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DEPARTMENT OF MECHATRONICS ENGINEERING

DIRECT IGNITION

General Description

Direct ignition is in a way the extension of the distributor less ignition. This system hasan inductive coil for each cylinder. Figure 16.58 shows a cross section of the direct ignition coil. These coils are mounted directly on the spark plugs. The use of an individual coil for each plug provides a very fast rise time for the low inductance primary winding, which ensures a very high voltage and high energy spark. This voltage can be in excess of 40 kV, due to which efficient initiation of the combustion process takes place under cold starting conditions and with weak mixtures. Some direct ignition systems such as the SAAB system use capacitor discharge ignition. Igniter units are used to switch the ignition coils and these units can control up to threecoils. These in fact are simply the power stages of the control unit, but located in a separate container to avoid interference in the main ECU due to heavy current switching.

Control of Ignition

Ignition timing and dwell are controlled in the same manner as described in previoussystems. One important additional feature in this system is a camshaft sensor used toidentify the cylinder, which is on the compression stroke. The Bosch Motronic 1.8 system also uses information from the automatic transmission control unit. This helpsin retardation of timing in order to assist gear changes. A system is available, which does not require a sensor such as a crankshaft sensor to determine the cylinder that is on compression. To do this initially all of the coils are fired. A voltage is then appliedacross the plugs. The measurement of the current of each spark indicates the cylinderthat is on its combustion stroke. The cylinder with the highest current at this point isthe cylinder on the combustion stroke, because a burning mixture has a lower resistance.

An additional feature is provided in some systems where the engine is cranked over for an excessive time, causing flooding. The plugs are all fired with multi-sparks for a period of time after the ignition is left in the on position for five seconds.This burns away any excess fuel. In difficult starting conditions, multi-sparking is alsoused by some systems (SAAB) during 70 degrees of crank rotation before TDC. This assists with starting and then, once the engine is running, the timing retrns to its normalcalculated position.

SPARK PLUG

The spark plug provides the gap across which the high-tension current jumps to givethe spark for ignition of the petrol air mixture. Since the Frenchman Etienne Lenoir invented the spark plug in I860, many significant improvements have taken place thereafter, but the basic construction has remained the same, which is consisted of a highly-insulated electrode connected to the HT cable and an earth electrode joined tothe plug body.

Functional Requirements

The spark plug allows a spark to form within the combustion chamber, which initiatesburning. While achieving this plug withstands severe conditions. For example, a four-cylinder four-stroke engine with a compression ratio of 9 to 1, running at speeds up to5000 rpm, the following conditions is typical. At this speed the four-stroke cycle is repeated every 24 ms.

- End of induction stroke is at 88 kPa and 338 K.
- Ignition firing point at 883 kPa and 623 K.
- Highest value during power stroke at 4415 kPa and 3273 K.
- Power stroke completed at 392 kPa and 1373 K.

Besides the above, the spark plug must withstand severe vibration and a harsh chemical environment. Also, the spark plug's insulation must with stand voltages upto40 kV.

Construction

The construction details of a typical spark plug are shown in Fig. 1. A stud connectsto the centre electrode to the top terminal. The electrode is made of a nickel-based alloy. Silver and platinum are also used for some applications. To improve the thermalconduction properties a copper core is also used in the electrode. The 'sillment compressed powder seals' prevent gas leakage past the insulator. A gasket or tapered seat stops leakage between the cylinder head and the shell. A single-earth electrode of rectangular cross-section is welded to the shell. A hexagon is machined on the shell for easy installation and removal of the plug. Ribs formed on theoutside of the insulator increase the length of the flashover or tracking down path outside of the plug insulation and also improve the grip of the lead covers, fitted to prevent penetration of moisture. The insulating material is high grade ceramic basedand aluminium oxide, AI_2O_3 (95% pure) is a common choice. It is bonded into the metal parts and glazed on the outside surface. The

- **A Young's modulus of 340 kN/mm^2**
- **A coefficient of thermal expansion 7.8×10^{-6} K^{-1}**
- **A thermal conductivity of 15 – 5 W/mK (temperature range 473 – 1173 K)**
- **An electrical resistivity greater than 10^{13} Ω/m.**

properties of most suitable insulating material are.

