Ignition Devices for Two-Wheel Vehicles

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1. Introduction

Ignition devices for two-wheel vehicles are typically not discussed frequently. Two-wheel vehicles are usually referred to as motorcycles, and the ignition device is the device that sparks the fuel causing it to explode in order to turn the engine. As shown in Fig.1 (two-wheel vehicle electrical equipment wiring dia-gram), the electrical equipment used in two-wheel vehicles are extremely limited in comparison with that used in four-wheel vehicles (typically, automobiles). Among the small number of electrical equipment used in two-wheel vehicles (ignition device, battery charger, battery, generator [battery charging coil, ignition timing coil], lamps, resonance horn, meters and switches), without the generator that provides power and the ignition device, the engine will not be operational, or in other words, the ignition device can be said to be the heart of a motorcycle.

At Shindengen, we mainly develop and produce ignition devices and battery chargers used in two-wheel vehicles. In addition, in terms of the world market for these products, we currently retain 20% and 60% shares, respectively, with our products being sold to numerous motorcycle manufacturers.

Current ignition devices are composed of electronic components. As a result of the introduction of new technologies coupled with innovations in semiconductor technology, ignition devices are able to realize properties and accuracy which

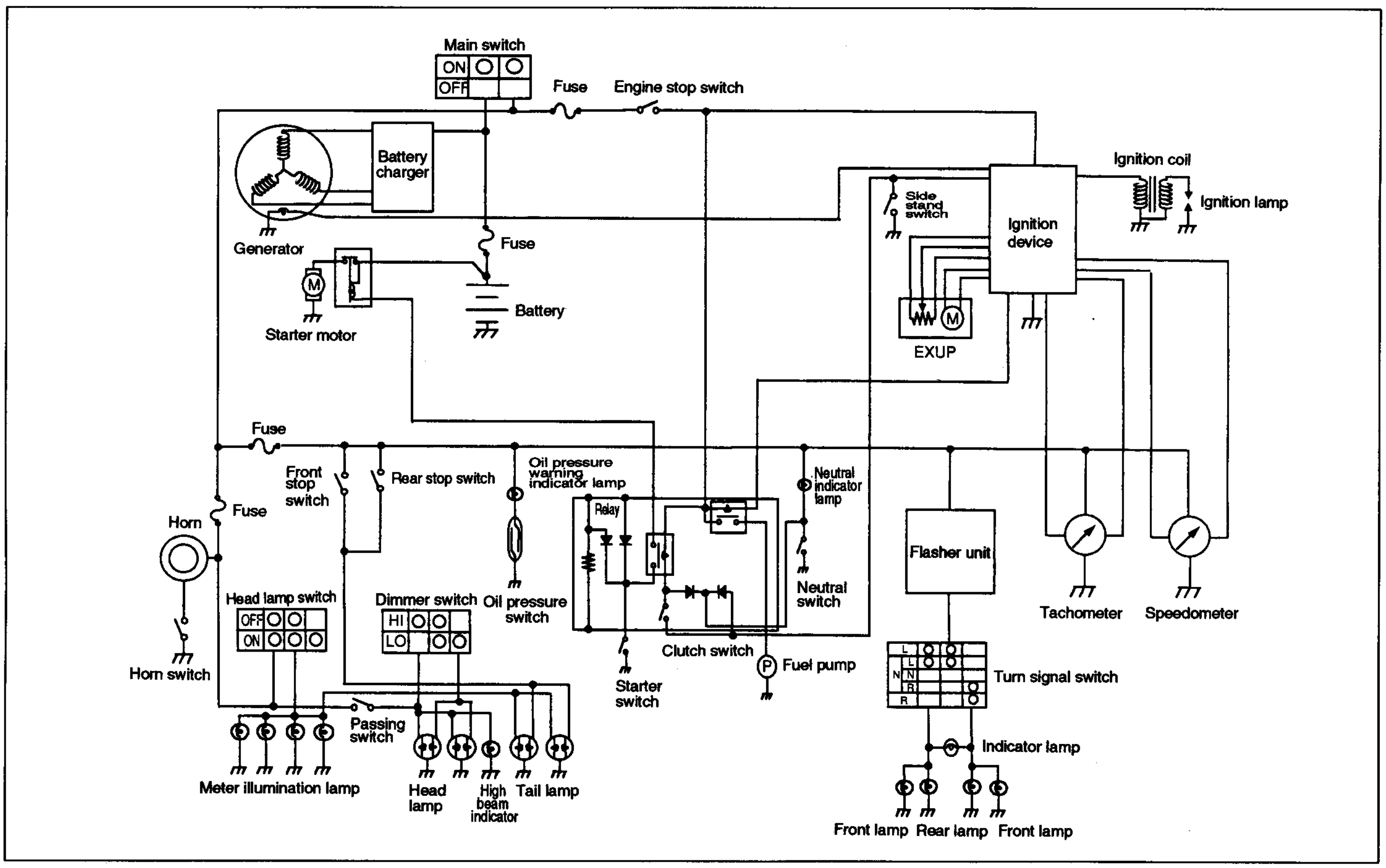

Fig. 1 Two-wheel vehicle electrical equipment wiring diagram

enables the engine to obtain optimum performance. In particular, much of the support for these improved properties and accuracy is due in a large part to electronic devices used in popular products such as video game devices and cameras.

