3 Starter Motors - Operating Principles

The function of the starter motor is: to drive the flywheel during start-up. A number of systems are assembled to form the starter motor (Fig. 14):

– Electric motor
– Electric activation system (relay)
– Mechanical activation system (engagement mechanism)

Activation System

The activation system (Fig. 15) consists of an electric and a mechanical component. The activation system ensures that the:

– Pinion is inserted into the starter gear ring
– The starter motor is activated and starts turning

Fig. 14 Starter Motor: three functional groups

1 Electric motor
2 Electric activation system (starter relay)
3 Mechanical activation system
(engagement mechanism)

Fig. 15 Components of the activation system

Starter gear ring
Contact strip
Switch contact
Coil
Relay core
Coupling lever
Pinion
Coupling lever
pivoting point

A **coupling lever** is used to switch on the starter motor. The coupling lever pushes the pinion into the starter gear ring. The coupling lever is controlled by an electromagnet. This electromagnet is called the starter relay. The starter relay consists of the following components:

– Coil
– Relay core
– Contact strip
– Switch contact

Once the starter relay is activated, the relay core shifts to the left. This in turn causes the coupling lever to insert the pinion into starter gear ring. As the pinion is being moved it turns slowly. This causes the pinion to grip the starter gear ring more easily. Once the current stops flowing through the coil of the starter relay, the relay core shifts back to the right. This causes the coupling lever to retract the pinion from the starter gear ring.

Due to the fact that the starter motor draws a tremendous amount of current, the switch that turns the starter motor on and off must be a heavy duty switch. This switch is made up of the contact strip and the switch contacts. After the pinion is inserted into the starter gear ring when the starter relay is activated, the contact strip is pushed against the switch contacts. The current to the starter motor is now switched on.

Starter Relay

Figure 16 shows a cross section of a starter relay. The starter relay contains two coils, the **activation coil** (2) and the **engagement coil** (3). Both coils are controlled by the ignition lock. As soon as the current flows, they are magnetised. The **relay core** (1) is attracted by the magnetic field and shifts to the left. The relay core is made of soft iron and is also referred to as the armature.

When the relay core shifts, two things happen in succession.
– The coupling lever mechanism is activated which causes the pinion to slide into the starter gear ring
– The heavy-duty switch contacts (7) are connected with each other via the contact bridge (9) which switches on the electric motor.

Fig. 16 Starter Relay

1 Relay core (armature)
2 Activation coil (retraction coil)
3 Holding coil (engagement coil)
4 Magnet core
5 Contact spring
6 Battery connecting bolt
7 Switch contacts
8 Electric motor connecting bolt
9 Contact strip
10 Locking pin for controlling the contact strip
11 Return spring

This sequence is fixed. If the electric motor starts turning before the pinion is inserted, the teeth of the pinion and the starter gear ring will be damaged. Therefore the pinion must first be inserted into the starter gear ring, after which the starter motor must start turning.

Activation Coil and Holding Coil

Figure 17 illustrates the complete starter motor.
To move the relay core and the coupling lever requires a strong magnetic field. To keep these components in place once they have been shifted requires a weaker magnetic field. The starter relay contains two coils for this purpose, the activation coil and the engagement coil. As soon as the starter switch is energised, current flows through both coils (Fig. 18). This causes the relay core to move. The coupling lever is attracted and the pinion is inserted into the starter gear ring.
The current that flows through the activation coil also flows through the field winding and the armature of the electric motor. This causes the electric motor to start turning slowly as the pinion is inserted. This reduces the probability that a pinion tooth precisely falls onto a tooth of the starter gear ring.

Fig. 17 Starter Motor diagram

Activation coil
Holding coil
Activation coil
Contact strip
Field winding
Carbon brush
Collector
Pole shoe Armature
Freewheel clutch
Pinion
Starter gear ring
Coupling lever
Relay core Starter switch

Fig. 18 Inserting the pinion into the starter gear ring

Coupling
lever
Activation
coil
Holding coil
Relay core
Field
winding
Armature

The contact strip only connects the switch contacts once the pinion is fully inserted (Fig. 19).
At that point the current flowing through the field winding and the armature is switched on. The relay core is now fully extended. As soon as the main current flows, both sides of the activation coil are connected to the plus terminal. This means that current no longer flows through the activation coil. The activation coil is switched off.
To be able to carry the high start-up current, the electrical wiring from the battery to the relay must have a large diameter. The control current from the ignition lock is much smaller, which means that this wire can be much thinner. The wires running between the starter motor and the battery are never grounded. Always take the necessary precautions therefore when you are working in the proximity of the starter motor. **For safety reasons, always disconnect the ground cable from the battery!**

Engagement Mechanism

The engagement mechanism (Fig. 20), in principle consists of the pinion, the freewheel clutch and the coupling lever.
The pinion/freewheel clutch combination is sometime referred to as the **bendix**.

Freewheel Clutch

Once the engine starts running, it is necessary to prevent the starter gear ring from driving the armature via the pinion. With a transmission ratio of 10 : 1, this would mean that in case of an engine speed of 40 Hz (2,400 RPM/min) the speed of the armature would be 40 x 10 = 400 Hz (24,000 RPM/min). This would damage the windings.

Fig. 19 Main current switched on

Fig. 20 Engagement mechanism with relay and armature

Armature
Pinion
Freewheel clutch
Coupling lever
Relay
Relay core

To prevent this, the pinion is equipped with a freewheel clutch (Fig. 21). The idle setting can transfer power in only one direction, see arrow (1). When the engine is started, the armature’s axis turns the outer portion with the butting edges (2) to the right. The rollers (4) now start to push against the slanted butting edges (2), which causes them to be jammed between the butting edge (2) and the pinion axis (6). This causes the pinion (7) to be carried along and allows the starter gear ring to be driven. Once the starter gear ring starts to drive the pinion, the rollers (4) disengage themselves from the slanted butting edges (2). The armature axis is now uncoupled from the pinion