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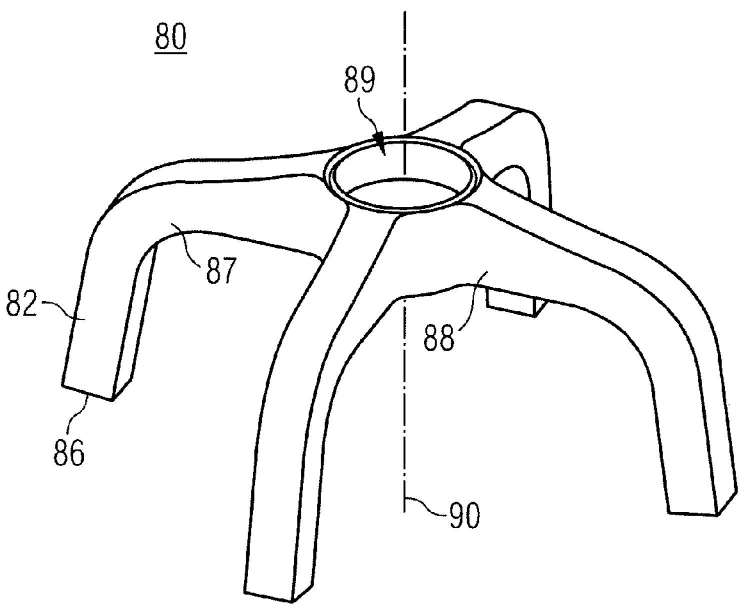
(54) Title: METHOD FOR MANUFACTURING AN IGNITION ELECTRODE

FIG 3



(57) Abstract: Ignition electrodes (80) having at least one electrode arm (82) may be exposed to high thermal and mechanical stress, which may lead to undesired fails of the material due to the known bending process when manufacturing cross-type ignition electrodes. Therefore, the present disclosure relates to a method for manufacturing an ignition electrode (80) of a spark plug (60) configured to be used in an internal combustion engine (10) and including a pre-combustion chamber (66). The method may comprise providing a mixture of powdered metal and binder material, forming the mixture of powdered metal and binder material into a desired shape, debinding the formed mixture of powdered metal and binder material for driving off the binder material, thereby forming a blank, and sintering the blank.

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Description

METHOD FOR MANUFACTURING AN IGNITION ELECTRODE

Technical Field

[01] The present disclosure generally relates to a method for manufacturing an ignition electrode of a spark plug configured to be used in an internal combustion engine, particularly in a gaseous fuel internal combustion engine.

Background

[02] It is known to use a spark plug including a prechamber (in the following referred to as "pre-combustion chamber") in some internal combustion engine applications, such as gaseous fuel applications. Typically, a pre-combustion chamber is a relatively small gas accumulating chamber located in the spark plug cap or in the engine cylinder head. The pre-combustion chamber is in fluid communication with the main combustion chamber of the internal combustion engine via a number of small flow channels. During operation, a spark plug ignites a mixture of gaseous fuel and air within the pre-combustion chamber (as opposed to igniting the gaseous fuel in the main combustion chamber). Ignition of the gaseous fuel in the pre-combustion chamber generates a front of burning fuel which is jetted or otherwise advanced through the flow channels into the main combustion chamber thereby igniting the mixture of gaseous fuel and air therein.

[03] In prior art systems, the ignition electrode may be provided in a crucial shape. In such case, the ignition electrode may include a plurality of electrode arms extending upright from a connecting section into the interior of the pre-combustion chamber.

[04] In the prior art, the manufacturing process of the ignition electrode may include some mechanical manufacturing steps including, for example, cutting a crucial piece out of a metal sheet, bending each electrode arms into the desired position, and applying a metal coat, such as, for instance, an iridium coat to the bended ignition electrode. However, the mechanical bending process may be limited due to, for example, the material's yield strength and, during operation of the ignition electrode, the electrode arms may break as the bending radius were to small for the used material and used material thickness.

[05] US 2012/0025689 A1 discloses a pre-chamber spark plug comprising an ignition electrode with several electrode arms. The ignition electrode is made of a cross-shaped blank that is cut out of sheet metal and then the electrode arms are set upright by bending.

[06] US 5 554 908 A discloses a pre-combustion chamber device containing an electrode carrier extending into the pre-combustion chamber and on it at least one ignition electrode is attached, which has at least one ignition portion, which cooperates with an internal wall surface of the pre-combustion chamber in defining at least one spark gap extending substantially athwart the longitudinal axis of the pre-combustion chamber.

[07] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of prior systems.

Summary of the Disclosure

[08] In an aspect of the present disclosure, a method for manufacturing an ignition electrode of a spark plug configured to be used in an internal combustion engine and including a pre-combustion chamber may be disclosed. The ignition electrode may be configured to at least partially protrude into the pre-combustion chamber. The disclosed method may comprise providing a mixture of powdered metal and binder material, forming the mixture of powdered metal and binder material into a desired shape, debinding the formed mixture of

powdered metal and binder material for driving off the binder material, thereby forming a blank, and sintering the blank.

