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(71) Applicant *(for all designated States except US)*: **WÄRTSILÄ FINLAND OY** [FI/FI]; Tarhaajantie 2, FI-65380 Vaasa (FI).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **ANTTINEN, Teemu** [FI/FI]; Talkootie 21 A 3, FI-65280 Vaasa (FI). **SAARI, Petri** [FI/FI]; Rantakatu 10 D 10, FI-65100 Vaasa (FI). **SAVOLAINEN, Matti** [FI/FI]; Laippakatu 2 A 6, FI-65320 Vaasa (FI).

(74) Agent: **AWEK INDUSTRIAL PATENTS LTD OY**; PL 230, FI-00101 Helsinki (FI).

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(54) Title: SPARK PLUG

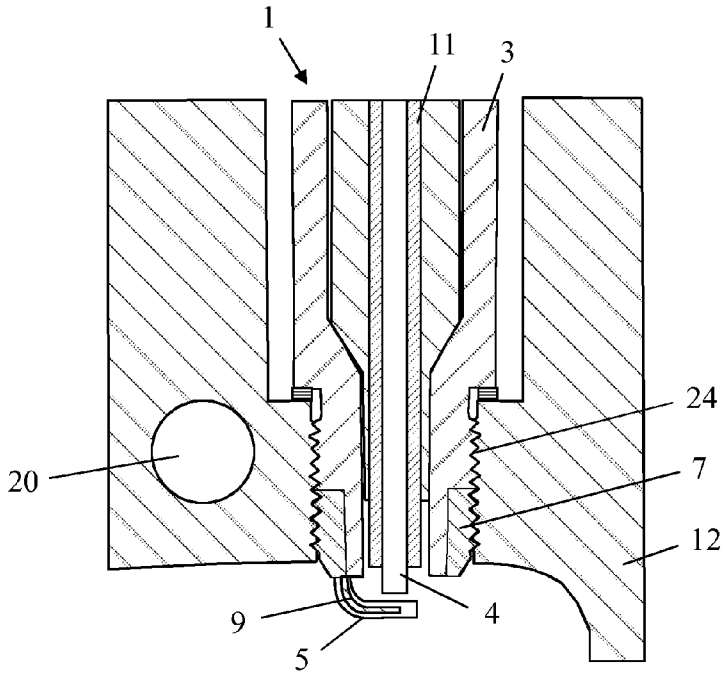

FIG. 4

[Continued on next page]

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(57) Abstract: A spark plug (1) for an internal combustion engine,which spark plug (1) comprises a body (3), a center electrode (4), a side electrode (5), a thread (24) arranged around the outer surface of the spark plug body (3)and an insulating layer (11) arranged between the center electrode (4) and the body (3). At least part of the spark plug (1) is made of a material with high thermal conductivity to increase heat transfer away from the side electrode (5).

SPARK PLUG

Technical field of the invention

The present invention relates to a spark plug for an internal combustion engine, as defined in the preamble of claim 1.

Background of the invention

Spark plugs are used in large gas engines operating according to the Otto cycle to ignite a mixture of gas and air in a pre-chamber. Due to the high cylinder pressures and temperatures related to the high engine outputs, the spark plugs have to withstand high thermal and mechanical loads. To extend the lifetime of the spark plugs, a cooling arrangement is needed in the pre-chamber. To cool the spark plugs, the pre-chamber is usually provided with drilled channels and cooling water is conducted from the cylinder head to the channels. Heat is conducted from the spark plugs through the spark plug body to the walls of the pre-chamber and from there to the cooling water.

Conventionally, spark plug bodies have been made of structural steel. A prior art spark plug 1 is shown in Fig. 2. The prior art spark plug comprises a body 3, a center electrode 4, a side electrode 5, a thread 24 arranged on the outer surface of the spark plug body 3 and an insulator layer 11 arranged around the center electrode 4. The spark plug body 3 is made of structural steel. The thermal conductivity of steel depends on the temperature and the amount and type of the alloying elements, but is approximately in the range between 15 and 50 W/(m·K). If compared to the thermal conductivity of for instance aluminum (approx. 250 W/(m·K)) or copper (approx. 400 W/(m·K)), it can be seen that the thermal conductivity of steel is relatively low. This means that heat transfer from the prior art spark plugs is not effective and thermal loads affecting the spark plugs are high. Especially the side electrodes encounter very high temperatures and are often the limiting factor for the spark plug lifetime. Some arrangements for cooling the center electrode are known from the prior art, but the problem with the heating of the side electrode has not been solved satisfactorily before.

