Lesson 3　Engine Constructions

Internal combustion gasoline engines run on a mixture of gasoline and air. The ideal mixture is 14.7 parts of air to one part of gasoline (by weight). One part of gas that is completely vaporized into 14.7 parts of air can produce tremendous power when ignited inside an engine.

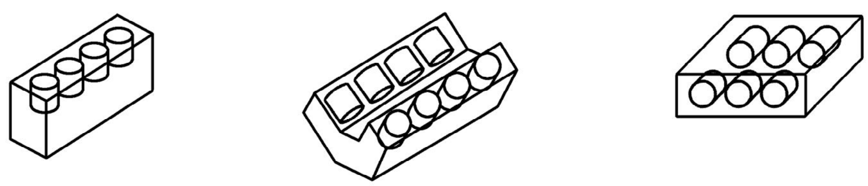
Air enters the engine through the air cleaner and proceeds to the throttle plate. You control the amount of air that passes through the throttle plate and into the engine with the gas pedal. It is then distributed through a series of passages called the intake manifold, to each cylinder. At some point after the air cleaner, depending on the engine, fuel is added to the air-stream by either a fuel injection system or, in older vehicles, by the carburetor[1].

Once the fuel is vaporized into the air stream, the mixture is drawn into each cylinder as that cylinder begins its intake stroke. When the piston reaches the bottom of the cylinder, the intake valve closes and the piston begins moving up in the cylinder compressing the charge. When the piston reaches the top, the spark plug ignites the fuel-air mixture causing a powerful expansion of the gas, which pushes the piston back down with great force against the crankshaft[2].

1　Engine Types

The majority of engines in motor vehicles today are four-stroke, spark-ignition internal combustion engines.

There are several engine types which are identified by the number of cylinders and the way the cylinders are laid out. Motor vehicles will have from 3 to 12 cylinders which are arranged in the engine block in several configurations. The most popular of them are shown Fig.3.1. In-line engines have their cylinders arranged in a row (Fig.3.1(a)). The "V" arrangement(Fig.3.1(b)) uses two banks of cylinders side-by-side and is commonly used in V-6, V-8, V-10 and V-12 configurations. Flat engines(Fig.3.1(c)) use two opposing banks of cylinders and are less common than the other two designs. Flat engines are also used in some Ferraris with 12 cylinders.



(a) In-Line 4 Cylinder　　(b) V-8　　(c) Flat 6

Fig.3.1　Typical cylinder arrangements

Most engine blocks are made of cast iron or cast aluminum. Each cylinder contains a piston(Fig.3.2) that travels up and down inside the cylinder bore. All the pistons in the engine are connected through individual connecting rods to a common crankshaft.

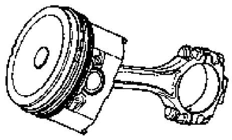


Fig.3.2 A typical piston and connecting rod

The crankshaft(Fig.3.3) is located below the cylinders on an in-line engine, at the base of the V on a V-type engine and between the cylinder banks on a flat engine. As the pistons move up and down, they turn the crankshaft.

A cylinder head(Fig.3.4) is bolted to the top of each bank of cylinders to seal the individual cylinders and contain the combustion process that takes place inside the cylinder. Most cylinder heads are made of cast aluminum or cast iron. The cylinder head contains at least one intake valve and one exhaust valve for each cylinder. This allows the air-fuel mixture to enter the cylinder and the burned exhaust gas to exit the cylinder. Many newer engines are using multiple intake and exhaust valves per cylinder for increased engine power and efficiency[3]. Modern engine designs can use anywhere from 2 to 5 valves per cylinder.

