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Engine Types – Multi Cylinders

Below are illustrated various engine layouts; there are others such as the V 12.

Generally speaking, the more cylinders there are, the more power the engine will produce and the smoother the engine will run.

These layouts are not limited to petrol engines, diesel engines can also vary in layout.

The only limit to the variety of layouts is the designers imagination, except to say that, it is uneconomical (both in manufacturing costs and capacity, and use) to design and build an engine of say 4 litre V8 layout when a 2 litre V6 would be adequate.
Piston Engine Types

- Single
- V Twin
- Inline 3
- Inline 4
- Inline 5
- V 5
- V 6
- V 8

Piston Engine Types - Layouts
Engine Types – Firing Order

All multi-cylinder internal combustion piston engines operate under the same operating cycle of:-

- Induction ‘Suck’
- Compression ‘Squeeze’
- Power ‘Bang’
- Exhaust ‘Blow’

Every power stroke is used to power the vehicle, drive the other cylinders during other parts of the cycle and overcome friction.

It is important that the firing order is timed to even out all of the power stroke forces on the engine components and provide a smooth running engine where damaging vibration levels are kept to an absolute minimum.

We have already looked at the firing order for the ‘Inline 4’ engine, and below is illustrated the firing order for the ‘Flat 4’, typical of the original VW Beetle and Porsche series cars, and the ‘Vee 8’ used in many high performance supercars.

The firing order of various other engines are listed below: -

- Inline 6: 1 - 5 - 3 - 6 - 2 - 4
- V 4: 1 - 3 - 4 - 2 (as per the Inline 4)
- V 6: 1 - 4 - 2 - 5 - 3 - 6

On Vee engines the angle between the rows of cylinders (banks) is also important; 60° being ideal for 6 cylinders and 90° for larger engines.
Piston Engine Types - Layouts

Horizontally Opposed (Or flat) 4

Firing Order: -

1 – 4 – 3 – 2

Vee 8

Firing Order: -

1 – 8 – 4 – 3 – 6 – 5 – 7 – 2
Engine Types – The ‘Two-stroke’ Cycle

As its name suggests, the operating cycle of this engine is completed in two strokes, i.e. one complete revolution of the crankshaft.

The two strokes are described below, starting with compression:

**Stroke 1 – the Upward stroke**

Above the piston, air and fuel is trapped and being compressed when both the cylinder inlet and exhaust parts are closed.

At around top dead centre combustion is initiated either by spark, compression induced heat or by ‘glow plug’ (explained later).

Below the piston, the increasing volume under the piston and in the crankcase draws a charge of fuel and air into the crankcase.

**Stroke 2 – the Downward stroke**

Above the piston, the expanding gases force the piston down the cylinder, providing power. When the exhaust port is opened, burnt gases escape out of the cylinder.

Below the piston, the piston moving down closes the crankcase inlet port, opens the cylinder inlet and the exhaust ports. The downward traveling piston forces the charge of air/fuel from the crankcase into the cylinder (induction) above the piston, and helps to force out the last of the exhaust gases from the cylinder.

Valve opening and closing is simply the piston movement covering or uncovering the ports.

**Other variants**

Some 2 stroke engines, have a ‘reed’ valve mechanism. This is a flap type valve, opened by the suction effect when the piston rises and is pressured closed when the piston descends.

**Applications**

2 strokes are used where a small lightweight power supply is required, such as in Chainsaws, Outboard Motors, Strimmers, small motor cycles and model installations.

**Lubrication**

Because the crankcase is integral to the supply of the air/fuel mixture, there is no easy means of providing a recirculating oil lubricating system. Therefore, oil is added to the fuel to provide the necessary lubrication.

**Glow Plugs and Ignition systems**

Glow plugs are like small spark plugs, but instead of a spark gap, there is a coil. This is heated electrically for starting, then remains hot from the combustion process. Used extensively in model type engines.

Some 2 strokes feature a sparking ignition system, similar to spark plugs in the 4 stroke cycle engines.
Piston Engine Types – 2 Stroke Cycle

**Stroke 1**

Piston rising pulls fuel/air mixture into crankcase; compression causes combustion.

**Stroke 2**

Piston pushed down forces fuel/air mixture into cylinder.

Port B – Cylinder Inlet

Port C – Exhaust

Port A – Crankcase Inlet

Piston at TDC

Piston at BDC

Piston at TDC

Piston at BDC
Engine Types – The Diesel

In a Diesel engine the operating cycle is the same as petrol engines, i.e. this engine features similar valve mechanism and oil systems etc.

The big difference is that diesels do not have an ignition system nor spark plugs.

In the diesel engine, combustion is initiated by the temperature increase in the compressed air/fuel mixture.

This means that ignition is timed exactly when required without relying on the timing of a spark.

Fuel feed

Because the diesel engine operates at higher compression ratios, fuel needs to be injected to obtain the correct supply rate.

Fuel is injected either Indirectly i.e. into the inlet manifold just outside the inlet valve or Directly i.e. into the cylinder.

The injection of fuel is timed with the compression of air in the cylinder, ensuring fuel is introduced at the right time and in the right quantity.

Fuel injection systems are described in the fuel section.
Mechanical Arrangement – Diesel

Same mechanical set-up as petrol engine

Combustion initiated by hot compressed air

But no spark plugs!
Engine Types – The Wankel Engine - Description

This engine was designed by Felix Wankel and first fitted to a car, the NSU Ro 80, in 1967.

