The Bosch Yellow Jackets **Edition 2001** | Technical Instruction | Gasoline-engine management

Gasoline-engine management
Basics and components

BOSCH

Automotive Technology

- EGAS electronic throttle control
- Gasoline direct injection
- NO_x accumulator-type catalytic converter

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The call for environmentally compatible and economical vehicles, which nevertheless must still satisfy demands for high performance, necessitates immense efforts to develop innovative engine concepts. The increasingly stringent exhaust-gas legislation initially caused the main focus of concentration to be directed at reducing the toxic content of the exhaust gas, and the introduction of the 3-way catalytic converter in the middle of the eighties was a real milestone in this respect.

Just lately though, the demand for more economical vehicles has come to the forefront, and direct-injection gasoline engines promise fuel savings of up to 20%.

This Yellow Jacket technical instruction manual deals with the technical concepts employed in complying with the demands made upon a modern-day engine, and explains their operation.

Another Yellow Jacket manual explains the interplay between these concepts and a modern closed and open-loop control system in the form of the Motronic. This manual is at present in the planning stage.

Basics of the gasoline (SI) engine

The gasoline or spark-ignition (SI) internal-combustion engine uses the Otto cycle[1]) and externally supplied ignition. It burns an air/fuel mixture and in the process converts the chemical energy in the fuel into kinetic energy.

For many years, the carburetor was responsible for providing an A/F mixture in the intake manifold which was then drawn into the cylinder by the downgoing piston.

The breakthrough of gasoline fuel-injection, which permits extremely precise metering of the fuel, was the result of the legislation governing exhaust-gas emission limits. Similar to the carburetor process, with manifold fuel-injection the A/F mixture is formed in the intake manifold.

Even more advantages resulted from the development of gasoline direct injection, in particular with regard to fuel economy and increases in power output. Direct injection injects the fuel directly into the engine cylinder at exactly the right instant in time.

Operating concept

The combustion of the A/F mixture causes the piston (Fig. 1, Pos. 8) to perform a reciprocating movement in the cylinder (9). The name reciprocating-piston engine, or better still reciprocating engine, stems from this principle of functioning.

The conrod (10) converts the piston's reciprocating movement into a crankshaft (11) rotational movement which is maintained by a flywheel (11) at the end of the crankshaft. Crankshaft speed is also referred to as engine speed or engine rpm.

Four-stroke principle

Today, the majority of the internal-combustion engines used as vehicle power plants are of the four-stroke type.

The four-stroke principle employs gas-exchange valves (5 and 6) to control the exhaust-and-refill cycle. These valves open and close the cylinder's intake and exhaust passages, and in the process control the supply of fresh A/F mixture and the forcing out of the burnt exhaust gases.

1st stroke: Induction

Referred to top dead center (TDC), the piston is moving downwards and increases the volume of the combustion chamber (7) so that fresh air (gasoline direct injection) or fresh A/F mixture (manifold injection) is drawn into the combustion chamber past the opened intake valve (5).

The combustion chamber reaches maximum volume (V_h+V_c) at bottom dead center (BDC).

2nd stroke: Compression

The gas-exchange valves are closed, and the piston is moving upwards in the cylinder. In doing so it reduces the combustion-chamber volume and compresses the A/F mixture. On manifold-injection engines the A/F mixture has already entered the combustion chamber at the end of the induction stroke. With a direct-injection engine on the other hand, depending upon the operating mode, the fuel is first injected towards the end of the compression stroke.

At top dead center (TDC) the combustion-chamber volume is at minimum (compression volume V_c).

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[1]) Named after Nikolaus Otto (1832-1891) who presented the first gas engine with compression using the 4-stroke principle at the Paris World Fair in 1878.

3rd stroke: Power (or combustion)

Before the piston reaches top dead center (TDC), the spark plug (2) initiates the combustion of the A/F mixture at a given ignition point (ignition angle). This form of ignition is known as externally supplied ignition. The piston has already passed its TDC point before the mixture has combusted completely.