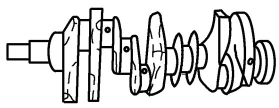


Fig.3.3 Crankshaft

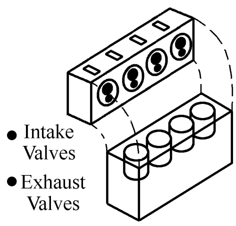


Fig.3.4 Typical cylinder head

The valves are opened and closed by means of a camshaft. A camshaft(Fig.3.5) is a rotating shaft that has individual lobes for each valve. When the lobe pushes against the lifter, the lifter in turn pushes the valve open. When the lobe rotates away from the lifter, the valve is closed by a spring that is attached to the valve. A common configuration is to have one camshaft located in the engine block with the lifters connecting to the valves through a series of linkages. The camshaft must be synchronized with the crankshaft so that the camshaft makes one revolution for every two revolutions of the crankshaft[4]. In most engines, this is done by a "Timing Chain" (similar to a bicycle chain) that connects the camshaft with the crankshaft. Some engines have two camshafts on each head, one for the intake valves and one for the exhaust valves. These engines are called Double Overhead Camshaft (D.O.H.C.) Engines while the other type is called Single Overhead Camshaft (S.O.H.C.) Engines.

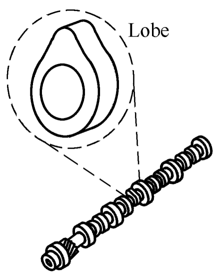


Fig.3.5 Camshaft

Since the same process occurs in each cylinder, we will take a look at one cylinder to see how the four stroke process works.

The four strokes are Intake, Compression, Power (or Combustion) and Exhaust. The piston travels down on the Intake stroke, up on the Compression stroke, down on the Power stroke and up on the Exhaust stroke.

Intake

As the piston starts down on the Intake stroke, the intake valve opens and the fuel-air mixture is drawn into the cylinder. When the piston reaches the bottom of the intake stroke, the intake valve closes, trapping the air-fuel mixture in the cylinder.

Compression

The piston moves up and compresses the trapped air fuel mixture that was brought in by the intake stroke. The amount that the mixture is compressed is determined by the compression ratio of the engine.

Power

The spark plug fires, igniting the compressed air-fuel mixture which produces a powerful expansion of the vapor. The combustion process pushes the piston down the cylinder with great force turning the crankshaft to provide the power to propel the vehicle.

Exhaust

With the piston at the bottom of the cylinder, the exhaust valve opens to allow the burned exhaust gas to be expelled to the exhaust system. Since the cylinder contains so much pressure, when the valve opens, the gas is expelled with a violent force (that is why a vehicle without a muffler sounds so loud). The piston travels up to the top of the cylinder pushing all the exhaust out before closing the exhaust valve in preparation for starting the four stroke process over again[5].

2 Oiling System

Oil is the life-blood of the engine. An engine running without oil will last about as long as a human without blood. Oil is pumped under pressure to all the moving parts of the engine by an oil pump. The oil pump is mounted at the bottom of the engine in the oil pan and is connected by a gear to either the crankshaft or the camshaft. There is an oil pressure sensor near the oil pump that monitors pressure and sends this information to a warning light or a gauge on the dashboard. When you turn the ignition key on, but before you start the car, the oil light should light, indicating that there is no oil pressure yet, but also letting you know that the warning system is working[6]. As soon as you start cranking the engine to start it, the light should go out indicating that there is oil pressure.

3 Cooling System

Internal combustion engines must maintain a stable operating temperature, not too hot and not too cold. With the massive amounts of heat that is generated from the combustion process, if the engine did not have a method for cooling itself, it would quickly self-destruct. While some engines are air-cooled, the vast majority of engines are liquid cooled. The water pump circulates coolant throughout the engine, hitting the hot areas around the cylinders and heads and then sends the hot coolant to the radiator to be cooled off.