Summary of the invention

The object of the present invention is to provide a new spark plug design that is both simple and cost effective and will improve heat conduction from the spark plug and especially from the side electrode to the walls of the pre-chamber. The characterizing features of the present invention are given in the characterizing part of claim 1.

According to the present invention, a spark plug for an internal combustion engine comprises a body, a center electrode, a side electrode, a thread arranged on the outer surface of the spark plug and an insulating layer arranged between the center electrode and the body. At least part of the spark plug is made of a material with high thermal conductivity to increase heat transfer away from the side electrode. As part of the spark plug is made of a material with high thermal conductivity, heat conduction from the spark plug is improved and lower thermal loads in the spark plug are achieved. This will extend the life time of the spark plug and reduce the operating costs of the engine.

According to a preferred embodiment of the invention, an insert made of a material with high thermal conductivity is arranged on the inner surface of the spark plug body and close to the side electrode.

According to another preferred embodiment of the present invention, an insert made of a material with high thermal conductivity is arranged on the outer surface of the spark plug body and close to the side electrode.

According to another preferred embodiment of the present invention, the thread is arranged at least partly on the outer surface of the insert.

According to another preferred embodiment of the present invention, an insert made of a material with high thermal conductivity is arranged inside the spark plug body and close to the side electrode.

According to another preferred embodiment of the present invention, at least part of the insert is arranged in that part of the spark plug that is located between the end points of the thread.

According to another preferred embodiment of the present invention, the insert extends in the direction of the longitudinal axis of the spark plug over the whole area covered by the thread.

According to another preferred embodiment of the present invention, the whole spark plug body is made of a material with high thermal conductivity.

According to another preferred embodiment of the present invention, the spark plug body is made of steel.

According to another preferred embodiment of the present invention, the side electrode is connected to the part having high thermal conductivity.

According to another preferred embodiment of the present invention, a core made of a material with high thermal conductivity is arranged inside the side electrode.

According to another preferred embodiment of the present invention, the core is connected to the part having high thermal conductivity.

According to another preferred embodiment of the present invention, the material with high thermal conductivity has thermal conductivity of at least 100 W/(m·K), preferably at least 200 W/(m·K). According to one embodiment, the material with high thermal conductivity is copper or copper alloy.

According to another preferred embodiment of the invention, the spark plug is arranged in an engine comprising a pre-chamber and heat is conducted from the spark plug to the wall of the pre-chamber.

Brief description of the drawings

Fig. 1 shows a simplified illustration of part of a gas engine with a pre-chamber.

Fig. 2 shows a prior art spark plug.

Fig. 3 shows an embodiment of the invention with a thermally conductive part on the inner surface of the spark plug body.

Fig.4. shows an embodiment of the invention with a thermally conductive part on the outer surface of the spark plug body.

Fig. 5 shows an embodiment of the invention with a thermally conductive part inside the spark plug body.

Fig. 6 shows an embodiment of the invention where the whole spark plug body is made of a thermally conductive material.

Detailed description of the invention

Some preferred embodiments of the present invention are now described with reference to the accompanying drawings.

Fig. 1 shows part of a large reciprocating internal combustion engine that uses gas, such as natural gas, as a fuel. The engine is a four-stroke gas engine operating according to the Otto cycle. Those kind of engines are used for instance as compressor drives or for the production of electricity and heat. The engine comprises a cylinder 13, a cylinder liner 14, a piston 15 and a cylinder head 16. Only one cylinder 13 is shown, but the engine can comprise any practical number of cylinders 13 arranged for instance inline or in V-configuration. In the cylinder head 16, there are arranged an intake valve 17 and an exhaust valve 18 in a conventional manner. Only one intake valve 17 and one exhaust valve 18 are shown, but there could be for instance two intake valves 17 and two exhaust valves 18 for each cylinder 13. The cylinder head 16 also comprises a pre-chamber 2. Between the pre-chamber wall 12 and the cylinder head 16 there is arranged a conduit 19 for cooling water. Also the pre-chamber wall 12 is provided with a cooling water drilling 20, which is connected to the conduit 19 in the cylinder head 16.

