United States Patent

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[54] SPARK ADVANCE MECHANISM FOR SOLID STATE IGNITION SYSTEMS

6 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** ..... **123/148 E,** 123/149, 310/159
[51] **Int. Cl.** **F02p 3/04**
[50] **Field of Search** ..... 123/148 AC, 148 E, 149, 149 D; 310/159

[56] **References Cited**

UNITED STATES PATENTS

2,446,671	8/1948	Short et al.	123/148 E
3,277,875	10/1966	Miki	123/148 E
3,447,521	6/1969	Pifeo	123/148 E
3,465,739	9/1969	Burson	123/148 E X
3,490,426	1/1970	Farr	123/148 E X

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ABSTRACT: A spark advance mechanism for an internal combustion engine is included in a variable reluctance voltage generator comprised of a magnet embedded in a member rotating in synchronism with the engine which moves the magnet passed a sensor coil having a shaped core. When the voltage generated in the sensor coil by the rate of change of flux from the magnet rises to a given threshold amplitude it triggers an ignition circuit thereby producing a spark to ignite fuel in the engine. Spark advance is accomplished by varying the rate of change of flux through selectively shaping the portion of the core which is adjacent to the path of the magnet.

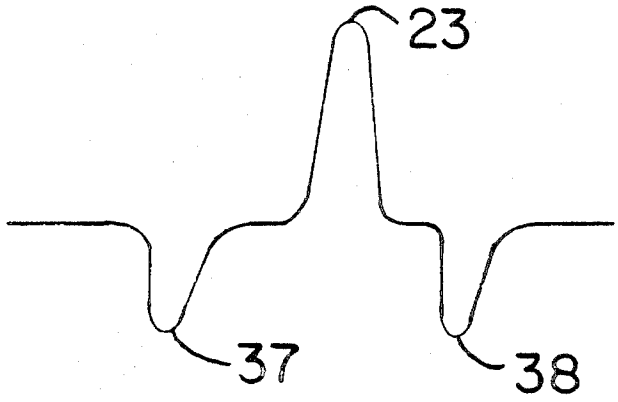


FIG. 3

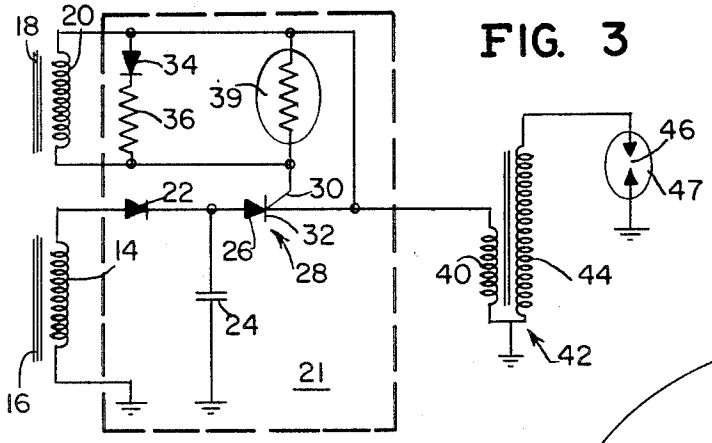


FIG. 1

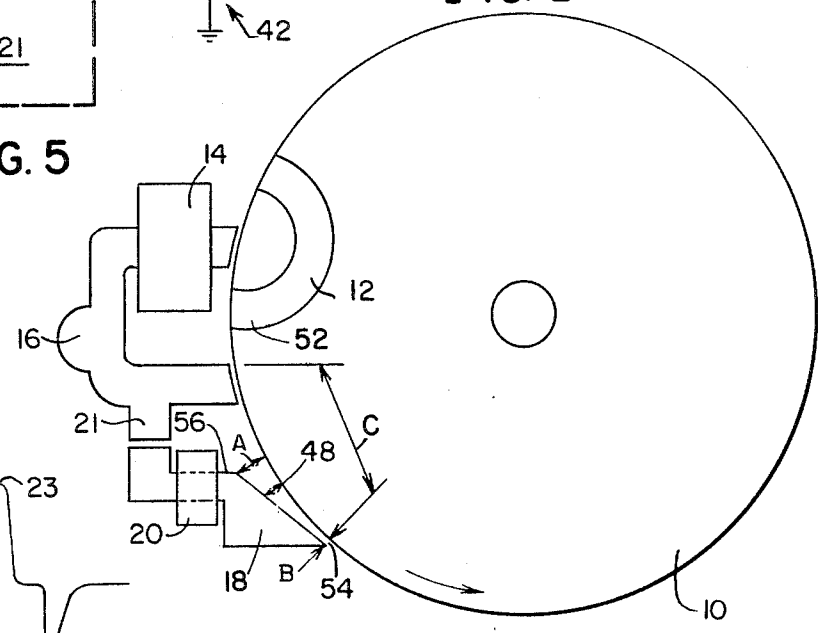


FIG. 5

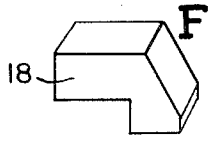


FIG. 2

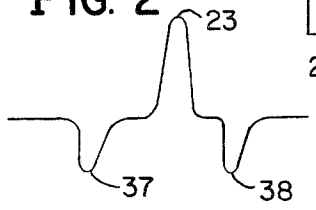
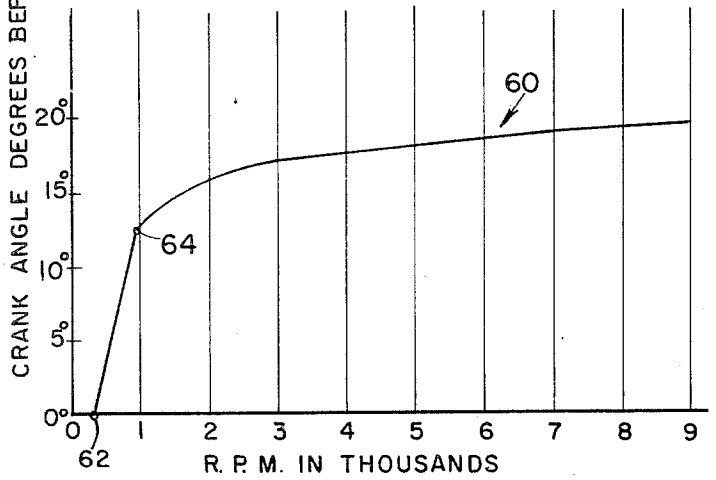


FIG. 4



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SPARK ADVANCE MECHANISM FOR SOLID STATE IGNITION SYSTEMS

BACKGROUND OF THE INVENTION

Breakerless capacitor discharge ignition systems utilizing solid state devices in place of prior art mechanical breaker points have been proposed for use in many types of internal combustion engines. Contact burning and timing drift which plague the prior art systems are representative of the problems eliminated by these breakerless systems. Electronic spark advance mechanisms with no moving parts in contact with each other have also been designed to further improve the breakerless ignition systems by replacing mechanical spark devices.

