# S.E. MECH.-APPLIED THERMODYNAMICS

## IC ENGINE STARTING SYSTEMS(PART OF UNIT 5)

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Introduction -

- A starter (also self starter, self, cranking motor, or starter motor) is a device used to rotate (crank) in an internal combustion engine so as to initiate the engine's operation under its own power.
- Starters can be electric, pneumatic, or hydraulic. In the case of very large engines, the starter can even be another internal combustion engine.
- Internal combustion engines are feedback systems, which, once started, rely on the inertia from each cycle to initiate the next cycle. In a four stroke engine, the third stroke releases energy from the fuel, powering the fourth (exhaust) stroke and also the first two (intake, compression) strokes of the next cycle, as well as powering the engine's external load.
- To start the first cycle at the beginning of any particular session, the first two strokes must be powered in some other way than from the engine itself. The starter motor is used for this purpose and is not required once the engine starts running and its feedback loop becomes self sustaining.

Earlier methods used –

1. Hand crank method –

- This method used a removable crank handle which engaged the front of the crankshaft.
- Engine was started by turning the crank handle manually.
- This method was inconvenient, difficult and dangerous. The behaviour of an engine during starting is not always predictable. The engine can kick back, causing sudden reverse rotation, thereby causing the crank to unexpectedly and violently jerk, possible injuring the operator.
- Many manual starters included a one dimensional slip or release provision so that once engine rotation began, the starter would disengage from the engine.
- Increasingly larger engines with higher compression ratios have made hand cranking more difficult.
- This method is still used on some small sized engines used on experimental set ups.

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Earlier methods used (continued) –

2. Cord wound starter (Rope starter) –

- This method used a cord / rope wound around a starter pulley connected to the crankshaft.
- Engine was started by pulling the cord / rope manually, to start rotation of the starter pulley.
- This method was also inconvenient, difficult and dangerous. A kickback could pull the operator towards the engine, or swing the starter cord at high speed around the starter pulley.
- This method is still used on some small sized engines used on experimental set ups and for starting of some rikshaw engines.

3. Air starter motors were also used on some engines.

4. Some engines used spring motors (sometimes referred to as clockwork motors), which used the energy stored in a spring through a reduction gear.

Present day methods –

- In the present days, any of the following methods is used –
  - Electric starter
  - Pneumatic starter
  - Hydraulic starter
  - Non motor starter – Spring starter, Fuel starting

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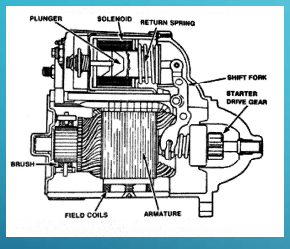


Fig. 1 Starter motor

Electric starter motor (Cranking motor) – Refer Fig. 1

- This is the most common type used on petrol engines and small diesel engines.
- The modern starter motor is either a permanent-magnet or a series-parallel wound direct current electric motor with a starter solenoid (similar to a relay) mounted on it.
- When DC power from the starting battery is applied to the solenoid, usually through a key operated switch (the ignition switch), the solenoid engages a lever that pushes out the f=drive pinion on the starter driveshaft and meshes the pinion with the starter ring gear on the flywheel of the engine.
- The solenoid also closes high current contacts for the starter motor, which begins to turn.
- Once the engine starts, the key operated switch is opened, a spring n the solenoid assembly pulls the pinion gear away from the ring gear, and the starter motor stops.
- The starter's pinion is clutched to its drive shaft through an overrunning sprag clutch which permits the pinion to transmit drive in only one direction. In this manner, drive is transmitted through the pinion to the flywheel ring gear.
- If the pinion gear remains engaged (because the operator fails to release the key as soon as the engine starts, or if there is a short and the solenoid remains engaged), the pinion will spin independently of its drive shaft. This prevents the engine driving the starter, for such backdrive would cause the starter to spin so fast as to fly apart.

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Electric starter motor (Cranking motor) (continued) –

- The standard starter motor is typically designed for intermittent use, which would preclude its use as a generator.
- The starter's electrical components are designed only to operate for typically under 30 seconds before overheating, to save weight and cost.
- Most automobile manuals instruct the operator to pause for at least ten seconds after each ten or fifteen seconds of cranking the engine, when trying to start an engine that does not start immediately.
- A variant on the electric starter motor is the inertia starter. Here the starter motor does not turn the engine directly. Instead, when energized, the motor turns a heavy flywheel built into its casing (not the main flywheel of the engine). Once the flywheel / motor unit has reached a constant speed the current to the motor is turned off and the drive between the motor and flywheel is disengaged by a freewheel mechanism. The spinning flywheel is then connected to the main engine and its inertia turns it over to start it. These stages are commonly automated by solenoid switches, with the machine operator using a two position control switch, which is held in one position to spin the motor and then moved to the other to cut the current to the motor and engage the flywheel to the engine.
- The advantage of the inertia starter is that, because the motor is not driving the engine directly, it can be of much smaller power than the standard starter for an engine of the same size. This allows for a motor of much lower weight and smaller size, as well as lighter cables and smaller batteries to power the motor. This made the inertia starter a common choice for aircraft with large radial piston engines. The disadvantage is the increased time required to start the engine – spinning up the flywheel to the required speed can take between 10 to 20 seconds. If the engine does not start by the time the flywheel has lost its inertia, then the process must be repeated for the next attempt.

