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Internal-Combustion Engine

(III)

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PREFACE

This text book on the Internal-Combustion Engine was written for use by the Marine Engineering Course trainees of the Training Department, SEAFDEC. It constitutes the third volume in the Text Book series published by the Department.

We intend to issue further volumes in the same series the first volume to serve as an introduction, the second on the structure of four-cycle diesel engines, the fourth on gas turbines, the fifth on engine performance, and the sixth on operation and maintenance.

The author gratefully acknowledges the help of Miss B. Mountfield, who carefully read the manuscript and made many helpful suggestion.

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Internal-Combustion Engine - III

Gasoline Engines

Contents

Page

List of Figures

1. OUTLINE OF GASOLINE ENGINES

The gasoline engine is a typical spark ignition engine. It takes in gasoline and air on the suction stroke, which are ignited by an electric spark at the end of the compression stroke and burn. The gasoline engine may be considered to be of the constant volume cycle change type as will be explained under the engine performance of the fifth volume of this series. Its thermal efficiency is related to the compression ratio. However, the compression ratio cannot be increased excessively if the characteristics of fuel are considered from the practical point of view. The compression ratio of spark-ignition engines and consequently also their thermal efficiency are lower than those of compression-ignition engines. On the other hand, the gasoline engine can be constructed so as to be light in weight since it is not required to be very sturdy.

Gasoline engines are divided into the four-cycle and two-cycle types. The two-cycle engine is simple in construction, but is uneconomical as part of the gasoline escapes from the exhaust port together with scavenge air. For this reason, four-cycle engines are widely favoured whereas the use of two-cycle engines is limited to small-sized ones having a 60 mm cylinder bore. For marine application, two-cycle engines are used as outboard motors.

2. STRUCTURE OF GASOLINE ENGINE

2.1 Carburetor

The carburetor is provided in the fuel suction system for the purpose of feeding into the cylinder a gas consisting of a homogeneous mixture of air and fuel. Air-fuel ratio for complete combustion of gasoline is theoritically fifteen to one in weight. Actually, however, thirteen times as much air is required to obtain maximum power output, and about seventeen times as much for economical operation. If the gas mixture is leaned, irregular ignition is liable to occur, while if it is too rich, incomplete combustion and engine knocking may result. Generally, the mixing ratio is within the range of eight to twenty times as much air as gasoline in weight.

(1) Principles of a carburetor

The operating principles of the carburetor are shown in Fig. 1. A flow of suction air goes round of the small nozzle (4) which opens in the throat of a venturi tube (3) to suck in and atomize the fuel by the resultant negative pressure around the nozzle. Thus, air and fuel are mixed. If the level of fuel in the nozzle (lowered by h from the tip of nozzle) rises, the fuel will overflow during engine stopping, while if the level is too low, the supply of gasoline will not be sufficient. To prevent this, a float (6) is used to regulate the fuel level at about 10 to 15 mm below the tip of the nozzle.

The outlet of the carburetor is provided with a throttle valve (1), which controls the suction rate of mixed gas into the cylinder. Its inlet is equipped with a choke valve (5) which, when closed, will increase negative pressure to enrich the gas mixture. Fig. 2 shows an example of a carburetor.

(2) Mixing ratio adjusting devices for carburetors

(a) Auxiliary air valve: With a rise in engine speed the gas mixture will be enriched. To prevent this, as in Fig. 3, a poppet valve is provided at the outlet of the venturi tube, and is pressed down onto the valve seat by means of a spring. When the engine speed increases, the auxiliary valve serves to reduce the pressure in the venturi tube: the valve is opened by overcoming the spring force, and the inflow of air is reduced. As a result, the gas mixture is leaned.

(b) Low-speed nozzle: When the engine runs at a partial load (especially at a very light load), the throttle valve will be almost closed. Consequently the suction effort of the venturi tube will be reduced to nought. For this reason, as in Fig. 4, a low-speed nozzle is provided near the position where the throttle valve closes almost totally. In this arrangement, the velocity of the air passing through the gap between the venturi tube and the throttle valve becomes high, developing an excessive negative pressure, which will easily suck up the fuel through the low-speed nozzle. When the throttle valve is opened, the pressure at that point will be high and the low-speed nozzle will not operate.

