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(54) **SPARK PLUG WITH DOUBLE ELECTRICAL DISCHARGE**

(57) The present invention refers to a spark plug with double electrical discharge comprising: a central electrode (3) having a discharge surface (3a), a ground electrode (4) having a discharge surface (4a), an insulator (2) located concentrically on a longitudinal central axis (y) of the spark plug, between electrodes (3) and (4) on whose exterior circumference there is a groove accommodating an intermediate electrode (1) having two opposing superior (1.3) and inferior (1.4) discharge surfaces, **wherein** the electrode (1) has a shape of a flat washer with a central hole and protrusions (8) allowing the placement on the electrode (1) of at least two superior mini electrodes (5) on the surface (1.3) of the electrode (1), of at least two inferior mini electrodes (6) on surface (1.4) of electrode (1), at a distance between these mini electrodes (5, 6), on the surface (4a) of electrode (4) are placed at least two ground mini electrodes (7), at a distance from the mini electrodes (5, 6), and the total number of mini electrodes (5, 6, 7) is at least 6 and at most 54, while the number of mini electrodes (6) equals the number of mini electrodes (7), **such that** a simultaneous ignition of an electrical discharge between electrode (3) and electrode (1) and of an electrical discharge between electrode (1) and electrode (4) upon initiation of combustion is generated.

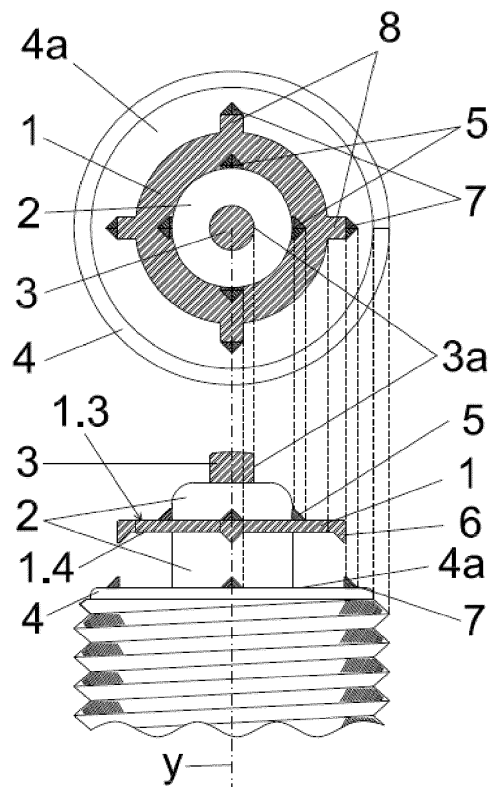


Figure 1

Description

[0001] This invention refers to the special design of a spark plug with double electrical discharge that may be used for all types of internal combustion engines having a spark-ignition system fueled by gas or other light combustion fuels.

[0002] The technical field of the present invention belongs to the ignition systems for internal combustion engines based on spark plugs having optimized configurations and which, when installed on an engine, do not require structural modifications of the engine or of the electrical system.

[0003] A double spark plug which provides two simultaneous discharges, and contains an intermediate electrode in the shape of a star washer placed on a ceramic insulator between the central electrode of rod type and the ground electrode is known. In the case of this spark plug, a discharge between the lateral end of electrode and the upper part of the intermediate electrode is induced on a flat segment thereof, and a discharge between one of the edges of the star washer and the surface of the ground electrode. This solution has the disadvantage of using a high breakdown voltage which wears and ages the insulation of the power supply circuit. At the same time, due to the flat shape of the ground electrode and of the intermediate electrode having the shape of a star washer in the area where the discharge is ignited between the central electrode and the ground electrode, the calamine deposit takes place, which is a phenomenon resulting in the deterioration of the operating conditions; see [1] B. Hnatiuc, S. Pellerin, E. Hnatiuc, R.

Burlică, N. Cerqueira, D. Astaneî, "Spectroscopic diagnostic of transient plasma produced by a spark plug", *Romanian Journal of Physics*, Vol. 56S, pp. 109-113, 2011, and [2] D. Astaneî, F. Faubert, S. Pellerin, B. Hnatiuc, M. Wartel, "A New Spark Plug to Improve the Performances of Combustion Engines: Study and Analysis of Unburned Exhaust Gases", *Plasma Chemistry and Plasma Processing*, vol. 38, issue 5, pp. 1115-1132, 2018, and [3] D. Astaneî, F. Faubert, S. Pellerin, B. Hnatiuc, M. Wartel, "Evaluation of the efficiency of a double spark plug to improve the performances of combustion engines: pressure measurement and plasma investigations", *Plasma Chemistry and Plasma Processing*, manuscript, vol. 40, pp. 283-308, 2020.

