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BREAKERLESS IGNITION SYSTEM WITH AUTOMATIC SPARK ADVANCE USING TRIGGERING COIL

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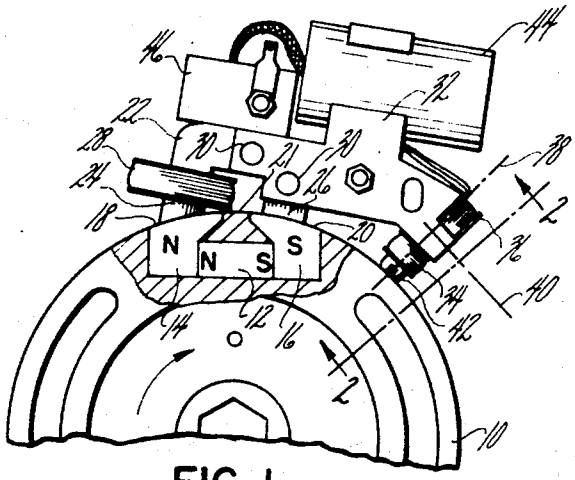
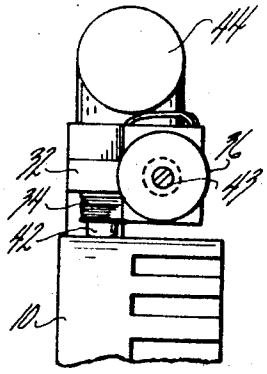


FIG. 1

FIG. 2



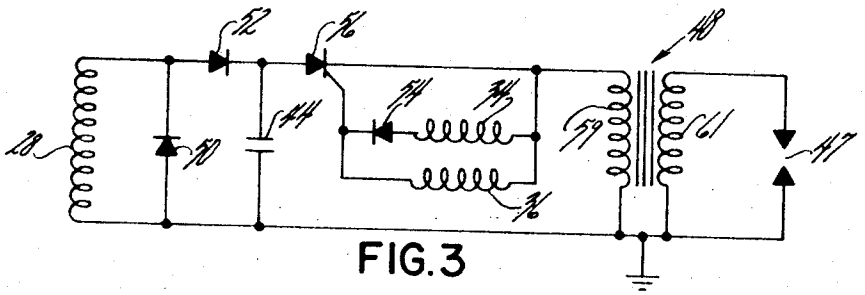


FIG. 3

FIG. 5

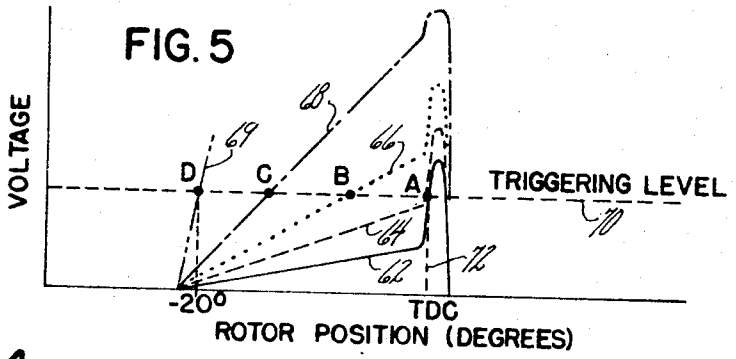
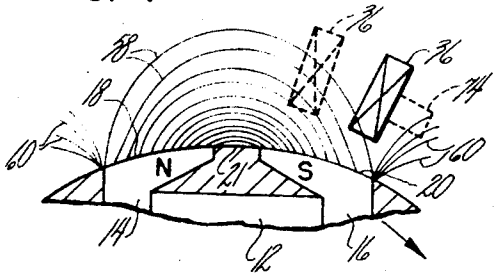


