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[54] **IGNITION-TIMING APPARATUS**
10 Claims, 1 Drawing Fig.

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[50] Field of Search ...... 123/148 AC, 148 E, 149

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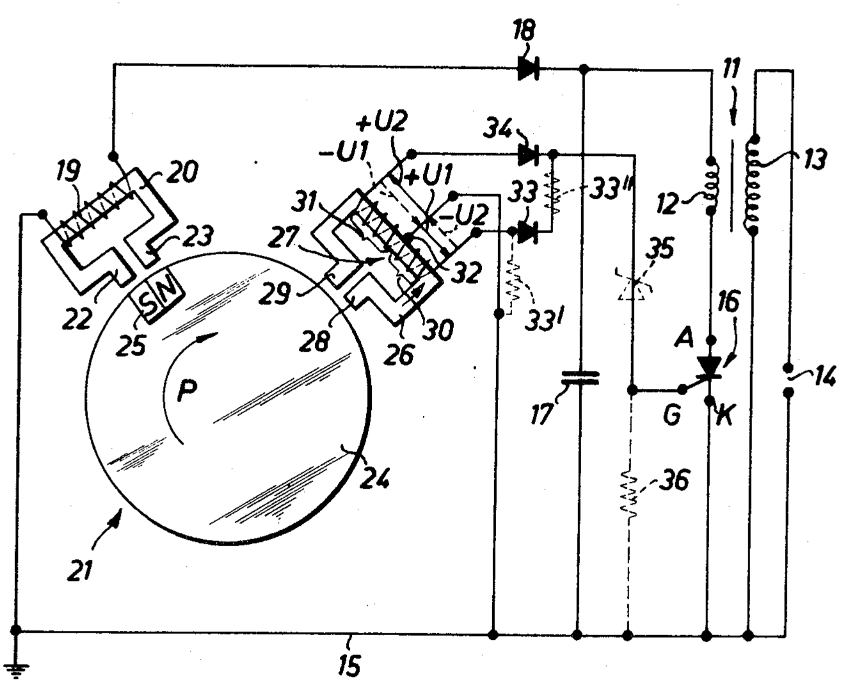
ABSTRACT: Two electrically different windings are successively influenced by a magnetic flux and generate different successive voltage pulses, of which the first generated pulse has a lower peak value. The pulses are transmitted to the control electrode of an electronic switch which controls an ignition coil and a spark plug. At low-starting speeds, the first voltage pulses are below the threshold voltage of the switch so that the spark is caused later by the second voltage pulse. At the high-normal speed of the combustion engine, the first voltage pulse exceeds the threshold voltage, and the spark is earlier produced.



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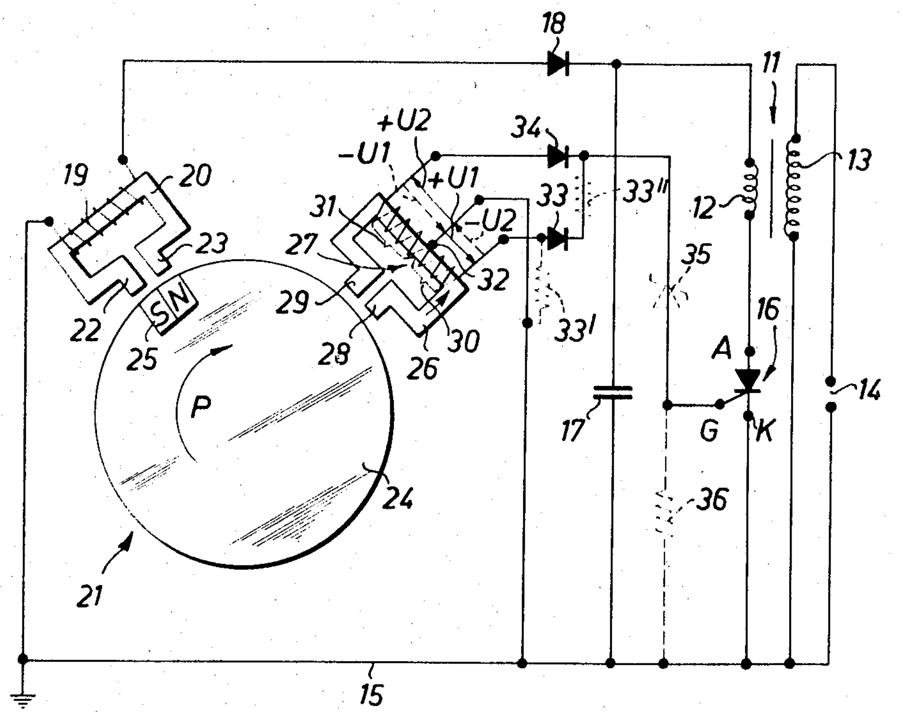