Part of the gas is injected into the pre-chamber 2 through a pre-chamber gas injection valve 21 and ignited by means of a spark plug 1. Main part of the gas is introduced into the air intake channel 23 through a gas admission valve 22 located upstream from the intake valve 17. The spark plug 1 according to the present invention is shown in more detail in Figs. 3–6. The spark plug 1 comprises a body 3, a center electrode 4, a side electrode 5 and a thread 24 arranged on the outer surface of the spark plug 1 close to that end of the spark plug 1 where the side electrode 5 is located. The thread 24 is used to fasten the spark plug 1 to the pre-chamber wall 12. The thread 24 can be arranged on the outer surface of the spark plug body 3, or alternatively on the outer surface of an insert that is arranged on the outer surface of the spark plug body 3. It is also possible that the thread 24 is arranged partly on the outer surface of the spark plug body 3 and partly on the outer surface of an insert. The side electrode 5 is connected to the electrically conductive spark plug body 3 and thus grounded. Alternatively, the side electrode 5 can be connected to an insert that is used to improve heat transfer from the side electrode 5. The center electrode 4 is electrically insulated from the spark plug body 3 by an insulating layer 11, which is arranged between the center electrode 4 and the spark plug body 3.

Figs. 3–5 show embodiments of the invention where major part of the spark plug body 3 is made of a material that is conventionally used in spark plugs, such as structural steel. Structural steel has low thermal conductivity, approximately in the range between 15 and 50 W/(m·K), and therefore the heat produced by the combustion is not effectively conducted from the conventional spark plugs to the pre-chamber walls 12. Especially the heat transfer from the side electrode 5 is problematic and shortens the lifetime of the spark plug 1. In the embodiments shown in Figs. 3–5, this problem is solved by an insert made of a material having high thermal conductivity. The insert is arranged close to the side electrode 5. Preferably at least part of the insert is arranged in that part of the spark plug 1that is located between the end points of the thread 24. Preferably the insert extends in the direction of the longitudinal axis of the spark plug 1 over the whole area covered by the thread 24. The insert is in close contact with the spark plug body 3 to allow effective heat transfer. For instance threads or shrink fit can be used to attach the insert to the spark plug body 3. Other alternatives for attaching the insert to the spark plug body 3 are welding, brazing, form-locking or snap rings.

In the embodiment of Fig. 3, the insert is a sleeve 6 that is arranged on the inner surface of the spark plug body 3. The sleeve 6 is arranged close to the side electrode 5 to enhance heat transfer especially from the side electrode 5 to the pre-chamber wall 12. The side electrode 5 is fastened to the spark plug body 3. Since there is only a thin layer of conventional spark plug body material with low thermal conductivity between the side electrode 5 and the sleeve 6, heat is effectively conducted from the side electrode 5 to the sleeve 6. Because the sleeve 6 is made of a material with high thermal conductivity and there is only a relatively thin layer of a material with lower thermal conductivity around the sleeve 6, heat is effectively conducted through the whole outer surface of the sleeve 6 to the spark plug body 3, and from the spark plug body 3 to the pre-chamber wall 12. From the pre-chamber wall 12, heat is further conducted to the cooling water that flows in the cooling water drilling 20. Of course, since the side electrode 5 is fastened to the spark plug body 3, part of the heat is conducted directly through the spark plug body 3 to the pre-chamber wall 12. The side electrode 5 could also be fastened to the sleeve 6, if the spark plug body 3 did not cover the lower end of the sleeve 6.

In Fig. 4, the insert is a sleeve 7 that is arranged on the outer surface of the spark plug body 3. The thread 24 is arranged partly on the outer surface of the sleeve 7. In Fig. 4, the sleeve 7 extends only over part of the threaded area of the spark plug 1, but it could also be arranged so that the whole thread 24 was on the outer surface of the sleeve 7. Also in this embodiment, the sleeve 7 is arranged close to the side electrode 5. The side electrode 5 is fastened to the sleeve 7. To further enhance heat conduction from the side electrode 5, the side electrode 5 comprises a core 9 that is made of a material having high thermal conductivity. The core 9 and the sleeve 7 are connected to each other to ensure effective heat transfer between the side electrode 5 and the sleeve 7. However, this not necessary, but the core 9 can also be connected to the spark plug body 3, if the side electrode 5 is also connected to the spark plug body 3.