[0004] There are known spark plugs having the main electrode connected to a power supply source and multiple secondary electrodes mounted on the ground electrode of the device made from the thread restraint system thereof; see [4]- DE602004006220 (T2) NGK SPARK PLUG CO, [5] DE102005036949 "Spark plug with multiple ground electrodes", DENSO CORP, NIPPON SOKEN, and [6] WO2016026597 "Spark plug with a multiple ground electrode", BOSCH ROBERT GMBH. The secondary electrodes are bent towards the rod of the main electrode. The main disadvantage of the solutions pre-

sented above is that they provide a single electrical discharge of spark type between the central electrode and one of the ground electrodes while the generated plasma volume is low.

[0005] There are also known spark plugs with multiple electrodes generating multiple discharges of spark type to initiate combustion in the combustion room of the internal combustion engines, see [7] DE102009036732, Gau Timo et.al., "Spark plug i.e. multi-spark plug, has mass electrodes comprising capacity with finite conductivity so that successive ignition sparks lies at different mass electrodes, and control device controlling ignition coil", DAIMLER AG and [8] DE602005001573, Agneray Andre, Rivere Jean-Pierre, "Multiple spark surface discharge spark plug, RENAULT SA. The disadvantage of these solutions consists in the need to modify the electric power supply system for ignition or to use an additional electronic system.

[0006] There is also known the spark plug using a single central electrode to generate plasma; see [9] A. Mariani and F. Foucher, "Radio frequency spark plug: An ignition system for modern internal combustion engines," *Applied Energy*, vol. 122, pp. 151 - 161, 2014, and [10] US2011163654 Malek Nadim, Agneray Andre, "Open-chamber multi-spark plug", Applicant RENAULT SA, but this solution has the disadvantage of using a power supply system that generates high voltage impulses in the field of radiofrequency.

[0007] The technical problems that this invention solves consist in the generation of high volume of plasma generated by two simultaneous electrical discharges in order to provide a high quality combustion of the air-fuel mixture in the combustion chamber of the internal combustion engines without the need to make modifications of the electrical system, with breakdown voltage values comparable to those of a conventional system, thus preventing the deposit of calamine on electrodes.

[0008] The present invention solves the technical problems already mentioned by the fact that the spark plug contains an intermediate electrode placed on a ceramic insulator between a central electrode connected to a power supply and the ground electrode. The intermediate electrode has a floating electric potential, and the values of the electric potential range between the electric potential of the central electrode and the one of the ground electrode, the electric potential value being dependent on the power supply voltage's amplitude of the central electrode, on the location of the intermediate electrode with regards to the central electrode and the ground electrode or on the shape of the ceramic insulator. Both the intermediate electrode and the ground electrode contain mini electrodes.

[0009] According to the invention, this spark plug has the following advantages:

- it generates two simultaneous electric discharges providing, through the cumulated length of said two discharges, a high quality initiation of combustion of

the air-fuel mixture in the extinction chamber. The length of an electric discharge equals the distance between the areas of ignition thereof on the surface of electrodes.

- the electrical energy consumed by the discharges, and the level of breakdown voltage upon ignition of discharges are similar to those specific to a conventional ignition system.
- it prevents the deposit of calamine on electrodes.
- when mounted on internal combustion engines, it does not require structural modifications of the engine or of the electric system.

[0010] It is presented below an example of carrying out the invention in relation to figures 1, 2, 3, 4 representing:

- Figure 1 presents the spark plug with double electrical discharge according to an example of carrying out the invention in side view and top view.
- Figure 2 presents the spark plug with double electrical discharge according to an example of carrying out the invention in longitudinal section through the spark plug and a detail for the fastening of the intermediate electrode.
- Figure 3 presents an embodiment of a mini electrode used in the manufacturing process of a spark plug with double electrical discharge in front view, side view and top view.
- Figure 4 presents embodiments of the intermediate electrode used in the manufacturing process of a spark plug with double electrical discharge in side view, top view and bottom view in configurations with different numbers of mini electrodes and distinct positions of the mini electrodes on the surface of the intermediate electrode.

DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

[0011] According to the invention, the spark plug is made of an intermediate electrode **1** mounted on a ceramic insulator **2** placed between a central principal electrode **3**, and a ground electrode **4**. The intermediate electrode **1** contains superior mini electrodes **5** on the upper surface **1.3** oriented towards the spark surface **3a** of the central electrode **3** and inferior mini electrodes **6** on the lower surface **1.4** oriented towards the discharge surface **4a** of the ground electrode **4**. Ground mini electrodes **7** are mounted on the surface of the ground electrode **4**.