One of these electronic spark advance mechanisms is built into a variable reluctance voltage generator wherein a shaped reluctance segment, fastened to and rotated with the flywheel of an internal combustion engine, shifts the rate of change of magnetic flux in a magnetic pickup thereby generating a voltage pulse in coincidence with each revolution of the flywheel. The rotational positions of the flywheel when each of these pulses occur varies as a function of the angular velocity of the flywheel because of the spaced reluctance segment. When each of these subsequent voltage pulses reaches a threshold or trigger amplitude, it activates circuit elements in an ignition circuit which discharge an ignition capacitor through an ignition transformer thus providing a high tension igniting spark in a spark plug.

The magnetic pickup of the generator is comprised of a permanent magnet fixed in abutting relation to a core which is part of a flux path including an airgap through which the spaced segment is moved. Also included in the magnetic pickup is a coil electrically coupled to the flux so as to develop the trigger or voltage pulses in response to the rate of change thereof.

Problems inherent in the construction of this magnetic pickup, however, reduce its reliability and the adaptability of the spark advance mechanism. One particular problem relates to mechanically fixing the magnet to the core of the coil. Sometimes the magnet is held to the core by a clip or by an adhesive either of which tends to weaken with age and heat. The magnet, consequently, can be vibrated loose thereby reducing the longivity and reliability of the ignition system. Furthermore, while designing or improving the ignition system it is often desirably to modify the spark advance characteristic of the generator. In the foregoing prior art embodiment it may be necessary to disassemble the engine and remachine the flywheel and the shaped reluctance segment to accomplish the desired modification.