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Pneumatic starter –

- Some gas turbine engines and diesel engines, particularly on trucks, use a pneumatic self starter.
- In ground vehicles, the system consists of a geared turbine, an air compressor and a pressure tank. Compressed air released from the tank is used to spin the turbine, and through a set of reduction gears, engages the ring gear on the flywheel, much like an electric starter. The engine, once running, drives the compressor to recharge the tank.
- Aircraft with large gas turbine engines are typically started using a large volume of low pressure compressed air, supplied from a very small engine referred to as an auxiliary power unit, located elsewhere in the aircraft. Alternately, aircraft gas turbine engines can be rapidly started using a mobile ground based pneumatic starting engine, referred to as a "start car" or "air start cart".
- On larger diesel generators found in large shore installations and especially on ships, a pneumatic starting gear is used. The air motor is normally powered by compressed air at pressures of 10-30 bar. The air motor is made up of a center drum, about the size of a soap can, with four or more slots cut into it to allow for the vanes to be placed radially on the drum to form chambers around the drum. The drum is offset inside a round casing so that the inlet air for starting is admitted at the area where the drum and vanes form a smaller chamber compared to the others. The compressed air can only expand by rotating the drum, which allows the smaller chamber to become larger and puts another one of the chambers in the air inlet. The air motor spins much too fast to be used directly on the flywheel of the engine; instead a large gearing mechanism, such as a planetary gear, is used to lower the output speed.
- Large diesel generators and almost all diesel engines used as the prime mover of ships use compressed air acting directly on the cylinder head. This is not ideal for smaller diesel engines, as it provides too much cooling on starting. Also, the cylinder head needs to have enough space to support an extra valve for the air start system.

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Pneumatic starter (continued) –

- As soon as the air start valve is opened, the compressed air is admitted and the engine will begin turning. It can be used on 2-cycle and 4-cycle engines and on reversing engines. On large 2-stroke engines less than one revolution of the crankshaft is needed for starting.
- Since large trucks typically use air brakes, the system does double duty, supplying compressed air to the brake system.
- Pneumatic starters have the advantages of delivering high torque, mechanical simplicity and reliability. They eliminate the need for oversized, heavy storage batteries in prime mover electrical systems.

Hydraulic starter –

- Some diesel engines from 6 to 16 cylinders are started by means of a hydraulic motor.
- Hydraulic starters and the associated systems provide a sparkless, reliable method of engine starting over a wide temperature range.
- Typically, hydraulic starters are found in applications such as remote generators, lifeboat propulsion engines, offshore fire pumping engines and hydraulic fracturing rigs.
- The system used to support the hydraulic starter includes valves, pumps, filters, a reservoir, and piston accumulators.
- The operator can manually recharge the hydraulic system; this can not readily be done with electric starting systems, so hydraulic starting systems are favoured in applications wherein emergency starting is required.
- With various configurations, hydraulic starters can be fitted on any engine. These starters employ the high efficiency of the axial piston motor concept, which provides high torque at any temperature or environment, and guarantees minimal wear of the engine ring gear and pinion.

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Spring motor –

- A spring starter uses potential energy stored in a spring wound up with a crank to start an engine without a battery or alternator.
- Turning the crank moves the pinion into mesh with the engine's ring gear, then winds up the spring. Pulling the release lever then applies the spring tension to the pinion, turning the ring gear to start the engine. The piston automatically disengages from the flywheel after operation.
- Provision is also made to allow the engine to be slowly turned over by hand for engine maintenance. This is achieved by operating the trip lever just after the pinion has engaged with the flywheel. Subsequent turning of the winding handle during this operation will not load the starter.
- Spring starters can be found in engine generators, hydraulic power packs, and on lifeboat engines, with the most common application being backup starting system on seagoing vessels.

Fuel starting –

- Some modern petrol engines with 12 or more cylinders always have at least one or more pistons at the beginning of its power stroke and are able to start by injecting fuel into that cylinder and igniting it.
- If the engine is stopped at correct position, the procedure can be applied to engines with fewer cylinders. It is one way of starting an engine of a car with stop-start system.

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