(c) Economizer: To reduce the output from full load, it is more advantageous to lean the air-gas mixture to an economic ratio with the throttle valve totally opened than to decrease the opening of the throttle valve, as the fuel metering port is opened (Figs. 5 and 6). For this reason, the practice is to set the fuel metering port at the economic mixing ratio and to supply rich gas. Once the throttle valve has been totally opened. The device is called an "economizer", which is divided into two types: one in which the fuel metering port can be adjusted and the other in which an economizer valve is used. The former method is more popular than the latter; it is subdivided into two: interlocking of the metering pin and the throttle valve; and use of a vacuum developed by the venturi tube. Figs. 5 and 6 show the operating principles of the most widely applied interlocked type economizer and a suction-actuated type economizer.

(d) Accelerator: When it is required to increase the engine output quickly, opening the throttle valve all at once will immediately increase the inflow of the air but the fuel will fail to follow such a sudden change because of inertia, momemtarily causing a lean gas mixture. To avoid this, as shown in Fig. 7, a piston type pump, which works interlockingly with the throttle valve, is used to supply more fuel to keep pace with air supply. When the throttle valve is opened suddenly, the valve seat will be depressed to open the valve port to deliver more fuel. But when the throttle valve is opened slowly the fuel will flow out of the piston gap, keeping the valve seat position unchanged, and this action prevents the acceleration pump from actuating.

2.2 Ignition device

There are two ignition systems:

(1) The high-tension magneto ignition system;

(2) A system using a high-tension induction coil and battery.

In the past, two systems were applied, one using a low-tension magneto with a high-tension induction coil, the other using a low-tension magneto or battery for interrupting sparking. The above two systems are almost the same in principle, except that the former uses a magneto generator for its electric power supply while the later uses the battery for the same purpose.

(a) Battery type ignition device: Fig. 8 shows the operating principles of a battery type ignition device. When the switch is turned on a current will flow through the primary coil. If an interruptor, which works interlockingly with the engine crank, is provided in the coil circuit so as to interrupt the primary circuit quickly at the right moment, an extremely high voltage will be induced in the secondary coil. This high voltage is conveyed by the distributor to the spark plugs of the cylinder according to the firing order. The high voltage then causes a spark between the electrode of the plug and the cylinder wall. The interruption of the primary coil current gives rise to two bad effects; these are (1) damage to the contact surface of the interruptor by sparks and (2) reduction of the voltage induced in the secondary coil by sparking. To eliminate these, a capacitor is usually provided to absorb electric energy. Fig. 9 shows the operating principles of an ignition coil whose transformation ratio of the secondary coil to the primary coil is 50 to 120, to rise several thousands to several tens of thousands of volts in the secondary coil.

(b) High-tension magneto ignition system: In the high-tension magneto ignition system the primary current is obtained from a magneto. Whereas the battery type requires a generator for battery charging, the magneto type does not and is therefore lighter in weight than the battery type.

The magneto type, however, has disadvantages in that the ignition cannot be achieved unless the magneto obtains a certain range of rotation. For this reason, it requires in addition a starting magneto, with a high rotating speed, whose ignition voltage is higher than in the battery type, to ensure of ignition. These are the various types of high-tension magneto ignition systems. Many of them, however, are very similar such as an a.c. generator, in which a magnet or a coil is turned to change fluxes to develop the primary current which, as in the battery type, is converted into 10 to 12 KV of high voltage in the secondary coil.

The high-tension-magneto ignition system is roughly divided into armature type and induction magnet type according to whether the rotating element is a coil or a magnet. Typical types are shown in Fig. 10. Fig. 11 illustrates the wiring diagram and magnetic path of an induction type magneto, which is chiefly applied in small engines.

For connecting the magneto to the crankshaft flexible coupling is generally used for the purpose of protecting the magneto from vibrations and preventing the dislocation of the crankshaft and the magneto. For the effective control of ignition timing a vernier coupling is installed (Fig. 12). For example, if the number of right and left teeth is 18 and 20 respectively, the control of ignition timing achievable is obtained by the following calculation:

$$\frac{1}{18} - \frac{1}{20} = \frac{2}{360},$$

and therefore this becomes 2°.

The rotating ratio of the magneto to the crankshaft for a 4 cycle engine is given by the following formula:

$$\frac{n_m}{n} = \frac{1}{2} \times \frac{Z}{S},$$

where n_m : Speed of main magneto shaft

n : Speed of crankshaft

Z : Number of cylinders

S : Number of ignitions per revolution of magneto main shaft.

For the armature type magneto, $S = 2$, therefore we have

$$\frac{n_m}{n} = 1 \quad \text{for 4-cylinder engine,}$$

and

$$\frac{n_m}{n} = 3/2 \quad \text{for 6-cylinder engine.}$$

Since the distributor is required to revolve at a rate of one revolution per two revolutions of the crankshaft, the following relationships are established:

$$\frac{n_d}{n} = \frac{1}{2}$$ for revolution ratio to crankshaft,

and

$$\frac{n_d}{n_m} = \frac{Z}{S}$$ to magneto main shaft,

where n_d is the speed of distributor.