Digital ignition devices are becoming increasingly common. As a result of using a single-chip microcomputer for the control circuit, in addition to "generating a spark", the device is able to control all aspects of the engine, including fuel supply regulation, piston internal pressure regulation, chassis anti-theft function, monitor display (vehicle speed, engine speed, distance traveled, oil level) and so forth. Although the ignition device is able to offer many functions as indicated above, this report will focus on the basic functions of the ignition device.

2. Role of the Ignition Device from the Perspective of the Engine

2-1 Operating Principle of Four-Cycle Engines

The role of the ignition device from the perspective of the engine is explained using the individual strokes of a four-cycle engine as an example, which is shown in Fig. 2. To begin with, during one rotation of the crankshaft, the piston moves up and down. During the reciprocal motion of the piston, the position of the piston at which cylinder volume reaches a minimum is referred to as "top dead center", while the position of the piston at which it reaches a maximum cylinde volume is referred to as "bottom dead center". The movement of the piston between these two points is referred to as the "stroke", and engines in which a single cycle is completed in four strokes (two turns of the crankshaft) is referred to as a four-cycle (four-stroke) engine. The four strokes consist of (a) intake stroke (intake of fuel and air), (b) compression stroke (compression of the fuel and air taken in), (c) expansion stroke (combustion gas expands while exploding), and (d) exhaust stroke (combustion gas is discharged to the outside). The combustion operation performed by the ignition apparatus is performed during (e) ignition in the vicinity of top dead center between the compression stroke and expansion stroke. During the combustion resulted from ignition, the expansion energy causes torque to be applied to the crankshaft in the direction of crankshaft rotation, after which rotation continues due to inertia of the flywheel and so forth.