The above values may be considered as a guide only, as actual values vary with slight manufacturing changes. The electrically conductive glass seal between the electrode and terminal stud is also used as a resistor. This resistor damps the current at the instant of ignition. Therefore, it prevents burn off of the centre electrode, and also it reduces radio interference.

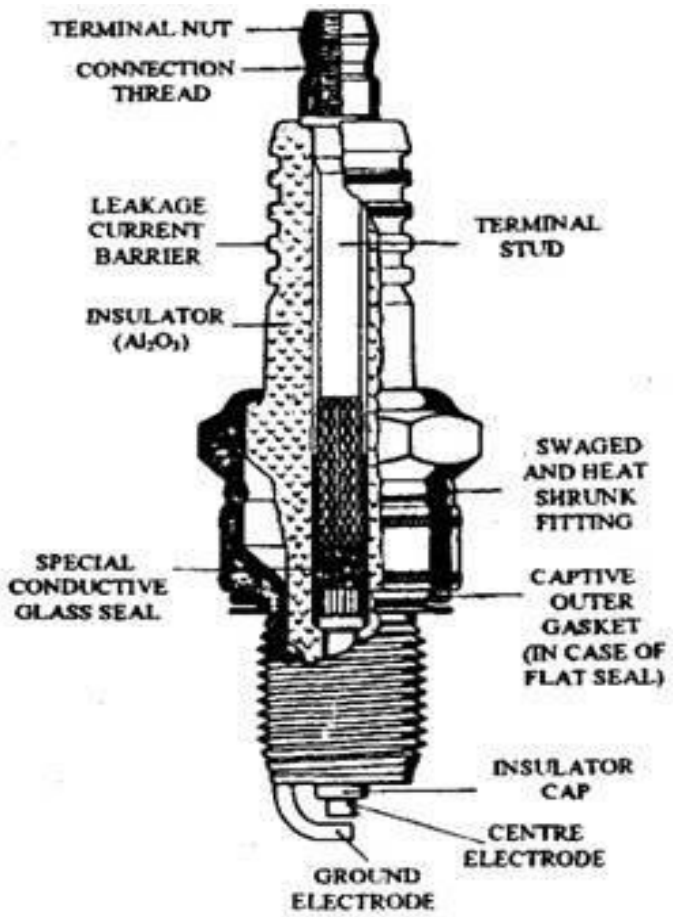

Fig. 1. Typical spark plug (Bosch).

Electrode Features and MaterialsElectrode

Features.

Generally, nickel alloy is used for plug electrodes, which provides resistance to corrosive attack by combustion products or erosion from high-voltage discharges. Platinum is sometimes used in engines where corrosion and erosion are severe. Bothelectrodes must be strong to withstand vibration from combustion effects. They mustalso be correctly shaped for the production of a spark with minimum voltage (Fig. 2A).

Under normal operating conditions, electrodes are eroded and hence after a period oftime the earth electrode shape becomes pointed (Fig. 2B). In this condition it requiresa higher voltage to produce a spark. The increase in the voltage requirement of the plug is accompanied by the deterioration in the output voltage of the ignition generatorsystem. If regularly not attended the system may fail, and most likely this happens during starting of the engine on a cold, damp day.

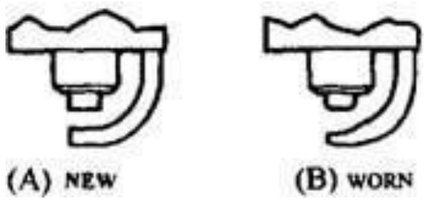

Fig. 2. Electrode shape.

