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Smith

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[54] **MAGNETIC SPARK SPREADER**

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[52] **U.S. Cl.**..... **313/118,** 313/124, 313/136, 313/141, 313/142, 313/158

[51] **Int. Cl.**..... **H01t 13/42,** H01t 13/04

[58] **Field of Search** ..... 313/118, 141, 123, 124, 313/136, 142, 157, 158, 145; 252/63.5, 519; 123/169 EL, 169 G, 169 R

[56] **References Cited**

UNITED STATES PATENTS

1,482,422	2/1924	Workman	313/145 X
1,518,462	12/1924	Smith	313/118 X
2,208,030	7/1940	Holmes	313/145 X
2,626,445	1/1953	Schoenberg	252/519 X
3,219,866	11/1965	Dingman	313/157 X
3,229,032	1/1966	Willis	313/136 X

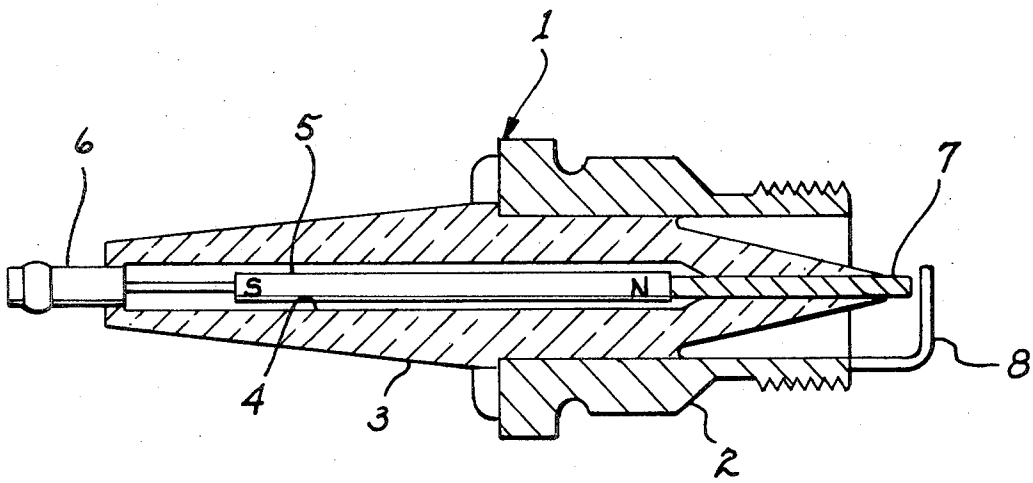
Primary Examiner—Alfred L. Brody

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[57] **ABSTRACT**

A spark plug having a superimposed magnetic field for use in internal combustion engines is disclosed. A magnetic field generator, such as a magnet, is disposed in proximity to the anode of the spark plug. The magnet produces a magnetic field which field alters the conductive properties of the envelope surrounding the anode and cathode electrodes. The resultant nonisotropic conductivity, in turn, promotes a larger arc envelope or plasma and hence a better probability of ignition of the combustible mixture within the engine.

