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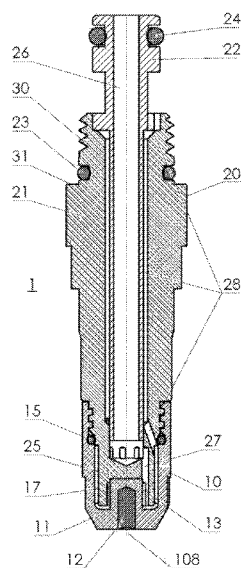


Fig.2

(57) Abstract: Electrode assembly (1) of the plasma arc torch according to the invention has an electrode holder (20) detachably connected to a replaceable part (10) of the electrode, wherein the electrode holder (20) is formed substantially in the shape of a hollow cylinder, the rear end of which is adapted to be connected to the plasma arc torch; and wherein the replaceable part (10) of the electrode is formed in the shape of a rotationally symmetrical body, at the front end of which an emissive insert (12) is coaxially mounted; wherein the front end of the electrode holder (20) extends into an inner space (18) of the electrode replaceable part (10) and comprises a first contact surface (25); the front end of the replaceable part (10) of the electrode has a second contact surface (13) on the inside of the inner space (18) in conductive contact with the first contact surface (25); and wherein the second contact surface (13) is immediately followed by a cooled surface (16) along its entire circumference, at least partially exposed to the cooling medium.

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Electrode assembly for plasma arc torch with the improved electric current transfer

Field of the Invention

The technical solution relates to an electrode assembly for use in liquid-cooled plasma torches intended for metals' thermal decomposition. The electrode assembly is a portion of the plasma arc torch that supplies and transmits electric current to the plasma arc. This electrode assembly consists of an electrode holder and an electrode replacement part.

State of the Art

Liquid-cooled plasma torches are generally manufactured with an electrode holder (also called a cathode) substantially in the shape of a hollow cylinder made of electrically conductive material. The electrode holder is located in the centre of the plasma torch, where the axis of the electrode holder coincides with the axis of the plasma torch. At the rear, the electrode holder is shaped for a fixed or detachable mounting in the body of the plasma torch. On the front side, the electrode holder is shaped for detachable mounting of the electrode on the electrode holder. The electrode holder is made of an electrically conductive material, most often a copper alloy due to higher electrical conductivity, or stainless steel due to electrocorrosion resistance. An electric current is supplied from the plasma torch body to the electrode holder via an interconnection. The electric current then passes through the body of the electrode holder towards the electrode, into which it enters at the point of mutual detachable connection. The electric current energy is needed

to create a plasma arc, and subsequently, plasma current whose energy results in the thermal decomposition of metallic materials. The primary function of the electrode holder is to fix the electrode in the desired position, and to conduct an electric current. Another function of the electrode holder is to supply coolant to the electrode, and to drain coolant from the electrode. The cooling liquid serves to cool the individual parts of the plasma torch, which are heated by the plasma arc, and by the heated cut material. The cooling liquid conduction is an important function of the electrode holder in the liquid-cooled plasma torch. For the correct direction of the coolant flow to the electrode, a cooling tube is placed in the electrode holder, which structurally allows the supply of cooling liquid from the plasma torch via the electrode holder to the electrode. It also allows the subsequent return of cooling liquid from the electrode via the electrode holder to the plasma torch body. The mounting of the cooling tube in the electrode holder is fixed or detachable, allowing the replacement of one cooling tube with another. The electrode holder does not wear out during use.

The plasma electrodes for the liquid-cooled plasma torch are manufactured with the body substantially in the shape of a hollow cylinder. At the inlet end, the electrode is designed for mounting to/on the electrode holder. At the point of connection with the electrode holder, the electrode comprises a contact surface through which a direct electric current flows from the electrode holder to the electrode. At the output end, the electrode contains an emissive insert. The primary function of the electrode is to conduct direct electric current to the emissive insert, and then to transfer the electric direct current to a plasma arc formed by an electrically conductive ionized gas. The output of electric

current from the electrode to the plasma arc is enabled by the emissive insert, which is located in the body of the electrode, in its axis, at the place of output of electric current from the electrode. The emissive insert is made of a material with high electrical emissivity and high thermal resistance, such as zirconium, hafnium or tungsten. Further, the electrode is designed to allow coolant to flow in and out, and includes surfaces for cooling by the coolant. The electrode is the most heated part of the plasma torch. The electrode body receives heat from the emissive insert, which is in contact with the plasma arc, and conducts the received heat to the cooled surfaces, where it transfers it to the cooling medium. The electrode body is made of a material with high thermal and electrical conductivity, such as copper, silver, and their alloys. The electrode wears out during use. The electrode is a replaceable part of the plasma arc torch.

In the current state of the art, the electric current is conducted in the axial direction through the cylindrical body of the electrode holder via a mutual contact surface into the cylindrical body of the electrode, where it further flows in the axial direction into the outlet part of the electrode. In the outlet part of the electrode, the electric current is supplied in a radial direction to the emissive insert. Due to the fact that the electric current flows through the homogeneous material in the shortest possible direction, it flows in the radial direction directly to the part of the emissive insert that is in contact with the plasma arc. In this part of the electrode is the highest concentration of electric current flowing. The electric current flows towards the emissive insert only around its circumference at the point of contact with the plasma arc, into which the electric current subsequently passes. Only a small part of the contact area between the electrode body and the emissive insert is

used to transfer electric current from the electrode body to the emissive insert. The electrode wears out during operation. The wear of the electrode causes the emissive insert to burn out, specifically during ignition, burning and termination of the plasma arc. The wear causes the entrainment of molten molecules of the emissive insert material by a stream of electrons passing from the emissive insert into the plasma arc (plasma stream). The wear of the electrode causes a change in the direction of flow of the electric direct current which passes through the body of the electrode to the emissive insert only from the radial direction. This wear of the electrode negatively affects the properties of the plasma arc. Extending the life of the plasma electrode, and/or reducing its manufacturing costs, is solved by various prior art design solutions that are close to our plasma electrode assembly design.

The extension of the life of the plasma electrode is solved by the known design of the electrode according to the patent US6215090B1 (Oct 28, 1998). In this patent, the life of the electrode is extended by placing a non-emissive silver alloy insert around the emissive insert. The non-emissive silver alloy insert ensures better heat removal from the heated emissive insert. This results in slower wear of the emissive insert and longer life of the plasma electrode.

The state of the art according to patent CZ/EP2647265B1 (Dec 1, 2010) describes a solution to extend the life and reduce production costs of a plasma electrode, with an inner protrusion, allowing the electrode to be attached to the electrode holder. By direct cooling of the protrusion, a longer service life of the plasma electrode is achieved. The reduction of production costs for the electrode is achieved by its shortening.

Furthermore, the design of the electrode assembly according to patent EP 2 642 832 (Mar 23, 2012) is known in the art, which is also divided into two parts; the front part with an emissive insert, which wears out when the electrode is used, and on the rear mounting part, which does not wear out when the electrode is used, and can be used repeatedly. This reduces the production costs for the part of the electrode that needs to be replaced after use.

The applicant of this application has already developed an electrode with improved durability, as described in patent CZ307748. This patent describes the design and manufacture of an electrode for a plasma arc torch, which consists of an electrode body, an emissive insert and a highly conductive insert that surrounds the emissive insert, and is fixed in the electrode body by plastic deformation under counter-pressing. This design extends the life of the electrode while maintaining low manufacturing costs.

Summary of the Invention

The invention is based on the idea of creating an electrode assembly for plasma arc torch with improved electric current transfer to the plasma arc so that the electric current will flow uniformly to the emissive insert in the electrode from all directions, i.e. radial and axial. The construction of the electrode assembly consists of an electrode holder and a replaceable electrode part.

The electrode holder according to the invention is formed substantially in the shape of a hollow cylinder, the rear end of which is adapted for detachable connection to the plasma arc torch, and the front end of which is adapted for

detachable connection of the electrode replaceable part. In the front part, the electrode holder has a contact surface which is adapted to transfer electric current from the electrode holder to the replaceable part of the electrode.

The replaceable part of the electrode is formed in the shape of a rotationally symmetrical body, the rear end of which is open and adapted to be connected to the electrode holder and in the front end of which the emissive insert is coaxially mounted.

The emissive insert is pressed or soldered in the electrode. A highly conductive insert made of silver or an alloy thereof may be placed between the electrode body and the emissive insert. The electric current flows from the electrode holder via the contact surface to the replaceable part of the electrode, and from there it flows in the axial and subsequently radial direction to the emissive insert. This ensures that the electric current flows evenly to the emissive insert in the replaceable part of the electrode from all directions, i.e. radial and axial. Thus, a uniform current load of the emissive insert is achieved at its contact surface with the body of the replaceable part of the electrode.