New Words & Terms

gasoline	[ˈgæsəliːn]	n.汽油
vaporize	[ˈveipəraiz]	vt.& vi.（使）蒸发；（使）汽化
manifold	[ˈmænifəuld]	n.歧管
cylinder	[ˈsilində]	n.汽缸
configuration	[kənˌfigjuˈreiʃən]	n.构造，轮廓
camshaft	[ˈkæmʃɑːft]	n.凸轮轴
lobe	[ləub]	n.凸齿
valve	[vælv]	n.阀门
lifter	[ˈliftə]	n.推杆
spring	[spriŋ]	n.弹簧
exhaust	[igˈzɔːst]	vi.排气；n.排气装置，排气管[孔]
expel	[iksˈpel]	vt.赶走
violent	[ˈvaiələnt]	adj.粗暴的
muffler	[ˈmʌflə]	n.消音器
monitor	[ˈmɔnitə]	n.监视器；vt.监听
gauge	[geidʒ]	n.测量仪表
dashboard	[ˈdæʃˌbɔːd]	n.仪表板
ignition	[igˈniʃən]	n.（汽油机的）点火装置
coolant	[ˈkuːlənt]	n.冷却液
radiator	[ˈreidieitə]	n.散热器

Internal combustion gasoline engines　内燃汽油机

gas pedal　加速踏板　　lay out　设计

cast aluminum　铸铝　　cast iron　铸铁

cylinder bore　汽缸内径　　Timing Chain　正时链

self-destruct　自毁

Notes

1. At some point after the air cleaner, depending on the engine, fuel is added to the air-stream by either a fuel injection system or, in older vehicles, by the carburetor.

对于不同的发动机在空滤器后不同的位置，燃油通过燃油喷射系统或在早期汽车中的化油器加到空气流中。

2. When the piston reaches the top, the spark plug ignites the fuel-air mixture causing a powerful expansion of the gas, which pushes the piston back down with great force against the crankshaft.

当活塞到达顶点时，火花塞点燃燃油空气混合气，引起气体的强烈膨胀，克服来自曲轴的强力推动活塞下行。

3. Many newer engines are using multiple intake and exhaust valves per cylinder for increased engine power and efficiency.

许多新发动机每缸采用多进排气门来提升发动机的功率和效率。

4. The camshaft must be synchronized with the crankshaft so that the camshaft makes one revolution for every two revolutions of the crankshaft.

凸轮轴必须与曲轴同步，因此曲轴转两转凸轮轴只转一转。

5. The piston travels up to the top of the cylinder pushing all the exhaust out before closing the exhaust valve in preparation for starting the four stroke process over again.

活塞上行到达气缸顶点，在排气门关闭前排出废气，为下一四冲程重新开始做准备。

6. When you turn the ignition key on, but before you start the car, the oil light should light, indicating that there is no oil pressure yet, but also letting you know that the warning system is working.

当转动点火开关但还没有起动车辆时，机油压力警告灯应当亮，表示没有油压，但同样告诉你警告系统工作正常。

Questions

1. What is the four stroke of the IC engine?
2. Tell us what types of engine have you known.
3. What is the function of the Oiling System?

Reading Materials

Internal Combustion Engine Classification

The internal combustion engine is an engine in which the combustion of a fuel (generally, fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine the expansion of the high temperature and pressure gases, which are produced by the combustion, directly applies force to a movable component of the engine, such as the pistons or turbine blades and by moving it over a distance, generate useful mechanical energy.

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar four-stroke and two-stroke piston engines, along with variants, such as the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described.

The internal combustion engine (or ICE) is quite different from external combustion engines, such as steam or Stirling engines, in which the energy is delivered to a working fluid not consisting of, mixed with or contaminated by combustion products. Working fluids can be air, hot water, pressurised water or even liquid sodium, heated in some kind of boiler by fossil fuel, wood-burning, nuclear, solar etc.

A large number of different designs for ICEs have been developed and built, with a variety of different strengths and weaknesses. Powered by an energy-dense fuel (which is very frequently petrol, a liquid derived from fossil fuels), the ICE delivers an excellent power-to-weight ratio with few safety or other disadvantages. While there have been and still are many stationary applications, the real strength of internal combustion engines is in mobile applications and they dominate as a power supply for cars, aircraft, and boats, from the smallest to the biggest. Only for hand-held power tools do they share part of the market with battery powered devices.