In the embodiment of Fig. 5, an insert 8 is arranged inside the spark plug body 3 so that a sandwich structure is formed. As shown in the figure, the insert 8 extends in the direction of the longitudinal axis of the spark plug 1 over the whole area covered by the thread 24. This ensures very effective heat transfer away from the spark plug 1. The side

electrode 5 is fastened to the spark plug body 3. The insert 8 is arranged close to the side electrode 5. The insert 8 is preferably arranged on the whole circumference of the spark plug body 3. There is only a thin layer of material having low thermal conductivity between the side electrode 5 and the insert 8, and therefore heat is effectively conducted from the side electrode 5 to the insert 8. To further enhance heat transfer away from the side electrode 5, a core 9 made of a material having high thermal conductivity is arranged inside the side electrode 5. As shown in the figure, the core 9 is connected to the insert 8. From the insert 8, heat is effectively conducted through the whole outer surface of the insert 8 to the spark plug body 3, and from the spark plug body 3 to the prechamber wall 12.

In the embodiment shown in Fig. 6, the whole spark plug body 3 is made of a thermally conductive material. The side electrode 5 is fastened to the spark plug body 3. This is the most effective way to enhance heat conduction from the spark plug 1 to the prechamber wall 12. However, if the whole spark plug body 3 is made of a material with high thermal conductivity, it might be necessary to provide the spark plug body 3 with a corrosion resistant coating. Also in the embodiments shown in Figs. 3 and 4, those parts of the inserts 6, 7 that are exposed to the gases in the combustion chamber 2 might need a corrosion resistant coating. Of course, the need for the coating depends on the properties of the thermally conductive material.

The material used to enhance heat transfer from the side electrode 5 has suitably thermal conductivity of at least 100 W/(m·K), preferably at least 200 W/(m·K). Preferably the material is copper, of which thermal conductivity is approximately 400 W/(m·K), or copper alloy. Also other materials having thermal conductivity that is significantly higher than the thermal conductivity of conventional materials used in spark plug bodies and suitable mechanical properties could be used. If the side electrode 5 is provided with a core 9, the core 9 can be made of the same material as the other parts with high thermal conductivity. It is also possible to select different materials for different parts.

It should be noted that also many combinations of the embodiments presented above are possible. For instance, a side electrode 5 having a core 9 made of a material having high thermal conductivity could be used in connection with the embodiments shown in Figs.

3 and 6. The embodiments of Figs. 4 and 5 would also work without the core 9. Also, it would be possible to combine the embodiments of Figs. 3 and 4 and form a sandwich construction having the spark plug body 3 in the middle and layers of a material with high thermal conductivity on both sides of the body. Although the invention has been described here in connection with an engine comprising a pre-chamber, it is obvious to those skilled in the art that the invention could also be used in other types of engines. In that case, heat would be conducted from the spark plug to the cylinder head.

Claims

1. A spark plug (1) for an internal combustion engine, which spark plug (1) comprises a body (3), a center electrode (4), a side electrode (5), a thread (24) arranged on the outer surface of the spark plug (1) and an insulating layer (11) arranged between the center electrode (4) and the body (3), **characterized** in that the spark plug (1) comprises an insert (6, 7, 8) that is made of a material with high thermal conductivity to increase heat transfer away from the side electrode (5).

2. A spark plug (1) according to claim 1, **characterized** in that an insert (6) made of a material with high thermal conductivity is arranged on the inner surface of the spark plug body (3) and close to the side electrode (5).

3. A spark plug (1) according to claim 1 or 2, **characterized** in that an insert (7) made of a material with high thermal conductivity is arranged on the outer surface of the spark plug body (3) and close to the side electrode (5).

4. A spark plug (1) according to claim 3, **characterized** in that the thread (24) is arranged at least partly on the outer surface of the insert (7).

5. A spark plug (1) according to any of claims 1–4, **characterized** in that an insert (8) made of a material with high thermal conductivity is arranged inside the spark plug body (3) and close to the side electrode (5).

