United States Patent [19]
Siegle

[11] 3,742,280
[45] June 26, 1973

[54] PRE-IGNITION GAP FOR COMBUSTION ENGINE IGNITION SYSTEMS

[75] Inventor: Gert Siegle, Renningen, Germany

[73] Assignee: Robert Bosch GmbH, Stuttgart, Germany

[22] Filed: Nov. 12, 1971

[21] Appl. No.: 198,228

[30] Foreign Application Priority Data
Nov. 16, 1970 Germany .... P 20 56 235.0

[52] U.S. Cl. 313/118, 313/124, 313/135, 313/184, 313/136
[51] Int. Cl. H01t 13/54
[58] Field of Search 313/118, 123, 124, 313/184, 51, 1, 135, 182, 183, 136

[56] References Cited
UNITED STATES PATENTS

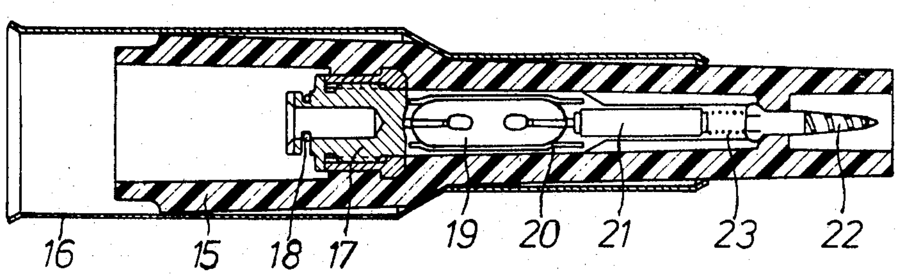
2,215,300	9/1940	Ryde	313/184
2,275,739	3/1942	Dellian et al.	313/184 X
2,505,150	4/1950	Schwartzwalder et al.	313/124 X
3,621,322	11/1971	Rehmet	313/184
3,317,777	5/1967	Algar et al.	313/182
2,965,779	12/1960	Zalesak	313/51
3,683,232	8/1972	Baur	313/51

Primary Examiner—Alfred L. Brody
Attorney—Michael S. Striker

[57] ABSTRACT

An ignition system for combustion engines includes a pre-ignition gap which consists of a closed compartment and a pair of electrodes in the compartment, the ends of the electrodes being spaced from each other. A gas which is chemically inert relative to the electrodes surrounds the electrodes at a pressure of between 1 and 10 atmospheres and, after each spark, allows an after-discharge between the electrodes without sparking. The free ends of the electrodes are spaced apart at a distance of between 1 and 5 mm and at last in the region of the free ends the electrodes are composed of a material which is resistant to vaporization and disintegration.

31 Claims, 3 Drawing Figures



PATENTED JUN 26 1973 3,742,280

Fig. 1

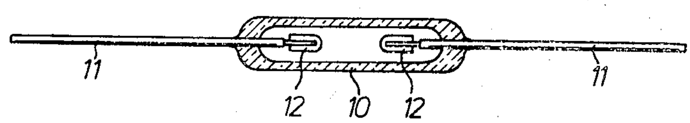


Fig. 2

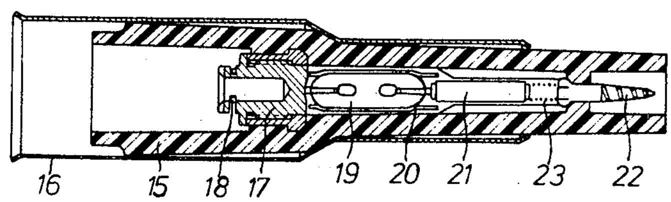
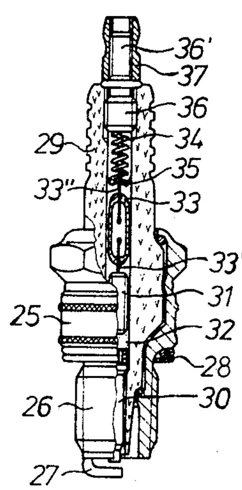


Fig. 3



INVENTOR

GERT SIEGLE

BY

ATTORNEY

PRE-IGNITION GAP FOR COMBUSTION ENGINE IGNITION SYSTEMS

BACKGROUND OF THE INVENTION

The present invention relates generally to ignition systems for internal combustion engines, and more particularly to pre-ignition spark gaps for use in such ignition systems. The invention also relates to a method of making electrodes for such pre-ignition spark gaps.