The gas-exchange valves remain closed and the combustion heat increases the pressure in the cylinder to such an extent that the piston is forced downward.

4th stroke: Exhaust

The exhaust valve (6) opens shortly before bottom dead center (BDC). The hot (exhaust) gases are under high pressure and leave the cylinder through the exhaust valve. The remaining exhaust gas is forced out by the upwards-moving piston.

A new operating cycle starts again with the induction stroke after every two revolutions of the crankshaft.

Valve timing

The gas-exchange valves are opened and closed by the cams on the intake and exhaust camshafts (3 and 1 respectively). On engines with only 1 camshaft, a lever mechanism transfers the cam lift to the gas-exchange valves.

The valve timing defines the opening and closing times of the gas-exchange valves. Since it is referred to the crankshaft position, timing is given in “degrees crankshaft”. Gas flow and gas-column vibration effects are applied to improve the filling of the combustion chamber with A/F mixture and to remove the exhaust gases. This is the reason for the valve opening and closing times overlapping in a given crankshaft angular-position range.

The camshaft is driven from the crankshaft through a toothed belt (or a chain or gear pair). On 4-stroke engines, a complete working cycle takes two rotations of the crankshaft. In other words, the camshaft only turns at half crankshaft speed.

1 Complete working cycle of the 4-stroke spark-ignition (SI) gasoline engine (example shows a manifold-injection engine with separate intake and exhaust camshafts)

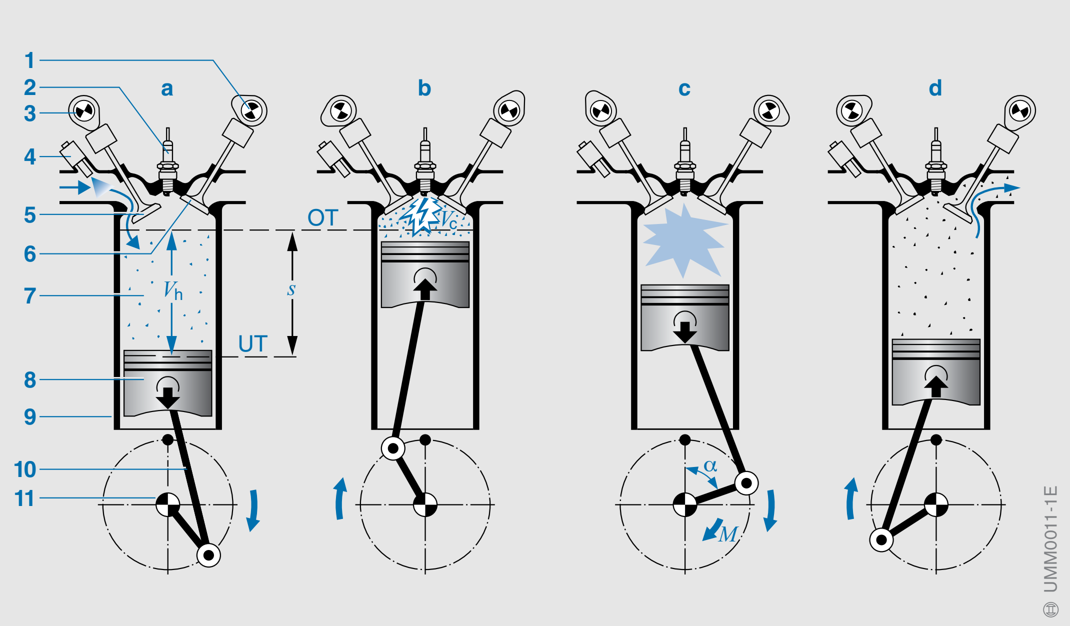

Figure 1

a	Induction stroke
b	Compression stroke
c	Power (combustion) stroke
d	Exhaust stroke
1	Exhaust camshaft
2	Spark plug
3	Intake camshaft
4	Injector
5	Intake valve
6	Exhaust valve
7	Combustion chamber
8	Piston
9	Cylinder
10	Conrod
11	Crankshaft
M	Torque
α	Crankshaft angle
s	Piston stroke
V_h	Piston displacement
V_c	Compression volume

Compression

The compression ratio $\varepsilon = (V_h+V_c)/V_c$ is calculated from the piston displacement V_h and the compression volume V_c.