6 Claims, 5 Drawing Figures



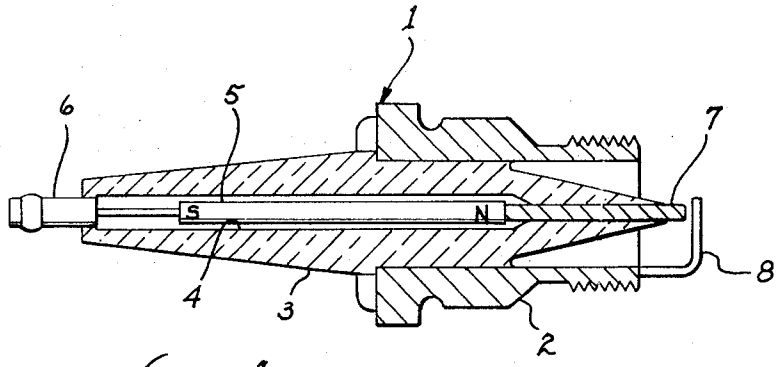


fig. 1

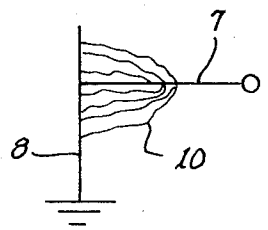


fig. 2

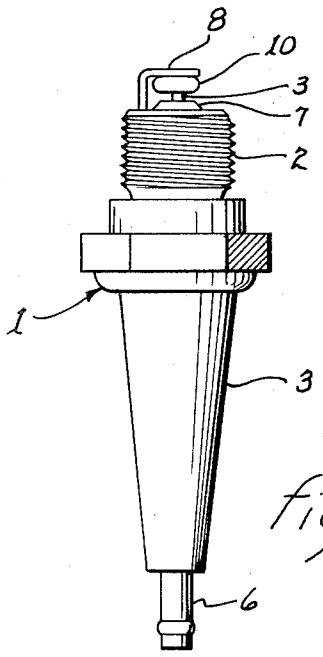


fig. 3a

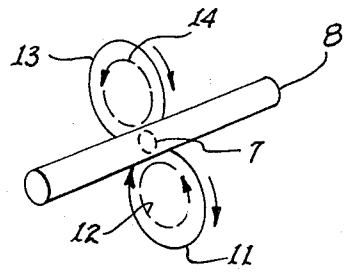


fig. 3b

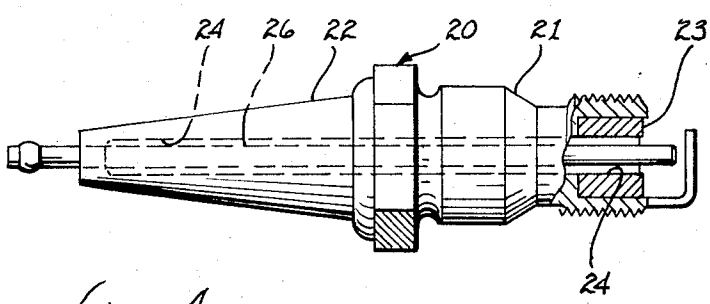


fig. 4

MAGNETIC SPARK SPREADER

The present invention relates to spark plugs for internal combustion engines, and, more particularly, to spark plugs generating a magnetic field in proximity to the anode and cathode electrodes.

It has been known that the generation of an electric arc within a magnetic field produces an arc having a greater envelope than if the same arc were generated without any magnetic field. To take advantage of this fact in spark ignition internal combustion engines, spark plugs have been developed which operate within a magnetic field.

In U.S. Pat. No. 1,482,422, a coil is disposed about the anode. The magnetic field produced by the coil is generated with the occurence of the spark. Because a finite time is required to build the magnetic field, its effect on an arc of normal duration is minimal at best. In U.S. Pat. No. 1,518,462, there is described a three electrode spark plug. One of the side electrodes is connected through a coil to a timed current source. The central electrode is connected to a soft iron bundle, which bundle is disposed within the aforementioned coil and insulated therefrom. The other side electrode is grounded. In operation, the magnetic field generated by the central electrode will start to buildup when the arc occurs. Thus, the effect of the magnetic field is very minor. Further, the requirement for three electrodes presents a substantial practical problem in adjusting the correct gaps.

The series coils of the above-mentioned patents have several time delay effects. A first effect is that of an LC time delay of the voltage wave reaching the electrode. This delay can be compensated or overcome by well-known spark advance mechanisms. A second effect results because of the creation of a large magnetic field. This delay cannot be compensated and the reduced ignition probability function will increase timing fluctuations and associated problems. A third effect is that of an increase of a source impedence of the arc. The source impedence increase will produce the desirable results of stabilizing the arc once initiated and reduce the spurious oscillations and radio noise generated in the arc. The beneficial aspects of increasing the source impedence can be better achieved in external circuitry than by incorporating the feature within a spark plug.

It is therefore a primary object of my invention to provide a magnetic field surrounding the electrodes of a spark plug.

Another object of my invention is to generate an enlarged arc envelope for spark plugs.

Yet another object of my invention is to increase the probability of correctly timed ignition of the combustible mixture within internal combustion engines.

A further object of my invention is to force the spark plasma of a spark plug to expand helically.

A still further object of my invention is to reduce the quantity of super hot arc plasma intermediate the electrodes of a spark plug which errode the electrode matter.

These and other objects of the present invention will become apparent to those skilled in the art as the description thereof proceeds.

The present invention may be described with more specificity and clarity with reference to the following figures in which:

FIG. 1 illustrates a spark plug incorporating the teaching of the present invention.

FIG. 2 is a representation of the plasma pattern of the present invention.

