

a Engine power output
b Running-resistance curve
v Full-load limitation zone

the scale there are 2-stroke heavy-duty engines designed for maximum economy in continuous duty. Such slow-running engines (< 300 rpm) achieve effective levels of efficiency of up to 55%, which represent the highest attainable with piston engines.

Large-scale engines are generally run on cheap heavy oil. This requires pretreatment of the fuel on board. Depending on quality, it has to be heated to temperatures as high as 160°C. Only then is its viscosity reduced to a level at which it can be filtered and pumped.

Smaller vessels often use engines originally intended for large commercial vehicles. In that way, an economical propulsion unit with low development costs can be produced. Once again, however, the engine management system has to be adapted to the different service profile.

Multi-fuel engines

For specialized applications (such as operation in regions with undeveloped infrastructures or for military use), diesel engines capable of running on a variety of different fuels including diesel, gasoline and others have been developed. At present they are of virtually no significance whatsoever within the overall picture, as they are incapable of meeting the current demands in respect of emissions and performance characteristics.

Engine characteristic data

Table 1 shows the most important comparison data for various types of diesel and gasoline engine.

The average pressure in petrol engines with direct fuel injection is around 10% higher than for the engines listed in the table with inlet-manifold injection. At the same time, the specific fuel consumption is up to 25% lower. The compression ratio of such engines can be as much as 13:1.

1 Comparison of diesel and gasoline engines

Fuel-injection system	Rated speed n_{rated} [rpm]	Compression ratio ε	Mean pressure [1] p_e [bar]	Specific power output $p_{e,\,spec.}$ [kW/l]	Power-to-weight ratio $m_{spec.}$ [kg/kW]	Specific fuel consumption [2] b_e [g/kWh]
Diesel engines						
IDI [3] conventionally aspirated car engines	3,500...5,000	20...24:1	7...9	20...35	1:5...3	320...240
IDI [3] turbocharged car engines	3,500...4,500	20...24:1	9...12	30...45	1:4...2	290...240
DI [4] conventionally aspirated car engines	3,500...4,200	19...21:1	7...9	20...35	1:5...3	240...220
DI [4] turbocharged car engines with i/clr [5]	3,600...4,400	16...20	8...22	30...60	4...2	210...195
DI [4] convent. aspirated comm. veh. engines	2,000...3,500	16...18:1	7...10	10...18	1:9...4	260...210
DI [4] turbocharged comm. veh. engines	2,000...3,200	15...18:1	15...20	15...25	1:8...3	230...205
DI [4] turboch. comm. veh. engines with i/clr [5]	1,800...2,600	16...18	15...25	25...35	5...2	225...190
Construct. and agricultural machine engines	1,000...3,600	16...20:1	7...23	6...28	1:10...1	280...190
Locomotive engines	750...1,000	12...15:1	17...23	20...23	1:10...5	210...200
Marine engines (4-stroke)	400...1,500	13...17:1	18...26	10...26	1:16...13	210...190
Marine engines (2-stroke)	50...250	6...8:1	14...18	3...8	1:32...16	180...160
Gasoline engines						
Conventionally aspirated car engines	4,500...7,500	10...11:1	12...15	50...75	1:2...1	350...250
Turbocharged car engines	5,000...7,000	7...9:1	11...15	85...105	1:2...1	380...250
Comm. veh. engines	2,500...5,000	7...9:1	8...10	20...30	1:6...3	380...270

Table 1

1) The average pressure p_e can be used to calculate the specific torque $M_{spec.}$ [Nm]:

$$M_{spec.} = \frac{25}{\pi \cdot p_e}$$

2) Best consumption

3) Indirect Injection

4) Direct Injection

5) Intercooler