According to the invention, the front end of the electrode holder extends into the inner space of the electrode replaceable part and comprises a first contact surface, preferably lying in a plane perpendicular to the torch axis, the front end of the electrode replaceable part having a second contact surface on the inside in the inner space, preferably also lying in a plane perpendicular to the torch axis and in conductive contact with the first contact surface. The second contact surface is immediately followed by a cooled

surface along its entire circumference, at least partially exposed to the cooling medium.

Inside the replaceable part of the electrode, there is preferably an inner protrusion which projects axially into the inner space, the second contact surface and the part of the cooled surface immediately adjacent to the second contact surface being located on the surface of this inner protrusion. The second contact surface together with the part of the cooled surface thus preferably projects axially into the inner space of the replaceable part of the electrode. The emissive insert can be partially located radially inside said inner protrusion.

Preferably, at least one supply channel for supplying the cooling medium to the cooled surface and at least one discharge channel for discharging the cooling medium are arranged inside the electrode holder. Thus, the cooling medium can flow between the electrode holder and the electrode replaceable part. The cooling medium bypasses and thus cools the inner surface of the replaceable part of the electrode in the area around the emissive insert. Furthermore, the cooling medium drains from the replaceable part of the electrode through an opening in the body of the electrode holder.

The surface of the front end of the electrode holder adjacent to the first contact surface and the cooled surface of the electrode replaceable part are preferably formed in a mutually complementary shape, said surface of the front end of the electrode holder and the cooled surface defining spaces for passage of the cooling medium.

The cooling medium supply is preferably realized in such a way that a cooling medium supply connector is pressed coaxially

inside the electrode holder and comprises a cooling medium passage for the cooling medium to flow towards the replaceable part of the electrode.

The electrode holder according to this preferred embodiment of the invention consists of two parts, namely the body of the electrode holder, which provides the conduction of electric current, and the cooling medium supply connector, which provides the conduction of cooling medium. The cooling medium supply connector is pressed into the electrode holder body as an inner liner, and a cooling medium passage is formed between the connector and the electrode holder body. The cooling medium enters from the torch into said connector, which has an opening in the axis, and flows through it into the outlet part of the electrode holder. In the outlet part of the electrode holder, there is at least one passage in the body of the electrode holder, through which the cooling medium flows to the replaceable part of the electrode. The cooling medium cools the inner surface of the electrode and flows through at least one opening in the electrode holder body into the passage formed between the electrode holder body and the cooling medium supply connector back into the torch body. At the inlet from the torch to the electrode holder, the cooling medium is sealed by a seal located on the cooling medium supply connector inside the electrode holder. At the outlet from the electrode holder to the torch, the cooling medium is sealed with a seal on the body of the electrode holder and a seal on the cooling medium supply connector. When passing from the electrode holder to the electrode, the cooling medium is sealed by a seal located at the connection between the cathode and the electrode.

The electrode assembly of the plasma arc torch according to the invention can advantageously be designed in such a way

that several types of replaceable part of the electrode, adapted to different current loads, can be fitted and used on one type of the electrode holder. Conversely, one type of replaceable part can be fitted and used with multiple types of electrode holder, adapted for mounting in different arc plasma torches.

The design of the electrode assembly consisting of the electrode holder and the replaceable part of the electrode according to the invention allows a uniform current loading of the emissive insert on its contact surface with the electrode body. The electrode assembly of the plasma arc torch according to the invention has an extended service life compared to hitherto conventional electrodes.

Explanation of Drawings

The plasma arc torch electrode assembly with improved electric current transfer according to the invention is shown in more detail in the drawings, in which:

- Fig. 1 shows a longitudinal section of the plasma torch comprising an electrode assembly according to the invention,
- Fig. 2 shows a longitudinal detailed section of the electrode assembly according to the first embodiment of the invention,
- Fig. 3 shows a longitudinal detailed section of a replaceable part of the electrode according to the first embodiment of the invention,
- Fig. 4 shows a longitudinal detailed section of an electrode holder according to the first embodiment of the invention,

- Fig. 5 shows a longitudinal detailed section of the electrode holder according to the alternative embodiment of the invention,
- Fig. 6 shows a longitudinal detailed section of the replaceable part of the electrode according to an alternative embodiment of the invention,
- Fig. 7 shows a longitudinal detailed section of the electrode according to another alternative embodiment of the invention,
- Fig. 8 shows a longitudinal detailed section of the replaceable part of the electrode according to yet another alternative embodiment of the invention,
- Fig. 9 shows a longitudinal detailed section of the electrode assembly according to the second embodiment of the invention,
- Fig. 10 shows a longitudinal detailed section of the electrode holder according to the second embodiment of the invention,
- Fig. 11 shows a longitudinal detailed section of the replaceable part of the electrode according to the second embodiment of the invention,
- Fig. 12 shows a longitudinal detailed section of the replaceable part of the electrode according to an alternative embodiment of the invention.

Examples of the Embodiments

The present invention will now be described in more detail by way of example with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. The invention may be embodied in other different ways and is not limited to the embodiments set forth herein.

Fig. 1 generally shows a longitudinal section of the plasma arc torch comprising an electrode assembly 1 according to the first embodiment of the present invention. The plasma arc torch consists, inter alia, of a torch body 100, a torch body portion 107 in which the electrode assembly 1 is mounted, which is a replaceable part of the plasma arc torch. Other replaceable parts of the plasma arc torch are a nozzle 101, a nozzle holder 102, a swirl ring 103, a protective shield 104, a protective shield holder 105 and a nozzle holder 106. All of these replaceable parts of the plasma arc torch are detachably connected to the torch body 100 and together with the other parts form the plasma arc torch. The plasma arc torch with individual parts shown in Fig. 1 has a substantially cylindrical rotational shape through which an axis 108 of the torch passes in the middle.

The electrode assembly 1 according to the first embodiment of the invention, which is shown in Fig. 1, is also shown in a longitudinal detailed section in Fig. 2. This electrode assembly 1 consists of an replaceable part 10 of the electrode and an electrode holder 20. The replaceable part 10 of the electrode consists of an electrode replaceable part body 11 and an emissive insert 12. The electrode holder 20 consists of an electrode holder body 21 and a cooling medium supply connector 22. The replaceable part 10 of the electrode and the electrode holder 20 are detachably connected to each other. This detachable connection comprises a first seal 15. Further, the electrode assembly 1 comprises a second seal 23 and a third seal 24. Both of these seals are located at the detachable connection between the electrode assembly 1 and the torch body portion 107. At this place, the electrode assembly 1 comprises a third connecting shape 30. The electrode assembly 1 according to the first embodiment of the invention comprises a third contact surface 31 which abuts the

corresponding surface of the torch body portion 107 at the detachable connection between the electrode assembly 1 and the torch body portion 107. The body 21 of the electrode holder of the torch body is made of an electrically conductive material, in the exemplary embodiment specifically of copper.

The electrode assembly 1 according to the first embodiment of the invention shown in Fig. 1 and Fig. 2 includes a cooling medium passage 26, a supply channel 27 and a discharge channel 28. The cooling medium passage 26 passes through the centre of the cooling medium supply connector 22 at the axis 108 of the plasma torch. The supply channel 27 passes through the body 21 of the electrode holder. The discharge channel 28 passes through the electrode holder 20. Further, the electrode assembly 1 comprises a first contact surface 25 and a second contact surface 13. The first contact surface 25 is perpendicular to the axis 108 of the torch and is located at the front of the body 21 of the electrode holder. The second contact surface 13 is also perpendicular to the axis 108 of the torch and is located on the inside of the body 11 of the replaceable part of the electrode. The first contact surface 25 and the second contact surface 13 abut each other. An inner protrusion 17 is located on the replaceable part 10 of the electrode.