SUMMARY OF THE INVENTION

An object of one embodiment of the invention is to provide an improved mechanism for electronically advancing ignition sparks for use by an ignition system.

Another object is to provide an ignition system having a spark advance mechanism which reliable, easy to install, and contains a minimum number of parts.

The improved spark advance mechanism of one embodiment of the invention is included in a variable reluctance voltage generator which supplies pulses to trigger a capacitor discharge ignition circuit. The components of the ignition circuit respond at a threshold amplitude of each pulse to discharge an ignition capacitor through an ignition transformer connected to a spark-producing device for providing a spark which ignites fuel in the engine. This voltage generator includes a magnet fastened to a rotatable member synchronized with the engine and a sensor coil wound on a core of low reluctance material having a shaped portion adjacent to the path of the magnet. The changing flux from the magnet flowing through the core produces a trigger pulse in the sensor coil which has an amplitude proportional to the rate of change of flux. As the magnet passes the core the shaped portion thereof provides a gap between it and the magnet

which varies at a rate depending on the speed of the magnet thus changing the reluctance and magnetic flux through the core at a predetermined rate for a given angular velocity of the rotatable member. The rate of change of magnetic flux is, consequently, a function of both the angular velocity of the rotating member and the shape of the gap. The amplitude of each trigger pulse, therefore, rises to the firing amplitude at a rotational position of the magnet which varies with the angular velocity of the rotatable member and the shape of the core to produce spark advance. The placement and shape of the core can be conveniently tailored to provide different spark advance versus r.p.m. characteristics for different engines and operating conditions. Since the spark advance mechanism of the preferred embodiment of the invention does not include the magnetic pickup and reluctance segment of the prior art, the problems associated therewith are eliminated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of the variable reluctance generator of one embodiment of the invention;

FIG. 2 illustrates the waveform of the voltage induced by the changing magnetic flux in the charge and sensor coils;

FIG. 3 is a schematic diagram of a capacitor discharge ignition circuit;

FIG. 4 is a graph illustrating spark advance as a function of engine r.p.m.; and

FIG. 5 shows an outline of a core for the sensor coil used in one application.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to FIG. 1, the variable reluctance voltage generator includes member 10 which is the flywheel or some other member rotating in synchronism with the internal combustion engine. Magnet 12 is embedded in or fastened to member 10 and moved therewith. Charge coil 14 and its pole piece 16 are positioned in a spaced relation to the path of magnet 12. Moreover, core 18 of sensor coil 20 is positioned in a spaced relation to pole piece 16 and the path of magnet 12. As magnet 12 is rotated in a counterclockwise direction past pole piece 16, the changing flux from the magnet passing through pole piece 16 induces an alternating voltage across charge coil 14 having the general shape of the waveform in FIG. 2. The magnet then proceeds to pass shaped core 18 to likewise induce a voltage of the shape shown in FIG. 2 across coil 20.

It should be noted that the flux path for core 18 includes the adjacent leg 21 of pole piece 16. The advantage of this structural arrangement will be subsequently pointed out.

In FIG. 3 charge coil 14 and sensor coil 20 are shown connected to ignition circuit 21. Charge coil 14 is connected between ground or a reference potential, and a rectifying diode 22 is connected thereto. The diode 22 is poled to allow the positive pulse 23 (FIG. 2) of the voltage induced in coil 14 to charge ignition capacitor 24. The capacitor 24 is connected to anode 26 of silicon-controlled rectifier (SCR) 28. Sensor coil 20 is connected across gate 30 and cathode 32 of SCR 28. The series combination of diode 34 and resistor 36 is connected in parallel with sensor coil 20 and gate cathode junction by of SCR 28. Diode 34 protects the gate cathode junction by conducting on the negative portions 37 and 38, shown in FIG. 2, of the waveform induced across sensor coil 20. Resistor 36 limits the current flow through the circuit comprised of coil 20, diode 34, and resistor 36 thus reducing hysteresis or saturation recovery problems in core 18 caused by voltage having large amplitudes which are generated at high r.p.m. of member 10.