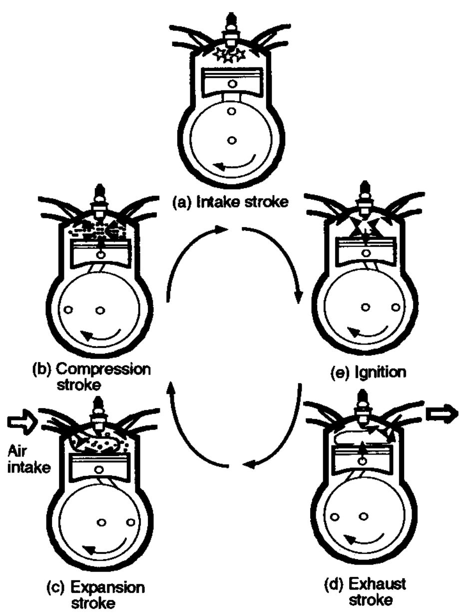

Fig. 2 Operational diagram of the strokes composing a four-cycle engine

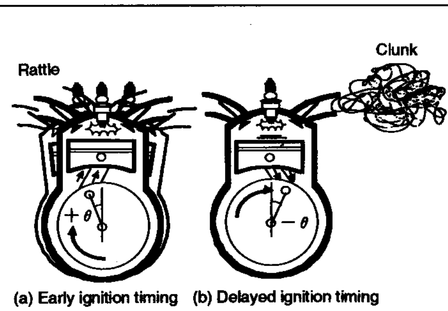

Fig. 3 Effects of shifts in ignition timing on engine operation

2-2 Conditions Required by Ignition Devices

The following provides an explanation of the conditions required by ignition devices. Although a spark is provided to the engine when the piston and crankshaft are in the vicinity of top dead center, the ignition timing is an important factor for this to occur properly. The following explains the effects on piston shaft reciprocal motion when the ignition timing is early and late as shown in Fig.3 (operation of a four-cycle engine due to shift in ignition timing). In the case the ignition timing is early, the air-fuel mixture is ignited when the piston shaft is still rising toward top dead center. As a result, combustion expansion occurs during the compression stroke. Due to this force of expansion, a force acts to push the piston down causing the engine to run unevenly. In the worst case, the piston may be damaged. Next, in the case the ignition timing is late the air-fuel mixture is ignited after the piston shaft passes top dead center. As a result, piston pressure decreases resulting in incomplete combustion. Residual combustion is discharged as heat causing the exhaust pipe to become hot. What is more, since sufficient combustion expansion does not occur, the engine does not generate the specified horsepower. In this manner, the ignition timing must not be early or late and a timing must be set that ensures good engine performance corresponding to each engine speed. This is referred to as the "ignition timing". In addition, since the inside of the cylinder is at high pressure, it is necessary to generate a high voltage (15-30 kV) even at high engine speeds in order to ignite the air-fuel mixture.

To summarize the role of the ignition device can be said to consist of 1: ignition performance in terms of providing a suitable spark, 2: ignition timing in terms of providing the spark at the proper timing, and 3: controlling sparking and igniting the air-fuel mixture under the proper conditions, to enable the engine to be operated.

3. Types of Ignition Devices for Two-Wheel Vehicles

At present, current interruption ignition coil systems and capacitor discharge ignition systems are used to generate the high voltage used in the ignition devices of two-wheel vehicles. Generally speaking, CDI systems are used in small- and medium-sized two-wheel vehicles, while current interruption ignition coil systems are used in large two-wheel vehicles.

3-1 Current Interruption Ignition Coil Systems

Since transistor current is typically controlled with a transistor in many current interruption ignition coil systems, these ignition systems are also referred to as "transistor ignition systems". These are explained based on the block diagram of transistor ignition systems shown in Fig. 4a. When transistor Q_1 is switched on, current a1 flows through the primary side of the ignition coil from the battery power supply for a fixed period of time. Next, current a1 is interrupted as a result of transistor Q_1 being switched off according to the ignition timing, resulting in a kick voltage being generated on the primary side of the ignition coil. At the same time, since a high voltage is also generated on the secondary side, the insulation between the plug gap is broken down resulting in electrical discharge. In other words, in this type of system, the energy accumulated in the ignition coil is discharged in the form of a kick voltage between the plug gap as a result of the current being interrupted with a transistor (when Q_1 is switched from on to off), thereby resulting in ignition. This method is basically the same in automobiles as well.