[09] In a further aspect of the present disclosure, an ignition electrode for a spark plug comprising a pre-combustion chamber and being configured to at least partially extend into a main combustion chamber of an internal combustion engine may comprise a connecting section configured to be attached to a middle electrode extending through of the spark plug for supplying electric energy to the ignition electrode, and at least one electrode arm integrally formed with the connecting section and extending at least partially into the pre-combustion chamber, wherein the ignition electrode may be manufactured by metal sintering.

[10] In a further aspect of the present disclosure, a spark plug of an internal combustion engine may comprise a spark plug main body forming at least a portion of a pre-combustion chamber, a spark plug cap attached to the spark plug body and forming at least a portion of the pre-combustion chamber, a middle electrode configured to extend through the spark plug main body and to at least partially extend into the pre-combustion chamber, and an ignition electrode according to the present disclosure, wherein the ignition electrode may be attached to the middle electrode.

[11] In some embodiments, the disclosed method may be performed by the so-called metal injection molding process.

[12] In some embodiments, the disclosed ignition electrode may be manufactured by the disclosed method for manufacturing an ignition electrode.

[13] Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

<u>Brief Description of the Drawings</u>

[14] Fig. 1 is a diagrammatic cross-sectional view of an internal combustion engine with a spark plug including an ignition electrode of the

present disclosure shown installed in a cylinder head of the internal combustion engine;

Fig. 2 is a diagrammatic cross-sectional view of the spark plug of Fig. 1 shown in greater detail; and

Fig. 3 is a perspective view of an exemplary ignition electrode of the present disclosure.

Detailed Description

[15] The following is a detailed description of exemplary embodiments of the present disclosure. The exemplary embodiments described therein and illustrated in the drawings are intended to teach the principles of the present disclosure, enabling those of ordinary skill in the art to implement and use the present disclosure in many different environments and for many different applications. Therefore, the exemplary embodiments are not intended to be, and should not be considered as, a limiting description of the scope of patent protection. Rather, the scope of patent protection shall be defined by the appended claims.

[16] The present disclosure may be based in part on the realization that manufacturing an ignition electrode by a molding process may increase the degree of freedom in designing and constructing ignition electrodes. Specifically, the shape of the electrode arms may be provided in a desired shape with desired diameters or thickness at the different positions. For example, by molding the ignition electrode, the diameter of the electrode arms may be increased at locations of high thermal and mechanical stress for preventing the electrode arms from braking off from the connecting section configured to receive the respective ends of each electrode arm. Further, negative impact of, for example, the bending process of the ignition electrode, which may limit the degree of freedom in providing the ignition electrode in a desired shape with respect to the bending

radius, may be prevented. Therefore, the ignition electrode may be provided in a desired shape without any influence of the specific material properties.

[17] The present disclosure may be further based in part on the realization that manufacturing an ignition electrode by a metal injection process may support in shaping and forming the ignition electrode with a desired shape. Additionally, the material composition of the ignition electrode may be adjusted as desired such that any postprocessing of the molded ignition electrode, especially any mechanical postprocessing process, may be omitted resulting in lowering the manufacturing costs and increasing the efficiency in manufacturing.

[18] Referring now to the drawings, an exemplary embodiment of an internal combustion engine 10 is illustrated in Fig. 1. The internal combustion engine 10 may include features not shown, such as fuel systems, air systems, cooling systems, peripheries, drivetrain components, turbochargers, etc. For the purposes of the present disclosure, the internal combustion engine 10 is considered a four-stroke gaseous fuel internal combustion engine. One skilled in the art will recognize, however, that the gaseous fuel internal combustion engine 10 may be any type of engine (turbine, gas, diesel, natural gas, propane, two-stroke, etc.) that would utilize a spark plug having an integrated pre-combustion chamber. Furthermore, the internal combustion engine 10 may be of any size, with any number of cylinders, and in any configuration ("V," in-line, radial, etc.). The internal combustion engine 10 may be used to power any machine or other device, including locomotive applications, on-highway trucks or vehicles, off-highway trucks or machines, earth moving equipment, generators, aerospace applications, marine applications, pumps, stationary equipment, or other engine powered applications.

[19] The internal combustion engine 10 includes an engine block 12 having a plurality of cylinders 14 (one of which is illustrated in Fig. 1). A piston 16 is slidably disposed within the cylinder 14 to reciprocate between a top-dead-center position and a bottom-dead-center position. A connecting rod 18 connects

the piston 16 to an eccentric crankpin 20 of a crankshaft 22 such that reciprocating motion of the piston results in rotation of the crankshaft 22.