[0012] The intermediate electrode **1** has the shape of a flat washer with a central hole and protrusions **8** arranged towards the exterior circumference of the washer

on which mini electrodes **6** are placed on the lower surface **1.4**. The protrusions **8** have spaces between them allowing the development of the combustion flame initiated by the electric discharge ignited between one of the pairs of mini electrodes **6** and **7** both in a radial direction with regards to the longitudinal central axis **y** of the spark plug and in a parallel direction with it. The double spark plug with intermediate electrode of star washer type known from the state of the art mentioned above, allows for the evolution of combustion flame initiated by the electric discharge ignited between one of the tips of the star washer and the ground electrode only in radial direction with regards to the longitudinal central axis **y** of the spark plug.

[0013] The mounting position of the intermediate electrode **1** on the ceramic insulator **2** must be chosen in such a way so that the ratio between the length of discharge generated between the intermediate electrode **1** and the ground electrode **4** and the length of the discharge generated between the central electrode **3** and the intermediate electrode **1** should be between 1.4 and 1.8, this value being dependent on the diameter of the ceramic insulator and on the shape thereof. This ratio allows that the ignition voltage's value of the two discharges may be approximately the same, knowing that the discharge between the electrodes **3** and **1** is a discharge generated on the surface of the ceramic insulator **2** ignited between a cylindrical surface and a superior mini electrode **5**, while the discharge generated between the electrodes **1** and **4** is ignited between two inferior **6** and ground **7** mini electrodes.

[0014] In a preferred example, the mini electrodes **5**, **6** and **7** have the shape of an irregular polyhedron (AB-CDEFG), according to figure 3, having a polygonal base with 5 sides (BCEFG) in contact with the intermediate and ground electrodes or creating a common body with them, a lateral side ABC in the shape of an isosceles triangle oriented for the mini electrodes **5** and **7** towards the longitudinal central axis **y** of the spark plug and towards the circumference of the spark plug in the case of the mini electrodes **6**, and an ignition edge AD. The BC base of the isosceles triangle is common with one of the laterals of the polygon representing the base of the mini electrode **5**, **6** or **7** coming into contact with the electrode **1** in the case of the mini electrodes **5** and **6** or with the electrode **4** in the case of the mini electrodes **7**, and the plane created by the ABC triangle is perpendicular on the plane described by the polygonal base having 5 sides of the mini electrode **5**, **6** or **7**, BCEFG.

[0015] The sharpening degree of the mini electrodes is given by a θ angle defined as a sharpening angle that is formed by the congruent sides AB and AC of the isosceles triangle ABC corresponding to the mini electrodes **5**, **6** or **7**. The value of the sharpening angle θ which is opposite the base of the isosceles triangle ABC, may have values between at least 30° and at most 120° . A value which is less than 30° for this angle will result in an accelerated erosion of the mini electrode while reducing

the performances of the spark plug and shortening the lifespan thereof. A value which is more than 120° for this angle will result in a larger width of the protrusion **8** of the intermediate electrode, thus limiting the space for the development of the combustion flame initiated by the electrical discharge produced between the intermediate electrode and the ground electrode on a direction parallel with the longitudinal central axis **y** of the spark plug.

[0016] The mini electrodes **5**, **6** and **7** have discharge ignition edges whose sharpening angles range between at least 30° and at most 120° in order to provide a breakdown voltage (discharge ignition voltage) with lower values considering the distance between electrodes as compared to the situation where a discharge is ignited in the same pressure, humidity and nature of the fluid between electrodes conditions, between two planar or spherical electrodes known in the state of the art.

[0017] The discharges' ignition voltage in case of the double spark plug is comparable to the one encountered in the conventional ignition systems and with values between 40 and 60% of the breakdown voltage afferent to the use of the double spark plug with intermediate electrode in the shape of a star washer, as known from the state of the art mentioned above, the breakdown voltage of a discharge being much lower when the ignition takes place between electrodes with edges as compared to the ignition between two planar electrodes, as known from the theory of electrical discharges. In the case of the double spark plug with intermediate electrode in the shape of a star washer, as known in the state of the art mentioned above, the electrical discharge generated between the central electrode and the intermediate electrode is started between two planar electrodes, the circumferential surface of the central electrode and a flat upper surface in proximity of the ceramic insulator of the intermediate electrode of star washer type. The second discharge in the case of the double spark plug with intermediate electrode in the shape of a star washer is of tip-flat surface type ignited between a tip of the star washer similar to a pyramid tip oriented towards the ground electrode and the flat surface of the ground electrode.

[0018] The use of mini electrodes with edges on whose surface electrical discharges are ignited also ensure the avoidance of calamine deposit in the area of discharge ignition, a phenomenon that would reduce the performances of the spark plug, since the deposit of calamine on edges is less encountered than in the case of surfaces. The repeated ignition of electrical discharges in limited areas, on edges, also ensures the self-cleaning of discharge ignition areas of the mini electrodes.