It is already known to interpose pre-ignition spark gaps in the high voltage conductors of ignition systems for combustion engines, immediately ahead of the spark plugs or even incorporated in the spark plugs themselves. As is well known, the generally used ignition systems are so constructed that the potential at the spark plugs rises only relatively slowly until ignition potential at the spark plug electrodes has been reached. If, now, the spark plug is fouled, that is if for instance the ceramic body which electrically insulates the electrodes of the spark plug from one another, is for example coated with a layer of soot and lead residue, or if it is wet or oily, then the thus existing electrical leakage path or short permits sufficient energy to be drained off to the electrodes during the build-up of potential, so that the necessary ignition potential or voltage cannot be reached. This problem is by no means new and it is well known that by properly configurating the combustion chamber in the engine, by providing proper combustible mixture and by utilizing the proper type of spark plug, in many instances the danger of fouling of the spark plugs —and in consequence the danger of misfiring due to shorting as outlined above — can be at least reduced. However, in the case of two stroke engines, Wankel engines, (i.e., generally rotary piston engines for which the term "Wankel engine" is becoming a synonym) and high performance engines the development of such shorts cannot be reliably excluded under all circumstances. In ignition systems with high internal impedance the provision of pre-ignition gaps has been found helpful, because these substantially reduce the tendency of spark plugs to lose ignition voltage due to shorting, as long as the ignition voltage of the pre-ignition gap is made sufficiently high and after sparking is supplied almost fully to the electrodes of the spark plug itself.

With the potential benefits to be derived from pre-ignition gaps thus being well known, a variety of attempts has been made to provide effective as well as relatively inexpensive pre-ignition gaps for use with ignition systems of combustion engines. Attempts have been made to provide such pre-ignition gaps either as separate components which are for instance accommodated in the spark plug connectors, or as integral components of the spark plugs themselves. In particular it is known to provide spark plugs in which the pre-ignition gaps are incorporated as integral components, wherein the gas-filled compartment of the pre-ignition gap is constituted by a bore provided in the spark plug itself and communicating with the ambient atmosphere. These co-called "vented gaps" have, however, been found to be less than fully satisfactory because the electrical characteristics of such pre-ignition gaps are not independent over the life time of the spark plug itself of the ignition frequency, the temperature and the ambient humidity. Instead, after they have been placed in service they develop nitric oxides and exhibit an ignition voltage which initially rises with the number of spark; if condensation of moisture in the discharge compartment of the electrodes occur the ignition voltage decreases to ineffective values below 5 kV.

Another known construction of such pre-ignition gaps utilizes an evacuated discharge chamber, or a closed discharge chamber which is filled with a mixture of N_2 and O_2 after the electrodes of the pre-ignition gap have previously been treated for a period of between 20 and 40 hours in air. These preliminary treatments of the electrodes require of course substantial expenditures in terms of time and labor and tend to make such constructions expensive. In addition these constructions have the disadvantage that oxides form in their discharge spaces which atomize or vaporize off the electrodes and form a coating on the inner wall bounding the discharge chamber; this coating may lead to shorting along the wall and to a decrease in the ignition potential as a result of a disturbance of the electric field between the electrodes caused by the coating. Particularly if the discharge chamber diameter is small in such pre-ignition gaps, the gas composition in the chamber is changed as a result of such occurrences and this in turn changes the ignition voltage and its frequency dependency.

SUMMARY OF THE INVENTION

It is, accordingly, an object of the present invention to provide an improved pre-ignition gap for use in ignition systems of combustion engines.

More particularly it is an object of the present invention to provide such an improved pre-ignition gap which is not possessed of the disadvantages outlined above with respect to the prior art.