[20] The internal combustion engine 10 also includes a cylinder head 24 engaged with the engine block 12 to cover the cylinder 14, thereby defining a main combustion chamber 26. The cylinder head 24 defines intake and exhaust openings 28 that allow intake gases into the main combustion chamber 26 and exhaust gases out of the main combustion chamber 26, respectively. The engine valves 30 are positioned to selectively open and close the openings 28. Each cylinder 14 includes multiple intake and exhaust openings 28.

[21] The internal combustion engine 10 includes a series of valve actuation assemblies 40 (one of which is illustrated in Fig. 1). The multiple valve actuation assemblies 40 are provided per cylinder 14. For example, one valve actuation assembly may be used to open and close the intake valves and another valve actuation assembly may be provided to open and close the exhaust valves.

[22] The valve actuation assembly 40 includes a rocker arm 46. The rocker arm 46 is pivotally mounted in the cylinder head 24 and attaches to the engine valves 30 at one end and attaches to a push rod 48 at the other end. Oscillation of the rocker arm 46 about its pivot point 50 causes the valves 30 to move between an open position and a closed position. The valve actuation assembly 40 also includes valve springs 52 that bias the valves 30 toward the closed position (i.e. closing the intake and exhaust openings 28).

[23] The other end of the push rod 48 engages a lifter 54 which may engage a camshaft 56. The camshaft 56 operatively engages the crankshaft 22. The camshaft 56 is connected with crankshaft 22 in any manner readily apparent to one skilled in the art where rotation of the crankshaft 22 results in rotation of the camshaft 56. For example, camshaft 56 may be connected to crankshaft 22 through a gear train (not shown).

[24] As shown in Fig. 1, a first cam lobe 58 is disposed on the camshaft 56 to engage the lifter 54. One skilled in the art may recognize that the camshaft

56 may include additional cam lobes to engage with other lifters in order to actuate additional engine valves.

[25] The internal combustion engine 10 also includes a spark plug 60 having a pre-combustion chamber 66 (see Fig. 2). In Fig. 1, the spark plug 60 is not explicitly shown, but an ignition plug sleeve denoted with reference sign 60 is shown, which accommodates the ignition plug. The spark plug 60 is positioned within the cylinder head 24 between the valves 30. The spark plug 60 may be configured in a variety of ways. Any assembly capable of being positioned in the cylinder head 24 to support a combustion event outside of the main combustion chamber 26, and direct the combustion into the main combustion chamber 26 may be used.

[26] Referring now to Fig. 2, the spark plug 60 of Fig. 1 is shown in greater detail. The spark plug 60 includes a spark plug main body 62 and a spark plug cap 70 attached to the spark plug main body 62. The spark plug main body 62 includes a threaded portion 64 configured to engage with a threaded portion of the cylinder head 24 (see Fig. 1).

[27] Both the spark plug main body 62 and the spark plug cap 70 may be formed by casting. Preferably, the spark plug cap 70 may be formed by metal sintering and may consist of a material having a high thermal and mechanical stress resistance, such as, for example, a chrome-nickel alloy.

[28] The spark plug main body 62 and the spark plug cap 70 are disposed about a center axis 90 and include a substantially cylindrical cross-section. The spark plug main body 62 defines a first portion 68 of a pre-combustion chamber 66. The spark plug cap 70 defines a second portion 69 of the pre-combustion chamber 66. The first portion 68 and the second portion 69 are in fluid communication with each other. A sealing mechanism 98 may be provided at the first portion 68 of the pre-combustion chamber 66 for sealing the pre-combustion chamber 66 with respect to the upper portion of the pre-combustion chamber 66.

[29] At least one middle electrode 85 extends along the center axis 90 and is attached to an ignition electrode 80 including at least one electrode arm 82 at least partially extending into the first and second portions 68, 69 of the pre-combustion chamber 66. At least one ignition electrode 80 may be electrically connected to an engine control unit (not shown) and may be configured to generate a spark at the at least one electrode arm 82 upon an electric signal provided by the engine control unit via the middle electrode 85. As indicated in Fig. 2, the at least one ignition electrode 80 is connected via, for instance, a weld 83 to the middle electrode 85 supported by an insulator 84, such as, for example, a ceramic insulator. For example, the weld 83 may be a laser beam weld, a friction weld, an electronic beam weld, or any other weld suitable for attaching the at least one ignition electrode 80 to the middle electrode 85.

[30] The spark plug cap 70 comprises a connecting portion 72 and a nozzle portion 74. The connecting portion 72 is configured to be inserted into a receiving portion 65 of the spark plug main body 62. As shown in Fig. 2, the connecting portion 72 and the receiving portion 65 have a cylindrical shape substantially corresponding to each other, such that the connecting portion 72 of the spark plug cap 70 at least partially form-fits into the receiving portion 65 of the spark plug main body 62.