Thermistor 39, connected in parallel with sensor coil 20, has a negative temperature coefficient. It temperature compensates for the lowering threshold or firing voltage of SCR 28 at high temperature by decreasing its resistance to the induced potential applied to the gate 30 thereby requiring correspondingly more voltage to fire the SCR. In addition, it com-

pensates for the raising threshold voltage at lowering temperature by increasing its resistance to the induced voltage in coil **20**, thereby requiring correspondingly less voltage to fire the SCR **28**. The overall result, consequently, is that the firing amplitude of the trigger voltage across sensor coil **20** remains constant with temperature even though the characteristics of SCR **28** are changing.

In operation as magnet **12** passes charge coil **14**, a positive voltage is developed across ignition capacitor **24**. An instant of time later as magnet **12** passes core **18** of sensor coil **20**, a positive voltage begins to build up between the gate and cathode of SCR **28**. When the positive voltage reaches the threshold or firing potential, the SCR conducts to discharge ignition capacitor **24** through the primary winding **40** of ignition transformer **42** thereby producing a high tension voltage in secondary winding **44** which appears across spark gap **46** of spark plug **47** to ignite fuel in the internal combustion engine.

For the internal combustion engine to operate at maximum efficiency, it is necessary for each ignition spark to occur at a variable period of time before the piston reaches top dead center (TDC). An ignition spark occurring before TDC is said to be "advanced" and the amount of advance is measured in terms of crank angle degrees before TDC. The optimum amount of spark advance for best power and minimum fuel depends on many conditions but in general it should increase as the engine r.p.m. increases.

The spark advancing function of shaped core **18** which is made of ferrite or some other low reluctance material will now be explained. Referring back to FIG. **1**, as magnet **12** approaches core **18** it reaches a point on its path where the magnetic flux therefrom encounters a gap **48** initially having the width of dimension A which diminishes to a width of dimension B. This gap deviates, therefore, at a predetermined rate for a given rate of rotation of member **10**. Since the flux through core **18** varies as the reluctance controlled by the gap width, the rate of change of flux will correspondingly vary as determined by the changing gap width for a fixed angular velocity of member **10**. The rate of change of flux also varies with the speed of magnet **12** which is controlled by the angular velocity and the diameter of member **10**.

The amplitude of the voltage produced across sensor coil **20** is proportional to the rate of change of flux. Consequently, at a slow angular velocity of member **10**, the rate of change of flux from magnet **12** might not be great enough to produce the firing amplitude across sensor coil **20** until a point in time when pole **52** of magnet **12** approaches tip **54** of the shaped core **18**. Alternatively, when member **10** is rotating at a high angular velocity the rate of change of flux, because of the increase in speed of magnet **12**, will produce the firing amplitude at a point in time when the pole **52** of magnet **12** is approaching the leading edge **56** of shaped core **18**. As a result, the amplitude of the trigger pulse in the sensor coil rises to the firing amplitude at the rotational position of magnet **12** which varies in accordance with the angular velocity of member **10** thus producing the desired spark advance.

By placing core **18** in a spaced relation to leg **21** on pole piece **16**, the total reluctance in the flux path for sensor coil **20** is reduced thus enabling the change in reluctance across varying gap **48** to be a greater proportion of the total reluctance and thereby increasing the sensitivity of the spark advance mechanism. Pole piece **16**, therefore, provides most of the flux path for charge coil **14** and a portion of the flux path for sensor coil **20**. Moreover, by utilizing pole piece **16** in this manner less overall weight is added to the generator than would be the case if an additional flux return leg was built into core **18**.

The combination of sensor coil **20** and its core **18** replace the magnetic pickup units employed in the prior art, which used a variable reluctance segment in place of magnet **12**. Reluctance gap **48** of the preferred embodiment of the invention can be easily modified by changing the shape of core **18** adjacent flywheel **10**. To modify the prior art variable reluctance generator, however, it is usually necessary to remove the flywheel from the engine and the shaped segment from the flywheel and reform both the flywheel and the segment. In addition magnet **12** of the preferred embodiment is embedded in the material of the flywheel rather than being attached to a flux core where it would be subject to vibration which might shake it loose thereby rendering the ignition system inoperative.