An additional object of the invention is to provide such a pre-ignition gap which is particularly suitable for use with combustion engines utilizing conventional coil-type ignition systems with an internal impedance of 200 – 500 kΩ, discharge energy of about 100 m Joule and combustible mixtures which inherently tend to make ignition more difficult.

A concomitant object of the invention is to provide such an improved pre-ignition gap which in a simple manner assures a reliable ignition of even lean fuel-air mixtures.

In pursuance of these objects, an of others which will become apparent hereafter, one feature of the invention resides in an ignition system for combustion engines, and more particularly in a pre-ignition gap in such an ignition system for operation at an ignition voltage of between substantially 8,000 and 30,000 volts. This pre-ignition gap comprises, briefly stated, wall means surrounding a closed compartment, and a pair of electrodes in this compartment and having juxtaposed free ends spaced from another at a distance between substantially 1 and 5 mm, such electrodes being composed at least in the region of sparking of a material resistant to vaporizing and disintegration. A body of gas chemically insert relative to the electrodes is accommodated in the compartment and surrounds the electrodes at a pressure of between substantially 1 and 10 atmospheres.

Sparking at this novel pre-ignition gap results in a steep voltage increase which in turn assures that the ignition energy will not flow off via any existing short or leakage path, but instead will result in sparking at the spark gap of the subsequently arranged spark plug.

By utilizing a suitable gas the novel pre-ignition gap supplies —as a substantial improvement over the known constructions— an after-discharge lasting between 0.2 and 1 ms and free of after sparking; this after discharge is maintained at least during the lifetime of a spark plug independently of the ambient temperature, the ambient humidity and the sparking frequency and is obtained right from the beginning of the formation of each spark, without any break-in period. Moreover, these results are obtained with a pre-ignition gap whose overall dimensions are such that it can be readily incorporated either in a spark plug connector or in a bore provided in the body of a spark plug itself.

Advantageously the electrodes of the novel pre-ignition gap will be accommodated in a glass tube which defines the gas-filled compartment and in whose wall they are fused. The gas filling the compartment is advantageously nitrogen with a degree of purity of at least 98 percent. Under some circumstances it may be advisable to add up to 10 percent, preferably between 0.5 and 2 percent of hydrogen to the nitrogen gas. This is for instance advisable if the inner diameter of the gas compartment is smaller than 5 mm because in this case the addition of hydrogen reduces the frequency dependence of the sparking voltage to less than 20 percent up to frequencies of 150 Hz despite the small inner diameter.

On the other hand, however, an increase in the amount of hydrogen beyond 10 percent raises the potential of the after-discharge and thus decreases the duration of the after-discharge under a simultaneous increase of the vaporization rate and disintegration of the electrodes, because in this case a substantial part of the ion flow is made up of hydrogen ions and no longer of nitrogen ions.

If the ignition voltage is below approximately 12,000 volts the gas compartment may, instead of being filled with nitrogen, be filled with argon having a degree of purity of 99 percent, or with a mixture of argon and nitrogen and, if desired, an additive of up to 10 percent —preferably 0.5–2 percent— of hydrogen or noble gases.

It must be pointed out, however, that whichever gas or gas mixture is utilized, its degree of contaminants (H_2O, O_2 and halogen) must in every case be below 5.10^{-3} percent, because such contaminants cause a rise in the voltage of the after discharge, the development of after-sparking during the after discharge, and the formation of a coating on the wall bounding the chamber or compartment which coating is composed of vaporized electrode material.

The spacing between the juxtaposed free ends of the electrodes of the novel pre-ignition gap should be between approximately 1 and 5 mm, and is preferably between approximately 1.5 and 3 mm, in order to maintain the voltage of the after-discharge as low as possible; in other words, the voltage should be maintained at values lower than one quarter of the ignition voltage, preferably less than one tenth of the ignition voltage of the pre-ignition gap.