[31] The spark plug cap 70 is fixedly attached to the spark plug main body 62 by means of welding, such as, for example, laser beam welding. It is understood that the beam weld circumferentially extends around the entire flange formed between the bottom end of the spark plug main body 62 and a shoulder 71 of the nozzle portion 74 of the spark plug cap 70. In some embodiments, the spark plug cap 70 may be fixedly attached to the spark plug main body 62 by means of, for instance, soldering or any other suitable means. In some other embodiments, the spark plug cap 70 may be removably attached to the spark plug main body 62 by means of, for instance, snap fit, pressure fit, or any other suitable means.

[32] As further indicated in Fig. 2, the spark plug cap 70 comprises an inner surface 75 forming the second portion 69 of the pre-combustion chamber 66. The inner surface 75 includes a bottom portion 76 having a generally convex funnel-like shape. It is preferred that the bottom portion 76 is cup-like shaped having a convex form.

[33] The spark plug cap 70 includes an outer surface 73 configured to at least partially extend into the main combustion chamber 26 of the internal combustion engine 10. The spark plug cap 70 includes at least one flow channel 110 disposed at the nozzle portion 74. Specifically, the at least one flow channel 110 is configured to fluidly connect the pre-combustion chamber 66 with the main combustion chamber 26 (see Fig. 1). It is further preferred that the at least one flow channel 110 fluidly connects the pre-combustion chamber 66 at the bottom portion 76 with the main combustion chamber 26.

[34] As shown in Fig. 2, the ignition electrode 80 may include four electrode arms 82. However, in some embodiments, the ignition electrode may include, for example, five or six electrode arms 82, or any other suitable quantity of electrode arms. Each electrode arm 82 is configured to generate a spark at the portion between the inner wall of the pre-combustion chamber 66 and the electrode arm 82..

[35] The at least one electrode arm 82 may generally extend along the inner wall of the pre-combustion chamber 66 in direction of the spark plug cap 70. The at least one electrode arm 82 may include a distal end 86 and a proximal end 87 configured to be attached to a connecting section 88 of the ignition electrode 80. Therefore, the at least one electrode arm 82 may extend upright from the connecting section 88 configured to be directly attached to the middle electrode 85 via the weld 83.

[36] As further illustrated in Fig. 2, the at least one electrode arm 82 may include a longitudinal axis 92. In some embodiments, the electrode arms 82 may extend upright from the connecting section 88, for example, the electrode

arms 82 may perpendicular extend from the connecting section 88. In some other embodiments, the longitudinal axis 92 may form an angle α with the center axis 90. The angle α may range from about 0° to about 20°, such that the distal end 86 of the electrode arm 82 is closer to the inner wall of the pre-combustion chamber 66 than the proximal end 87 of the electrode arm 82. In such case, it may be ensured that the spark may be generated at the gap between the distal end 86 and the inner wall of the pre-combustion chamber 66, which results in that the electrode arm 82 is worn in a direction from the distal end 86 to the proximal end 87, such that falling off of the electrode arm 82 from the connecting section 88 may be prevented. Further, due to the inclined electrode arms 82, demolding of the casted ignition electrode 80 may be facilitated.

[37] Referring to Fig. 3, an exemplary ignition electrode 80 having the connecting section 88 and four electrode arms 82 is illustrated. However, the ignition electrode 80 may also comprise, for example, two, three, five or six electrode arms 82 or any other suitable quantity of electrode arms 82. As illustrated in Fig. 3, the ignition electrode 80 is provided in a cross like shape having symmetrically arranged electrode arms 82. In some other embodiments, the ignition electrode 80 may include six symmetrically arranged electrode arms 82 having, for instance, an angle of 60° to each other. In some cases, the electrode arms 82 may include alternating angles of 40° and 80° to each other. In some other embodiments, the ignition electrode 80 may have a flat shape having a predetermined quantity of flat electrode arms 82. In some other embodiments, instead of electrode arms 82, the ignition electrode 80 may comprise a cup-like shaped plate or a semispherical shape.

[38] As shown in Fig. 3, the electrode arms 82 may include a rectangular cross-section. In some embodiments, the at least one electrode arm 82 may include a circular cross-section, an oval cross-section, or any other suitable cross-section. As further illustrated, the electrode arms 82 may include a substantially constant cross-section from the proximal end 87 to the distal end 86.

However, in some embodiments, the electrode arms 82 may include a variable cross-section. For example, the cross-section of the electrode arms 82 may gradually decrease from the distal end 86 to the proximal end 87.

[39] The electrode arms 82 may include a diameter or thickness ranging from about 0.1 mm to 1.6 mm and may have a length from the proximal end 87 to the distal end 86 ranging from about 1 mm to 3 mm. The connecting section 88 may include a thickness being substantially higher than the diameter of the electrode arms 82, as the thermal and mechanical stress at the connecting section 88 may be higher than the stress at the electrode arms. Thus, the thickness of the connecting section 88 may range from about 0.4 mm to 2.0 mm.