The replaceable part 10 of the electrode according to the first embodiment of the invention shown in Fig. 1 and Fig. 2 is further shown in detail in Fig. 3. This replaceable part 10 of the electrode is formed in the shape of a rotationally symmetrical body, at its front end an emissive insert 12 is coaxially mounted, and which is adapted at the rear end for a detachable connection with the electrode holder 20. The replaceable part 10 of the electrode consists of a body 11 of the electrode replaceable part and an emissive insert 12. The

body 11 of the electrode replaceable part is made of copper. The emissive insert 12 in this exemplary embodiment is made of hafnium. The replaceable part 10 of the electrode has an inner space 18 inside the body 11 of the electrode replaceable part. This inner space 18 is open at the rear end of the replaceable part 10 of the electrode. In the open rear end of the replaceable part 10 of the electrode there is a second connecting shape 14 and a first seal 15. In the inner space 18 of the replaceable part 10 of the electrode there is also an inner protrusion 17 with a second contact surface 13 and a cooled surface 16. The second connecting shape 14 is adapted for detachable connection of the replaceable part 10 of the electrode with the electrode holder 20. The second connecting shape 14 in this embodiment is that of a trapezoidal thread. The first seal 15 has an annular shape and is made of a resilient material. The second contact surface 13 is perpendicular to the axis 108 of the torch and is located on the inner protrusion 17. The cooled surface 16 extends between the first seal 15 and the second contact surface 13, to which it is directly adjacent. The inner protrusion 17 has a rotationally symmetrical shape and protrudes from the body 11 of the electrode replaceable part into the inner space 18 of the electrode replaceable part. In a preferred embodiment, the emissive insert 12, which is coaxially mounted at the front end of the replaceable part 10 of the electrode, extends with its rear part up to the inner protrusion 17.

The electrode holder 20 according to the first embodiment of the invention, which is shown in Fig. 1 and Fig. 2, is further shown in detail in Fig. 4. This electrode holder 20 is substantially formed in the shape of a hollow cylinder, the rear end of which is adapted for detachable connection to the plasma arc torch, and the front end is adapted for detachable connection to the replaceable part 10 of the electrode, and

comprises a first connecting shape 29. The electrode holder 20 consists of the electrode holder body 21 and a cooling medium supply connector 22. The cooling medium supply connector 22 is made of a copper alloy CuZn40Pb2. The body 21 of the electrode holder is firmly connected to the connector 22 of the cooling medium supply. The cooling medium supply connector 22 is pressed into the body 21 of the electrode holder with an overlap. The cooling medium supply connector 22 passes through a coaxial passage 26 of the cooling medium, which is located in the axis 108 of the torch. It is followed by a supply channel 27, which is located in the body 21 of the electrode holder adjacent to the first contact surface 25. The first contact surface 25 is perpendicular to the axis 108 of the torch, and is located inside the electrode holder 21 at its front end. The electrode holder 20 further includes a discharge channel 28. The discharge channel 28 begins at the front of the electrode holder 20, between the first contact surface 25 and the first connecting shape 29, where it extends from the outer surface of the electrode holder body 21 into the inner space between the electrode holder body 21 and the cooling medium supply connector 22 and opens into a space between the second seal 23 and the third seal 24. The second seal 23 is made of a resilient material and is located at the rear end of the electrode holder 20 between the third contact surface 31 and the third connecting shape 30 for detachably connecting the electrode holder 20 to the plasma arc torch. The third seal 24, which is made of a resilient material, is located at the rear end of the electrode holder 20 between the cooling medium passage 26 and the discharge channel 28.

Fig. 5 shows a longitudinal detailed section of the electrode holder 20 according to an alternative embodiment to the first embodiment of the invention of the electrode holder 20 shown in Fig. 1, Fig. 2 and Fig. 4, and described above. This

alternative electrode holder 20 differs from the first embodiment in that the third contact surface 31 is offset towards the rear part of the electrode holder 20, and is located between the second seal 23 and the third connecting shape 30.

Fig. 6 shows a detailed sectional view of the replaceable part 10 of the electrode according to an alternative embodiment to the first embodiment of the invention of the replaceable part 10 of the electrode shown in Fig. 1, Fig. 2 and Fig. 3, and described above. This alternative embodiment of the replaceable part 10 of the electrode differs from the first embodiment in that the replaceable part 10 of the electrode further comprises a highly conductive insert 19 which has a rotationally symmetrical body shape and is located at the front end of the replaceable part 10 of the electrode between the emissive insert 12 made of hafnium and the body 11 of the replaceable part of the electrode made of copper. The emissive insert 12 is coaxially mounted in the highly conductive insert 19 and the body 11 of the electrode replaceable part. According to the exemplary embodiment, the highly conductive insert 19 is made of Ag90Cu silver alloy, but can be made of another high-silver alloy or of the silver itself.

Fig. 7 shows a detailed section of the replaceable part 10 of the electrode according to another alternative embodiment to the first embodiment of the invention of the replaceable part 10 of the electrode shown in Fig. 1, Fig. 2 and Fig. 3, and described above. This further alternative embodiment differs from the first embodiment in that the emissive insert 12, which is coaxially mounted at the front end of the replaceable part 10 of the electrode, passes through the body 11 of the electrode replaceable part, at the location of the inner protrusion 17. Thereby, the second contact surface 13, which

is perpendicular to the axis 108 of the torch and located at the front of the inner protrusion 17, is formed jointly by the surface on the electrode replaceable body 11 and the surface on the emissive insert 12. The electrode replaceable body 11 is made of copper and the emissive insert 12 is made of tungsten.

Fig. 8 shows a detailed sectional view of the replaceable part 10 of the electrode according to yet another alternative embodiment to the first embodiment of the invention of the replaceable part 10 of the electrode shown in Fig. 1, Fig. 2 and Fig. 3, and described above. This yet another alternative embodiment of the replaceable part 10 of the electrode differs from the first embodiment in that the replaceable part 10 of the electrode further comprises a highly conductive insert 19 which has a rotationally symmetrical body shape and is located at the front end of the replaceable part 10 of the electrode between the emissive insert 12 made of hafnium and the body 11 of the electrode replaceable part made of copper. The emissive insert 12 is coaxially mounted in the highly conductive insert 19. The inner protrusion 17 is entirely formed by the highly conductive insert 19. The highly conductive insert 19 is made of pure silver. The contact surface 13, which is perpendicular to the axis 108 of the torch and is located at the front of the inner protrusion 17, is thus formed on the highly conductive insert 19.

Fig. 9 shows a longitudinal section of the electrode assembly 1 according to the second embodiment of the invention. This electrode assembly 1 consists of the replaceable part 10 of the electrode and the electrode holder 20. The replaceable part 10 of the electrode consists of the electrode replacement body part 11 and the emissive insert 12. The electrode holder 20 consists of the electrode holder body 21 and the cooling

medium supply connector 22. The replaceable part 10 of the electrode and the electrode holder 20 are detachably connected together. This detachable connection comprises the first seal 15. Further, the electrode assembly 1 comprises the second seal 23 and the third seal 24. Both of these seals are located at the detachable connection between the electrode assembly 1 and the torch body portion 107. At this place, the electrode assembly 1 comprises the third connecting shape 30. The electrode assembly 1 according to the second embodiment of the invention comprises the third contact surface 31 which abuts the front surface of the torch body portion 107 at the detachable connection between the electrode assembly 1 and the torch body portion 107. The electrode assembly 1 comprises the cooling medium passage 26, the supply channel 27 and the discharge channel 28. The cooling medium passage 26 goes through the centre of the cooling medium supply connector 22 at the axis 108 of the plasma torch. The supply channel 27 goes through the body 21 of the electrode holder. The discharge channel 28 goes through the electrode holder 20. Further, the electrode assembly 1 comprises the first contact surface 25 and the second contact surface 13. The first contact surface 25 is located on the electrode holder 20 and is perpendicular to the axis 108 of the torch. The second contact surface 13 is located on the replaceable part 10 of the electrode and is perpendicular to the axis 108 of the torch. The first contact surface 25 and the second contact surface 13 abut each other and are in electrical contact. Inside the replaceable part 10 of the electrode, there is the inner protrusion 17.

The replaceable part 10 of the electrode according to the second embodiment of the invention, which is shown in Fig. 9, is further shown in detail in Fig. 11. This replaceable part 10 of the electrode is formed in the shape of a rotationally

symmetrical body, at the front end of which the emissive insert 12 is coaxially mounted, and which is adapted at the rear end for a detachable connection with the electrode holder 20. The replaceable part 10 of the electrode consists of the body 11 of the replaceable part of the electrode and the emissive insert 12. The body 11 of the replaceable part of the electrode is made of copper. The emissive insert 12 is made of hafnium. The replaceable part 10 of the electrode includes the inner space 18 within the electrode replaceable part body 11. This inner space 18 is located at the rear end of the replaceable part 10 of the electrode. It has a rotationally symmetrical shape, and includes the second connecting shape 14, the second contact surface 13, the cooled surface 16 and the inner protrusion 17. The second connecting shape 14 is adapted for detachable connection of the replaceable part 10 of the electrode to the electrode holder 20. The second connecting shape 14 in this embodiment is that of a trapezoidal thread. The second contact surface 13 is perpendicular to the axis 108 of the torch and is located on the inner face of the body 11 of the electrode replaceable part, and is formed by a surface on the body 11 of the electrode replaceable part. The cooled surface 16 extends between the second connecting shape 14 and the second contact surface 13, and further extends from the second contact surface 13 over the entire surface of the inner protrusion 17. The second contact surface 13 adjoins the cooled surface 16 on both sides. The inner protrusion 17 has a rotationally symmetrical shape, and is basically the inner protrusion of the body 11 of the electrode replaceable part.