The electrodes of the novel pre-ignition gap itself may be configurated in pin-shape like configuration or in nail-shaped configuration, so that they can be readily mounted even in small and narrow compartments. The diameter of a pin-shaped electrode will be approximately 2 mm, the diameter of the nail head up to approximately 5 mm. However, if the dimensions of the gas-filled compartment so permit, the electrodes can of course also be configurated in plate-shaped or in pot-shaped configuration.

It is essential that the electrodes, or at least those portions thereof where the spark develops, be made only of materials resistant to vaporization or disintegration. This for instance includes nitrides of Al, Ce, Hf, La, Nb, Ta, Ti, V and Zr. It also includes mixtures of such nitrides having an oxide or oxide nitride content corresponding to an oxygen content of less than 25 atomic per cent of the combination. Particularly suitable, as tests have shown, are electrodes which in the region of the developing spark contain zirconium nitride of at least 90 percent by weight, preferably 99 percent by weight.

The electrodes for the novel pre-ignition gap may be made by producing an electrode base body of wolfram or another suitable metal, on which one of the metals Al, Ce, Hf, La, Nb, Ta, Ti, V or Zr, or a mixture of these metals is deposited, whereupon at least at the surface this metal is converted into its (or their-provided a mixture of metals is involved-) nitrides by processing in an atmosphere containing nitrogen or ammonium. However, the nitrides may also be deposited on the electrode base body by plasma spraying as described in Metal 24/1970, page 823 or by deposition directly out of the gaseous phase as described in Pohl et al, Vapor Deposition, Wiley 1966.

I have found to be specially suitable such electrodes which contain nitrides of at least 90 percent by weight in sintered form, as long as the diameter of the sinter particles at the surface of the electrode is smaller than the diameter of the developing sparks at the base of the sparks.

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

FIG. 1 illustrates in somewhat diagrammatic form one embodiment of the invention;

FIG. 2 illustrates the embodiment of FIG. 1 incorporated in a spark plug connector; and

FIG. 3 illustrates the embodiment of FIG. 1 incorporated directly in a spark plug.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Discussing now the drawing in detail, and firstly FIG. 1 thereof, it will be seen that the illustrated pre-ignition gap shown in FIG. 1 has a glass tube 10 whose outer diameter in this instance is 4.5 mm and whose length is 20 mm. The electrodes of the pre-ignition gap are here illustrated as each consisting of an electrode base body 11 of wolfram wire which extends through the wall of the tube 10 from the exterior to the interior thereof and is fused into this wall. Within the confines of the tube 10, that is, within the closed compartment defined and surrounded by the same, the free ends of the wolfram wires 11 are provided in the region of the spark development with coatings 12 of 99 percent by weight of zirconium nitride which in this embodiment is directly deposited by a plasma deposition. The oxygen content of the nitride after application is less than 25 atomic per cent of the combination.

It will be seen that the spacing between the free ends of the complete electrodes 12 is 2 mm. The interior of the tube **10** is filled with gas under pressure which in this embodiment is assumed to be at 4 atmospheres, but which may be between 1 and 10 atmospheres. The gas here is 98 percent nitrogen and 2 percent hydrogen.

FIG. **2** shows the pre-ignition gap according to the present invention incorporated in a spark plug connector. The connector has an insulating body **15** surrounded by a metallic shield **16.** Located within the body **15** is a contact element **17** with a clamping spring **18** with which a pre-ignition gap **19** constructed according to the embodiment of FIG. **1** is connected. In turn, the pre-ignition gap **19** is accommodated in a protective sleeve **20** which advantageously is in form of a section of silicon tubing.