Internal combustion engines are most commonly used for mobile propulsion in vehicles and portable machinery. In mobile equipment, internal combustion is advantageous since it can provide high power-to-weight ratios together with excellent fuel energy density. Generally using fossil fuel (mainly petroleum), these engines have appeared in transport in almost all vehicles (automobiles, trucks, motorcycles, boats, and in a wide variety of aircraft and locomotives).

Where very low power-to-weight ratios are not required, internal combustion engines appear in the form of gas turbines. These applications include jet aircraft, helicopters, large ships and electric generators.

1 Classification

At one time the word, "Engine" (from Latin, via Old French, ingenium, "ability") meant any piece of machinery—a sense that persists in expressions such as siege engine. A "motor" (from Latin motor, "mover") is any machine that produces mechanical power. Traditionally, electric motors are not referred to as "Engines"; however, combustion engines are often referred to as "motors." (An electric engine refers to a locomotive operated by electricity.)

Engines can be classified in many different ways: By the engine cycle used, the layout of the engine, source of energy, the use of the engine, or by the cooling system employed.

2 Principles of operation

Reciprocating:

- Two-stroke cycle
- Four-stroke cycle
- Six-stroke engine
- Diesel engine
- Atkinson cycle

Rotary:

- Wankel engine

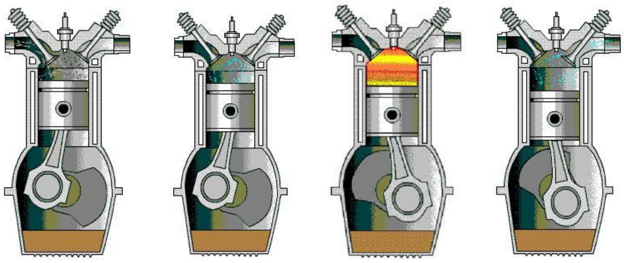
Continuous combustion:

Brayton cycle:

- Gas turbine
- Jet engine (including turbojet, turbofan, ramjet, rocket etc.)

Internal combustion engines can be classified by their configuration.

Four stroke configuration



Four-stroke cycle (Intake、Compression、Power、Exhaust)

- Intake
- Compression
- Power
- Exhaust

As their name implies, operation of four stroke internal combustion engines have four basic steps that repeat with every two revolutions of the engine:

Intake

Combustible mixtures are emplaced in the combustion chamber.

Compression

The mixtures are placed under pressure.

Power

The mixture is burnt, almost invariably a deflagration, although a few systems involve detonation. The hot mixture is expanded, pressing on and moving parts of the engine and performing useful work.

Exhaust

The cooled combustion products are exhausted into the atmosphere.

Many engines overlap these steps in time; jet engines do all steps simultaneously at different parts of the engines.

All internal combustion engines depend on the exothermic chemical process of combustion: the reaction of a fuel, typically with oxygen from the air (though it is possible to inject nitrous oxide in order to do more of the same thing and gain a power boost). The combustion process typically results in the production of a great quantity of heat, as well as the production of steam and carbon dioxide and other chemicals at very high temperature; the temperature reached is determined by the chemical make up of the fuel and oxidisers (see stoichiometry).

The most common modern fuels are made up of hydrocarbons and are derived mostly from fossil fuels (petroleum). Fossil fuels include diesel fuel, gasoline and petroleum gas, and the rarer use of propane. Except for the fuel delivery components, most internal combustion engines that are designed for gasoline use can run on natural gas or liquefied petroleum gases without major modifications. Large diesels can run with air mixed with gases and a pilot diesel fuel ignition injection. Liquid and gaseous biofuels, such as ethanol and biodiesel (a form of diesel fuel that is produced from crops that yield triglycerides such as soybean oil), can also be used. Some engines with appropriate modifications can also run on hydrogen gas.

Internal combustion engines require ignition of the mixture, either by spark ignition (SI) or compression ignition (CI). Before the invention of reliable electrical methods, hot tube and flame methods were used.