[0019] The edge of the mini electrodes **5**, **6** or **7** on whose surface the discharge is ignited, also known as ignition edge is the segment AD, corresponding to a common side of two lateral faces identical in shape of a mini electrode (**5**, **6**, **7**), namely between the faces ACED and ADGB, according to figure 3, describing a sharpening angle θ as defined above. The body of the mini electrodes (**5**, **6**, **7**) has the shape of a polyhedron. The AD edge is

a line segment placed substantially parallel to the plane created by the base of the mini electrode's body (BCEFG), at a minimum distance from it and non-zero. The mentioned base is located on a discharge surface (**1.3**, **1.4**, **4a**). The minimum distance between the ignition edge (AD) and the plane created by the base of the mini electrode **5**, **6** or **7** (BCEFG) ensures the avoidance of calamine deposit on the area adjacent to the discharge ignition edge (AD). Discharges are ignited only on the ignition edges AD of the mini electrodes **5**, **6** or **7**. The shortest ways to ignite discharges are comprised between the spark surface **3a** of the central electrode **3** and the AD edge of the mini electrodes **5**, and between the AD edges of the pairs of mini electrodes **6** and **7**.

[0020] The shape of a straight edge on whose surface the discharge is ignited ensures the reduction of wear of the mini electrodes as compared to the double discharge spark plug with intermediate electrode in the shape of a star washer, as known from the state of the art mentioned above, whose discharge ignition points between the intermediate electrode and the ground electrode are similar to the tip of a pyramid, a tip that erodes more easily as compared to an edge.

[0021] The ignition edge (AD) of the mini electrodes **5**, **6** or **7** has a length value lower than the value of the minimum distance between the point **F** and the BC side, according to figure 3. This way thermal transfer and heat dissipation are ensured from the area of the ignition edges of the mini electrodes towards the intermediate electrode **1** when referring to the superior mini electrodes **5** and inferior mini electrodes **6** and respectively towards the ground electrode **4** when referring to the ground mini electrodes **7**.

[0022] The superior mini electrodes **5** are arranged circumferentially about the longitudinal central axis **y** of the spark plug, at equal distances between them, and the end of the ignition edge related to the superior mini electrode **5**, defined as point A described in figure 3, comes into contact with the surface of the cylindrical insulator **2**.

[0023] The inferior mini electrodes **6** are arranged at equal distances between them and about the longitudinal central axis **y** of the spark plug, in the exterior part of the protrusions **8** corresponding to the maximum diameter thereof, the number of inferior mini electrodes **6** being equal to the number of protrusions **8**.

[0024] The ground mini electrodes **7** are arranged circumferentially about the longitudinal central axis **y** of the spark plug, at equal distances between them. The number of mini electrodes **7** is equal to the number of mini electrodes **6**, and they are arranged in pairs as they are coplanar in vertical planes comprising the longitudinal central axis **y** of the spark plug. The arrangement in different planes may result in the ignition of discharges between the flat regions of the electrodes, which may be covered in calamine, and the mini electrodes that would lead to the increase of the breakdown voltage value. The mini electrodes **6** and **7** are arranged in such a way so that the segment defined by the tips (ends) of the edges

of mini electrodes located towards the central electrode (point D in case of mini electrodes **6** and point A in case of mini electrodes **7** in figure 3) should be parallel to the longitudinal central axis **y** of the spark plug.

[0025] The arrangement of the mini electrodes **5**, **6** and **7** at equal distances between them provides the possibility to ignite discharges in different regions in the combustion room, regardless of the position of the spark plug resulted following the mounting thereof by screwing up in the cylinder head of the internal combustion engine. Although from the constructive viewpoint the distances between the mini electrodes **5**, **6** or **7** may be different and still the spark plug would function, such a configuration would not bring any benefits from the technical viewpoint since it would no longer ensure the ignition of discharges in different regions of the engine combustion room.

[0026] The number of mini electrodes **5**, **6** and **7** may range between 2 and 18 for each type of mini electrode **5**, **6** or **7**. By using a minimum number of 2 mini electrodes of each type of mini electrodes **5**, **6** or **7** arranged at equal distances, the ignition of electrical discharges between electrodes **3** and **1** and respectively **1** and **4** in regions of the combustion room of the internal combustion engine is ensured thus allowing the development of the combustion flame and ensuring a quick and full combustion of the air-fuel mixture. The use of more than 18 superior mini electrodes **5** results in the reduction or disappearance of the distance between them, and this may cause calamine deposit which triggers faster erosion thereof. The use of a number of pairs of mini electrodes **6** and **7** higher than 18 would also cause, apart from calamine deposit through the reduction or disappearance of the space between ground mini electrodes **7**, to the reduction or disappearance of the space between protrusions **8** of the intermediate electrode **1** which ensure the easier development of the combustion flame. The selection of the number of mini electrodes depends on the size of the exterior diameter of the ground electrode and of the spark plug thread. At the same time, the use of a high number of mini electrodes is not justified from the economic viewpoint since it requires the increase of the number of technological operations and of the quantity of material used thus resulting in a higher cost of production.