[40] The ignition electrode 80 may further include a receiving section 89 for accommodating an end of the middle electrode 85. The receiving section 89 may be, for instance, a recess configured to accommodate an end of the middle electrode 85. Therefore, the shape of the receiving section 89 may correspond to the shape of the end of the middle electrode 85. After having positioned the middle electrode 85 in the receiving section 89 of the ignition electrode 80, both elements may be welded to each other via the laser beam weld 83 (see Fig. 2).

[41] As further illustrated in Fig. 3, the connecting section 88 configured to accommodate the proximal ends 87 of the electrode arms 82 may have a variable cross-section. As indicated, the cross-section of the connecting section 88 may decrease from the proximal ends 87 to the receiving section 89 configured to be centered at the center axis 90 of the spark plug 60. In other words, the thickness of the connecting section 88 may be substantially larger than the thickness of the electrode arms 82. This may provide more thermal and mechanical stress resistance at the connecting section 88, as at this position, the ignition electrode 80 may be exposed to high thermal and mechanical stress.

Industrial Applicability

[42] In the following, an exemplary manufacturing process of the ignition electrode 80 may be described in greater detail with respect to Figs. 1 to 3.

[43] The ignition electrode 80 may be manufactured by metal sintering. A metal sintering process is a process in which a mixture of powdered metal and binder material is applied with heat for debinding the binder material and melting the powdered metal together for generating, for instance, a work piece with a desired shape.

[44] First, a mixture of powdered metal and binder material may be provided. The mixture of powdered metal and binder material may include a predetermined mixing ratio. The powdered metal may include transition metals selected from the group consisting of, for example, platinum, titanium, cobalt, palladium, hafnium, iridium, etc. The binder material may include wax materials or synthetics selected from the group consisting of, for instance, polyamide, polyethylene, polypropylene, etc.. The binder material may be mixed with the powdered metal such that the binder material microscopically envelops the powdered metal.

[45] In a next step, the mixture of powdered metal and binder material is formed into a desired shape. Specifically, the mixture of powdered metal and binder material is inserted into a casting mold provided in the negative shape of the desired shape. In some embodiments, the mixture of powdered metal and binder material may be injected via a so-called injection molding process. Due to subsequent heating processes, the shaped parts of the mixture of powdered metal and binder may be exposed to shrinking. Therefore, the shaped parts may be typically 10 % to 20 % larger than the finished products. The shaped parts may be referred to as “green parts”.

[46] After having inserted the mixture of powdered metal and binder material into the casting mold for creating the “green parts”, the depending

process may start, which means that the binder is driven off from the green parts formed by the shaped powdered metal/binder material mixture. This may be achieved by, for example, applying heat to the casting mold. The applied heat may range from about 400° C to about 600° C. In some other cases, additionally or alternatively to applying heat, the debinding process may include applying solvents for removing most of the binder material. The above-mentioned debinding process may also be performed after having the casting mold evacuated, in other words in an evacuated environment. The parts after the debinding process may be referred to as blank or "brown parts".

[47] Subsequently, the blank obtained by the debinding process may be removed from the casting mold. The blank may be porous and brittle. Therefore, for increasing the strength of the blank, the blank may be sintered, which means that heat may be applied to the blank for heat-treating the same. Particularly, the sinter heat may be higher than the applied heat during the debinding process. In some cases, the sinter heat may be in a range from about 1500° C to about 2200° C. The sinter heat may be configured to melt the powdered metal with each other for providing a strong composition.

[48] In some embodiments, during the sinter process, the blanks may be sintered in vacuum-type furnaces. Further, the intense heat applied to the blanks or brown parts may shrink the parts in range from about 10 % to 20 % to almost complete density. However, the shrinkage has already been taken into consideration when the green parts were shaped. Subsequently, if necessary, some secondary machining or surface treatment may be available.

[49] Although the preferred embodiments of this invention have been described herein, improvements and modifications may be incorporated without departing from the scope of the following claims.

Claims

1. A method for manufacturing an ignition electrode (80) of a spark plug (60) configured to be used in an internal combustion engine (10) and including a pre-combustion chamber (66), the ignition electrode (80) being configured to at least partially protrude into the pre-combustion chamber (66), the method comprising:

providing a mixture of powdered metal and binder material;

forming the mixture of powdered metal and binder material into a desired shape;

debinding the formed mixture of powdered metal and binder material for driving off the binder material, thereby forming a blank; and

sintering the blank.

2. The method of claim 1, wherein forming the mixture of powdered metal and binder material into a desired shape includes compression molding.

3. The method of any one of the preceding claims, wherein the powdered metal includes transition materials selected from the group consisting of platinum, titanium, cobalt, hafnium, and/or palladium.

4. The method of any one of the preceding claims, wherein the binder material includes synthetics selected from the group consisting of polyamide, polypropylene, and/or polyethylene.

