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(54) IMPROVED SPARK IGNITION CIRCUIT

- (71) We, KABUSHIKI KAISHA SIGMA ELECTRONICS PLANNING, a Japanese Body Corporate, of 1-3-5, Akatsukashin-Machi, Itabashi-Ku, Tokyo-To, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-
- 5 This invention relates to a spark ignition circuit for intermittently firing a spark gap such as provided by a spark plug in an internal combustion engine of an automobile and, more particularly, to a spark ignition circuit provided with an ignition coil having a secondary winding connected in series with an auxiliary DC source so as to increase the effective ignition energy for minimizing the rate of mis-firing.
- 10 It has been known that an electrical spark in an internal combustion engine is a composite spark formed by a capacity spark discharge and a subsequent inductance spark discharge. In the capacity spark discharge, a large current flows for an extremely short duration as a result that the electromagnetic energy stored in the ignition coil is instantaneously discharged at a spark gap.
- 15 However, in the inductance spark discharge which takes place immediately after the capacity spark discharge, a small current flows for a relatively long period determined by the self- and/or mutual-inductance of the ignition coil. Accordingly, the capacity spark discharge is closely related to the mis-firing ratio, while the inductance spark discharge to the capability of ignition. In an ordinary spark ignition circuit, since the above-mentioned two kinds of discharges are actuated only by a high voltage induced across the secondary winding of the ignition coil, independent control or emphasis of the individual discharge is impossible. Accordingly, a proposal has been made in which an auxiliary DC or AC source is incorporated
- 20 in series with the secondary winding of the ignition coil in such a manner that the voltage for inductance discharge is raised to increase the ignition energy. As result of this construction, mis-firing is decreased to some extent, and better combustion of fuel is realized to improve the specific fuel consumption and to reduce harmful gas exhaustion. A constant voltage source with a low internal impedance is usually used as the auxiliary current source. In a spark ignition circuit provided with such an auxiliary current source, the duration of an inductance spark discharge is extended as the output voltage of the auxiliary current source is increased. However, the circuit has the following disadvantages:
- 25 (1) If the voltage of the auxiliary current source is maintained at a constant value, the spark intensifying effect depends upon the speed of the engine, namely, the effect is reduced as the speed increases. Therefore, a voltage determined to obtain a sufficient spark intensity in a range of high speeds becomes too high in a range of lower speeds, and results in (a) unstable sparking, (b) insufficient spark extinction, and (c) continuous sparking. From this point of view, the source voltage must be determined to be suitable for low speed operation. However, the voltage so determined will not provide a satisfactory spark intensifying effect at higher speeds.
- 30 (2) If the auxiliary current source is formed to have a constant voltage, the spark intensifying effect depends on the size of a plug gap. Since the spark intensifying effect decreases with increasing plug gap at a given engine speed, if the voltage is established at such point that a sufficient spark intensifying effect is obtained for a large plug gap, this voltage becomes too high for a small plug gap and causes the unfavorable result stated in the above item (1). Moreover, the gaps of the conventional plugs have not
- 35 40 45
- 50 55 60 65 70 75 80 85 90

always the same size and are destined to increase as the plugs wear, so that the voltage should be determined for a plug having a small gap or a new one. Accordingly, a satisfactory spark intensifying effect will not be obtained in a case where the plug gap is increased.

An object of this invention is to provide a spark ignition circuit having an auxiliary power source to develop a high internal source impedance of high output voltage for a light load and a low internal source impedance of low output voltage for a heavy load thereby to remove the above mentioned defects of conventional ones.

In accordance with this invention, there is provided a spark ignition circuit comprising a contact breaker in series with a primary winding of an induction coil of which the secondary winding is in series with a spark gap, and an auxiliary DC power source which has output terminals in series with the said secondary winding and the spark gap, the auxiliary source comprising a DC to DC converter, in which an input direct voltage is converted to an alternating signal and this signal is transformed and rectified to provide an output at said terminals, which converter includes a feedback loop which produces decrease of the auxiliary source's output voltage for an increase in its output current.

The principle, construction and operation of this invention will be clearly understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a circuit diagram illustrating an embodiment of this invention;

Figure 2 shows characteristic curves illustrating voltage-current relationships of the DC-DC converter section in *Figure 1*;

Figures 3A, 3B, 4A, 4B, 5A and 5B are waveform diagrams showing discharge currents supplied to a spark gap in the spark igniter of this invention and the prior art; and

Figures 6A and 6B are circuit diagrams each illustrating a modification of the embodiment shown in *Figure 1*.