6. A spark plug (1) according to any of claims 2–5, **characterized** in that at least part of the insert (6, 7, 8) is arranged in that part of the spark plug (1) that is located between the end points of the thread (24).

7. A spark plug (1) according to any of claims 2–6, **characterized** in that the insert (6, 7, 8) extends in the direction of the longitudinal axis of the spark plug (1) over the whole area covered by the thread (24).

8. A spark plug (1) according to any of the preceding claims, **characterized** in that the whole spark plug body (3) is made of a material with high thermal conductivity.

9. A spark plug (1) according to any of claims 1–7, **characterized** in that the spark plug body (3) is made of steel.

10. A spark plug (1) according to any of the preceding claims, **characterized** in that the side electrode (5) is connected to the part having high thermal conductivity.

11. A spark plug (1) according to any of the preceding claims, **characterized** in that a core (9) made of a material with high thermal conductivity is arranged inside the side electrode (5).

12. A spark plug (1) according to claim 11, **characterized** in that the core (9) is connected to the part having high thermal conductivity.

13. A spark plug (1) according any of the preceding claims, **characterized** in that the material with high thermal conductivity has thermal conductivity of at least 100 W/(m·K).

14. A spark plug (1) according any of the preceding claims, **characterized** in that the material with high thermal conductivity has thermal conductivity of at least 200 W/(m·K).

15. A spark plug (1) according to any of the preceding claims, **characterized** in that the material with high thermal conductivity is copper or copper alloy.

16. A spark plug (1) according to any of the preceding claims, **characterized** in that the spark plug (1) is arranged in an engine comprising a pre-chamber (2) and heat is conducted from the spark plug (1) to the wall (12) of the pre-chamber (2).