5. The method of any one of the preceding claims, wherein the sintering process is performed at a temperature ranging from about 1500° to about 2200°.

6. An ignition electrode (80) for a spark plug (60) comprising a pre-combustion chamber (66) and being configured to at least partially extend into a main combustion chamber (26) of an internal combustion engine (10), the ignition electrode (80) comprising:

a connecting section (88) configured to be attached to a middle electrode (85) extending through of the spark plug (60) for supplying electric energy to the ignition electrode (80); and

at least one electrode arm (82) integrally formed with the connecting section (88) and extending at least partially into the pre-combustion chamber (66),

wherein the ignition electrode (80) is manufactured by metal sintering.

7. The ignition electrode (80) of claim 6, wherein the ignition electrode (80) is manufactured according to a method of any one of claims 1 to 5.

8. The ignition electrode (80) of any one of claims 6 or 7, wherein the ignition electrode (80) includes four, five, or six electrode arms (82) symmetrically extending from the connecting section (88).

9. The ignition electrode (80) of any one of claims 6 to 8, wherein the at least one electrode arm (82) extends from the connecting section (88) with an angle ranging from about 0° to 20° with respect to a center axis of the middle electrode (85).

10. The ignition electrode (80) of any one of claims 6 to 9, wherein the at least one electrode arm (82) includes a first diameter, and the connecting section (88) includes a second diameter different to the first diameter.

11. The ignition electrode (80) of any one of claims 6 to 10, further comprising a receiving section (89) configured to receive a middle electrode (85) of the spark plug (60).

12. A spark plug (60) of an internal combustion engine (10), comprising:

a spark plug main body (62) forming a first portion (68) of a pre-combustion chamber (66);

a spark plug cap (70) attached to the spark plug main body (62) and forming at least a second portion (72) of the pre-combustion chamber (66);

a middle electrode (85) configured to extend through the spark plug main body (62) and to at least partially extend into the pre-combustion chamber (66); and

an ignition electrode (80) of any one of claims 6 to 10, the ignition electrode (80) being attached to the middle electrode (85).

13. The spark plug (60) of claim 12, further comprising an insulator (84) disposed within the spark plug main body (62) and configured to support the middle electrode (85).

14. The ignition electrode of any one of claims 12 or 13, wherein the ignition electrode (80) is attached to the middle electrode (85) via a weld (83).

15. The spark plug (60) of any one of claim 12 to 14, wherein the spark plug main body (62) includes an external thread (64) configured to be engage with a thread of a cylinder head (24) of the internal combustion engine (10).