A circuit of an embodiment of this invention shown in *Figure 1* comprises, an ignition coil 3 with a primary winding 1 and a secondary winding 2, a DC source 4 supplying a current to the primary winding 1, spark gaps 5 (constituted by spark plugs) to which a high voltage induced across the secondary winding 2 is applied through a distributor 21, a capacitor 6 connected in series with the primary winding 1, a contact breaker 7 connected in parallel with the capacitor 6, (which may be in parallel with a diode 25 as shown in *Figure 6B*) and a DC-DC converter. This DC-DC converter is formed by primary windings 8 and 8a,

secondary windings 9 and 9a, an output winding 10, a feedback winding 11, transistors 12 and 12a each having a collector connected to one terminal of the primary winding 8 or 8a, a base connected to one terminal of the secondary winding 9 or 9a and an emitter commonly connected to a DC power source 14 of the converter, a resistor 15 connected between the emitters and a point to which the other terminals of the secondary windings 9 and 9a are commonly connected, a resistor 16 connected between the above connection point of the secondary windings 9 and 9a and a common connection point of the primary windings 8 and 8a, a bridge rectifier 17 with a pair of input terminals connected across the feedback winding 11 and a pair of DC output terminals respectively connected to the common connection point of the windings 8 and 8a and the source 14 through a safety switch 13, a reactance element 18 (e.g. a capacitor in *Figure 1*) connected in series between the feedback winding 11 and the rectifier 17, a bridge rectifier 19 with input terminals connected across the output winding 10 and output terminals connected in series with the secondary winding 2 of the ignition coil 3, and a smoothing capacitor 20 connected across the output of the rectifier 19.

It is apparent that the DC-DC converter of this embodiment is characterized by the feedback winding 11, associated circuit elements and wirings, while other parts are substantially the same as those in conventional ones.

When the engine starts, the negative pressure produced in the engine closes the safety switch 13 to make either the transistor 12 or 12a conductive as mentioned below. If the transistor 12 is made conductive, a primary current from the battery 14 flows through the safety switch 13, the rectifier 17, the primary winding 8 and the collector-emitter path of the transistor 12, so that voltages are induced across the secondary windings 9 and 9a. The induced voltage across the winding 9 biases the transistor 12 in the forward direction, while the voltage across the winding 9a biases the transistor 12a in the backward direction. With this biasing, a positive feedback loop suddenly saturates the transistor 12. The current in the primary winding 8 excites the iron core and, when the magnetic flux density saturates in the core, no voltage appears across the secondary winding 9. In such a condition, the transistor 12 carries no base current so that the collector-emitter path thereof is cut-off. The magnetic flux in the core then begins to decrease and increasing reverse voltages are induced across the secondary windings 9 and 9a, providing the forward bias for the transistor 12a. The

primary current then flows in a loop including the power source 14, the switch 13, the rectifier 17, the primary winding 8a and the transistor 12a, so that a positive feedback similar to that mentioned above is established to saturate the transistor 12a. The excitation of the core increases until the magnetic flux density is saturated at the reverse direction. In this manner, the two transistors 12 and 12a become conductive alternately, so that an alternating voltage of rectangular form is induced across the output winding 10. The alternating voltage is rectified by the output rectifier 19 and serially added to the high voltage across the secondary winding 2 of the ignition coil 3. On the other hand, an alternating current of rectangular waveform generated at the feedback winding 11 is fed through the capacitor 18 to the rectifier 17, which provides a DC output voltage to be added to the voltage of the source 14 at the same polarity.

A curve 'A' shown in Figure 2 shows the voltage-current relationship of the DC-DC converter of Figure 1. In Figure 2, the increase of the load current causes decrease of the output DC voltage toward a given value E_0 , which is almost equivalent to the output DC voltage of the DC-DC converter after eliminating the feedback winding 11. For the convenience of comparison, a curve B illustrates the relationship between output DC voltage and load current of a converter having an AC feedback loop in the absence of the capacitor 18 and the rectifier 17 connected to the feedback winding 11.

As understood from the above description, the DC-DC converter to be used in the present invention has a drooping characteristic, the voltage rapidly decreasing as the load current increases. At the beginning of the discharge at the spark plug 5, the voltage generated by the DC-DC converter is superposed on the high voltage induced across the secondary winding 2 of the ignition coil 3 to provide a sufficiently high voltage, and the resultant high voltage is fed to the plug 5 to ensure the firing there. This results in a fact that the ignitability of the spark plug 5 is increased. When the discharge once starts at the spark plug 5, the voltage across the plug 5 decreases rapidly as the discharge current increases, so that the spark discharge at the plug 5 is stabilized. Moreover, the auxiliary source comprising a DC-DC converter with a feedback function increases the magnitude and duration of the discharge current and therefore ensures extinction of discharge (i.e. breaking the current) at closure of the breaker point 7.