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IGNITION-TIMING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an ignition-timing apparatus for a combustion engine which automatically effects an early spark when the combustion engine operates at full speed, and effects a delayed spark during starting of the combustion engine at lower speeds. It is known to control the primary winding of the ignition coil by an electronic switch which is connected in series with the primary winding, and such an arrangement has the advantage that mechanical switches are eliminated which due to inertia do not fully satisfactorily operate at high numbers of revolutions of the combustion engine. Furthermore, mechanical switches become soiled, and the contacts are worn off so that a perfect operation of the ignition timing apparatus is no longer assured.

The British Pat. No. 1,096,212 discloses an ignition control apparatus of this type, in which a control winding is connected at one end with the control electrode of an electronic switch, and at the other end with the base of the electronic switch. The spark is generated in the same position of the piston of the combustion engine, independently of the number of revolutions of the same. Since the combustion of the compressed air fuel mixture requires a certain time, the igniting of the combustible mixture takes place too late when the combustion engine operates at high rotary speed, so that high efficiency and output cannot be obtained.

SUMMARY OF THE INVENTION

It is one object of the invention to provide an ignition-timing apparatus which is free of the disadvantages of the prior art, and produces a spark earlier when the combustion engine operates at high speed, and later when the combustion engine operates at low speed, for example during starting operations.

Another object of the invention is to provide an electronic circuit, free of mechanical switches, for controlling the timing of the ignition sparks in relation to the piston movements and rotation of the crankshaft of the combustion engine.

With these objects in view, the invention provides a control device including two electrically different and nonequivalent control circuits including control windings which have a common connecting point and are wound in opposite directions on an iron core, while the outer ends of the control windings are connected with the control electrode of an electronic switch, preferably by a pair of diodes permeable for control voltage pulses. The voltage half-waves, whose polarity is suitable for the operation of the electronic switch, which are generated and induced in the control windings, include voltage half-waves generated by the first winding and voltage half-waves generated by the second winding later than the first half-waves. The first-generated half-waves, forming voltage pulses, have a lower peak voltage than the later generated half-waves and voltage pulses, so that they are not effective at low starting speeds of the combustion engine, but are effective when the combustion engine operates at full speed. The second generated half-wave forms a voltage pulse which is later supplied to the control electrode of the electronic switch, but has a higher peak voltage so that it is effective during the low starting speeds of the combustion engine before the first voltage pulse has a sufficient voltage to cause a spark.

One embodiment of the invention comprises an electronic switch including a first terminal connected with the primary winding of an ignition coil whose secondary winding is connected with a spark plug, a second terminal, and a control electrode responsive to voltages having at least a minimum threshold voltage to render the switch conductive between the first and second terminals for energizing the primary winding; means for applying a voltage to the primary winding and the second terminal of the switch, preferably including a capacitor and means for charging the same; a control device including two electrically different first and second control circuits respectively including first and second windings, and diode means connected to the control electrode, the first and second control windings being wound in opposite directions and having a pair of ends connected to each other and to the second terminal of the electronic switch, and having a pair of other ends connected with the diode means; and means for moving the flux-generating means and the control winding relative to each other in timed relation with the movements of the combustion engine so that the first and second control windings are successively influenced by the flux whereby different voltage pulses are successively generated in the first and second control circuit and transmitted to the control electrode.