FIG. 4



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ABSTRACT OF THE DISCLOSURE

An ignition system for use with an engine having a spark gap ignition device includes a first triggering coil having its axis arranged generally tangentially to the circular path of a magnet assembly fixed to a rotor rotated in synchronism with the operation of the engine. A ramp voltage is induced in the first coil and triggers an associated switching device to cause a spark when the induced voltage reaches a given triggering voltage, the steepness of the ramp being dependent on the rotor speed so that at different speeds the triggering voltage is reached at different rotor positions. A second triggering coil connected in parallel with the first coil and having its axis arranged generally radially of the circular magnet path produces a triggering voltage for causing a spark at a definite rotor position during low speed operation. The magnet assembly is also used in conjunction with another coil forming part of a condenser discharge system for generating the electrical power used to produce the spark.

Background of the invention

This invention relates to ignition systems for spark ignited engines, and deals more particularly with a breakerless ignition system having an automatic spark advance.

Several different breakerless ignition systems have been proposed in the past wherein the conventional mechanical breaker is replaced by a transistor, silicon controlled rectifier, thyratron or other electronic switch controlled in some manner by a triggering signal. These systems are generally desirable in that they usually can be made more compact than equivalent breaker systems and being less subject to mechanical wear and deterioration have a larger service life. Nevertheless, up to this time the providing of an automatic spark advance in breakerless systems has presented problems and the absence of a good means for obtaining an automatic advance has in many cases been a drawback to the acceptance of breakerless systems.

The general object of this invention is therefore to provide a breakerless ignition system having a simple, inexpensive and reliable means for automatically producing an advance in the timing of the spark as the speed of the associated engine increases. In the description which follows the means for producing the automatic advance is described in conjunction with a condenser discharge ignition system, and this is the presently preferred application. This however should not be taken as limiting the scope of the invention as the invention, at least in its broader aspects, may be applied as well to other breakerless systems.

Summary of the invention

In a breakerless ignition system for a spark ignition engine the spark is controlled by an electronic switch which in turn is controlled by a triggering coil positioned adjacent the circular path of a magnet assembly carried by a rotor rotated by the engine. The magnet assembly includes two poles, respectively charged magnetically

north and magnetically south, spaced from one another circumferentilaly of the magnet path so that magnetic flux flows from one pole to the other along flux lines in the shape of generally tangentially extending loops connecting the poles. The triggering coil has its axis arranged generally tangentially of the magnet path so that the flux lines in cutting it induce a generally ramp shaped voltage waveform therein. A second triggering coil is connected in parallel with the first triggering coil and has its axis arranged generally radially of the magnet path so that a spike shaped voltage waveform is induced therein for triggering the electronic switch at low engine speeds where the voltage induced in the first coil does not rise to the triggering level.

Brief description of the drawings

FIG. 1 is an elevational view of part of an ignition system embodying the present invention, part of the rotor being shown broken away to reveal the magnet assembly.

FIG. 2 is a view taken on the line **2**—**2** of FIG. 1.

FIG. 3 is a schematic wiring diagram of an ignition system of which the parts shown in FIG. 1 are a part.

FIG. 4 is a diagram showing the distribution of magnetic flux in the vicinity of the magnet assembly of FIG. 1 and illustrating how this flux field is cut by the tangential trigger coil.

FIG. 5 is a diagram illustrating the voltage waveforms produced by the two triggering coils at different speeds of the rotor of FIG. 1.

Description of the preferred embodiment

Turning to the drawings, and first considering FIGS. 1 and 2 the parts of the ignition system there shown include a rotor **10** which in its use is fixed to the crank shaft, cam shaft, or other rotating part of the associated engine so as to be rotated in synchronism with the operation of the engine. Fixed to the rotor **10**, as by being embedded in the base material of the rotor, is a magnet assembly consisting of a permanent magnet **12** and two pole pieces **14** and **16**. The magnet **12** is magnetically charged in a direction tangentially of the rotor **10** and the pole pieces **14** and **16** engage its opposite ends so as to be oppositely magnetically charged as indicated. The pole piece **14** has a pole face **18** and the pole piece **16** a pole face **20**. The pole faces **18** and **20** are located on the peripheral surface of the rotor and are tangentially spaced from one another by a short gap **21** filled with the base material of the rotor, such material being a non-magnetic material such as aluminum.