2.3 Spark plug

The spark plug is installed on the cylinder cover, and is supplied with high voltage from a battery or magneto to ignite the gas mixture by a spark. As shown in Fig. 13, the spark plug is composed of a center electrode, insulator, gasket and main body provided with a grounding electrode. The center electrode is made of steel, and its sparking tip is welded with nikel alloy to prevent oxidation and burn out. For the insulator, alumina or a similar material is used. The plug body is made of mild steel. In many cases, the number of grounding electrodes is one, and the gap between the center electrode and grounding electrode is usually 0.5 to 0.9 mm.

2.4 Starter

After preparation for start-up, small engines are started by hand. Manual start-up is done by turning the handle on the flywheel or by turning a handle to rotate the crankshaft through a bevel gear coupling or chain sheave. For engines of about 40 p.s. or larger, manual start demands considerable effort, and an electric starter (starting motor) actuates the pinion to rotate the flywheel.

At the time of start-up, especially when the engine is cold, a large torque is required. For this reason, a d.c. series wound motor, which has a large starting torque, is provided. Starting motors are divided into screw type, armature slide type, plunger type and so on, depending on the method required to engage the pinion with the flywheel gear. Fig. 14 shows an example of a plunger type starting motor.

3. OUTBOARD ENGINE

In recent years the very small 2-cycle gasoline engine has made marked progress, and has found favour in shallow-water fishery as an outboard engine of 2.5 to 35 p.s.

Sea weed cultivation, shell fishing, angling, etc. have become important activities, and the scope of application of outboard engines has become wider year by year. These engines are used mostly in calm waters because they attain a high-speed, but are not suitable for rough sea fishing operations. The reason why they have won popularity despite their drawbacks is that their initial investment cost is small. Drawbacks include poor durability and high operating costs because of the use of gasoline as a fuel. Fig. 15 shows a 2-cycle spark-ignition type outboard engine having a cylinder bore of 45 mm and a stroke of 50 mm and rated at a speed of 5,500 r.p.m. and a piston velocity of 9.2 m/sec. Its propeller speed is reduced to about half of the engine speed through the bevel gear in the propeller shaft housing.

The outboard engine is a very small high-speed engine, and its construction and performance are highly refined. It should, therefore, be handled with the utmost care and in accordance with the maker's instructions. The crankshaft, for example, and propeller shaft are equipped with ball bearings, and the cylinder cooling water pump is of a special type fitted with wings made of rubber. If the cooling water system is choked up with foreign matter the cooling water circulation will be hindered and cause piston. seizure. During operation, the operator is required carefully to check water discharge from the inspection hole. Also, special consideration should be given to the care of the engine after use for the purpose of protecting it from corrosion by sea water. The propeller shaft housing is immersed in the water and it should be checked to make sure it is filled with lubricating oil. To prevent the propeller from breaking if it hits snags in the water, a cotter pin is provided which will break if the propeller is jammed by foreign matter. The outboard engine is light in weight and easy to operate, but its daily maintenance, especially after operation, is important in order to prevent engine and other trouble.

APPENDIX

(FIGURES)

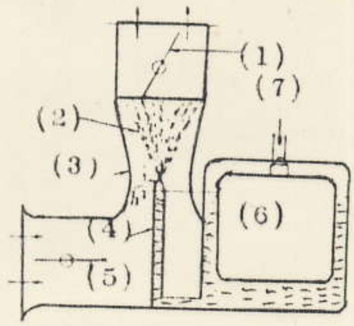

Fig. 1 Principles of carburetor.

(1) Throttle valve (2) Mixing chamber
(3) Venturi tube (4) Nozzle
(5) Choke valve (6) Float
(7) Fuel inlet

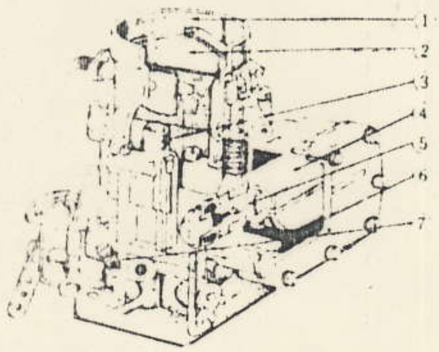

Fig.. 2 Carburetor.