The electrode holder 20 according to the second embodiment of the invention, which is shown in Fig. 9, is further shown in detail in Fig. 10. This electrode holder 20 is formed substantially in the shape of a hollow cylinder, the rear end

of which is adapted for detachable connection to a plasma arc torch, and the front end is adapted for detachable connection to the replaceable part 10 of the electrode, and comprises the first connecting shape 29 and the first seal 15. The electrode holder 20 consists of the electrode holder body 21 and the cooling medium supply connector 22. The body 21 of the electrode holder is made of copper. The cooling medium supply connector 22 is made of a copper alloy CuZn40Pb2. The body 21 of the electrode holder is firmly connected to the connector 22 of the cooling medium supply. The cooling medium supply connector 22 is pressed into the body 21 of the electrode holder with an overlap. The cooling medium supply connector 22 passes through the coaxial cooling medium passage 26 which is located in the axis 108 of the torch. It is followed by the supply channel 27, which is located in the body 21 of the electrode holder adjacent to the first contact surface 25. The first contact surface 25 is perpendicular to the axis 108 of the torch, and is located on the front of the electrode holder 21 at its front end. The electrode holder 20 further includes the discharge channel 28. The discharge channel 28 begins at the front of the electrode holder 20, between the supply channel 27 and the first connecting shape 29, where it extends from the outer surface of the electrode holder body 21 into the inner space between the electrode holder body 21 and the connector 22 of the cooling medium supply and opens into the space between the second seal 23 and the third seal 24. The second seal 23 is made of a resilient material, and is located at the rear end of the electrode holder 20, adjacent to the third contact surface 31. Further, at the rear end of the electrode holder 20, the electrode assembly 1 comprises the third connecting shape 30. The third seal 24 which is made of a resilient material is located at the rear end of the electrode holder 20 between the cooling medium passage 26 and the discharge channel 28.

Fig. 12 shows a detailed sectional view of the replaceable part 10 of the electrode according to an alternative embodiment to the second embodiment of the invention of the replaceable part 10 of the electrode shown in Fig. 9, and described above. This alternative embodiment of the replaceable part 10 of the electrode differs from the second embodiment in that the replaceable part 10 of the electrode further comprises a highly conductive insert 19 which has the shape of a rotationally symmetrical body and is located at the front end of the replaceable part 10 of the electrode between the emissive insert 12 made of hafnium and the body 11 of the electrode replaceable part made of copper. The emissive insert 12 is coaxially mounted in the highly conductive insert 19. This replaceable electrode part 10 does not have the inner protrusion 17. The highly conductive insert 19 is made of Ag90Cu silver alloy, and extends through the body 11 of the electrode replaceable part into the inner space 18. The surface of the highly conductive insert 19, which is part of the inner space 18, is one of the cooled surfaces 16. The second contact surface 13 perpendicular to the axis 108 of the torch is located on the inner face of the body 11 of the electrode replaceable part between the cooled surfaces 16. The further cooled surface 16 extends between the second connecting shape 14 and the second contact surface 13, and further extends over the entire inner surface of the highly conductive insert 19 from the second contact surface 13 towards the axis 108 of the torch.

Hereinafter, some embodiments according to the technical solution are more specifically described in the form of examples.

Example 1

The electrode assembly 1 was manufactured according to the first embodiment of the invention for a current load of 260 A, and is shown in Fig. 2. The electrode assembly 1 consists of the electrode holder 20 according to Fig. 4 and the replaceable part 10 of the electrode according to Fig. 3. The electrode holder 20 was made from the mutually pressed body 21 of the electrode holder 20 of copper Cu-ETP, and the cooling medium supply connector 22 of copper alloy CuZn40Pb2. The advantage of the mutually pressed connection of the body 21 of the electrode holder and the connector 22 of the cooling medium supply is its simplicity for production. The replaceable part 10 of the electrode was made from the body 11 of the electrode replaceable part made of CuOF copper and the emissive insert 12 made of hafnium according to ASTM B737 R1. The emissive insert 12 with a diameter of 2 mm is pressed into the body 11 of the replaceable part of the electrode which has an outer diameter of 10.4 mm and a length of 15 mm. The ratio of the total length of the replaceable part 10 of the electrode to its largest diameter is 1.44:1. The advantage of the mutually pressed connection of the emissive insert 12 and the body 11 of the replaceable part of the electrode is its simplicity for production. In the inner space 18 of the replaceable part 10 of the electrode, there is the inner protrusion 17 with a diameter of 4.1 mm. The diameter of the inner protrusion 17 affects the size of the second contact surface 13 and the distance of the cooled surface 16 located around the circumference of the inner protrusion 17 from the emissive insert 12. The smaller the distance between the cooled surface 16 and the emissive insert 12, the lower the temperature of the emissive insert 12. In the tested range of 3.5 mm to 5.0 mm, the diameter of the inner protrusion 17 with a value of 4.1 mm proved to be the best for this amperage. The second contact surface 13, which is at the front of the inner protrusion 17, thus has a total area of 13.2 mm². The emissive

insert 12 is located in the replaceable part 10 of the electrode in front of the second contact surface 13 in the direction of conducting the electric current. The mutual contact surface for the transition of the electric current between the first contact surface 25 and the second contact surface 13 is 13.2 mm^2 . Another mutual contact surface for the transition of electric current between the electrode holder 20 and the replaceable part 10 of the electrode is at the place of their mutually detachable connection. This electrode assembly 1 made according to the first embodiment of the invention showed a slower course of wear, and on average, 32% longer service life compared to the prior art 260 A electrode with only a radial electric current supply to the emissive insert. The electrode holder 20 did not wear out during the tests and can be used repeatedly. It was only necessary to replace the worn replaceable front part 10 of the electrode.

Example 2

The electrode holder 20 has been manufactured according to an alternative embodiment of the invention for a current load of 30 to 260 A, and is shown in Fig. 5. This electrode holder 20 is compatible with the replaceable part of the electrode according to Example 1 and Example 3. This electrode holder 20 is designed for a different type of plasma torch than the holder 20 in Example 1. This electrode holder 20 was made from the mutually pressed Cu-ETP copper electrode holder body 21 and a CuZn40Pb2 copper alloy connector 22 of the cooling medium supply. The electrode holder 20 did not wear out during the tests, and was used repeatedly. The electrode replaceable parts 10 used together with this electrode holder 20 had the same service life as in Example 1 when used with the electrode holder 20 made according to the first embodiment of the invention.

Example 3

The replaceable part 10 of the electrode has been made in accordance with yet another alternative embodiment of the invention for a current load of 400 A, and is shown in Fig. 8. This replaceable part 10 of the electrode was made of a CuOF copper electrode replaceable part body 11, a highly conductive pure silver insert 19 and a hafnium emissive insert 12 according to ASTM B737 R1. The emission insert 12 with a diameter of 2.25 mm is mounted in the highly conductive insert 19, and this is mounted in the body 11 of the replaceable part of the electrode which has an outer diameter of 10.35 mm and a length of 14.15 mm. The ratio of the total length of the replaceable part 10 of the electrode to its largest diameter is 1.38:1. In the inner space 18 of the replaceable part 10 of the electrode, there is an inner protrusion 17 with a diameter of 4.1 mm. The second contact surface 13, which is at the front of the inner protrusion 17, thus has a total area of 13.2 mm². The emissive insert 12 is located in the replaceable part 10 of the electrode in front of the second contact surface 13, in the direction of conducting the electric current. The mutual contact surface for the transition of electric current between the first contact surface 25 and the second contact surface 13 is 13.2 mm². Another mutual contact surface for the transition of electric current between the electrode holder 20 and the replaceable part 10 of the electrode is at the place of their mutually detachable connection. This replaceable part 10 of the 400A electrode showed an increased service life compared to the prior art 400A electrode with only a radial supply of electric current to the emissive insert. The electrode holders 20 of Example 1 and Example 2 were used in the test, depending on the type of plasma torch with which the tests were performed.