3-2 CDI Systems

CDI is the abbreviation for Capacitor Discharge Ignition systems. An explanation of these systems is provided based on the block diagram of a capacitor discharge ignition system shown in Fig. 4c. First of all, capacitor C_1 is charged to several hundred volts by the capacitor charging coil of the generator (external charging coil). Next, when the ignition timing signal is

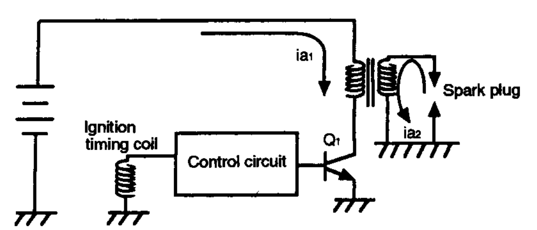

Fig. 4a Block diagram of transistor ignition system

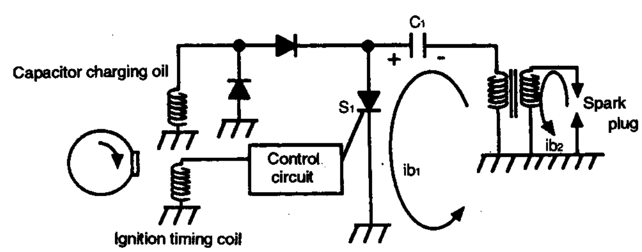

Fig. 4c Block diagram of capacitor discharge ignition system

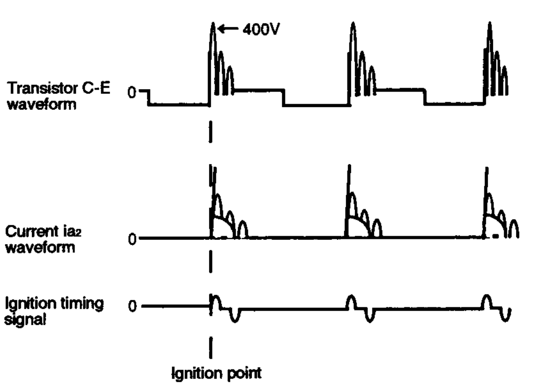

Fig. 4b Ignition waveform diagram during current

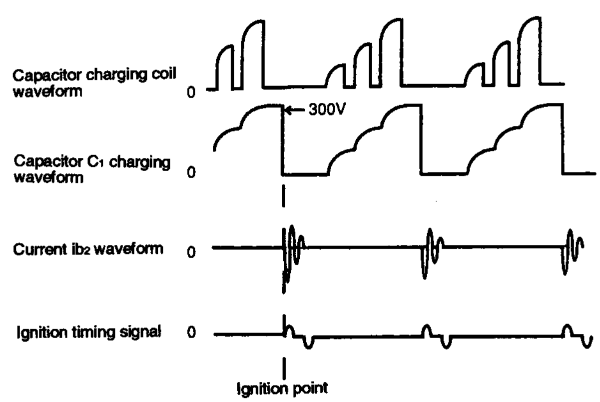

Fig. 4d Ignition waveform diagram of capacitor discharge ignition system

obtained, the charge of capacitor C_1 is rapidly discharged (i_{b1}) to the primary side of the ignition coil through thyristor S_1. Consequently, the energy generated at the primary side of the ignition coil is transmitted to the secondary side, which breaks down the insulation between the plug gap resulting is electrical discharge.

A comparison of the ignition characteristics of both ignition systems is shown in Table 1 indicating a comparison of the characteristics of the transistor ignition system and the CDI ignition system.

Item	Transistor Ignition System	CDI Ignition System
Power supply and supplied voltage	Battery, 12 V	Capacitor charging coil, several hundred volts
Ignition energy accumulation method	Ignition coil	Capacitor
Engine type **High-speed type** **Lean fuel type**	 Disadvantageous Advantageous	 Advantageous Disadvantageous
Ignition waveform type	Gentle rise with long duration of discharge (500μs)	Rapid-rising peak with short duration of discharge (100μs)

Table 1 Comparison of characteristics of the transistor ignition system and CDI ignition system

4. Actual Ignition Devices of Two-Wheel Vehicles

4-1 External Charging Coil Type

The most typical form of a capacitor discharge ignition device is shown in Photo 1. This type of ignition device is installed on 50 cc class two-wheel vehicles. This unit uses an external charging coil for the ignition energy supply source. Furthermore, refer to the CDI system described in section 3-2 for details concerning the operation of this unit.