Cooperating with the rotor **10** is a stator assembly including a laminated iron core **22** having two tangentially spaced legs **24** and **26** terminating in inwardly facing faces closely spaced from the rotor periphery. On the leg **24** is a generating coil **28**, and from FIG. 1 it will be evident that as the magnet assembly is moved past the core **22** a changing magnet flux is established in the leg **24** and in turn induces a changing voltage in the coil **28**.

Fixed to the core **22**, as by rivets **30**, **30**, is a bracket **32** of aluminum or other non-magnetic material which supports two triggering coils **34** and **36**. Both of these coils are arranged so as to be located forwardly of the stator core **22** with regard to the direction of rotation of the rotor **10**, as shown by the arrow in FIG. 1. Therefore, during each revolution of the rotor the magnet assembly first passes the core **22** and induces a voltage waveform in the generating coil **28** before reaching and inducing any significant voltages in the triggering coils **34** and **36**. In FIG. 1 the axis of the triggering coil **34** is indicated by the line **38** and the aixs of the triggering coil **36** is indicated by the line **40**. From this figure and FIG. 2, it will therefore be noted that the arrangement of these coils is such that the axis **38** of the coil **34** is

generally radially oriented relative to the rotor **10** and to the circular path traversed by the magnet assembly as the rotor rotates, and the axis **40** of the coil **36** is arranged generally tangentially to the rotor and the circular magnet assembly path. The two coils **34** and **36** are further located at approximately the same angular position along the circular path. The coil **34** is fixed to the supporting bracket **32** by a screw **42** of iron or other magnetic material which passes through the center of the coil and has a head located close to the peripheral surface of the rotor. The coil **36** is fixed to the bracket by a non-magnetic screw **43** and does not include any magnetic core which would tend to distort any magnetic field through which it passes.

The bracket **32** may also be used to support other parts of the ignition system and in the device illustrated in FIG. 1 supports a condensed **44** and a board **46** to which the diodes and silicon controlled rectifier of the circuit shown in FIG. 3 are fixed.

FIG. 3 is a schematic diagram showing the entire ignition system in which the parts of FIGS. 1 and 2 are used. Referring to this figure the system, in addition to the generating coil **28**, the triggering coils **34** and **36**, and the condenser **44** includes a spark plug **47**, or other spark gap ignition device, a step-up transformer **48**, diodes **50**, **52** and **54**, and a silicon controlled rectifier **56**, all connected as shown. This system will be recognized as being of the type generally referred to as a condenser discharge system. Basically its operation is as follows. During each revolution of the rotor **10** the magnet assembly induces a changing voltage waveform in the generating coil **28** having both positive and negative portions. The negative portion of each cycle is shorted out by the diode **50** connected across the generating coil **28** and the positive portion charges the condenser **44**, the diode **52** preventing leakage or discharge of the condenser through the coil **28** after it is charged. After the condenser is charged it is suddenly discharged through the primary coil **59** of the transformer **48** to induce a high voltage in the secondary coil **61**, and to thereby cause a spark at the spark plug **46**. This discharging of the capacitor **44** is in turn controlled by the silicon controlled rectifier **56** which is triggered by one or the other of the triggering coils **34** and **36**. The two triggering coils **34** and **36** are connected in parallel with one another across the cathode and gate terminals of the silicon controlled rectifier **56** and the diode **54** is connected in series with the coil **34** to prevent the voltage induced in the coil **36** from being dissipated in the coil **34**.