(1) Air intake port (2) Choke valve
(3) Venturi tube (4) Float
(5) Float valve (6) Float chamber
(7) Idling adjusting screw

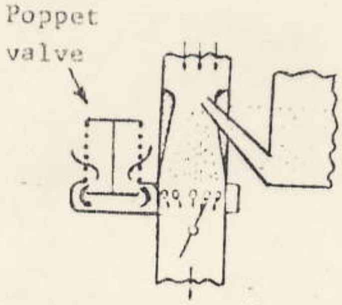

Fig. 3 Auxiliary air valve.

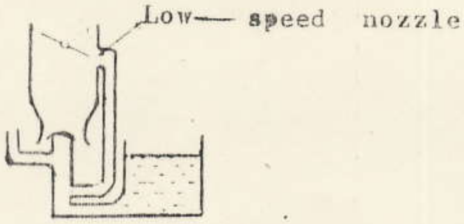

Fig. 4 Low— speed nozzle.

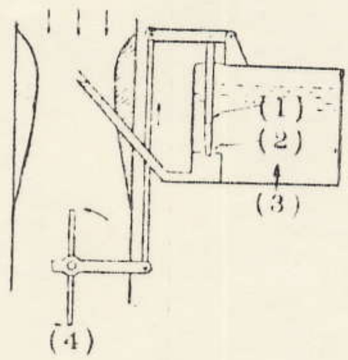

Fig. 5 Interlocked type economizer

(1) Metering pin
(2) Metering port
(3) Float chamber
(4) Throttle valve

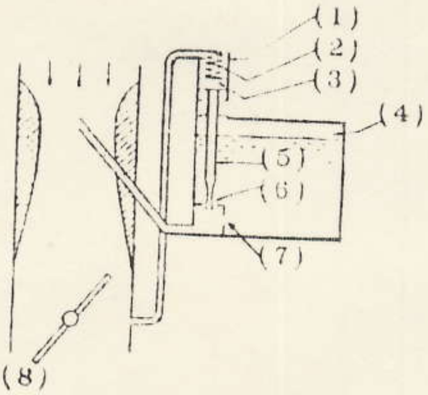

Fig. 6 Suction-actuated type economizer

(1) Vacuum chamber (2) Spring
(3) Piston (4) Float chamber
(5) Metering pin (6) Metering port
(7) Main metering port (8) Throttle valve

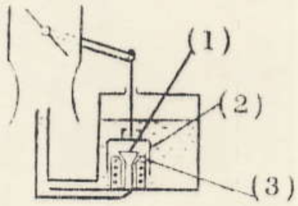

Fig. 7 Acceleretor.

(1) Valve (2) Piston
(3) Valve seat

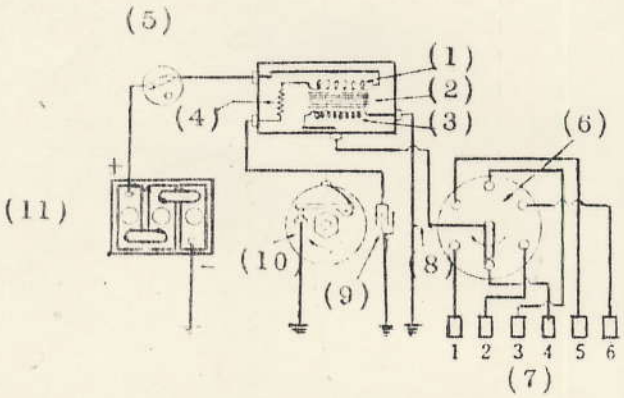

Fig. 8 Battery type ignition device.

(1)	Primary coil	(2)	Core
(3)	Secondary coil	(4)	Ballast coil
(5)	Switch	(6)	Distributor
(7)	Number of cylinder	(8)	Safety gap
(9)	Capacitor	(10)	Interruptor
(11)	Battery		

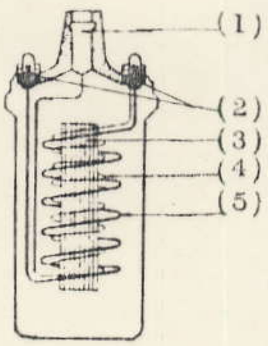

Fig. 9 Ignition device.

(1) Secondary terminal (High tension terminal)
(2) Primary terminal (Low tension terminal)
(3) Core
(4) Secondary coil
(5) Primary coil

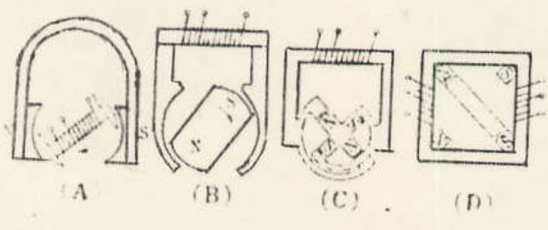

Fig. 10 Typical types of magneto ignition system.