4-2 DC-CDI Type

Photo 2 shows an ignition device in which the ignition energy source is obtained from the battery. Although an external charging oil that generates several hundred volts is used in CDI systems, this unit employs a DC converter system in which the battery power supply voltage is boosted from 12 V to 300 V with a transformer which is then used to charge a capacitor. Recently, this type of ignition system is used in numerous models. We refer to this type of ignition system as "DC-CDI" in distinguishing it from the external charging coil type. In addition, a block diagram of this type of ignition system is shown in Fig. 5.

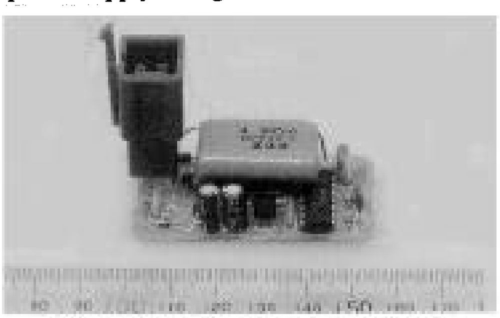

Photo 1 External charging coil type CDI

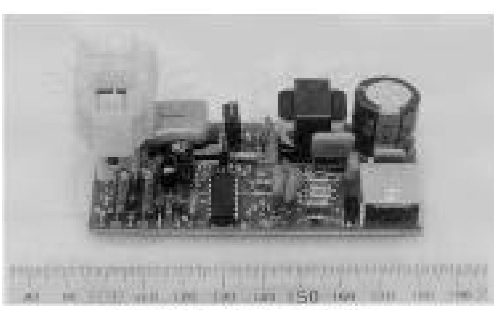

Photo 2 Converter type CDI

The operation of this type of ignition device is described below. Transistor Q_1 is repeatedly switched on and off by the switching waveform from oscillator OSC_1 (Fig.6a Waveform Diagram of Oscillator OSC_1) to drive the primary side of transformer T_1. Voltage V_{CE} (Fig.6b) between the collector and emitter of transistor Q_1 generates a kick voltage from the primary side coil of transformer T_1 when transistor Q_1 switches from on to off. On the other hand, since the direction of the windings of the primary and secondary side coils are reversed the output is generated to the secondary side coil when transistor Q_1 switches from on to off, the kick voltage generated on the primary side is transfered to the secondary side coil in the form of a voltage waveform that is double the number of windings of the primary and secondary coils. This kick voltage is then used to charge capacitor C_1. Although the kick voltage of one cycle is small in terms of energy, as a result of being repeated many times (for example, 180-200 times, 6000 rpm, f = 20 kHz), it is more than enough to charge the capacitor to an energy voltage