Connected with the pre-ignition gap **19** is a 1,000 ohm interference-resistor **21** and the element **22** against which the resistor **21** is supported by the illustrated coil spring **23** which provides an electrically conductive connection between the member **22** and the component **21.** The components **17–23** —with the exception of the spring **18**— are surrounded and embedded in the synthetic plastic material of the member **15.**

FIG. **3** shows that the novel pre-ignition gap of FIG. **1** can also be incorporated directly in a spark plug itself. In this Figure the spark plug has a housing **25** provided with a thread **26,** a mass electrode **27** and a copper-asbestos seal **28.** In addition, the spark plug has an insulator **29** provided with a bore of passage of 55 mm diameter. A center electrode **30** of nickel and a pressure bolt **31** of steel are mounted in the lower region of this bore with the aid of an electrically conductive glass melt **32.**

A pre-ignition gap **33** is supported against the bolt **31** and has a connecting electrode **33'** which extends into a bore in the bolt **31** and another electrode **33'** which engages in a depression of a member **35** which is subjected to the pressure of a spring **34.** The end of the spring **34** which faces away from the pre-ignition gap **33** is supported against a threaded member **36** mounted in the insulator **29,** with a bolt **36'** and a nut **37.**

The construction of the pre-ignition gap **33** is identically the same as in FIGS. **1** and **2,** both as to its structural features, including the provision of the body of gas, and its overall dimensions. The material of the electrodes and the spacing between the electrodes, the pressure conditions and the composition of the gas or gas mixture are all the same.

It will be appreciated that instead of utilizing a pre-ignition gap mounted in a glass tube and intended for accommodation in a bore provided in a spark plug insulator, it is also possible to mount a pre-ignition gap in a spark plug insulator whose bore itself constitutes the gas space or compartment of the pre-ignition gap. In this case the center electrode of the spark plug itself and its connecting bolt can be connected vacuum-tightly in known manner with the aid of a glass melt in the insulator of the spark plug. Of course, the construction of spark plugs of this latter type is difficult and more expensive than that of ordinary spark plugs in which a pre-ignition gap such as in FIG. **1** is incorporated as a unit, but except for the addition of work and

expense involved, the advantages and considerations of the present invention obtain here also.

The method of depositing the materials on the electrode base body, that is by plasma spraying, deposition out of the gaseous phase, or deposition of the metals and subsequent conversion into their nitrides, are well known and are not believed to require detailed discussion.

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 constructions differing from the types described above.

While the invention has been illustrated and described as embodied in a pre-ignition gap for use in combustion engine ignition systems, 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.

1. In an ignition system for combustion engines, a pre-ignition gap, comprising wall means surrounding a closed compartment; a pair of electrodes in said compartment having juxtaposed free ends spaced from one another, at least one of said electrodes being composed in at least the region of sparking in excess of 90 percent by weight of at least one metallic nitride; and a body of gas chemically inert relative to said electrodes accommodated in said compartment and surrounding said electrodes.

2. In an ignition system as defined in claim **1,** wherein said free ends are spaced at a distance of substantially 1–5 mm.

3. In an ignition system as defined in claim **2,** wherein said distance is between 1.5 and 3.0 mm.

4. In an ignition system as defined in claim **19,** wherein said pressure is between 2 and 5 atmospheres.

5. In an ignition system as defined in claim **1,** wherein said gas is nitrogen having a purity of at least 98 percent.

6. In an ignition system as defined in claim **1,** wherein said gas comprises nitrogen of a purity of at least 98 percent, and a hydrogen component of up to 10 percent of the total quantity of said body of gas.

7. In an ignition system as defined in claim **6,** wherein said hydrogen component amounts to between 0.5 and 2 percent of said total quantity.

8. In an ignition system as defined in claim **1,** wherein said gas is argon of 99 percent purity.

9. In an ignition system as defined in claim **1,** wherein said gas is a mixture of argon and nitrogen.

10. In an ignition system as defined in claim **1,** wherein said gas is a mixture of argon and nitrogen with an added component of hydrogen amounting to up to 10 percent of the total quantity of said body of gas.

11. In an ignition system as defined in claim 11, wherein said added component amounts to between 0.5 and 2 percent of said total quantity.

12. In an ignition system as defined in claim 1, wherein said gas is a mixture of argon and nitrogen with an added component of a noble gas amounting to up to 10 percent of the total quantity of said body of gas.

13. In an ignition system as defined in claim 12, wherein said added component amounts to between 0.5 and 2 percent of said total quantity.