The engine features a rotating triangular rotor running in an elongated chamber (almost figure of 8). The shape of the rotor and the chamber means that there is a small amount of lateral movement of the rotor.

The triangular rotor engages with a fixed (none-rotating) pinion gear. The rotor drives an output shaft via a crank off-set (similar in effect to a piston engine crankshaft).

For each rotation of the rotor, the output shaft is rotated four times.

There are four points of contact between the rotor and the chamber. The three corners of the rotor are in permanent sliding contact (illustrated by the yellow arrows on the diagram below) with the inner wall of the chamber. Sealing at this point is very important, any leakage and the engine loses power.

The contact indicated below by the yellow circle, changes from side to side with rotation of the rotor.

Wankel engines can have multiple rotors, each in its own chamber, just as piston engines can have more than one piston.
Mechanical Arrangement – Wankel Engine

Engine Cross Section

- Casing
- Inlet Port
- Exhaust Port
- Rotating Triangular ‘Piston’
- Fixed (non-rotating) Pinion
- Output Shaft
- Spark Plug
- Rotating ‘Crankshaft’
Engine Types – The Wankel Engine - Operation

There are three separate chambers formed by the triangular rotor and the casing, shown below as A, B and C. We will look at what is happening in each of these chambers.

**Chamber A**
As the rotor rotates, chamber A is expanding, this draws the fuel/air mixture into the engine. – Induction.

**Chamber B**
The fuel/air mixture has been compressed and is about to start the power stroke.

**Chamber C**
The exhaust port is open, and chamber C is getting smaller therefore the burnt gases are being forced out through the exhaust port.

**Chamber Sequencing**
As Chamber A rotates with the rotor, first it will draw fuel/air in (induction) then the chamber gets smaller (compression), the mixture is ignited by the spark plug; the expanding gases then force the rotor round. As the chamber rotates, the exhaust port is opened and the gases are forced out.

All three chambers follow the same sequence of Induction, Compression, Power and Exhaust; the same as a conventional piston engine.

In the Wankel engine there is a power stroke for every rotation of the crankshaft, for each rotor; in the piston engine there is a power stroke for every two turns of the crankshaft for every piston.
Engine Cycle

Mechanical Arrangement – Wankel Engine

Chamber A

Inlet Port

Exhaust Port

Chamber B

Chamber C
Engine Types – Radial/Rotary Types

Other types of engine, not in common use these days are the Radial and Rotary engines, both commonly used with early aircraft, particularly during WW1.

Radials and Rotary engines look similar, they both had a number of cylinders equally and radially spaced around the central crankshaft. The side views below have had some cylinders omitted for clarity.

The big difference in the two are:-

A. In Radial engines, the crankcase and cylinders are stationary (as with modern car engines) and the crankshaft rotated the propeller.

B. In Rotary engines, the crankcase and cylinders rotated driving the propeller, and the crankshaft was stationary.

Rotary engines, whilst being the best engine for power to weight ratio at the time, suffered some disadvantages, such as: -

Gyroscopic effect – rotating such a large mass caused aircraft handling problems.

Oil system – a total loss system was used as it was difficult to recirculate the oil. The oil used was castor oil which literally splashed everywhere after leaving the engine; pilots had to use a scarf to wipe the goo off their goggles so they could see to fly!

Radial engines were used quite commonly during WW2 in various transports, bombers and fighters.

Shown below are: -

A miniature radial for model aircraft applications
An aircraft type radial adapted to power a motorbike!
And the Pratt and Whitney Wasp had four banks of seven cylinders, twenty-eight cylinders in total. Such engines are extremely powerful but the weight of the engine restricted its use to the larger aircraft of the day.

We will see later how these engines became mostly obsolete when JET engines (gas-turbines), with their much improved power to weight ratio and simplicity, became common.

Note: making an engine obsolete does not mean it disappeared overnight, it would be far too expensive and technically difficult to remove all piston engines from existing aircraft and replace them with gas turbines.

It meant that gas turbines became the engine of choice in the design of new aircraft.

Having stated the above, some isolated engine changes were tried, notably the Rolls-Royce Dart Turbo-Props were fitted into both the P51 Mustang fighter (replacing a single Packard Merlin) and the McDonald Douglas Dakota transport (replacing two Pratt & Whitney R-1830-90 - a multi bank radial).

Firing order: - For the 9 cylinder = 1, 3, 5, 7, 9, 2, 4, 6, 8.
Radial/Rotary engines are designed for their unique mechanical arrangements. Radial engines, as viewed from the side, exhibit a circular layout of cylinders, with the cylinders arranged in a radial pattern around a central hub. Rotary engines, on the other hand, have a more angular arrangement, often resembling the shape of a crescent or a doughnut when viewed from the front. These engines are particularly suited for aircraft applications due to their compact design and effective cooling mechanisms. The positions of the aircraft nose are also indicated, showcasing how these engine designs integrate with the overall aircraft structure.
Engine Types - Sizes

Engine sizes can vary as the illustration below shows.
The small engine is used in model aircraft, gauge the size from the hand holding the engine.
Whereas the huge monster being assembled below could only be used in an oil tanker. Again gauge the size by comparing to the assembly technicians.

Size, use, complexity are only limited by imagination.

There are other types of engines, different types of valve mechanisms, all available for viewing on the internet.
Is there any limits to size?

They go from tiny: -

To fairly big!

Mechanical Arrangement – Engine Size