The effect of the triggering coils **34** and **36** is such as to cause the silicon controlled rectifier **56** to be switched from a non-conducting to a conducting state at different angular positions of the rotor in accordance with the rotor speed and to thereby advance the occurrence of the spark as the rotor and engine speed increases. The manner in which this is accomplished may best be understod by reference to FIGS. 4 and 5. In first considering FIG. 4, this figure shows the general character of the magnetic flux field located in the vicinity of the pole pieces **14** and **16**. It will be seen that the field consists of lines **58**, **58** of flux which are generally loop shaped and extend in a generally tangential direction from the pole face **18** to the pole face **20**. The lines **60**, **60** represent leakage flux from the leading end of the pole piece **16** and the trailing end of the pole piece **14**. The flux lines **58**, **58** are relatively close to one another in the vicinity of the gap **21** between the pole faces **18** and **20** and become more widely spaced in moving either tangentially or radially outwardly from the gap. The solid lines in FIG. 4 show the tangentially arranged triggering coil **36** at one position of the rotor and the broken lines show it at a subsequent position of the rotor. From this is can be seen that as the coil **36** is moved from the leading end of the pole face **20** toward the gap **21** an ever increasing number of flux lines pass through it, and as

a result of this movement a generally ramp shaped voltage waveform is therefore induced in the coil **36**. Furthermore, as the speed of rotation of the rotor **10** is increased the rate at which the flux passing through the coil **36** is varied is increased so that a steeper voltage waveform is induced in the coil.

The triggering coil **34**, which is arranged radially with respect to the rotor **10** and the circular magnet path and which has an iron core formed by the screw **42**, produces a waveform characterized by a relatively sharp spike which appears at the instant the coil passes the gap **21** between the two poles faces. This is due to the fact that as the coil **34** traverses the pole face **20** some small amount of flux will tend to flow through the screw and therefore through the coil **34**. When the screw **42** reaches the gap **21**, however, the screw head forms a low reluctance path for the flow of flux between the pole face **18** and the pole face **20**, and the flux passing through the coil **34** is suddenly reduced to produce a spike in the voltage appearing across the coil.

Since the coils **34** and **36** are connected in parallel the voltage applied to the gate terminal of the silicon controlled rectifier **56** is a combination of the waveforms appearing at the two coils, and the combined waveform is shown for different speeds of the rotor by the lines **62**, **64**, **66** and **68** of FIG. 5. The line **62** represents the waveform applied to the silicon controlled rectifier at a relatively low rotor speed such as obtained during cranking of the engine during starting, the line **64** represents the waveform applied at a somewhat higher rotor speed, the line **66** represents the waveform applied at a still higher rotor speed, and the line **68** represents the waveform applied at a yet higher speed. The line **69** represents part of the waveform obtained at or near a maximum speed. In each of the wafeorms **62**, **64**, **66** and **68** the generally ramp shaped portion appearing at the left is produced by the tangentially arranged triggering coil **36** and the spike shaped portion appearing at the right is produced by the radially arranged triggering coil **34**. The triggering level or voltage required to trigger the silicon controlled rectifier **56** is indicated by the line **70** in FIG. 5.

In considering FIG. 5, therefore, it will be noted that at low engine speeds the voltage waveform applied to the silicon controlled rectifier **56** is such that the ramp portion of the waveform does not rise to the triggering level **70** before the rotor reaches the top dead center position, represented by the line **72**, or other position at which it is desired to have the spark occur at low speeds. At this top dead center position, however, the spike shaped waveform produced by the coil **34** occurs and carries the voltage applied to the silicon controlled rectifier above the triggering level to cause the occurrence of a spark at this point. Therefore, for both of the low speed waveforms **62** and **64** the spark occurs at the point A. As the speed of the rotor increases, the steepness of the ramp shaped portion of the waveform increases and eventually the ramp voltage itself rises above the triggering level **70**, the triggering then taking place at the instant the voltage waveform crosses the triggering level as indicated at the point B for the waveform **66**, the point C for the waveform **68** and the point D for the waveform **69**.