The voltage pulse first generated in the first control winding is below the threshold value of the control electrode at starting speeds of the combustion engine, and above the threshold voltage at normal speeds, and the voltage pulse later generated in the second control winding is above the threshold value at starting speeds.

As a result, the electronic switch becomes earlier conductive at the normal speed under the control of the first control circuit and earlier causes a spark of the spark plug, than under the control of the second control circuit at the low starting speeds of the combustion engine.

In order to render the control circuits different, and nonequivalent, the first and second control windings may be coils having different numbers of turns, or be made of wires having different electric resistances, or the wires may have different cross sections. However, it is also possible to use identical coils, and include a resistor into one of its control circuits, or connect two diodes with the first and second windings, and connect the outputs of the diodes by a resistor.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE of the drawing is a schematic and diagrammatic view illustrating an embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The spark plug **14** is mounted in the cylinder of a combustion engine, not shown, and has one electrode connected to ground, and another electrode connected with one end of the secondary winding **13** of an ignition coil **11** which has a primary winding **12**. The other end of the secondary winding **13** is connected to ground. The primary winding **12** is connected in series with the terminals A and K of an electronic switch **16** whose terminal K is connected to ground. A capacitor **17** is connected in parallel with the primary winding **12** and the electronic switch **16**, and has one terminal connected to ground **15** and another terminal also connected with a diode **18** which permits the passage of positive voltage pulses and is connected with one end of a charging winding **19** whose other end is connected to ground **15**. Charging winding **19** is wound on a core **20** which has two parallel poles **22** and **23** which are radially directed toward a rotary member **24** which carries a permanent magnet **25** having a north pole and a south pole arranged to cooperate with poles **22** and **23** during rotation of the member **24**. Members **24** and **25** form a flux-generating system **21** which rotates in timed relation with the rotation of the crankshaft of the combustion engine, not shown. During operation of the combustion engine, permanent magnet **25** passes poles **22** and **23** so that charging pulses are generated in winding **19** and supplied through diode **18** to capacitor **17** for charging the same.

The electronic switch **16** is preferably a thyristor which responds to a voltage pulse to control electrode G to become conductive between the terminals A and K so that the capacitor **17** discharges through the primary winding **12**, and causes a spark between the electrodes of the spark plug **14**. The controlling voltage pulse is positive, and generated in the control winding means 27 which includes two control windings 30 and 31 wound on a core 26 which has poles 28 and 29 cooperating with the magnet 25 of the rotating flux-generating system 21.

Since poles 28, 29 follow poles 22, 23 in the direction P of rotation of member 24, permanent magnet 25 first generates a charging impulse in the winding 19 so that capacitor 17 is charged, and then generates a flux in poles 28 and 29 and core 26 for generating control pulses in windings 30 and 31.

Windings 30 and 31 are electrically different and nonequivalent. For example, winding 30 may have fewer turns than winding 31, or be wound of a wire having a higher resistance. Windings 30 and 31 are electrically different wound along a straight core portion of core 26 and have adjacent ends connected to each other at a point 32 which is connected to ground, and consequently to the terminal K of the electronic switch 16. Windings 30 and 31 are wound in opposite directions, and have outer ends respectively connected with diodes 33 and 34 which permit the passage of positive voltage pulses. The diodes 33 and 34 are connected to each other and to the control electrode G of the electronic switch 16.