[0027] The number of mini electrodes **5** and **6** may be the same or different, even an uneven number, and if the number of mini electrodes **5** equals the number of mini electrodes **6**, the mini electrodes **5** may be mounted in a coplanar manner with the mini electrodes **6** in vertical planes comprising the longitudinal central axis **y** of the spark plug, or in vertical planes comprising the longitudinal central axis **y** of the spark plug in different directions from those of vertical planes comprising the longitudinal central axis **y** of the spark plug corresponding to the mounting positions of the mini electrodes **6**. Constructive examples for the intermediate electrode **1** having the same number or a different number of mini electrodes **5** and **6** are given in Figure 4.

[0028] The mini electrodes **5**, **6** and **7** may be made from the same material as the intermediate electrode **1**, and as the ground electrode **4**, respectively since they have a common body with said electrodes, made of steel or they may be made separately from the body of the electrodes **1** and **4**, from materials having superior electrical properties and having a higher capacity of thermal transfer by conduction and resistant to high temperatures and erosion such as platinum or iridium, and being subsequently applied on the intermediate electrode **1**, and on the ground electrode **4** through welding, soldering or other known technical methods that may ensure high electrical and thermal conductivity.

[0029] The ceramic insulator **2** has a groove accommodating the intermediate electrode **1** with floating electrical potential to avoid the detachment of electrode **1** in conditions of vibrations, pressures and high temperature encountered in the combustion chamber of the internal combustion engines.

[0030] Upon the supply with voltage impulses of the central electrode **3** of rod type from a power supply source, an electrical discharge between the central electrode **3** and one of the mini electrodes **5** located on the intermediate electrode **1**, and a second electrical discharge between one of the mini electrodes **6** located on the intermediate electrode **1** and one of the mini electrodes **7** located on the ground electrode **4** are ignited simultaneously. The large contact surface between the plasma generated by the two discharges occurred and the air-fuel mixture in the combustion chamber of the internal combustion engines ensures the efficient initiation of combustion.

Claims

1. Spark plug with double electrical discharge comprising:

- a central electrode (3) connected to a pulse high voltage power supply having a discharge surface (3a), said central electrode (3) being placed concentrically on a longitudinal central axis (y) of the spark plug and extending along it; and
- a ground electrode (4) placed concentrically with the central electrode (3) having a discharge surface (4a) oriented towards the discharge surface (3a) of the central electrode (3),
- an insulator (2) placed concentrically on the longitudinal central axis (y) of the spark plug, between the central electrode (3) and ground electrode (4) on whose exterior circumference, in a parallel plane with the discharge surface (4a) of the ground electrode (4), there is a groove accommodating an intermediate electrode (1) provided with two superior (1.3) and inferior (1.4) opposing discharge surfaces, wherein

- the superior surface (1.3) is oriented towards the discharge surface (3a) of the central electrode (3), and
- the inferior surface (1.4) is oriented towards the discharge surface (4a) of the ground electrode (4),

characterized in that:

- the intermediate electrode (1) has a shape of a flat washer with a central hole and protrusions (8) arranged towards the exterior circumference of the washer allowing positioning of at least two superior mini electrodes (5) on the intermediate electrode (1), on the superior discharge surface (1.3) of the intermediate electrode (1), and of at least two inferior mini electrodes (6) on the inferior discharge surface (1.4) of the intermediate electrode (1), at a predetermined distance between said superior and inferior mini electrodes (5, 6);
- on the discharge surface (4a) of the ground electrode (4) there are at least two ground mini electrodes (7), placed at a predetermined distance from said superior and inferior mini electrodes (5, 6), and
- the total number of superior, inferior and ground mini electrodes (5, 6, 7) is at least 6 and at most 54, and the number of inferior mini electrodes (6) equals the number of ground mini electrodes (7),

such that a simultaneous ignition of an electrical discharge generated between the central electrode (3) and the intermediate electrode (1) and of an electrical discharge generated between the intermediate electrode (1) and the ground electrode (4) upon initiation of combustion is generated.

2. Spark plug according to claim 1, wherein the inferior and ground mini electrodes (6, 7) are placed in pairs in the same plane, which contains the longitudinal central axis (y) of the spark plug.
3. Spark plug according to claim 1 or 2, wherein the superior, inferior and ground mini electrodes (5, 6, 7) have a surface, of ignition edge type, onto which an electrical discharge is formed.
4. Spark plug according to claim 3, wherein the ignition edge of said mini electrodes (5, 6, 7) is a segment corresponding to a common side of two lateral faces, identical in shape, of a polyhedral body of a mini electrode (5, 6, 7), describing a sharpening angle θ ranging from about 30° to 120° , said segment being arranged substantially parallel and at a minimum

predetermined distance and non-zero, from a base of the mini electrode's (5, 6, 7) body, said base being placed on a discharge surface (1.3, 1.4, 4a).