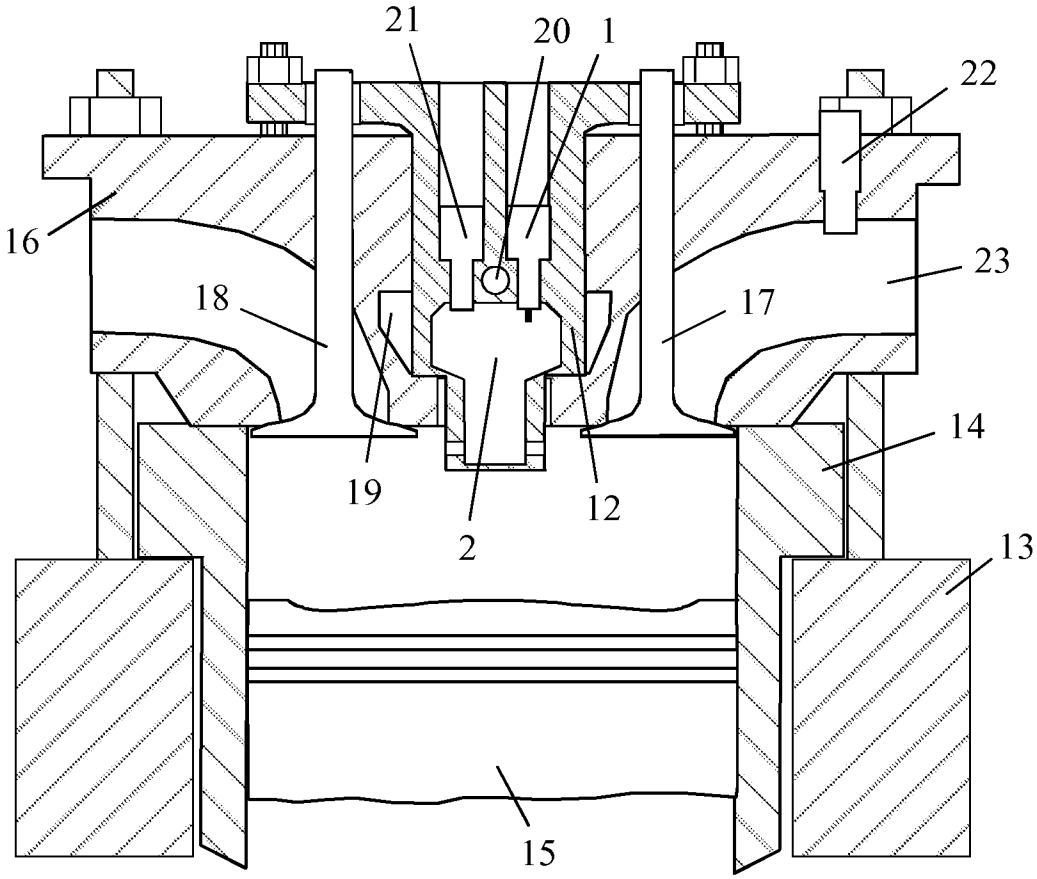

FIG. 1

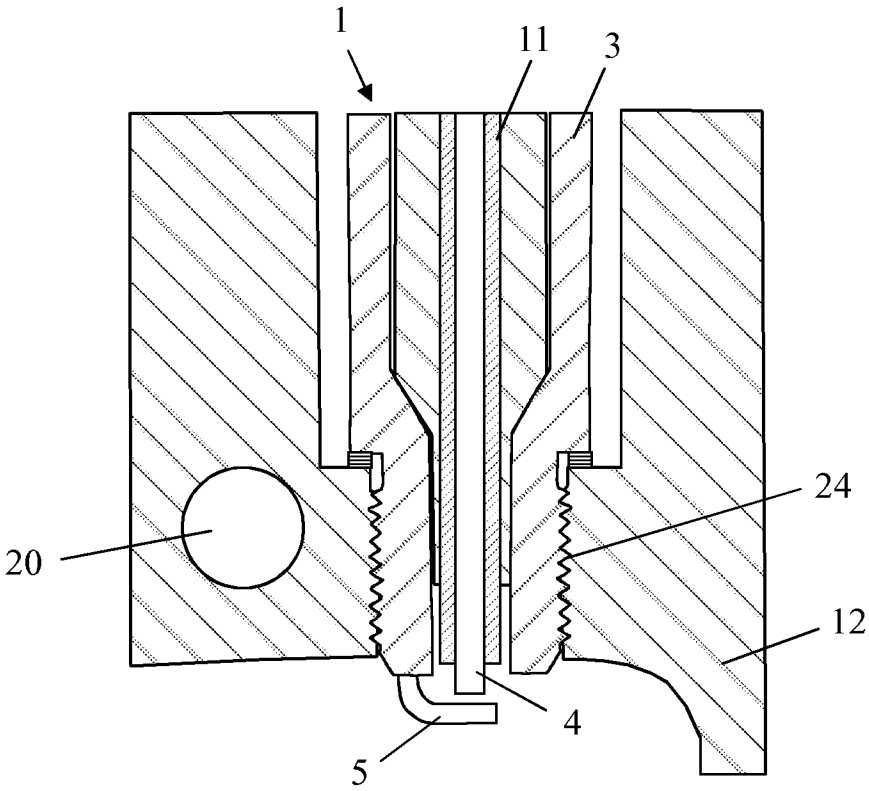

FIG. 2

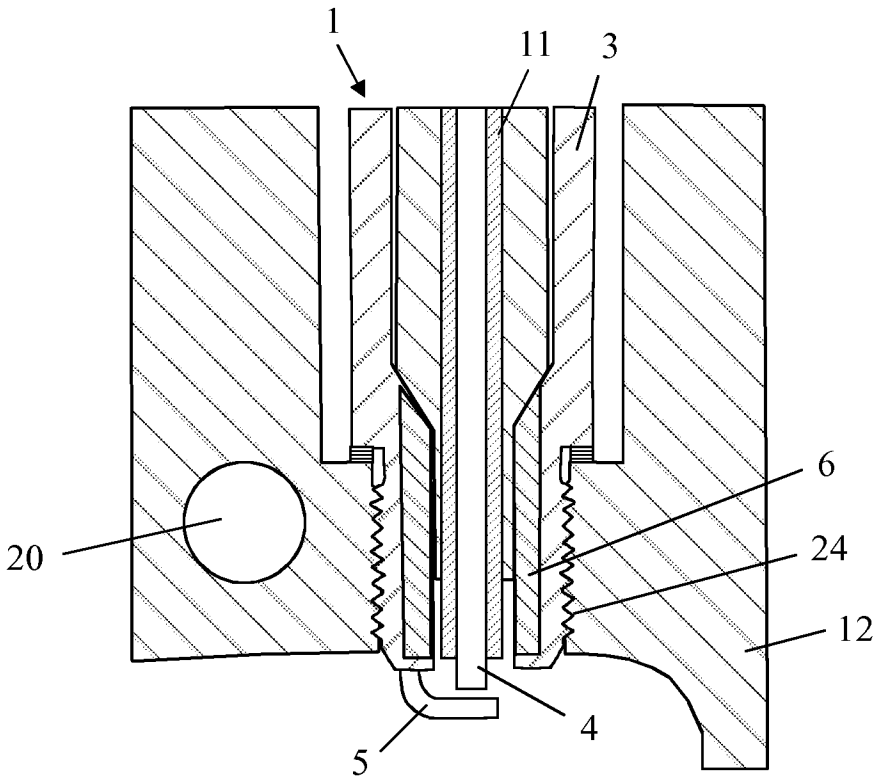

FIG. 3

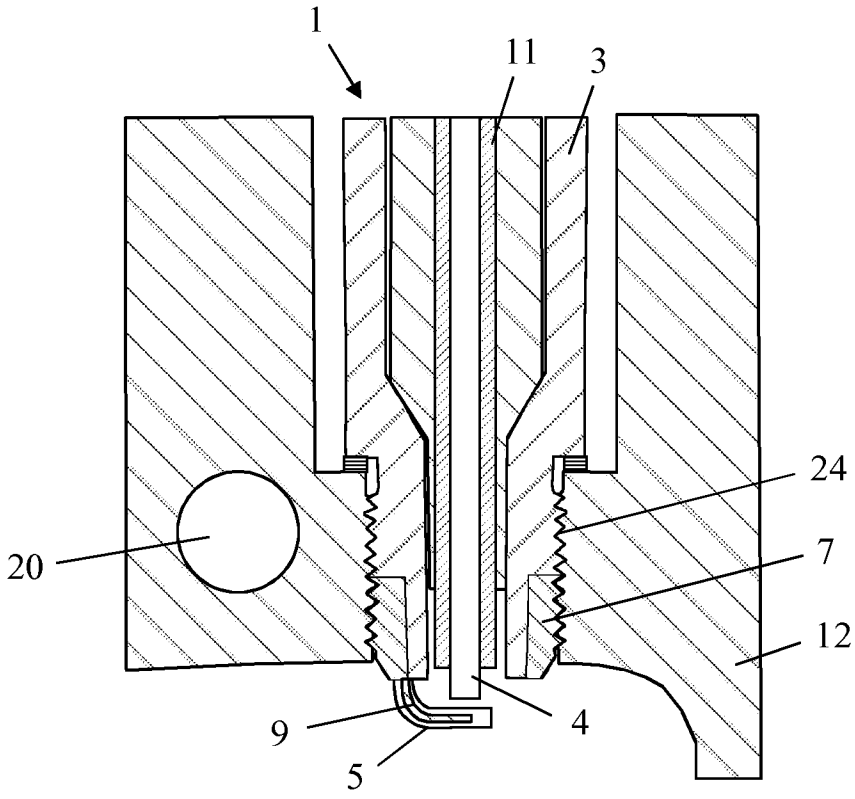

FIG. 4

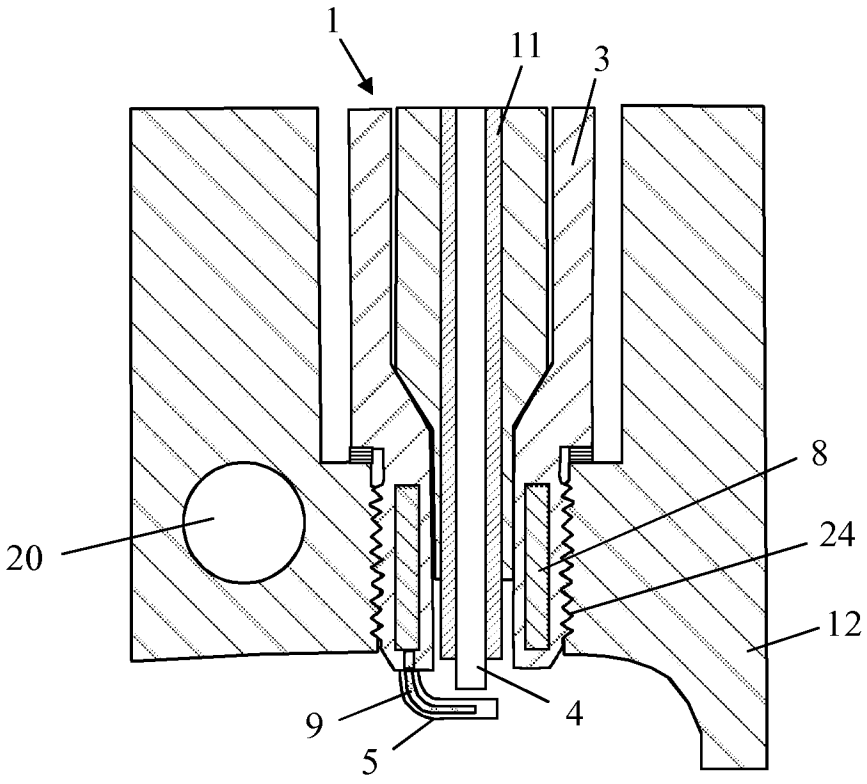

FIG. 5

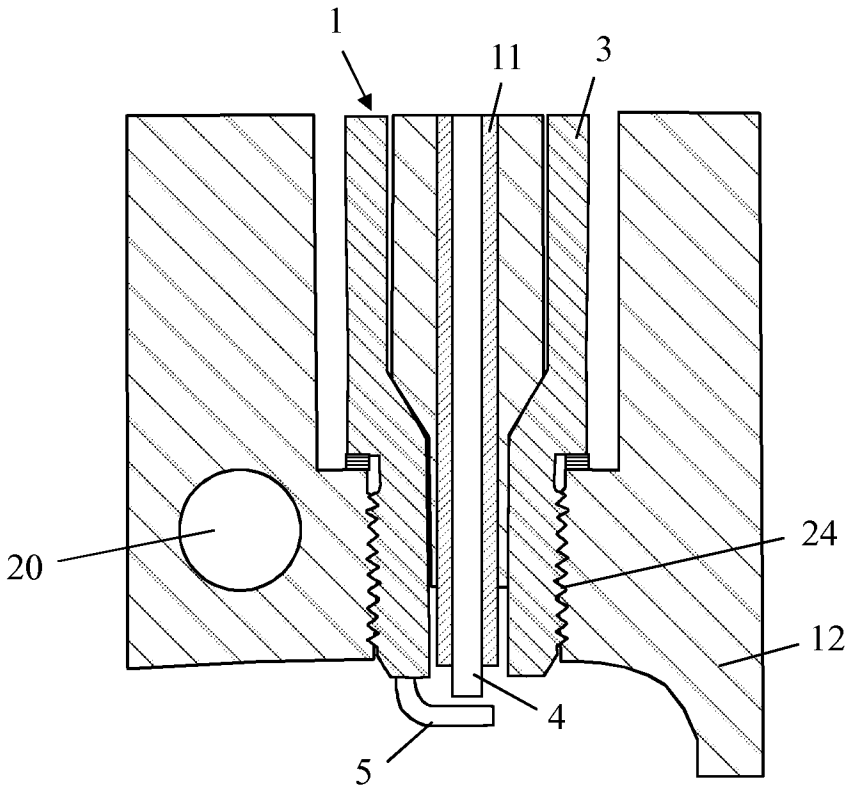

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2011/050095

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01T13/08 H01T13/16
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

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 practical, search terms used)
EPO-Internal, WPI Data

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 166298 A (NGK SPARK PLUG CO) 23 June 2005 (2005-06-23) abstract; figures 7-10	1-16
A	DE 31 19 193 A1 (BOSCH GMBH ROBERT [DE]) 9 December 1982 (1982-12-09) page 9, line 25 - page 10, last line; figures	1
A	US 2 146 722 A (DARBY ERNEST R) 14 February 1939 (1939-02-14) page 2, left-hand column, line 35 - line 45; figure 1	1
A	GB 2 202 274 A (WESTMORELAND & COMPANY LIMITED) 21 September 1988 (1988-09-21) abstract	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 April 2011	10/05/2011

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Marti Almeda, Rafael

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/FI2011/050095

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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