2.1 Gasoline Ignition Process

Gasoline engine ignition systems generally rely on a combination of a lead-acid battery and an induction coil to provide a high-voltage electrical spark to ignite the air-fuel mix in the engine's cylinders. This battery is recharged during operation using an electricity-generating device such as an alternator or generator driven by the engine. Gasoline engines take in a mixture of air and gasoline and compress it to not more than 12.8 bar (1.28 MPa), then use a spark plug to ignite the mixture when it is compressed by the piston head in each cylinder.

2.2 Diesel Ignition Process

Diesel engines and HCCI (Homogeneous charge compression ignition) engines, rely solely on heat and pressure created by the engine in its compression process for ignition. The compression level that occurs is usually twice or more than a gasoline engine. Diesel engines will take in air only, and shortly before peak compression, a small quantity of diesel fuel is sprayed into the cylinder via a fuel injector that allows the fuel to instantly ignite. HCCI type engines will take in both air and fuel but continue to rely on an unaided auto-combustion process, due to higher pressures and heat. This is also why diesel and HCCI engines are more susceptible to cold-starting issues, although they will run just as well in cold weather once started. Light duty diesel engines with indirect injection in automobiles and light trucks employ glowplugs that pre-heat the combustion chamber just before starting to reduce no-start conditions in cold weather. Most diesels also have a battery and charging system; nevertheless, this system is secondary and is added by manufacturers as a luxury for the ease of starting, turning fuel on and off (which can also be done via a switch or mechanical apparatus), and for running auxiliary electrical components and accessories. Most new engines rely on electrical and electronic control system that also control the combustion process to increase efficiency and reduce emissions.

2.3 Two Stroke Configuration

Engines based on the two-stroke cycle use two strokes (one up, one down) for every power stroke. Since there are no dedicated intake or exhaust strokes, alternative methods must be used to scavenge the cylinders. The most common method in spark-ignition two-strokes is to use the downward motion of the piston to pressurize fresh charge in the crankcase, which is then blown through the cylinder through ports in the cylinder walls.

Spark-ignition two-strokes are small and light for their power output and mechanically very simple; however, they are also generally less efficient and more polluting than their four-stroke counterparts. In terms of power per cubic centimetre, a single-cylinder small motor application like a two-stroke engine produces much more power than an equivalent four-stroke engine due to the enormous advantage of having one power stroke for every 360 degrees of crankshaft rotation (compared to 720 degrees in a 4 stroke motor).

Small displacement, crankcase-scavenged two-stroke engines have been less fuel-efficient than other types of engines when the fuel is mixed with the air prior to scavenging allowing some of it to escape out of the exhaust port. Modern designs (Sarich and Paggio) use air-assisted fuel injection which avoids this loss, and are more efficient than comparably sized four-stroke engines. Fuel injection is essential for a modern two-stroke engine in order to meet ever more stringent emission standards.

Research continues into improving many aspects of two-stroke motors including direct fuel injection, amongst other things. The initial results have produced motors that are much cleaner burning than their traditional counterparts. Two-stroke engines are widely used in snowmobiles, lawnmowers, string trimmers, chain saws, jet skis, mopeds, outboard motors, and many motorcycles. Two-stroke engines have the advantage of an increased specific power ratio (i.e. power to volume ratio), typically around 1.5 times that of a typical four-stroke engine.

The largest internal combustion engines in the world are two-stroke diesels, used in some locomotives and large ships. They use forced induction (similar to super-charging) to scavenge the cylinders; an example of this type of motor is the Wartsila-Sulzer turbocharged two-stroke diesel as used in large container ships. It is the most efficient and powerful internal combustion engine in the world with over 50% thermal efficiency. For comparison, the most efficient small four-stroke motors are around 43% thermal efficiency (SAE 900648); size is an advantage for efficiency due to the increase in the ratio of volume to surface area.