Example 4

The electrode assembly 1 is made according to the second embodiment of the invention for a current load of 80 A, and is shown in Fig. 9. The electrode assembly 1 consists of the electrode holder 20 according to Fig. 10, and the replaceable part 10 of the electrode according to Fig. 11. The electrode holder 20 was made from the mutually pressed Cu-ETP copper electrode holder body 21 and CuZn40Pb2 copper alloy connector 22 of the cooling medium supply. The advantage of the mutually pressed connection of the body 21 of the electrode holder and the connector 22 of the cooling medium supply is its simplicity for production. The replaceable part 10 of the electrode was made from a CuOF copper body 11 of the electrode replaceable part, and a hafnium emissive insert 12 according to ASTM B737 R1. The emissive insert 12 of Ø 1 mm is pressed into the body 11 of the replaceable part of the electrode which has an outer Ø of 10.4 mm and a length of 16.85 mm. The ratio of the total length of the replaceable part 10 of the electrode to its largest diameter is 1.62:1. The advantage of the mutually pressed connection of the emissive insert 12 and the body 11 of the replaceable part of the electrode is its simplicity for production. In the inner space 18 of the replaceable part 10 of the electrode, there is an inner protrusion 17 of Ø 2.5 mm. The second contact surface 13 is on the inner face of the replaceable part 10 of the electrode. The emissive insert 12 is located in the replaceable part 10 of the electrode in front of the second contact surface 13, in the direction of conducting the electric current. The mutual contact surface for the transition of electric current between the first contact surface 25 and the second contact surface 13 is 23.7 mm². Another mutual contact surface for the transition of electric current between the electrode holder 20 and the replaceable part 10 of the electrode is at the place of their mutually detachable connection. This electrode assembly 1 made

according to the second embodiment of the invention showed a slower course of wear, and on average, 12% longer service life compared to a prior art 80 A electrode with only a radial electric current supply to the emissive insert. The electrode holder 20 did not wear out during the tests and can be used repeatedly. It was only necessary to replace the worn replaceable front part 10 of the electrode. The great advantage of this replaceable part 10 of the electrode is that only 35 % of the amount of material is required for its production compared to the existing 80 A electrode, with only a radial supply of electric current to the emissive insert.

List of reference marks

- 1 electrode assembly
- 10 replaceable part of the electrode
- 11 body of the electrode replaceable part
- 12 emissive insert
- 13 second contact surface (in the inner space of the replaceable part of the electrode)
- 14 second connecting shape (on the replaceable part of the electrode for detachable connection with the electrode holder)
- 15 first seal (sealing connection between the electrode replaceable part and the electrode holder)
- 16 cooled surface (of the replaceable part of the electrode)
- 17 inner protrusion
- 18 inner space (of the replaceable part of the electrode)
- 19 highly conductive insert
- 20 electrode holder
- 21 electrode holder body
- 22 connector of the cooling medium supply
- 23 second seal (sealing connection between the electrode holder body and the torch body)

24 third seal (sealing connection between the cooling medium supply connector and the torch body)

25 first contact surface (at the front end of the electrode holder)

26 cooling medium passage (for the flow of cooling medium towards the replaceable part of the electrode)

27 supply channel (for supplying the cooling medium to the cooled surface)

28 discharge channel (for discharging the cooling medium from the directly cooled surface of the replaceable part of the electrode to the torch body)

29 first connecting shape (on the body of the electrode holder for detachable connection to the replaceable part of the electrode)

30 third connecting shape (on the electrode holder for detachable connection to the torch body)

31 third contact surface (on the electrode holder for the supply of electric current from the plasma torch)

100 torch body

101 nozzle

102 nozzle holder

103 swirl ring

104 protective shield

105 protective shield holder

106 nozzle holder

107 torch body portion (conducting electric current to the electrode assembly)

108 torch axis

Claims

1. An electrode assembly (1) of plasma arc torch having an electrode holder (20) detachably connected to the replaceable part (10) of the electrode;
wherein the electrode holder (20) is formed substantially in the shape of a hollow cylinder, the rear end of which is adapted to be connected to the plasma arc torch,
wherein the replaceable part (10) of the electrode is formed in the shape of a rotationally symmetrical body, at the front end of which an emissive insert (12) is coaxially mounted,

characterized in that

the front end of the electrode holder (20) extends into an inner space (18) of the replaceable part (10) of the electrode and comprises a first contact surface (25),
the front end of the replaceable part (10) of the electrode has in the interior of the inner space (18) a second contact surface (13) being in conductive contact with the first contact surface (25),
wherein the second contact surface (13) is immediately followed by a cooled surface (16) along its entire circumference, at least partially exposed to the cooling medium.

2. The plasma arc torch electrode assembly (1) according to claim 1 **characterized in that** both the first contact surface (25) and the second contact surface (13) lie in a plane perpendicular to the electrode axis (108).

3. The plasma arc torch electrode assembly (1) according to claim 1 or 2, **characterized in that** in the replaceable part (10) of the electrode there is an inner protrusion (17) which projects axially into the inner space (18), wherein the second

contact surface (13) and the part of the cooled surface (16) immediately adjacent to the second contact surface (13) are located on the surface of this inner protrusion (17).

4. The plasma arc torch electrode assembly (1) according to any of the preceding claims, **characterized in that** at least one supply channel (27) for supplying a cooling medium to the cooled surface (16) and at least one discharge channel (28) for discharging a cooling medium are arranged inside the electrode holder (20).

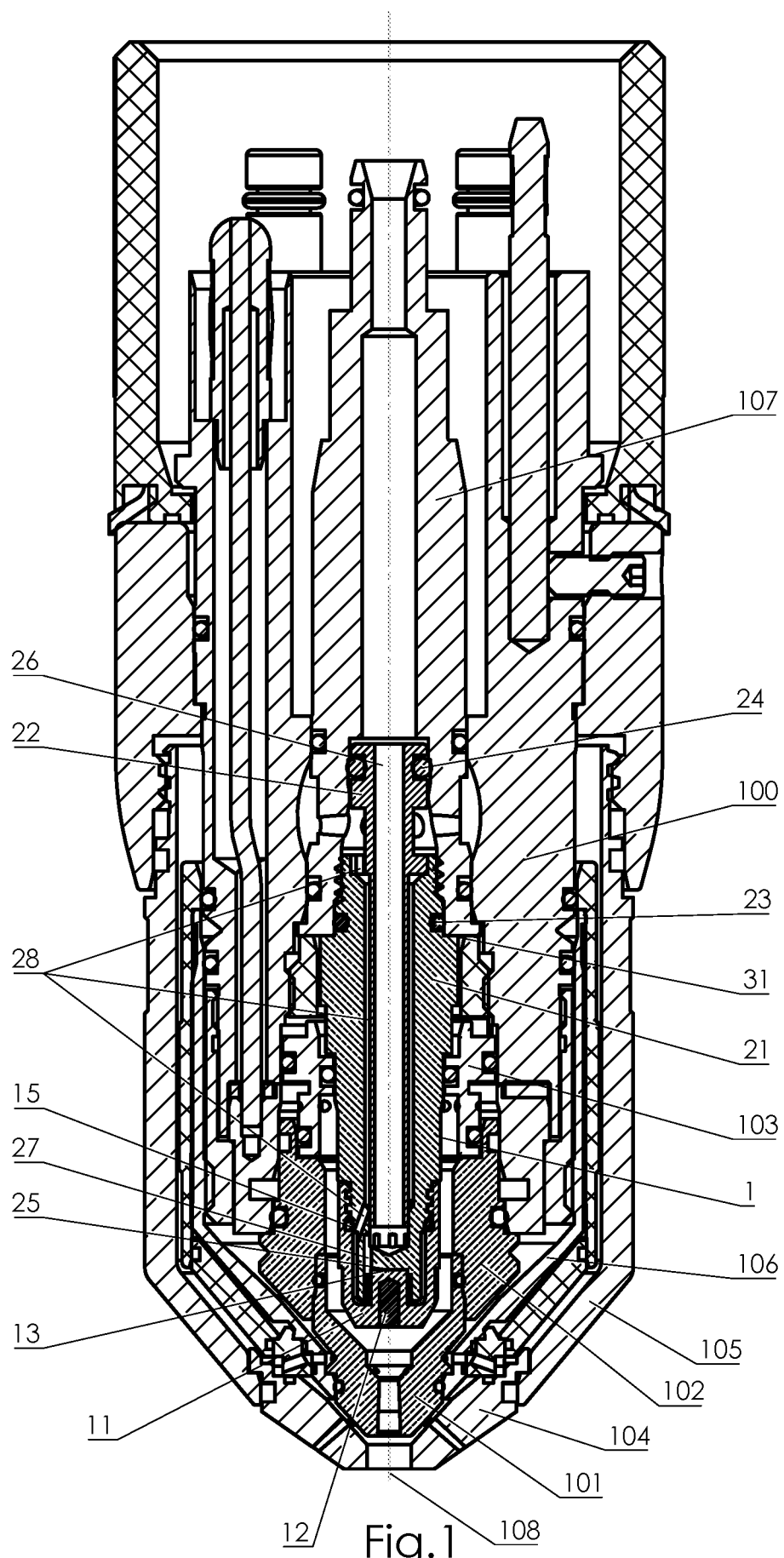
5. The plasma arc torch electrode assembly (1) according to any of the preceding claims, **characterized in that** at least one cooling medium passage (26) is arranged in the electrode holder (20) for supplying the cooling medium to the cooled surface (16).