14. In an ignition system as defined in claim 1, wherein said nitride is selected from the group composed of nitrides of Al, Ce, Hf, La, Nb, Ta, Ti, V and Zr.

15. In an ignition system as defined in claim 1, wherein said nitride is a mixture selected from the group of nitrides of Al, Ce, Hf, La, Nb, Ta, Ti, V and Zr, with an oxide or oxinitride content which corresponds to an oxygen content of the mixture of less than 25 atom percent.

16. In an ignition system as defined in claim 33, wherein said one electrode is composed in said sparking region of at least 90 percent by weight of zirconium nitride.

17. In an ignition system as defined in claim 16, wherein said zirconium nitride amounts to 99 percent by weight.

18. In an ignition system as defined in claim 1, wherein said nitride is in the form of sintered particles, and wherein the average diameter of said sintered particles at the surface of said one electrode is smaller than the base diameter of sparks originating at said gap.

19. In an ignition system for combustion engines, a pre-ignition gap, comprising wall means surrounding a closed compartment; a pair of electrodes in said compartment having juxtaposed free ends spaced from one another, at least one of said electrodes being composed in at least the region of sparking in excess of 90 percent by weight of at least one material selected from the group consisting of nitrides of Al, Ce, Hf, La, Nb, Ta, Ti, V and Zr, provided that the oxide or oxinitride content of said material corresponds to an oxygen content of less than 25 atom percent of said material; and a body of gas chemically inert relative to said electrodes accommodated in said compartment and surrounding said electrodes at a pressure of between substantially 1 and 10 atmospheres, said gas being composed of at least one substance selected from the group consisting of nitrogen of at least 98 percent purity and argon of at least 99 percent purity, said gas containing less than substantially 5.10^{-3} percent of impurities such as water, oxygen and halogens.

20. In an ignition system as defined in claim 19, wherein said gas comprises up to 10 percent of an added component, said added component being composed of at least one substance selected from the group consisting of hydrogen and noble gases.

21. In an ignition system as defined in claim 20, wherein said added component comprises substantially 0.5–2 percent of said gas.

22. In an ignition system as defined in claim 19, wherein said material comprises at least 90 percent by weight of zirconium nitride.

23. In an ignition system as defined in claim 22, wherein said material comprises at least 99 percent by weight of zirconium nitride.

24. In an ignition system as defined in claim 19, wherein said material comprises at least 90 percent by weight of sintered particles, the diameter of said particles at the surface of said one electrode being smaller than the base diameter of sparks originating at said gap.

25. In an ignition system for combustion engines, a pre-ignition gap, comprising wall means surrounding a closed compartment; a pair of electrodes in said compartment having juxtaposed free ends spaced from one another, at least one of said electrodes being composed in at least the region of sparking in excess of 90 percent by weight of a material selected from the group consisting of nitrides of Al, Ce, Hf, La, Nb, Ta, Ti, V and Zr; and a body of gas chemically inert relative to said electrodes accommodated in said compartment and surrounding said electrodes at a pressure of between substantially 1 and 10 atmospheres, said gas being composed of at least one substance selected from the group consisting of nitrogen of at least 98 percent purity and argon of at least 99 percent purity, said gas containing less than substantially 5.10^{-3} percent of impurities such as water, oxygen ahd halogens.

26. In an ignition system as defined in claim 25, wherein said pressure is between substantially 2 and 5 atmospheres.

27. In an ignition system as defined in claim 25, wherein said gas comprises up to 10 percent of an added component, said added component being composed of at least one substance selected from the group consisting of hydrogen and noble gases.

28. In an ignition system as defined in claim 27, wherein said added component comprises substantially 0.5–2 percent of said gas.

29. In an ignition system as defined in claim 25, wherein said material comprises at least 90 percent by weight of zirconium nitride.

30. In an ignition system as defined in claim 29, wherein said material comprises at least 99 percent by weight of zirconium nitride.

31. In an ignition system as defined in claim 25, wherein said material comprises at least 90 percent by weight of sintered particles, the diameter of said particles at the surface of said one electrode being smaller than the base diameter of sparks originating at said gap.

* * * * *