Electronic switch 16 has a threshold voltage. If control pulses arriving at control electrode G are below the threshold voltage of electronic switch 16, the same will not fire. A certain minimum voltage pulse is required at control electrode G to render electronic switch 16 conductive between terminals A and K. The winding 30 is so dimensioned that the voltage pulse generated in the same during operation of the combustion engine and of rotary member 24 at low starting speeds, has a voltage which is too low to exceed the threshold voltage of control electrode G and electronic switch 16. At the higher normal speed of the combustion engine, the flux generating means 24, 25, 21 also operate at higher speed, and the voltage of the pulse generated by winding 30 is sufficient to exceed the threshold value of the switch 16, so that the same becomes conductive, and permits discharge of capacitor 17 which results in a spark at the spark plug 14.

The winding 31 is designed so that a voltage pulse exceeding the threshold voltage of switch 16 is generated during passage of permanent magnet 25 even at low starting speeds.

The lower voltage of the control pulse generated in winding 30 as compared with the higher voltage of the pulse generated in winding 31, is due to the fact that the control circuits 30, 33 and 31, 34 are electrically different and nonequivalent. For example, control winding 30 may have fewer windings than control winding 31, and/or winding 30 may consist of a wire having a lower conductivity than the wire of winding 31, and/or the winding 30 may be wound of a wire having a smaller cross section than the wire of which winding 31 is wound. Furthermore, the nonequivalency of the control circuits 30, 33 and 31, 34 may be obtained by a resistor 33′ connected in parallel with winding 30, or by a resistor 33″ connected in series with control winding 30. If resistor 33′ is used, diode 33 may be omitted, and the respective control circuit include only the winding 30 and resistor 33″.

Resistors 33′ and 33″ are shown in broken lines since they represent modifications which may be used in addition to the control circuits shown in solid lines.

In any event, in accordance with the invention, two control circuits which respectively include the windings 30 and 31 successively generate voltage pulses having half waves having different peak values, and a polarity suitable for controlling the electronic switch 16 to whose control electrode G the pulses are transmitted.

Resistor 33″ is preferably temperature responsive so that it can be used for controlling the temperature of the combustion engine, not shown. If required, the resistors 33′ and 33″ may be constructed as adjustable resistors.

If necessary, control windings 30 and 31 are connected by a common Zener diode 35 with control electrode G of electronic switch 16, while a resistor 36 is connected in parallel with control electrode G and the grounded terminal K.

OPERATION

When the combustion engine is started, and the disc 24 of the flux generating system 21 moves in the direction of the arrow P with permanent magnet 25 past poles 22, 23 of core 20, a voltage is generated whose positive half-waves charge through diode 18 capacitor 17.

When the flux-generating system 21 continues its rotation, permanent magnet 25 passes the poles 28 and 29 of core 26 so that a magnetic flux created in core 26 and in windings 30, 31 first increases and then decreases. During the increase of the magnetic flux in core 26, a positive voltage half wave plus U1 is generated in winding 30, and a negative voltage half-wave minus U1 is generated in winding 31, the polarity of the half-waves being considered in relation to the connecting point 32 of windings 30 and 31. The decrease of the magnetic flux during further movement of permanent magnet 25, generates in winding 30 a negative voltage half-wave minus U2, and in winding 31, a positive voltage half-wave plus U2, also considered in relation to the connecting point 34. For operating the electronic switch 16 by voltage pulses transmitted to its control electrode G, only the positive polarity of the voltage pulses is useful, so that only the positive half-wave U1 of winding 30, and the following voltage half-wave plus U2 of winding 31 are effective. Diodes 33, 34, which form control circuits with windings 30, 31, assure that only positive voltage half-waves plus U1 and plus U2 are supplied to the control electrode G of switch 16. The diodes 33, 34 have the additional purpose of separating control windings 30 and 31.

As explained above, the electronic switch 16 has a threshold voltage, and becomes conductive only if a positive voltage pulse exceeding the threshold voltage is transmitted to control electrode G. In order to set the threshold value of switch 16 particularly accurately, the Zener diode 35 and resistor 36 may be added to the circuit, as shown in broken lines.