FIG. 3*a* and 3*b* illustrate the arc plasma in relation to a spark plug of the present invention.

FIG. 4 illustrates a modification of the present invention.

In a spark plug, the potential across the electrodes establishes an electric field. A magnet positioned in proximity to the spark plug electrodes establishes a magnetic field about the electrodes. The effects of each of these fields can be mathematically shown to be equal to

$$|F| = \sqrt{(\sigma E)^2 + (j^* B)^2}$$

Where,

σ = specific charge

E = electric field

j = electric current density

B = magnetic field By inspection, it can be seen that unless σE and $j * B$ are closely matched, one or the other will dominate.

Experimentally, it has been found that for a constant current, σE varies directly with the mass density, or, the pressure within the combustion chamber at the time of spark plug firing. Therefore, for internal combustion engines, the density of the magnetic field must be increased in proportion to the pressure increase within the combustion chamber in order to maintain the effect of the magnetic field relatively equal to that of the electric field.

Through other experiments it has been found that at atmospheric pressures the term $|\sigma E|$ and $|j^* B|$ are approximately equal when the current is five millamperes and the magmetic field is of a value approximately equal to one and a half kilogauss. For operation in internal combustion engines, the current should be increased to approximately forty-five milliamperes and the magnetic field should have a value of no less than one and a half kilogauss. Coincidentally, it has been found that when the present invention, the arc operating at forty-five milliamperes and 1.5 kilogauss has a plasma equivalent to that of an arc operating at sixty milliamperes and no magnetic field. The latter figure being the current value presently used in most conventional ignition systems.

It is well known that in conventional ignition systems, the spark volume varies as the logarithm of the current. With the present invention, however, the spark volume varies proportionally as the current varies if the * value exceeds σE. Thus, not only is the present invention readily adaptable for use in existing internal combustion engines, but the spark volume can be easily regulated by external current limiting circuitry.

Referring briefly to the previously cited patents, U.S. Pat. No. 1,482,422 and 1,518,462, some further comparisons can be made. The device shown in U.S. Pat. No. 1,482,422, requires a current of approximately 150 milliamperes D. C. to achieve an equality between the terms $|\sigma B|$ and $|j^* B|$ at atmospheric pressure. This high current requirement arises because of the inferior magnetic field produced by the small coil and high impedence in the magnetic path. The spark plug shown in U.S. Pat. No. 1,518,462, is more effective as the two coils present a lower series impedance thus more increasing peak currents, although partially cancelling each other's magnetic fields.

Referring now to the figures, the apparatus incorporating the teachings of the present invention will be described. In FIG. **1**, there is shown a spark plug **1** of generally conventional external structure. A threaded bushing **2** is disposed about one end of an insulator **3**. A cavity **4** is centrally disposed along the longitudinal axis of insulator **3**. A metallic magnet **5** is disposed within cavity **4** and interconnects a pair of electrodes **6** and **7**, which electrodes are partially disposed within the cavity and extend from either end of insulator **3**. Electrode **6** is usually connected to the distributor of the internal combustion engine and electrode **7** is the spark plug anode. The cathode electrode **8** is disposed in proximity to electrode **7** and is grounded to bushing **2**.

The magnet **5** is positioned within cavity **4** so that the north pole cooperates with one end of electrode **7**. The magnetic field established by magnet **5** is thus parallel to conductor **7**. The arc plasma **10** established by the electrostatic field between the anode electrode **7** and cathode electrode **8** is schematically shown in FIG. **2**. The path of the arc within plasma **10**, due to the magnetic field is a three dimensional volume resembling a football, as illustrated in FIG. **3***a*. This results because the locus of an arc streamer in parallel electric and magnetic fields is helical. When the electrodes are separated by a distance commensurate with the radius of the helix, the locii are all located within an envelope approximated by a revolution of a parabolic section. The enlarged arc plasma enhances the probability of controlled repeatible ignition of the combustible mixture within the cylinder.

The magnetic field, as discussed above, spreads the arc energy over a greater mass of air, thereby tending to lower the quantity of super hot arc plasma intermediate the electrodes. In addition, the magnetic field forces the arc to spread over the electrode surface rather than being concentrated over a very narrow area.