In Figures 3A, 3B, 4A and 4B discharge currents produced by an ignition circuit which has an auxiliary source according to the invention are plotted in comparison with those produced by a circuit utilizing an

ordinary low impedance auxiliary source which may be obtained by rectifying the commercial alternating current. Changes of the discharge current I at the spark plug 5 in the air are plotted with the time scale t . In this case, the circuit shown in Figure 1 is used, and values of the circuit elements are determined as follows: capacitors 18 and 20 are of 220 μ F and 0.047 μ F, respectively, and the engine's speed is 2,000 RPM. Figures 3A and 4A were obtained from commercial AC rectification source, and Figures 3B and 4B were obtained from the feedback type DC-DC converter according to this invention. In Figure 3A, the output voltage of the auxiliary source is varied from 0 (curve 1a) to 1,500 volts (curve 6a), and in Figure 3B the output voltage of the DC-DC converter is varied from 0 (curve 1b) to 2,800 volts (curve 6b). In Figure 3A, increase of the output voltage of the auxiliary source largely extends the spark discharge duration. At the voltage of 1,500 volts (curve 6a), the spark discharge grows with time lapse and hence it is instable. Moreover, closure of the breaker point 7 cannot perform complete extinction of the arc, and in this condition proper ignition cannot be obtained. Therefore, in this case, establishment of the voltage of the auxiliary source is critical and very difficult. On the contrary, in Figure 3B all spark discharge curves have similar and stable traces within the wide voltage range of the auxiliary source, so that stable spark discharge is obtained and a perfect extinction function is realized when the breaker point 7 is closed. In the examples shown in Figures 4A and 4B, sizes of spark gaps are distributed from 11 millimeters (curve 1c) to 5 millimeters (curve 7c), while the voltage of the auxiliary source in Figure 4A is 1,250 volts, and the voltage of the converter source in Figure 4B is 12 volts. In Figure 4A, discharge durations widely vary with their gap sizes, but in Figure 4B discharge durations vary only in a narrow limited range. In Figure 4B, the output voltage of the DC-DC converter changes from about 3,000 volts to 2,600 volts at the beginning of discharge depending upon the gap variation.

Figures 5A and 5B are diagrams illustrating the effect of the feedback circuit in the DC-DC converter according to this invention. The diagrams illustrate current wave forms for an engine speed of 750 RPM, and the spark gap discharge are 10 millimeters (curves 1e, 1f) or 6 millimeters (curves 2e, 2f). In Figures 5A, the ordinate and the abscissa are the discharge current and the duration, respectively, and curves were obtained by an auxiliary source without any feedback loop, and the durations fluctuate to a large extent in dependence on the change of gap sizes. On the other hand,

Figure 5B shows those obtained by the auxiliary source with the feedback loop according to this invention, and only a little change is found in the discharge current and in the duration due to the variation of gap distance.

As understood from the above description, the auxiliary source of the present invention operates at a light load as a constant current source which provides a high output voltage and a high source impedance, but operates at a heavy load as a constant voltage source providing a low output voltage and a low impedance, which render itself most suitable for use together with such a load as a spark gap having a complex characteristic impedance. To obtain the drooping output voltage characteristic, the converter of this invention employs a reactance element and a feedback loop, while the conventional converter employs a high series resistance, and hence the converter of this invention has a smaller power consumption in comparison with the conventional one, providing a high efficiency.

In the above embodiments, the reactance element serially inserted in the feedback circuit may be a capacitor of the order of several hundred micro farads, which sometimes has insufficient durability because of the large internal heating, therefore a parallel connection of an inductor and a capacitor shown in Figure 6A is more suitable for the serial reactance element. According to our test, Figures 3B, 4B and 5B roughly approximate the curves of the discharge currents generated by the DC-DC converter employing a reactance element formed by a parallel connection of a coil and a capacitor in a case where the values of the coil and the capacitor are of about 100 μ Henrys and 0.1 μ Farads, respectively. A test on a rotary engine equipped with this invention including the latter type of reactance element was performed under the following conditions: the primary main jet of the carburetor was throttled to a size of 0.084 millimeters in diameter to reduce the amount of gasoline supplied (its standard size being 0.094 mm.). The air inlet (i.e. the air bleed) was expanded from 0.08 mm. 0.090 mm. in diameter to increase the air flow. The result of the test indicated that the rotary engine had substantially the same drive-ability, durability, misfiring and output as those of standard ones. Accordingly, the auxiliary source of the present invention permits operation of an engine with a lower air-fuel ratio and yet minimizes the specific fuel consumption and noxious exhaust of the engine.