The voltage half-wave plus U2 generated in control winding 31 has a peak value which is higher than the threshold voltage of the electronic switch 16 even at the lowest starting speeds. However, the peak value of the voltage half-wave plus U1 of winding 30 is located below the threshold voltage of switch 16 at the low starting speeds.

Consequently, during operation of the combustion engine, and corresponding rotation of the flux generating system 21, at low starting speeds, the pulses generated in winding 30 have no effect, but the directly following pulse generated by winding 31 is sufficiently high to cause discharge of capacitor 17 through the primary winding and switch 16 for creating a spark at spark plug 14.

When the number of revolutions of combustion engine increases while the fuel mixture is ignited under the control of voltage pole pulses generated in winding 31, the flux generating system 21 also increases its speed so that the rising and falling of the magnetic flux in core 26 takes place at the higher speed, whereby the peak values of the voltage half-waves generated in control windings 30 and 31 are also increased. At a certain normal rotary speed of the combustion engine and of the flux-generating means 21, the peak value of the voltage half-wave plus U1 generated in winding 30 will exceed the threshold voltage of the electronic switch 16, and the voltage pulse supplied from winding 30 through diode 33 to control electrode G, will no longer be ineffective, and will render electronic switch conductive between terminals G and K so that the ignition coil 11 is energized and creates a spark at spark plug 14.

The voltage pulse plus U1 is generated before the voltage pulse plus U2, so that the latter is ineffective since the electronic switch 16 is already conductive when a voltage pulse plus U2 is transmitted to control electrode G.

Consequently, the later generated control pulse plus U2 is effective at low starting speeds, and the earlier generated control pulse plus U1 is effective at higher normal speeds, which means that ignition takes place sooner in the cycle of the piston of the combustion engine at the high normal speed, than at the low starting speeds.

When electronic switch **16** becomes conductive between terminals A and K, the capacitor **17** discharges through primary winding **12** so that a high-voltage pulse is generated in the secondary winding **13** which causes a spark of spark plug **14** by which the compressed air-fuel mixture in the cylinder of the combustion engine, not shown, is ignited until the predetermined normal speed of the combustion engine is reached. The positive voltage half-wave plus U2 of control winding **31** controls the ignition, and the spark is created when the piston is at, or shortly below the upper dead center in the cylinder. When the combustion engine has reached the predetermined speed, or exceeded the same, the earlier generated voltage half-wave plus U1 of control winding **30** becomes effective to fire the electronic switch **16**, so that the spark of the spark plug **14** ignites the fuel-air mixture when the piston is still a greater distance from the upper dead center position.

The time difference between the creation of sparks at different speeds of the combustion engine, is determined by the dimension, position, and construction of the flux generating system **21**, and of the core **26** of the two control windings **30** and **31**.

For the sake of simplicity, the ignition-timing apparatus of the invention has been described in relation to a single spark plug. It is self evident, that the secondary winding **13** of the ignition coil **11** can be used for supplying high-voltage pulses to the spark plugs of several cylinders by means of a distributor, not shown. Such an arrangement requires that for one revolution of the crankshaft, a corresponding number of control voltage pulses is generated. This can be obtained in a simple manner by a transmission, not shown, between the crank shaft of the combustion engine, not shown, and the rotary flux-generating system **21**. It is also possible to provide a plurality of control devices about the periphery of flux-generating system **21**, each including a core **26**, and windings **30** and **31** together with diodes **33** and **34** connected with the control electrode G of electronic switch **16**.

In the illustrated embodiment, the flux-generating system **21** rotates with the crank shaft of the combustion engine, and the control device **26** to **34** is stationary. It is, of course, also possible to provide a stationary permanent flux-generating magnet **25**, and to rotate the charging device **19** to **23**, and the control device **26** to **32** relative to permanent magnet **25**, and in timed relation with the crank shaft of the combustion engine.