5. Spark plug according to any of the previous claims, wherein the material from which the electrodes (1, 3, 4) and the mini electrodes (5, 6, 7) are made, is the same, and the mini electrodes (5, 6, 7) together with the electrodes (1, 3, 4) have a common body.
6. Spark plug according to claims 1 to 4, wherein the material from which the electrodes (1, 3, 4) and the mini electrodes (5, 6, 7) are made, is different, and the mini electrodes (5, 6, 7) and the electrodes (1, 3, 4) have an individual body.
7. Spark plug according to any claim 1 to 6, wherein the body of the mini electrodes (5, 6, 7) and of the electrodes (1, 3, 4) is made from materials such as platinum or iridium.
8. Spark plug according to any claim 3 to 7, wherein the superior mini electrodes (5) are arranged circumferentially about the longitudinal central axis (y) of the spark plug at an equal predetermined distance between them, and every end (A) of the ignition edge afferent to a superior mini electrode (5) is in contact with the cylindrical insulator (2).
9. Spark plug according to any previous claim, wherein the inferior mini electrodes (6) are arranged circumferentially at an equal predetermined distance between them, on the inferior discharge surface (1.4) of the intermediate electrode (1), at each exterior end of said protrusions (8).
10. Spark plug according to any previous claim, wherein the ground mini electrodes (7) are arranged circumferentially at an equal predetermined distance between them, on the discharge surface (4a) of the ground electrode (4) such that a straight line described by the ignition edges of the inferior and ground mini electrodes (6, 7), said edges being oriented towards the central electrode (3), is parallel to the longitudinal central axis (y) of the spark plug.