The material for the spark plug electrode must have

- High thermal conductivity,
- High corrosion resistance, and
- High resistance to burn-off.

For operation under normal conditions, alloy of nickel with chromium, manganese, silicon and magnesium as the alloying constituents are used for the electrode material.These alloys have excellent properties with respect to corrosion and burn-off resistance. To improve on the thermal conductivity, compound electrodes are preferred. This can have a greater nose projection for the same temperature range. Acommon example of this type of plug is the copper core spark plug.Silver electrodes are used for specialist applications because this material has very good thermal and electrical properties. Also, these plugs can have higher nose length within the same temperature range. The thermal conductivities of some electrode materials are:

- Silver – 407W/mK
- Copper – 384W/mK
- Platinum – 70W/mK
- Nickel – 59W/mK

Compound electrodes have an average thermal conductivity of about 200 W/mK Platinum tips are used for some spark plug applications as this material has very highburn-off resistance so that much smaller diameter electrodes can be used. This increases mixture accessibility. As platinum has a catalytic effect, it also accelerates the combustion process.

Copper-cored Electrode

By increasing the insulator nose length, the risk of carbon fouling can be reduced whenthe vehicle is operated on short journeys, but the spark plug seriously overheats if thevehicle is driven at high speeds for long period. To overcome this temperature problemexpensive electrode materials such as platinum, iridium, silver or gold-palladium, areused. A cheaper alternative to improve thermal conductivity is a copper-coredelectrode (Fig. 3).

Electrode Polarity.

When the centre electrode is negative with respect to the polarity of HT circuit a lowervoltage is needed to produce a spark at the plug. A hot surface emits electrons. The centre electrode being the hotter of the two, the natural flow of electrons is from the centre electrode to the earth electrode. If the circuit is connected to allow this directionof flow, then the natural flow of electrons aids, rather than opposing the electron movement provided by the ignition coil. The direction of electron flow in the secondarydepends on the polarity of the primary winding. Nowadays the LT terminals on most coils are marked (+) and (-) to indicate the connections required to give a negative spark. Electronic diagnostic equipment is used to test the coil's polarity. If this equipment is not available, a pencil test can be carried out (Fig. 4). Inspection of a plug, already used for a long time, shows more erosion on the earth electrode when the centre electrode is negative.

Fig. 3. Copper-cored electrode.

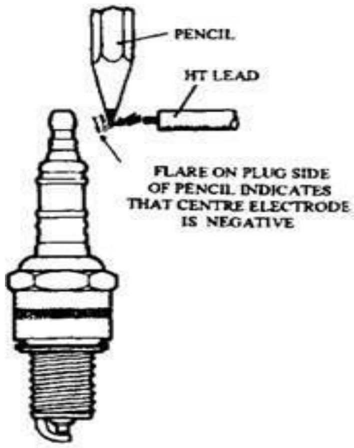

Fig. 4. Pencil test to determine polarity.

Electrode Gap

For cold starting an engine and for igniting weak mixtures, the duration of the spark iscritical. The plug gap must be as large as possible to allow easy access for the mixtureto prevent quenching of the flame. Wider gaps are sometimes used for engines, whichrun on a mixture weaker than normal. These mixtures are more difficult to ignite, so ahigher voltage is required.

Spark plug electrode gaps in general increases with the increase of power of the ignition systems driving the spark (leaving aside engine operating conditions). Since, the energy available to form a spark is constant at a fixed engine speed, a higher voltage when used across a larger gap results in a spark of shorter duration. Therefore,a smaller gap allows a longer duration spark. The final selection of the gap is thereforea compromise decided based on testing for a particular application. Plug gaps in the region of 0.7 to 1.0 mm is a common choice at present. A typical spark plug gap is 0.6mm.

An auxiliary gap (or booster gap) is used on some models. This series gap is formed between the terminal and the end of the electrode. This reduces the build-up of carbonon the insulator nose and so improves the plug performance when the engine is operated at low power for a considerable time.