Common cylinder configurations include the straight or inline configuration, the more compact V configuration, and the wider but smoother flat or boxer configuration. Aircraft engines can also adopt a radial configuration which allows more effective cooling. More unusual configurations such as the H, U, X, and W have also been used.

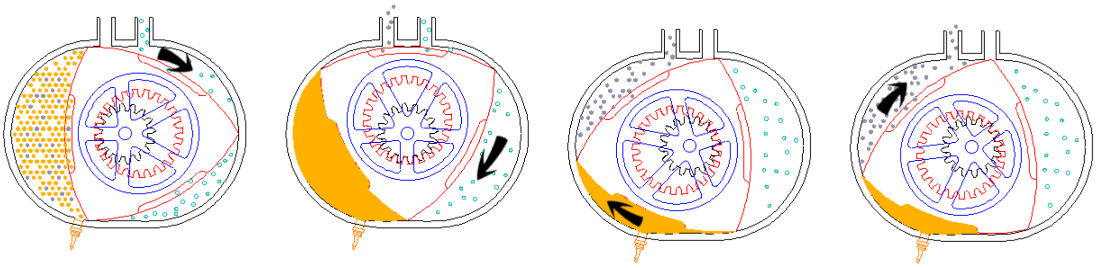
Multiple crankshaft configurations do not necessarily need a cylinder head at all because they can instead have a piston at each end of the cylinder called an opposed piston design. Because here gas in- and outlets are positioned at opposed ends of the cylinder, one can achieve uniflow scavenging, which is, like in the four stroke engine, efficient over a wide range of revolution numbers. Also the thermal efficiency is improved because of lack of cylinder heads. This design was used in the Junkers Jumo 205 diesel aircraft engine, using at either end of a single bank of cylinders with two crankshafts, and most remarkably in the Napier Deltic diesel engines. These used three crankshafts to serve three banks of double-ended cylinders arranged in an equilateral triangle with the crankshafts at the corners. It was also used in single-bank locomotive engines, and continues to be used for marine engines, both for propulsion and for auxiliary generators.

2.4 Six-stroke Configuration

First invented in 1883, the six-stroke engine has seen renewed interest over the last 20 or so years.

Four kinds of six-stroke use a regular piston in a regular cylinder (Griffin six-stroke, Bajulaz six-stroke, Velozeta six-stroke and Crower six-stroke), firing every three crankshaft revolutions. The systems capture the wasted heat of the four-stroke Otto cycle with an injection of air or water.

2.5 Wankel



The Wankel cycle (Intake、Compression、Power、Exhaust)

The shaft turns three times for each rotation of the rotor around the lobe and once for each orbital revolution around the eccentric shaft.

The Wankel engine (rotary engine) does not have piston strokes. It operates with the same separation of phases as the four-stroke engine with the phases taking place in separate locations in the engine. In thermodynamic terms it follows the Otto engine cycle, so may be thought of as a "four-phase" engine. While it is true that three power strokes typically occur per rotor revolution due to the 3/1 revolution ratio of the rotor to the eccentric shaft, only one power stroke per shaft revolution actually occurs; this engine provides three power 'strokes' per revolution per rotor giving it a greater power-to-weight ratio than piston engines. This type of engine is most notably used in the current Mazda RX-8, the earlier RX-7, and other models.

2.6 Gas Turbines

A gas turbine is a rotary machine similar in principle to a steam turbine and it consists of three main components: a compressor, a combustion chamber, and a turbine. The air after being compressed in the compressor is heated by burning fuel in it. About two-thirds of the heated air combined with the products of combustion is expanded in a turbine resulting in work output which is used to drive the compressor. The rest (about one-third) is available as useful work output.

2.7 Jet Engine

Jet engines take a large volume of hot gas from a combustion process (typically a gas turbine, but rocket forms of jet propulsion often use solid or liquid propellants, and ramjet forms also lack the gas turbine) and feed it through a nozzle which accelerates the jet to high speed. As the jet accelerates through the nozzle, this creates thrust and in turn does useful work.