(A) Armature type magneto
(B) Induction type magneto
(C) Quadripolar magneto
(D) Square magneto

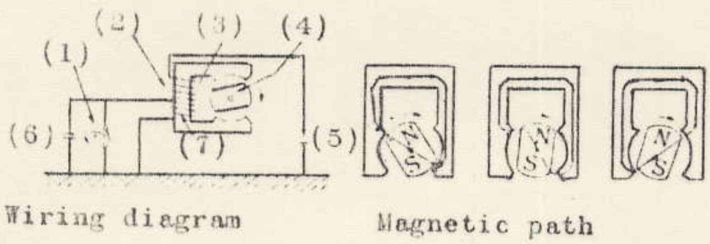

Fig. 11 Wiring diagram and magnetic path of induction type magneto.

(1) Interruptor (2) Armature
(3) Secondary coil (4) Magnet
(5) Ignition plug (6) Capacitor
(7) Primary coil

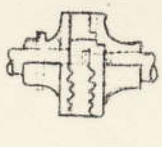

Fig. 12 Vernier coupling.

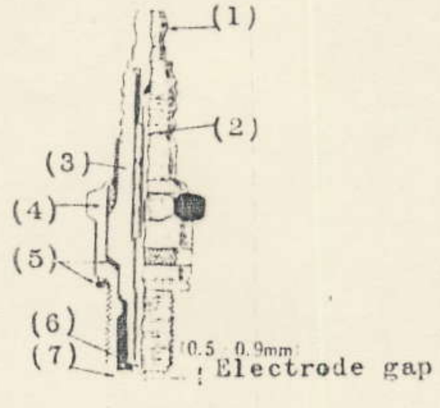

Fig. 13 Spark plug.

(1) Terminal (2) Center rod
(3) Insulator (4) Plug body
(5) Gasket (6) Center electrode
(7) Grounding electrode

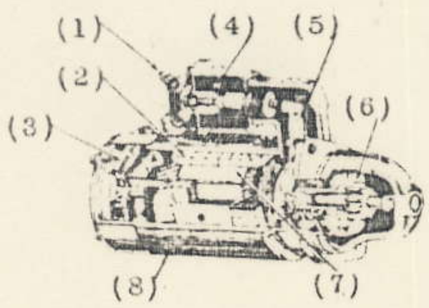

Fig. 14 Plunger type starting motor.

(1) Terminal (2) Field coil
(3) Brush (4) Magnet coil
(5) Lever (6) Pinion
(7) Armature (8) Yake

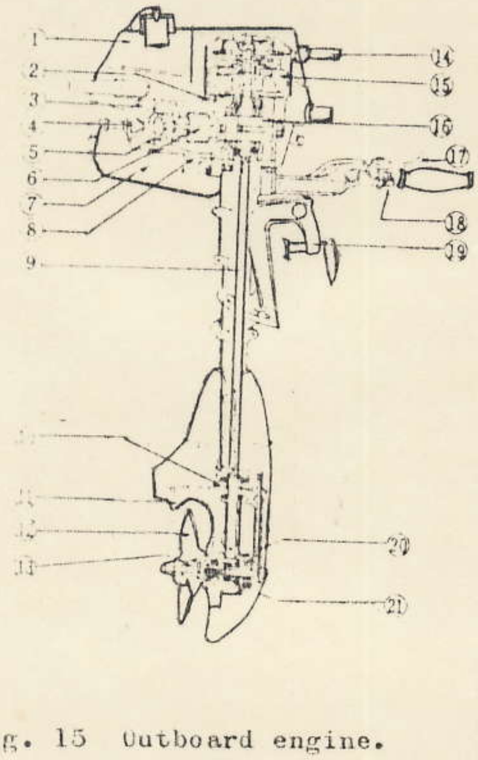

Fig. 15 Outboard engine.

(1) Fuel tank	(2) Cylinder	(3) Cylinder head
(4) Spark plug	(5) Piston	(6) Connecting rod
(7) Muffler	(8) Carburetor	(9) Transmission shaft
(10) Cooling water pump	(11) Suction port of cooling	(12) Propeller (3-blades)
(13) Propeller cusion rubber	(14) Starter with rope	(15) Flywheel type magneto
(16) Crankshaft	(17) Throttle lever	(18) Stop switch
(19) Bracket	(20) Bevel gear for reduction	(21) Clutch