FIG 1

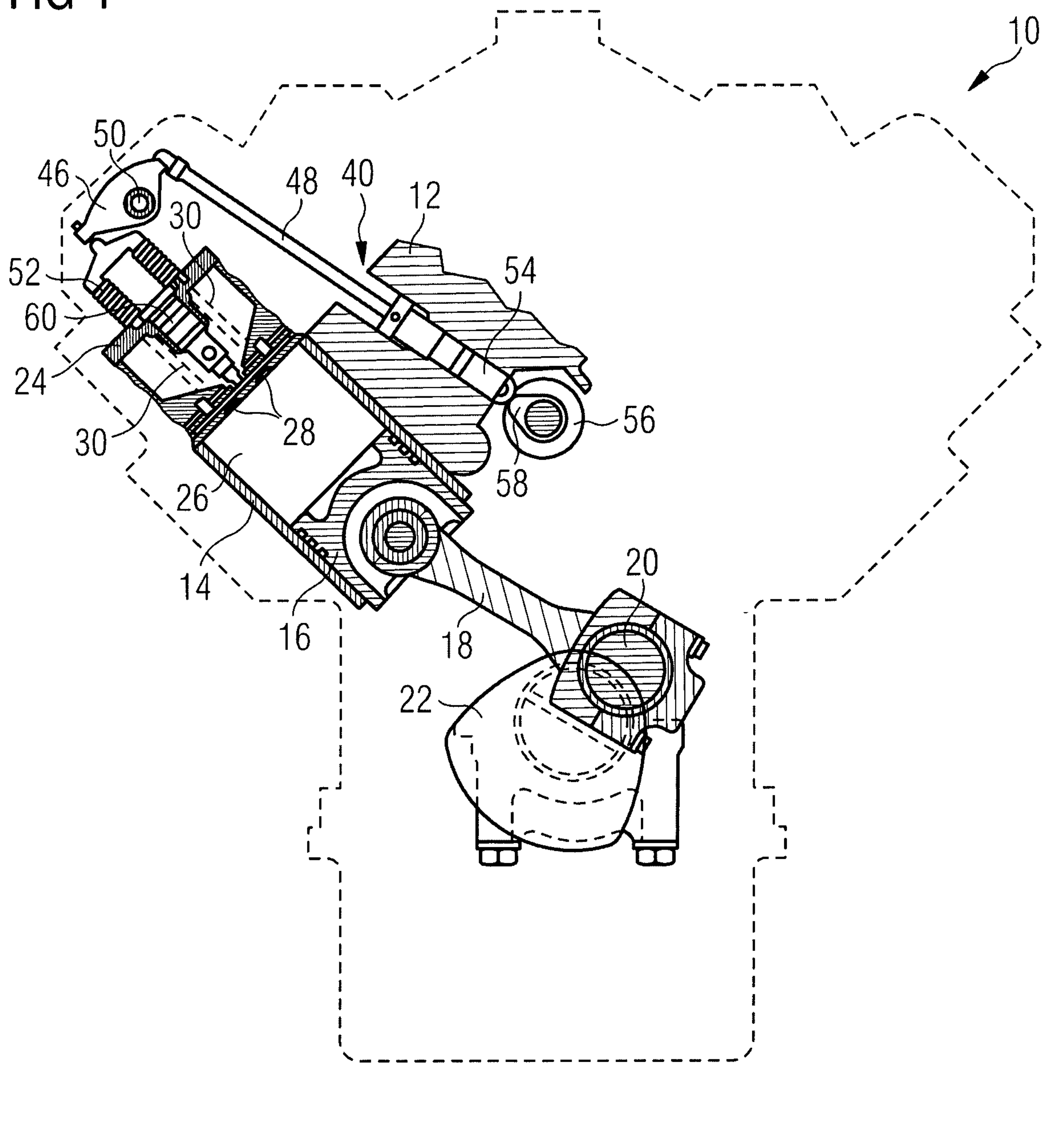

FIG 2

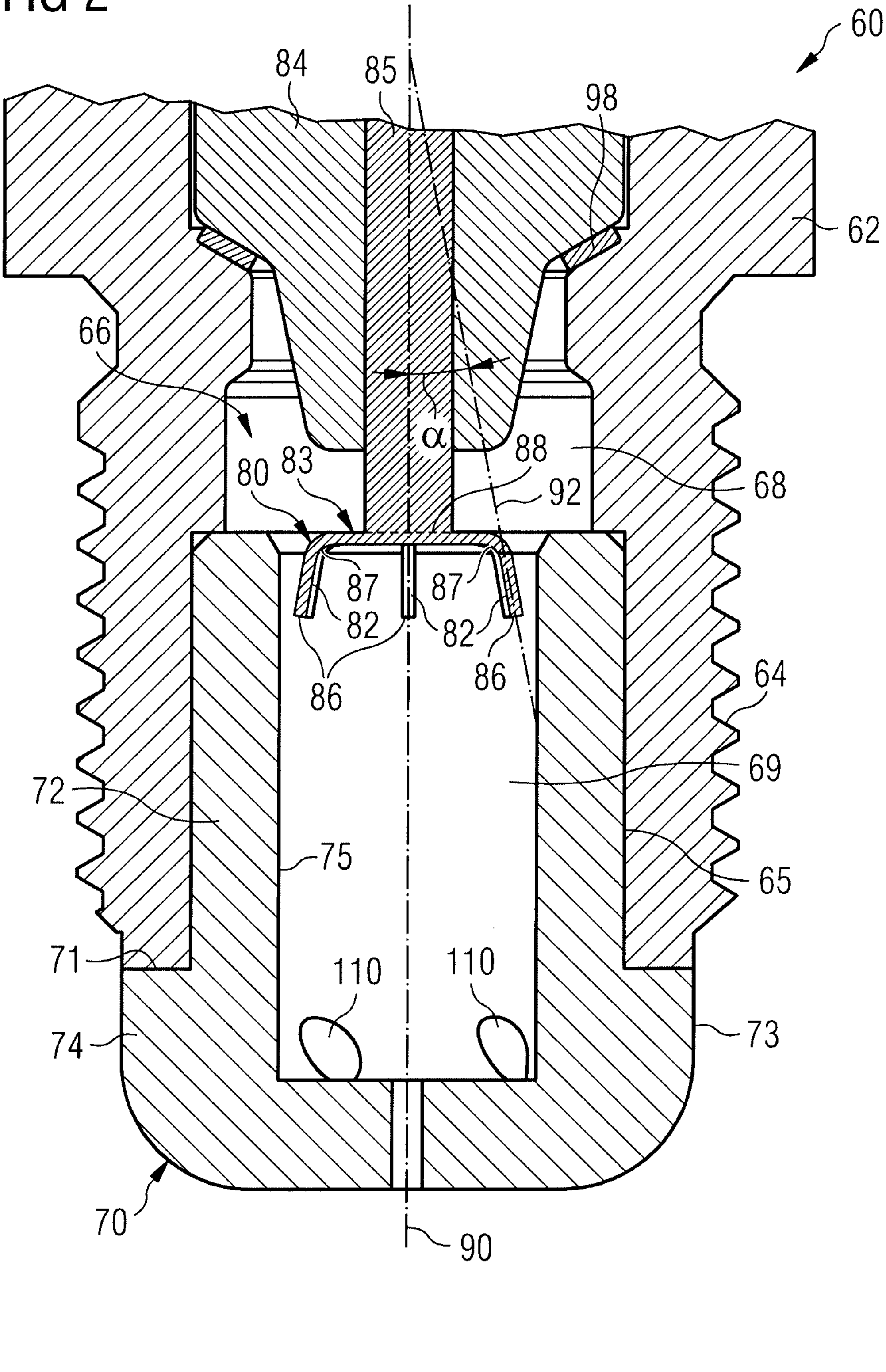
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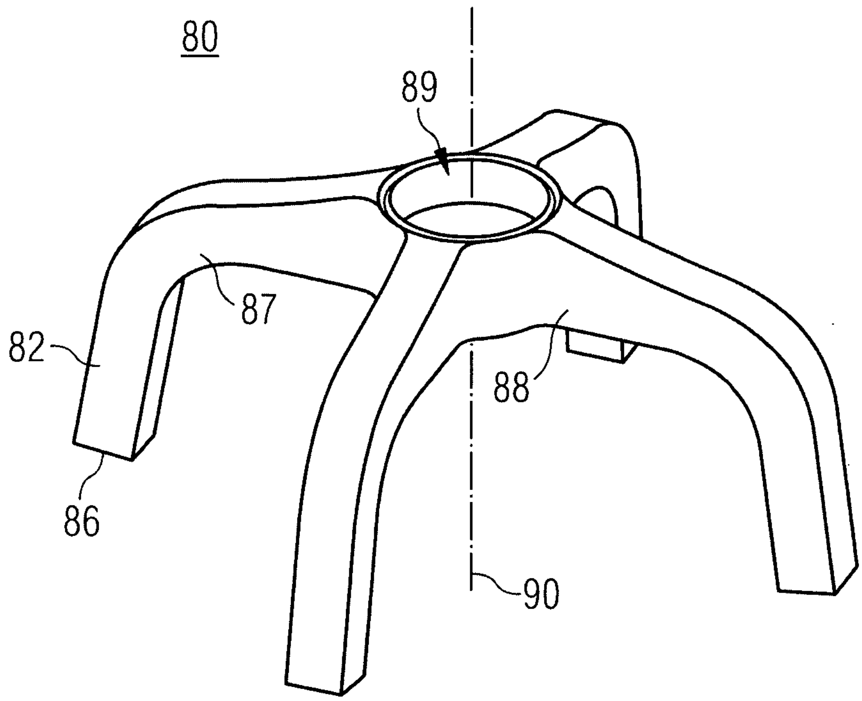
FIG 3