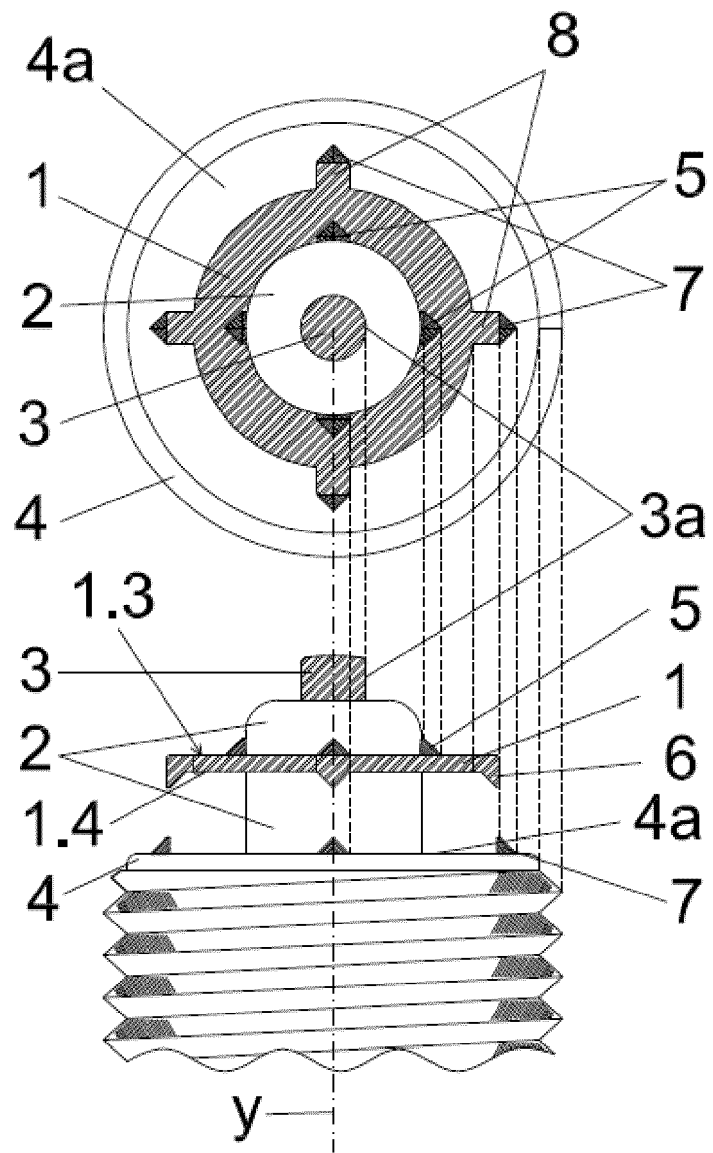


Figure 1

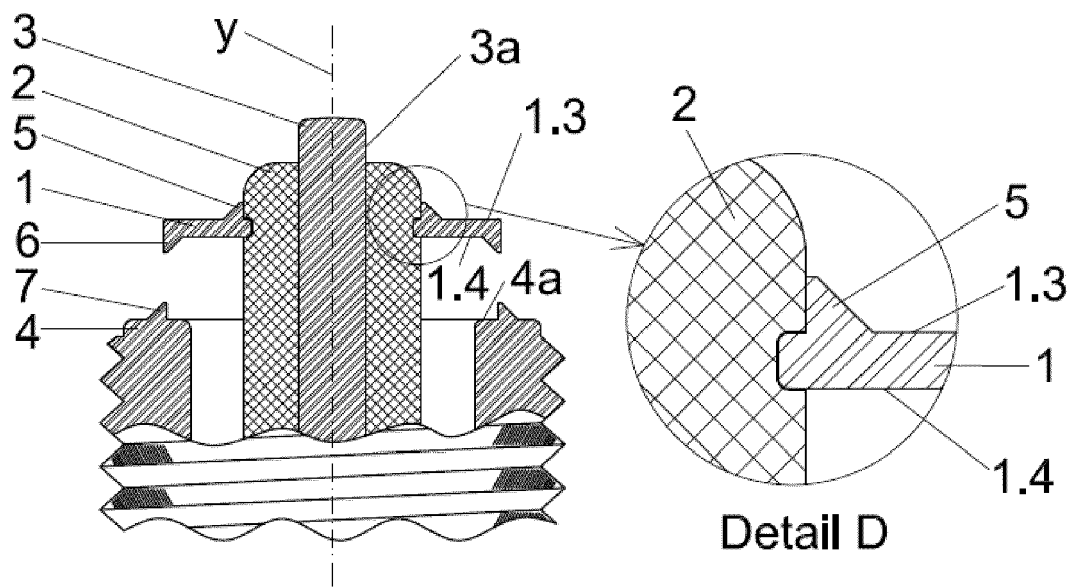


Figure 2

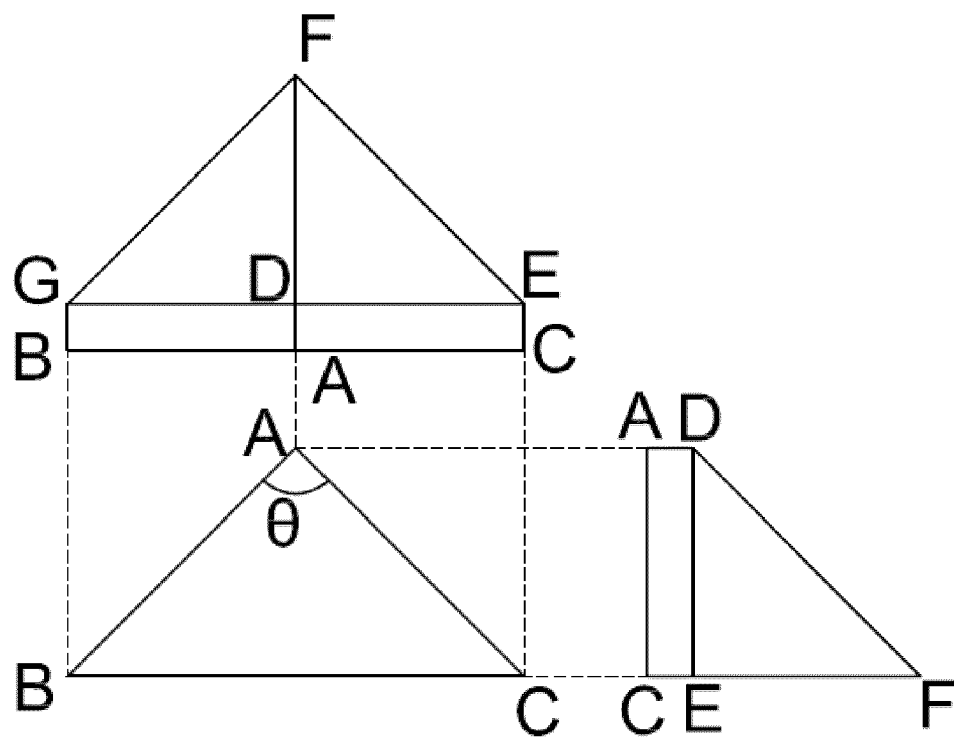


Figure 3

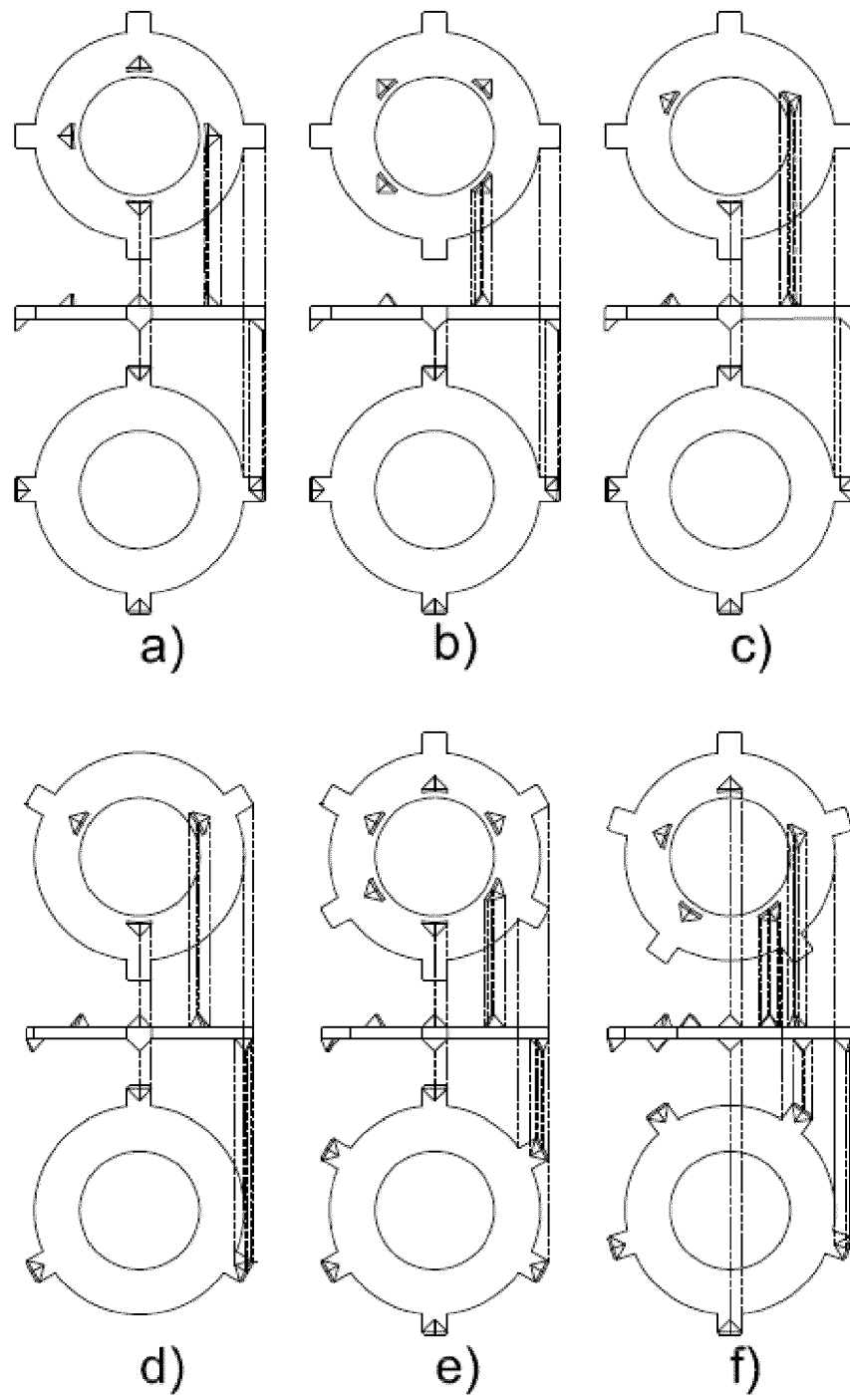


Figure 4



EUROPEAN SEARCH REPORT

Application Number
EP 20 46 5577

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	ASTANEI DRAGOS ET AL: "A New Spark Plug to Improve the Performances of Combustion Engines: Study and Analysis of Unburned Exhaust Gases", PLASMA CHEMISTRY AND PLASMA PROCESSING, PLENUM PRESS. NEW YORK, US, vol. 38, no. 5, 8 May 2018 (2018-05-08), pages 1115-1132, XP036554902, ISSN: 0272-4324, DOI: 10.1007/S11090-018-9903-5 [retrieved on 2018-05-08] * page 1117, line 6 - last line * * figure 1 *	1-10	INV. H01T13/20 H01T13/46
A	HNATIUC B ET AL: "Electrical modeling of a double spark at atmospheric pressure", 2014 INTERNATIONAL CONFERENCE ON OPTIMIZATION OF ELECTRICAL AND ELECTRONIC EQUIPMENT (OPTIM), IEEE, 22 May 2014 (2014-05-22), pages 1005-1010, XP032615770, DOI: 10.1109/OPTIM.2014.6851006 [retrieved on 2014-07-09] * page 1006, paragraph 2 - paragraph 3 * * figures 1, 3 *	1-10	TECHNICAL FIELDS SEARCHED (IPC) H01T
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 April 2021	Examiner Fribert, Jan
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