6. The plasma arc torch electrode assembly (1) according to any of the preceding claims, **characterized in that** the front end surface of the electrode holder (20) adjacent to the first contact surface (25) and the cooled surface (16) of the replaceable part (10) of the electrode are formed complementary to each other, wherein said surface of the front end of the electrode holder (20) and the cooled surface (16) define spaces for the passage of the cooling medium between them.

7. The plasma arc torch electrode assembly (1) according to any of the preceding claims, **characterized in that** a cooling medium supply connector (22) is pressed coaxially inside the electrode holder (20), which comprises a cooling medium passage (26) for the cooling medium to flow towards the replaceable part (10) of the electrode.

8. The plasma arc torch electrode assembly (1) according to any of the preceding claims, **characterized in that** at the detachable connection of the electrode holder (20) with the replaceable part (10) of the electrode there is a first seal (15) preventing the penetration of the cooling medium, and on the electrode holder (20) there is a second seal (23) and a third seal (24), these seals being located on one and the other side from the outlet of the discharge channel (28) from the electrode holder (20).

9. The plasma arc torch electrode assembly (1) according to any of the preceding claims, **characterized in that** the length and the outer diameter of the replaceable part (10) of the electrode are in a ratio of 3:1 to 0.5:1, preferably 1.5:1.



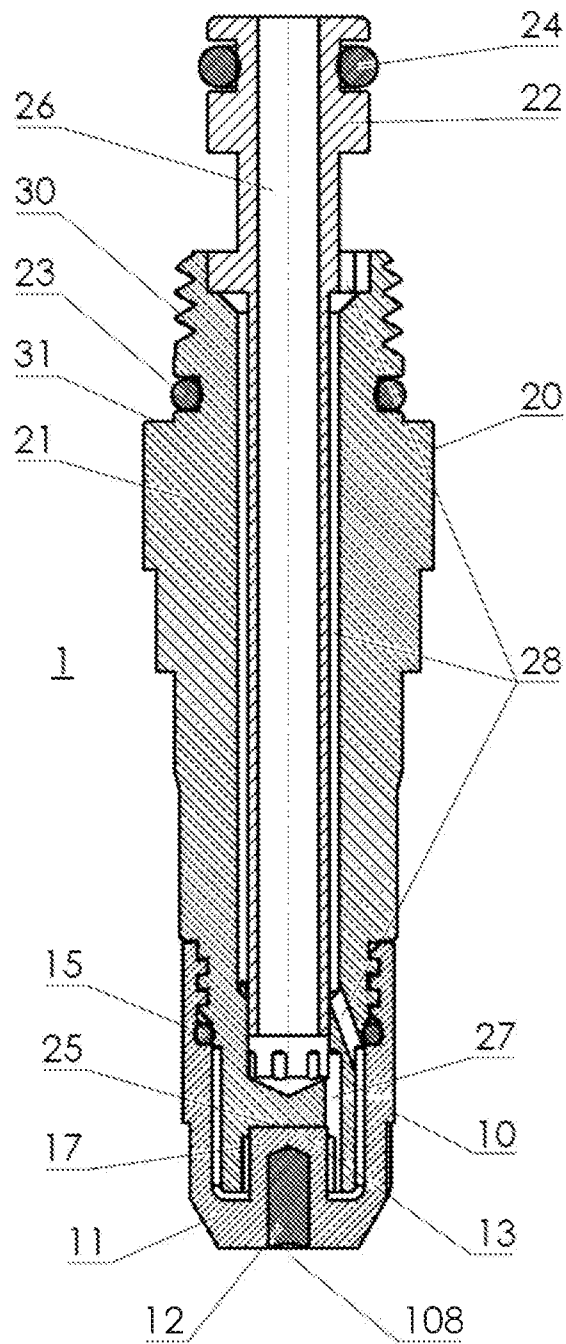


Fig.2

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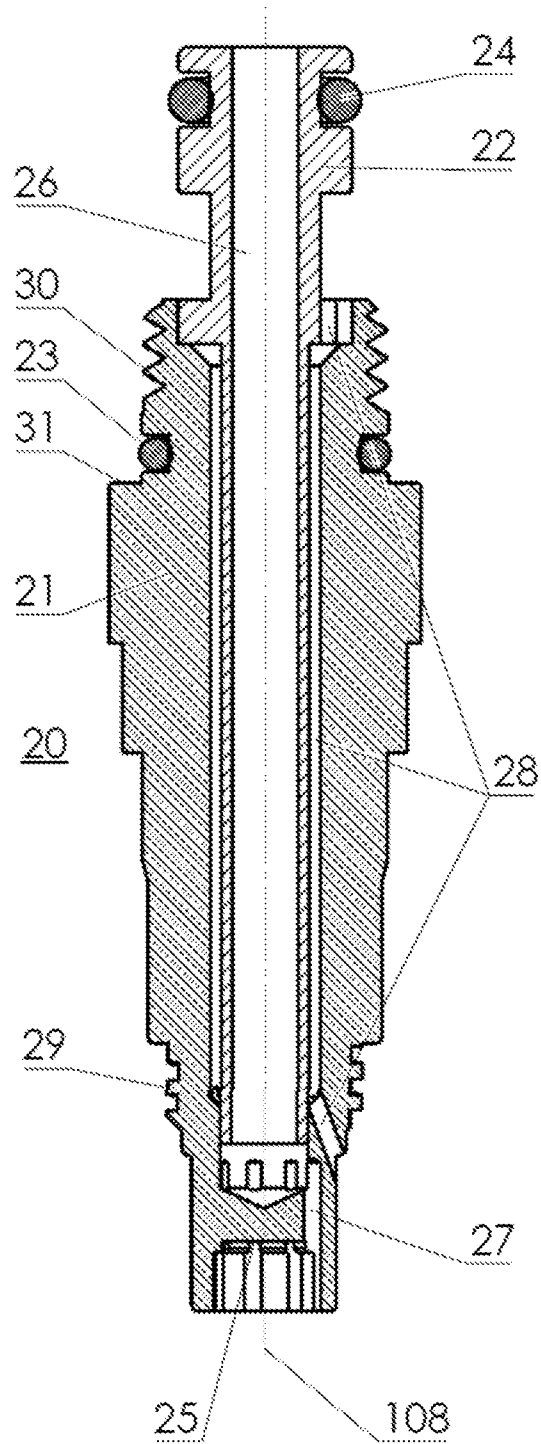


Fig.4

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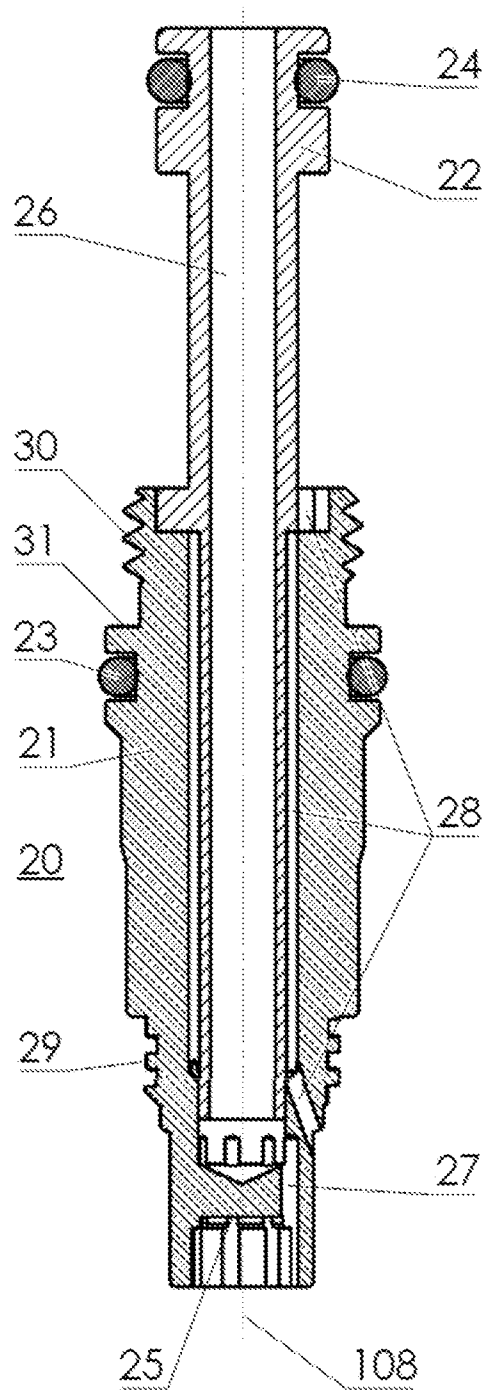