Referring now to FIGS. **3***a* and **3***b* there is shown the orientation of the arc plasma **10** with respect to the physical construction of the anode electrode **7** and cathode electrode **8** of spark plug **1**. The arc plasma **10**, of generally curved planar configuration, is oriented normal to the plane defined by cathode electrode **8**. It is essentially aligned with a line representing the minimum distance between the anode electrode and cathode electrode.

The electron flow paths **12** and **14** from the anode **7** to cathode **8** are helical and are believed to be in a counterclockwise direction as shown by the adjacent arrows. The ion flow paths **11** and **13** are also helical and are believed to be in a clockwise direction, as shown by the adjacent arrows. The two helixes shown in FIG. **3***b* produce the football shaped multiple arc path described above and shown in FIG. **3***a*.

It has been found that barium ferrite ($Ba\ Fe_{12}\ O_{19}$), when used in conjunction with the metal magnet has certain advantageous properties. It is an excellent insulator and is not easily demagnetized by transient external magnetic fields or other external forces such as heat and shock.

Further, the advantages physical properties of barium ferrite make it possible to achieve a low reluctance magnetic path everywhere except through the arc. If barium ferrite were not used, a second high reluctance magnetic path might occur between the spark plug bushing and the magnet disposed within the bushing. Thus, barium ferrite can be used within the combustion chamber of an internal combustion engine will not deleteriously affect its magnetic properties. It is therefore contemplated that the sparkplug bushing about the magnet be formed in part or even in whole, from barium ferrite.

In FIG. **4**, there is shown an essentially externally configured standard spark plug **20**. A threaded bushing **21** partially encircles insulator **22** and magnet **23**. Cavities **24** and **25** are centrally disposed within the insulator and magnet, respectively, and house anode electrode **26** extending therethrough.

The exact physical interplay between magnet **23**, insulator **22** and bushing **21** can be determined by those skilled in the art. It is anticipated that some type of mechanical interlocking mechanisms will be incorporated.

With the above described magnet **23**, several advantages are obtained over the device shown in FIG. **1**. In particular, the cavity within the insulator need not include a special cavity for housing the magnet; nor need the electrodes, forming the anode, be split. In addition, the positioning of the magnet in close proximity to the anode and cathode electrodes provides a strong magnet field therebetween for any given magnet strength.

While the principles of the invention have now been made clear in an illustrative embodiment, there will be immediately obvious to those skilled in the art many modifications of structure, arrangement, proportions, the elements, materials, and components, used in the practice of the invention which are particularly adapted for specific environments and operating requirements without departing from those principles.

I claim:

1. A spark plug for use in internal combustion engines, said spark plug being electrically connected to a source of periodically generated electrical current discharges, said spark plug comprising in combination:

A. an anode electrode connected to the source of electrical current discharges and said anode electrode extending from one end of said spark plug in juxtaposition with the longitudinal axis thereof;

B. a cathode electrode extending from said one end of said spark plug, said cathode electrode being formed in an L and having a first leg of the L parallel to but laterally displaced from the extending end of said anode electrode and a second leg of the L transverse to but displaced from the extremity of said anode electrode such that a current discharge from the source produces an electrostatic field intermediate said anode and cathode electrodes which field is generally parallel to said anode electrode;

C. an insulator for electrically shielding said anode electrode from said first leg of said cathode electrode;

a bushing for supporting said second leg of said cathode electrode, said bushing being grounded to the internal combustion engine; and

E. a magnet means disposed in proximity to said anode electrode for establishing a magnetic field parallel to said anode electrode and intersecting said second leg of said cathode; whereby, the electrostatic field intermediate said anode and said cathode is parallel with the magnetic field, which fields, in combination, produce an arc streamer

having a helical locus and a resulting parabolic arc plasma.

2. The combination as set forth in claim 1 wherein said anode electrode comprises a first segment for connection to the source of the current discharge and a second segment extending from said spark plug into proximity with said second leg of said cathode electrode, and said magnet being disposed intermediate said first and second segments.

3. The combination as set forth in claim 2 wherein said second segment, in combination with said cathode electrode, defines the arc plasma of the spark plug.

4. The combination as set forth in claim 1 wherein said magnet is disposed in proximity to one end of said insulator and generally proximate to the periodically generated arc plasma.

5. The combination as set forth in claim 4 wherein said anode electrode extends through said insulator along the longitudinal axis of said insulator.

6. The combination as set forth in claim 1 wherein said insulator is formed at least in part of barium ferrite ($Ba\ Fe_{12}\ O_{19}$).

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