The engine's compression ratio has a decisive effect upon

- The torque generated by the engine,
- The engine's power output,
- The engine's fuel consumption, and the
- Toxic emissions.

With the gasoline engine, the compression ratio $\varepsilon = 7...13$, depending upon engine type and the fuel-injection principle (manifold injection or direct injection). The compression ratios ($\varepsilon = 14...24$) which are common for the diesel engine cannot be used for the gasoline engine. Gasoline has only very limited antiknock qualities, and the high compression pressure and the resulting high temperatures in the combustion chamber would for this reason cause automatic, uncontrolled ignition of the gasoline. This in turn causes knock which can lead to engine damage.

Air/fuel (A/F) ratio

In order for the A/F mixture to burn completely 14.7 kg air are needed for 1 kg fuel. This is the so-called stoichiometric ratio (14.7:1).

The excess-air factor (or air ratio) λ has been chosen to indicate how far the actual A/F mixture deviates from the theoretical optimum (14.7:1). $\lambda = 1$ indicates that the engine is running with a stoichiometric (in other words, theoretically optimum) A/F ratio.

Enriching the A/F mixture with more fuel leads to λ values of less than 1, and if the A/F mixture is leaned off (addition of more air) λ is more than 1. Above a given limit ($\lambda > 1.6$) the A/F mixture reaches the so-called lean-burn limit and cannot be ignited.

2 A/F mixture distribution in the combustion chamber

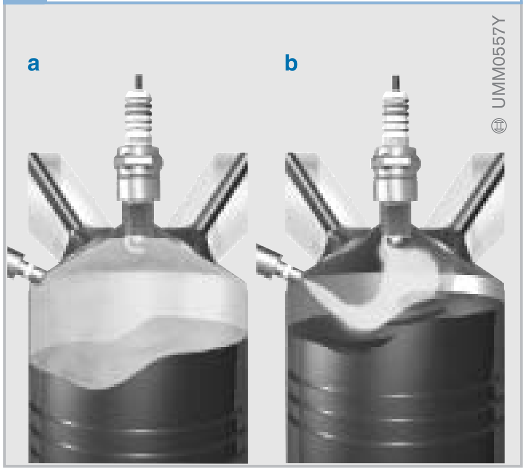

Figure 2
a Homogeneous A/F-mixture distribution
b Stratified charge

Distribution of the A/F mixture in the combustion chamber

Homogeneous distribution

On manifold-injection engines, the A/F mixture is distributed homogeneously in the combustion chamber and has the same λ number throughout (Fig. 2a). Lean-burn engines which operate in certain ranges with excess air, also run with homogeneous mixture distribution.

Stratified-charge

At the ignition point, there is an ignitable A/F-mixture cloud (with $\lambda = 1$) in the vicinity of the spark plug. The remainder of the combustion chamber is filled with either a very lean A/F mixture, or with a non-combustible gas containing no gasoline at all. The principle in which an ignitable A/F-mixture cloud only fills part of the combustion chamber is referred to as stratified charge (Fig. 2b). Referred to the combustion chamber as a whole, the A/F mixture is very lean (up to $\lambda \approx 10$). This form of lean-burn operation leads to fuel-consumption savings.

In effect, the stratified-charge principle is only applicable with gasoline direct injection. The stratified charge is the direct result of the fuel being injected directly into the combustion chamber only very shortly before the ignition point.