Fig.5

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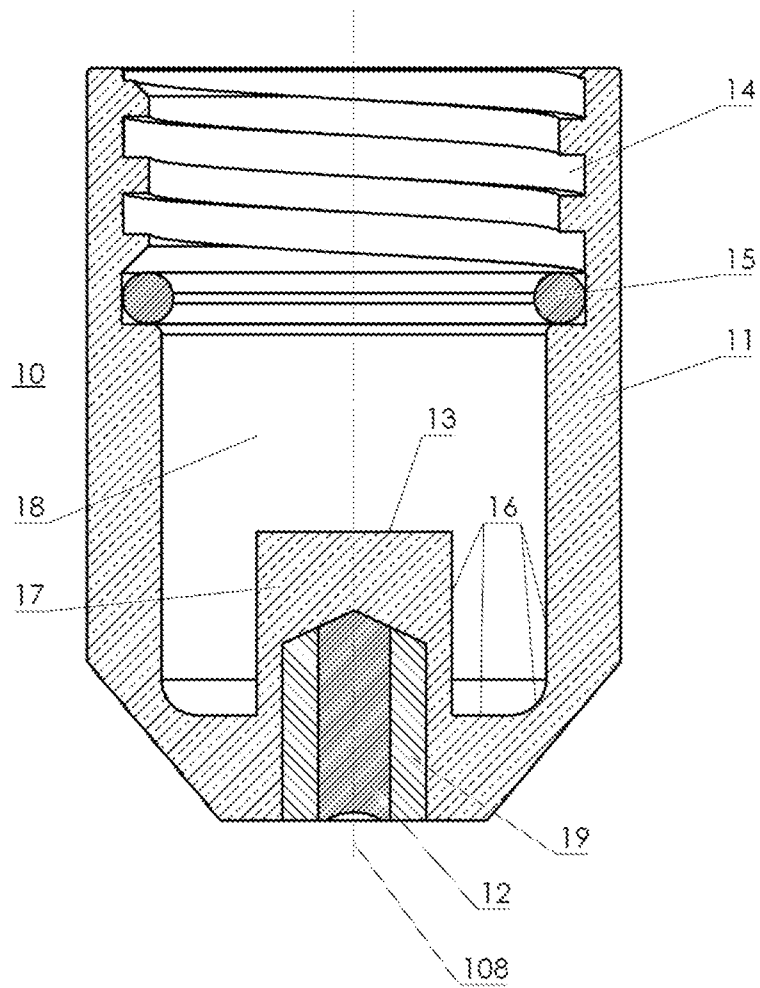