WHAT WE CLAIM IS:-

1. A spark ignition circuit comprising a contact breaker in series with a primary

winding of an induction coil of which the secondary winding is in series with a spark gap, and an auxiliary DC power source which has output terminals in series with the said secondary winding and the spark gap, the auxiliary source comprising a DC to DC converter, in which an input direct voltage is converted to an alternating signal and this signal is transformed and rectified to provide an output at said terminals, which converter includes a feedback loop which produces decrease of the auxiliary source's output voltage for an increase in its output current.

2. A spark ignition circuit according to claim 1, in which the feedback circuit includes a rectifier fed by a secondary winding of a transformer for the said alternating signal, and a passive reactive element disposed in series between this latter secondary winding and the said rectifier.

3. A spark ignition circuit according to claim 2, in which the said element comprises a capacitor.

4. A spark ignition circuit according to claim 3 in which the said capacitor is disposed in parallel with an inductor.

5. A spark ignition circuit according to any foregoing claim, in which a capacitor and diode are connected each in parallel with the contact breaker.

6. A spark ignition circuit substantially as hereinbefore described with reference to Figure 1 or Figure 1 as modified by either Figure 6A or Figure 6B of the accompanying drawings.

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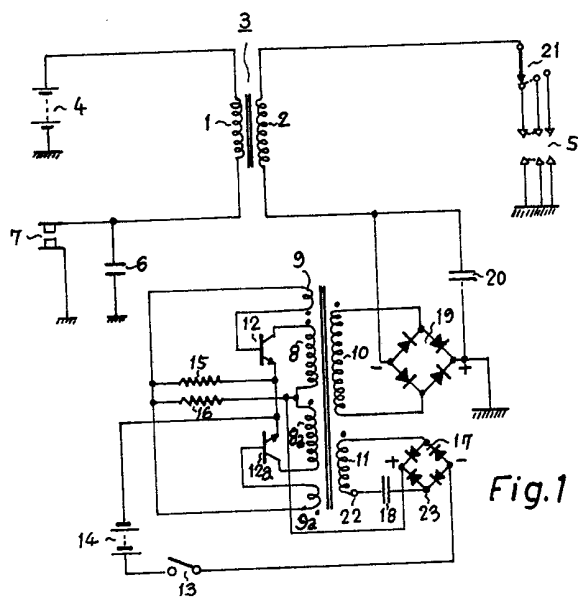


Fig. 1

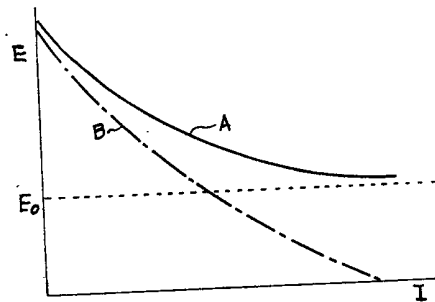
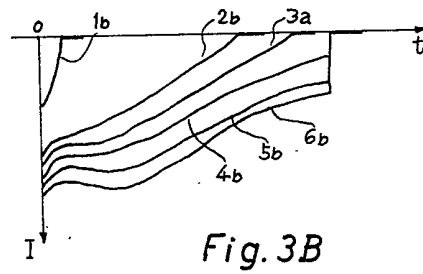
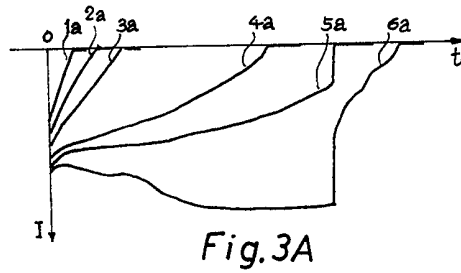


Fig. 2



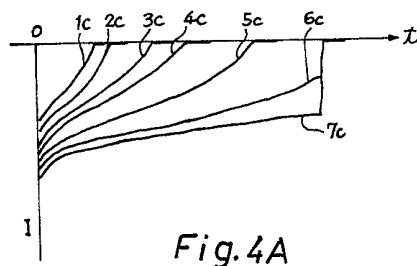


Fig. 4A

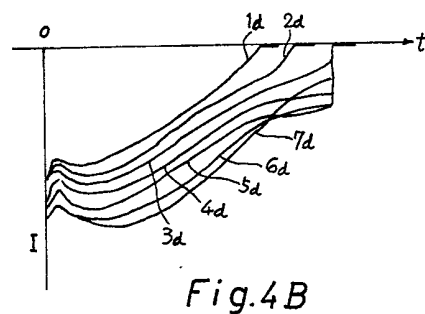


Fig. 4B