The automatic ignition timing adjustment in accordance with the invention can also be applied to an apparatus in which the capacitor is charged by a source of direct current through a direct current voltage transformer. It is also possible to interrupt at the ignition moment, the circuit of primary winding **12** of the ignition coil **11** by a transistor forming an electronic switch, preferably connected in series with a monostable multivibrator.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of ignition-timing apparatus for combustion engines differing from the types described above.

While the invention has been illustrated and described as embodied in a control device including two control circuits for successively generating voltage pulses having different peak values and controlling the generation of igniting sparks in a combustion engine, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

We claim:

1. Ignition timing apparatus for a combustion engine having at least one spark plug, comprising, in combination, ignition coil means including a primary winding, and a secondary winding connected with said spark plug; an electronic switch including a first terminal connected with said primary winding, and a second terminal, said switch being connected in series with said primary winding and having a control electrode responsive to voltage pulses having at least a minimum threshold voltage to actuate said switch for creating an impulse in said primary winding causing a spark; means for applying a voltage to said primary winding and said second terminal of said switch; a control device including two electrically different first and second control circuits respectively including first and second control windings, and diode means connected to said control electrode, said first and second control windings being wound in opposite directions and having a pair of ends connected to each other and to said second terminal, said second terminal being at ground potential, said first and second control windings having a pair of other ends connected with said diode means, said diode means being connected between said other ends of said control windings and said control electrode of said electronic switch; flux generating means; and drive means for moving said flux generating means and said control windings relative to each other in timed relation with the movements of said combustion engine so that said first and second control windings are successively influenced by the flux whereby different voltage pulses are successively generated in said first and second electrically different control circuits and transmitted to said control electrode, the voltage pulse first generated in said first control winding being below said threshold voltage of said control electrode at starting speeds of said combustion engine and of said drive means and above said threshold voltage at normal speed, and the voltage pulse later generated in said second control winding being above said threshold voltage at starting speeds so that said electronic switch is earlier actuated at said normal speed under the control of said first control circuit and earlier causes a spark of said spark plug than under the control of said second control circuit at the low starting speeds of said combustion engine.

2. Apparatus as claimed in claim **1** wherein said control device includes a core on which said first and second control windings are wound in opposite directions, said control windings having connected inner adjacent ends and other ends outwardly spaced from said inner ends so that during said relative movement positive and negative half-waves are generated in said first and second windings; and wherein said diode means include first and second diodes connecting said control electrode with said other ends of said control windings so that only positive half-waves pass through said first and second diodes to said control electrode, the half waves generated in said first control winding having a lower peak voltage than the half-waves generated in said second control winding at the same speed of said combustion engine.

3. Apparatus as claimed in claim **1** wherein said first and second control windings are coils having different numbers of turns.

4. Apparatus as claimed in claim **1** wherein said first and second control windings are made of different wires having different electric resistances.

5. Apparatus as claimed in claim **1** wherein said first and second control windings are made of different wires having different cross sections.

6. Apparatus as claimed in claim **1** wherein at least one of said first and second control circuits includes a resistor.

7. Apparatus as claimed in claim **1** comprising a Zener diode connected between said diode means and said control electrode; and a resistor connected between said control electrode and said second terminal.

8. Apparatus as claimed in claim 1 wherein said electronic switch has a normal nonconductive condition, and becomes conductive when actuated by a voltage pulse above said threshold voltage so that a pulse flows through said primary winding.

9. Apparatus as claimed in claim 1 wherein said means for applying a voltage includes a capacitor connected in parallel with said primary winding and said switch; and means for charging said capacitor including a permanent magnet rotating in timed relation with said combustion engine, a charging winding periodically energized by said rotating permanent magnet, and a diode connecting said charging winding with said capacitor.

10. Apparatus as claimed in claim 1 wherein said flux generating means includes a permanent magnet; and wherein said means for moving said flux-generating means includes a member carrying said permanent magnet and being rotatable in timed relation with said combustion engine, said permanent magnet moving past said first and second control windings for successively generating in the same said different voltage pulses.

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