Fig.6

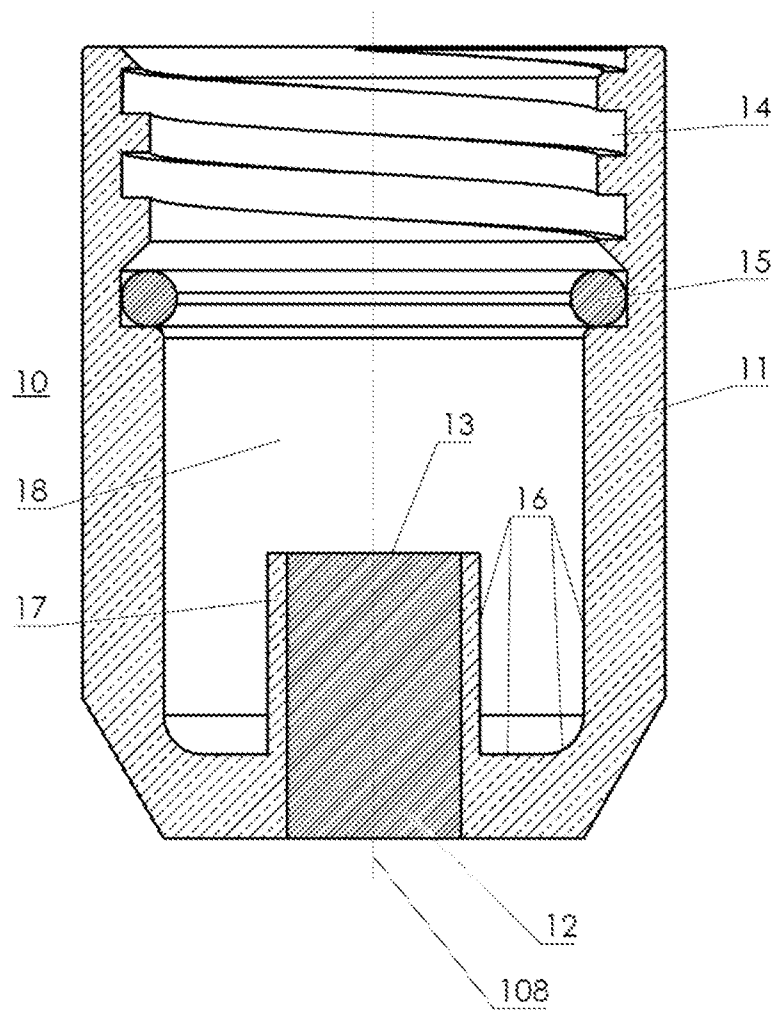


Fig.7

Fig.7

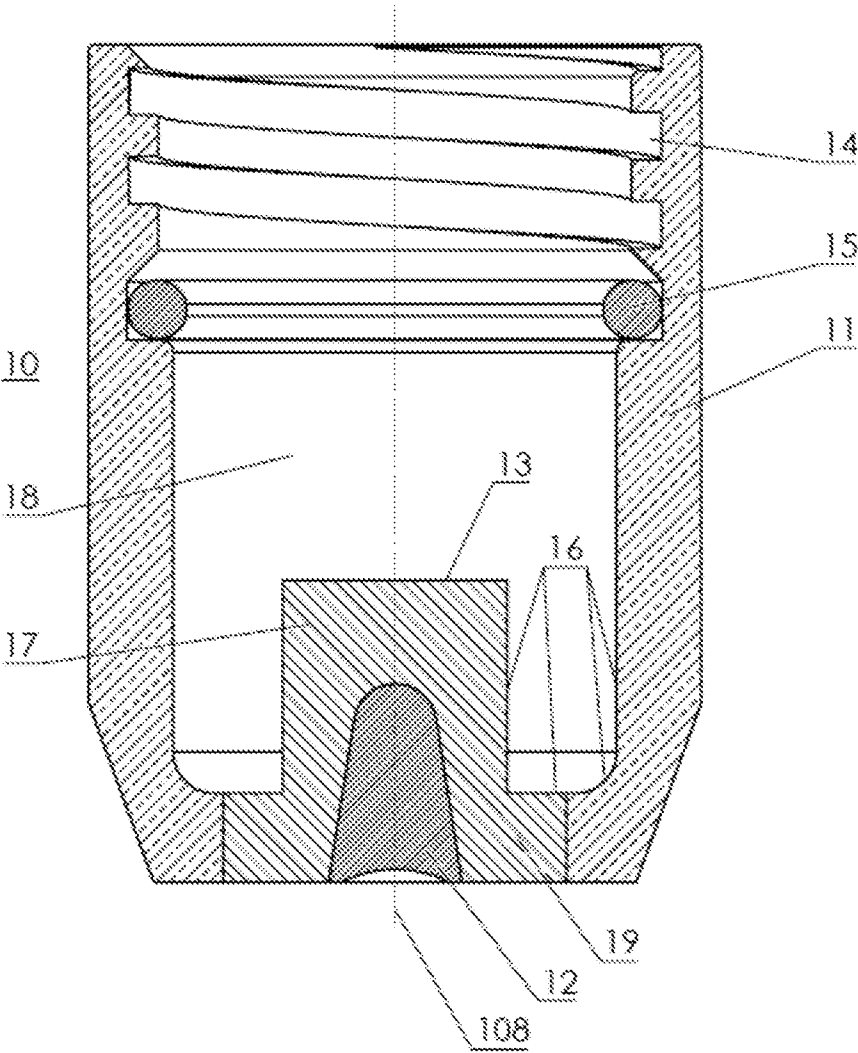


Fig.8

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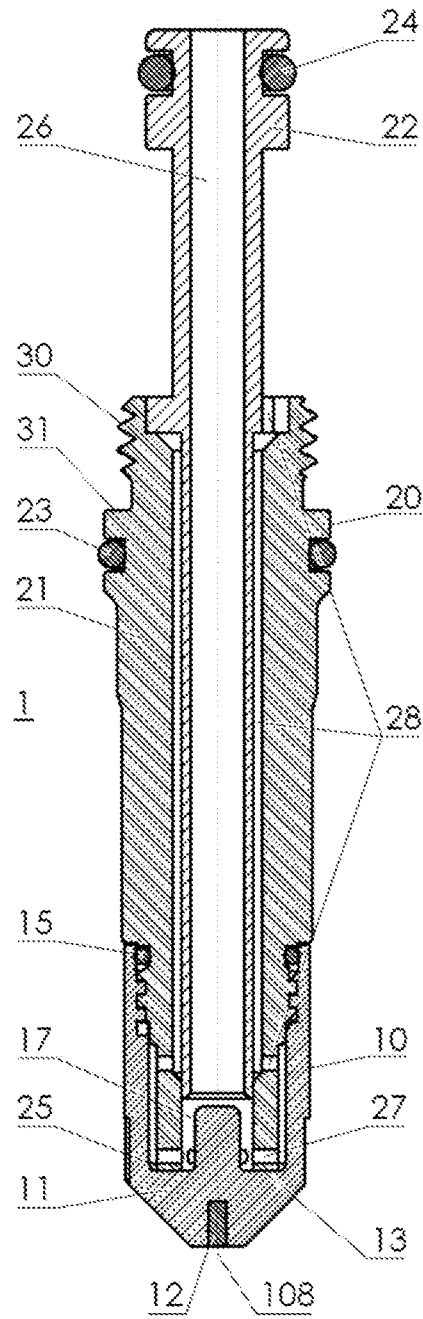


Fig.9

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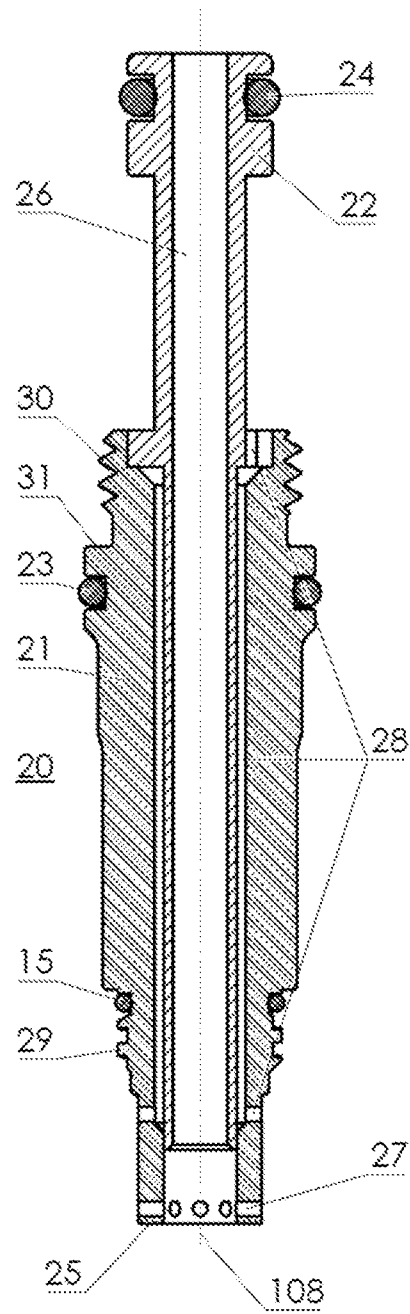


Fig.10

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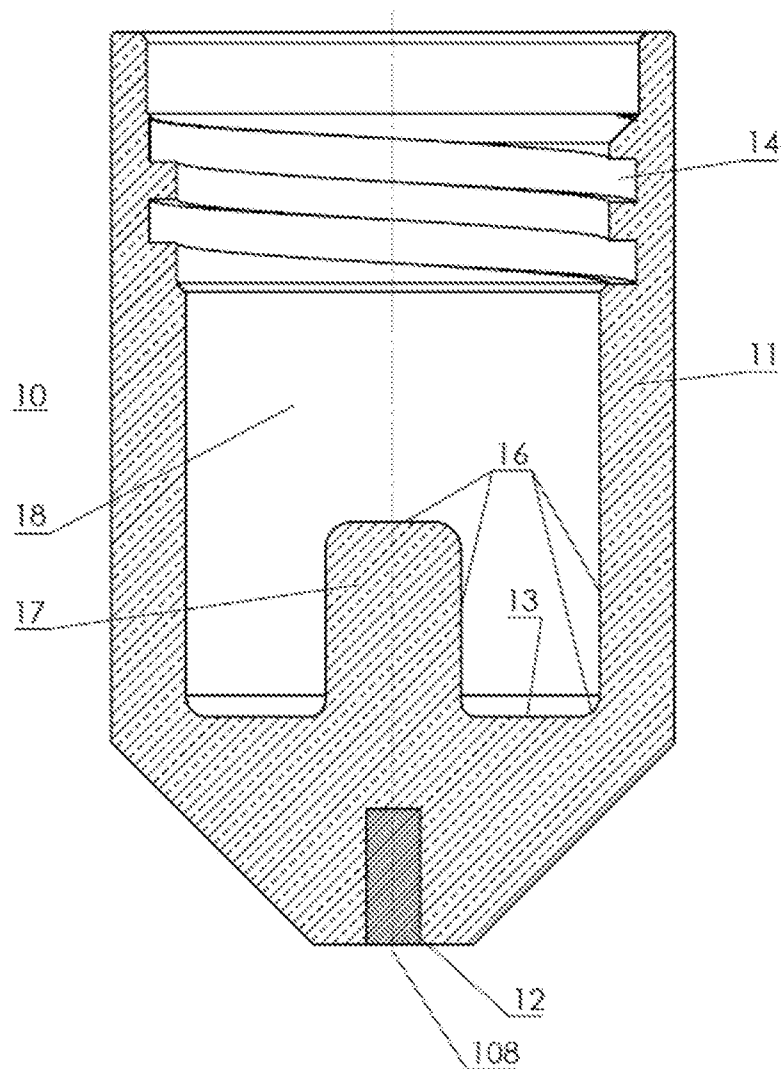


Fig.11

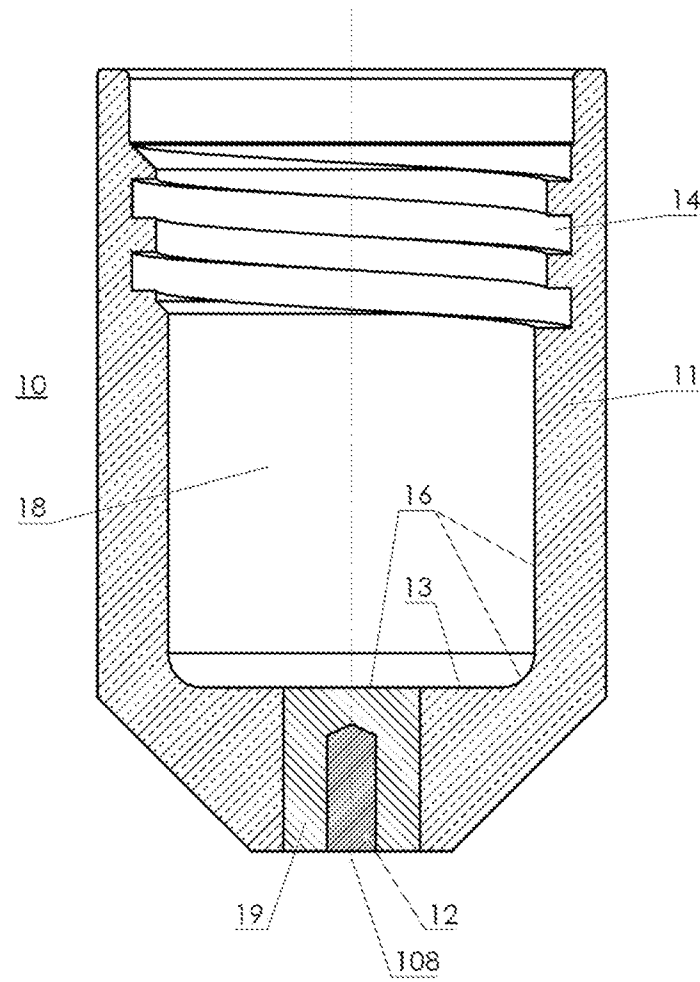


Fig.12

INTERNATIONAL SEARCH REPORT

International application No
PCT/CZ2021/050015

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05H1/34 H05H1/38
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)
H05H

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)

EP0-Internal, WPI Data

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

26 May 2021

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No
PCT/CZ2021/050015

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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