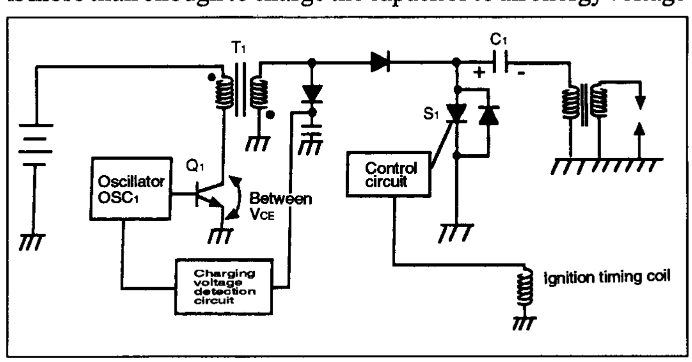

Fig. 5 Block diagram of converter type CDI

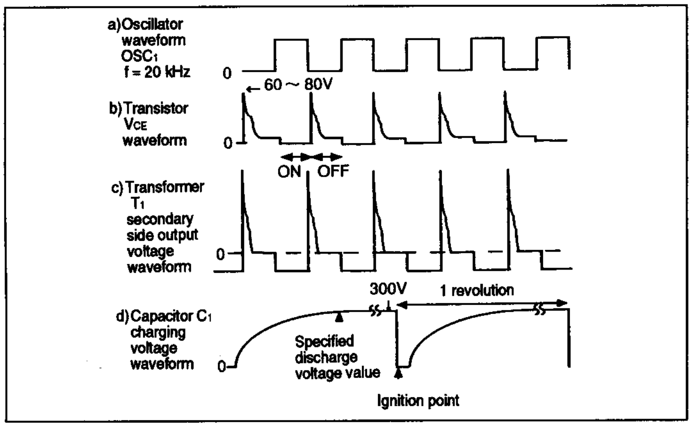

Fig. 6 Output waveform diagram of each component of a converter type CDI

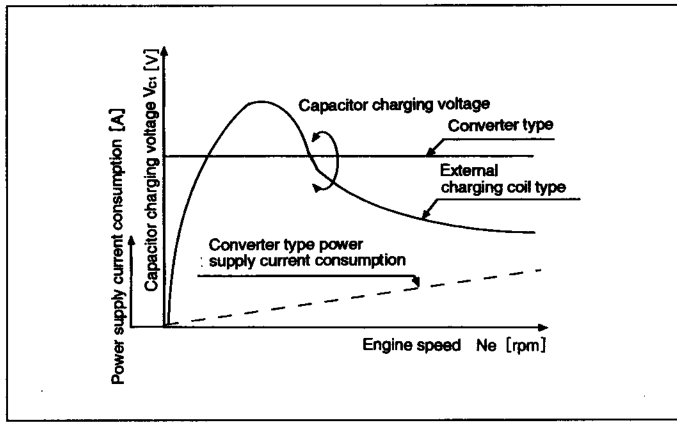

Fig. 7 Capacitor charging voltage characteristics diagram

required for ignition (Fig. 6d).

In addition, when capacitor C_1 reaches the specified voltage, the operation of oscillator OSC_1 is stopped by a signal from the charging voltage detection circuit to prevent condenser C_1 from being overcharged. After this, thyristor S_1 arcs due to input of the ignition timing signal causing the charge of capacitor C_1 to be applied to the ignition coil resulting in ignition. The same process is repeated for the next cycle.

Table 2 indicates the characteristics of the converter type and external charging coil type. It can be understood from this table that the converter type improves on the shortcomings of the external charging coil type. The DC-CDI type is able to start the engine even in the absence of a battery power supply. This is because the battery power supply voltage is on the order of several volts to 5 volts, which is enough to secure energy for capacitor C_1, and this is also no problem in terms of the rotating speed of the kick starter and the number of revolutions. There are some cases in which a large-capacity capacitor is used in place of a battery depending on the model.

Item	External Charging Coil Type System	Converter Type
Startability	Poor	Good (current consumption of the power supply during starting is low)
Capacitor charging performance	Low high and low speed regions	Constant regardless of engine speed
When capacitor charging voltage is high	No change	Converter portion becomes larger
Ignition timing variation range	Narrow (0−30°)	Wide (±30°)
Ignition unit composition	Simple	Somewhat complex
Handling on generator side	Handling of the capacitor charging coil is difficult, the wires are thin and there are a large number of windings	Can be used with all battery charging coils, improved battery charging performance

Table 2 Comparison of the characteristics of the external charging coil type and converter type

5. Conclusion

Digital components are being used with increasing frequency in the electrical equipment of two-wheel vehicles, and the control components are becoming increasingly integrated. The subject that remains is how to make improvements in the field of large-capacity devices. In the case of motor driven parts and so forth, it is believed that efforts will proceed in the direction of only the power unit of the electronic circuit being integrated with an actuator, and the control unit will control pulse modulation from a single location or perform remote control through radio transmission.

Reference Literature:

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