From FIG. 5 it can therefore be seen that as the speed of the rotor and engine increases the occurrence of the spark advances in relation to the rotor position. As indicated in FIG. 5 the system whose characteristics are illustrated by the illustrated waveforms is such that at the maximum engine speed represented by the waveform **69** the spark occurs approximately 20° in advance of the top dead center position. Various different amounts of maximum advance can be obtained, however, by varying the length of the pole faces **18** and **20**. That is, as the pole faces are lengthened the number of degrees of rotor rotation over which the voltage ramp occurs is likewise lengthened. Also, varying the spacing of the coil **36** from

the rotor periphery or the number of turns therein varies the maximum voltage to which the ramp voltage induced in the coil **36** will rise and the steepness of the ramp, and therefore also effects the spark timing.

The width of the coil **36** should be kept at a minimum so that as the rotor **10** rotates at high speed the coil does not move into the area of the leakage field represented by the lines **60, 60** before the point of maximum desired advance is reached. This is because once the core reaches the leakage field this field will induce a voltage in the opposite direction in the coil. Therefore, until the movement of the rotor causes the leakage field to be moved out of the coil **36** no triggering will take place. This fact may, however, be used for a given set of pole pieces to limit the amount of maximum advance. That is, when a given set of pole pieces exist the amount of maximum advance achieved may be varied by varying the length of the coil **36**. In place of lengthening the coil a magnetic core of prescribed length, such as indicated by the broken lines at **74**, in FIG. 4 may be inserted in the coil to bring the coil under the influence of the leakage flux at a given position of the rotor, and thereby to limit the maximum advance to this position.

I claim:

1. In a breakerless ignition system for a spark ignition engine, the combination comprising: a spark gap device, means including an electronic switch device for causing the occurrence of a spark at said spark gap device as said switch device is switched from a first state to a second state, a triggering coil coupled with said switching device and operable to switch said switching device from said first state to said second state when the voltage across said triggering coil rises to a pre-determined level, and a magnet assembly rotated in a circular path in synchronism with the operation of the associated engine, said triggering coil being located adjacent said circular path of said magnet assembly and arranged with its axis oriented generally tangentially thereto.

2. The combination defined in claim **1** further characterized by said magnet assembly including two poles respectively charged magnetically north and magnetically south spaced from one another circumferentially of said circular path.

3. The combination defined in claim **2** further characterized by said means for causing the occurrence of a spark including a generating coil located adjacent said circular path so as to have a voltage induced therein as said manget assembly moves therepast, a condenser coupled with said generating coil so as to be charged by the voltage induced therein during each revolution of said magnet assembly, and a step-up transformer having a secondary coil connected to said spark gap ignition device and a primary coil connected to said condenser through said electronic switch device.

4. The combination defined in claim **3** further characterized by said electronic switch device comprising a silicon controlled rectifier.

5. The combination defined in claim **2** further characterized by a second triggering coil connected in parallel with said first mentioned triggering coil, said second triggering coil being located adjacent said circular path of said magnet assembly and having its axis oriented generally radially of said path.

6. The combination defined in claim **5** further characterized by said first and second coils being located at approximately the same angular position along said circular path.

7. The combination defined in claim **5** further characterized by said second triggering coil including a magnetic core.

8. The combination defined in claim **2** further characterized by said triggering coil having a magnetic core which extends forwardly therefrom with respect to the direction of rotation of magnet assembly and in a generally tangential direction relative to said circular path so as to enter the leakage flux field adjacent the leading end of the leading one of said poles in advance of said coil as said coil is moved over said leading pole toward its leading edge.

9. The combination defined in claim **3** further characterized by said generating coil being received on a magnetic core positioned adjacent said circular path and said triggering coil being fixed to said core by a non-magnetic bracket.

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LAURENCE M. GOODRIDGE, *Primary Examiner.*

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