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/001308

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01T13/39 H01T13/46 H01T13/54 H01T21/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01T F02P C22C H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2005 285464 A (NGK SPARK PLUG CO) 13 October 2005 (2005-10-13)	1-5
Y	abstract	6-15
X	JP 2003 332020 A (NGK SPARK PLUG CO) 21 November 2003 (2003-11-21)	1-5
Y	abstract	6-15
X	US 6 045 601 A (TAN LYE KING [SG]) 4 April 2000 (2000-04-04)	1,2
A	claims 1-20; figure 1	3-15
X	US 2005/215160 A1 (KOLP COLONEL T [US]) 29 September 2005 (2005-09-29)	1,2
A	abstract; figure 7	3-15
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/001308

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/025689 A1 (KUHNERT DIETER [DE] ET AL) 2 February 2012 (2012-02-02) cited in the application the whole document -----	6-15
Y	US 5 554 908 A (KUHNERT DIETER [DE] ET AL) 10 September 1996 (1996-09-10) cited in the application the whole document -----	6-15

1

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2013/001308

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2005285464 A	13-10-2005	NONE	
JP 2003332020 A	21-11-2003	NONE	
US 6045601 A	04-04-2000	AT 247721 T	15-09-2003
		DE 60004613 D1	25-09-2003
		DE 60004613 T2	09-06-2004
		EP 1083239 A1	14-03-2001
		JP 4080133 B2	23-04-2008
		JP 2001081522 A	27-03-2001
		SG 82681 A1	21-08-2001
		US 6045601 A	04-04-2000
US 2005215160 A1	29-09-2005	NONE	
US 2012025689 A1	02-02-2012	DE 102010032412 A1	02-02-2012
		EP 2413442 A2	01-02-2012
		US 2012025689 A1	02-02-2012
US 5554908 A	10-09-1996	AT 156568 T	15-08-1997
		CA 2144489 A1	30-09-1995
		EP 0675272 A1	04-10-1995
		ES 2105791 T3	16-10-1997
		US 5554908 A	10-09-1996