One particular capacitor discharge ignition system for an internal combustion engine of a chain saw utilizing the spark advance mechanism of the preferred embodiment of the invention has the following dimensions: (See FIG. **1** for the placement of core **18** with respect to the flywheel **10** and pole piece **16**.) A =0.153 inch B =0.010 inch C =1.200 inch FIG. **5** shows the actual size and shape of the ferrite core **18** for spark advance mechanism of the ignition system.

The curve of FIG. **4** shows the resulting spark advance characteristic **60** in terms of crank angle degrees before TDC as a function of r.p.m. in thousands. For the particular chain saw engine and operating conditions it is desirable for the spark advance to rapidly increase from 300 r.p.m. to 1,000 r.p.m., as shown between points **62** and **64** on FIG. **4**. Less spark advance is required and thus provided above 1,000 r.p.m. The shape and placement of core **18** was adjusted to give the desired characteristic. The scope of the invention includes tailoring the shape and placement of core **18** to give other spark advance characteristics.

What has been described, therefore, is a simple spark advance mechanism which is reliable, easy to maintain, and inexpensive. The mechanism has no moving parts in contact with each other and it can be conveniently modified to produce specific spark advance characteristics by changing the shape and spacing of the core of the sensing coil.

We claim:

1. A capacitor discharge ignition system including a pulse-actuated circuit for discharging the capacitor to fire the engine, including in combination:

pulse generator means having a rotating member, magnet means providing flux and being integral with said rotating member, said magnet means being moved by said rotating member along a predetermined path;

a first pole piece having first and second leg portions each positioned in a spaced relation to said predetermined path of said magnet means a charging coil wound about one of said leg portions whereby said magnet means passing by said pole piece completes a flux path through said magnet and said first and second leg portions of said pole piece thereby inducing a current in said charging coil for charging the ignition capacitor subsequent to the discharge thereof;

a second pole piece having a first portion positioned in a spaced relation to said predetermined path of said magnet means and a second portion extending in a spaced relation to said second leg portion of said first pole piece, a pulse producing triggering coil wound about said second pole piece;

said magnet means further completing a flux path through said second leg portion of said first pole piece, said extended second portion of said pole piece and said second pole piece to generate a pulse in said triggering coil for discharging the ignition capacitor.

2. The capacitor discharge ignition system of claim **1** wherein the pulse-actuated circuit is responsive to said pulse reaching a threshold level to discharge the ignition capacitor to produce a spark for igniting fuel in the engine, and said first portion of said second pole piece has a selectively shaped portion positioned in s spaced relation to said predetermined path of said magnet means and producing a changing gap therebetween which varies at a rate responsive to the angular velocity of the rotating member, said changing gap varying the rate of change of magnetic flux from said magnet means as said magnet means passes said shaped portion to produce said pulse in said pulse-producing triggering coil which rises to said threshold level at a rotational position of said rotating member which varies in accordance with the angular velocity thereof thus providing a selected spark advance characteristic.

3. The electronic ignition system of claim 2 wherein said selectively shaped portion of said second pole piece provides a predetermined decreasing gap between it and said magnet means as said magnet means passes said shaped portion so that the degree of rotation of said rotating member at which said pulses reach said threshold level varies with the angular velocity of said magnet means to provide said selected spark advance characteristic.

4. The capacitor discharge ignition system of claim 1 wherein said rotating member is the flywheel of an internal combustion engine.

5. The capacitor discharge ignition system of claim 1 wherein the pulse actuated circuit is comprised of:

trigger means having input, control and output electrodes; said charging coil being connected to the ignition capacitor for charging the same; the ignition capacitor being connected to said input electrode of said trigger means; said pulse producing trigger coil being connected to said control electrode of said trigger means for operating the same, said trigger means being rendered conductive in response to each of said pulses to discharge said ignition capacitor to produce the sparks for igniting fuel in the engine.

6. The capacitor discharge ignition system of claim 5 wherein said trigger means is a semiconductor device having a trigger threshold level which changes with temperature deviation; temperature variable resistance means connected to said control electrode of said semiconductor device, said temperature variable resistive means having a resistance which changes with said temperature deviation to vary the amplitude of said pulses to compensate for said changes in said trigger threshold level so that said ignition system provides a spark advance characteristic which is substantially independent of said temperature deviation.