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(54) **Heating rod comprising an internal insulating rod with a concave tip, glow plug including the same**

Heizstab mit internem Isolierstab mit konkaver Spitze und Glühstift damit

Tige de chauffage comprenant une tige isolante interne avec une pointe concave, bougie de préchauffage comprenant cette dernière

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Description

[0001] The present invention relates to a heating rod and in particular, but not exclusively, to a heating rod of a glow plug used for preheating a diesel engine. It also relates to a glow plug including such a heating rod.

[0002] A heating rod of a glow plug is in the form of a rigid rod or bar, which extends longitudinally according to an axis, called the main axis, from a body of the plug into the combustion chamber. Throughout the text, the term "distal" and its derivatives designate directions, elements or parts which are situated axially on the side of the free extremity of the heating rod, which is intended to extend into the combustion chamber, and the term "proximal" and its derivatives designate directions, elements or parts which are situated axially on the opposite side, i.e. towards the connection towards the outside of the cylinder head of the engine on which the glow plug is intended to be fitted.

[0003] A heating rod extends from the plug body, and has a proximal extremity which is equipped with an electrical connection which forms a first electrical power supply terminal of the heating rod, in general with an electrode which axially and proximally extends beyond the proximal extremity of the heating rod.

[0004] Throughout the text, the term "cylinder" and its derivatives refer to the mathematical and geometrical definition that is to say a surface or a volume generated by a straight line remaining parallel to a fixed direction and moving on a base line. It includes not only the right circular cylinder but also any cylinder with a non-circular base. The expression "globally cylindrical" includes not only the perfectly cylindrical forms but also those which can have some irregularity or variation from a perfect cylindrical form, without changing the piece function.

[0005] Throughout the text, the terms "electrically insulator" and their derivatives relate to a dielectric material which electrical resistance is sufficient to prevent any passing of an electric current in predetermined operation conditions of the heating rod.

[0006] A glow plug includes a cylindrical plug body having a threaded external portion for fitting on a cylinder head, and, at the distal portion of the plug body, a cylindrical internal housing for receiving a proximal portion of the heating rod. Said housing has an opening for the passage of the heating rod such that the heating rod axially and distally extends, projecting (on the distal side) beyond said proximal portion and the opening. The heating rod has a distal heating portion extending from said opening as far as the distal extremity of the heating rod.

[0007] A known heating rod (US2010/0133252) includes:

- an external sheath made of a metal alloy, which is an electrically conductive material, axially extending along said main axis, and comprising an axially distal closed end and an axially proximal open end,
- a heating wire located in the external sheath, made

of an electrically conductive material, having an electrically conductive external surface and helically wound as a coil,

- a core made of an electrically insulating rod located inside the heating wire coil and,
- a filling made of an electrically insulating powder.

[0008] A heating rod of a glow plug must very quickly make a high temperature available to assist the ignition process, subsequently maintaining this temperature regardless of boundary conditions or even adapting it to suit them. The glow plug is located in the combustion chamber, and must sustain the operating conditions in the combustion chamber, in particular a temperature which can be up to 1400°C and a pressure which can be up to 20MPa. Also, during pre-heating, a high current flows via the electrode to the heating wire, therefore all the elements of a heating rod which are electrically conductive must sustain high currents, up to some amperes.

[0009] A known heating rod for a glow plug is generally manufactured as followed. First a core is inserted into a heating wire coil. The distal end of the external sheath is made in a thinned (tapered or rounded) shape and closed. The proximal end of the heating wire encircling the core is then connected to a distal end of an electrical terminal supply, such as an electrode. The heating rod connected to the electrode and the core are then disposed in the external sheath and the heating wire distal free end is welded to the external sheath distal closed end. Then the external sheath is filled with the electrically insulating powder. A sealing is placed between the external sheath proximal side and the electrode so as to seal the heating rod. Thereafter the heating rod is subjected to a swaging (rotation forging) step which reduces the heating rod diameter in order to make it compact. The thus-produced heating rod is inserted into the receiving housing of the glow plug body to complete the glow plug.

[0010] In a known heating rod, the function of the external sheath consists in assembling and maintaining all the heating rod pieces together. The external sheath is made of a metal alloy, which is an electrically conductive material. The electrically insulating powder located between the external sheath and the heating wire coil prevents any contact of both pieces with one another, avoiding any undesired short-circuit that could damage the glow plug and reduce its lifetime. Moreover, the electrically insulating powder has also a thermally conductive role. The heat generated by the heating wire has to be transmitted from the heating wire to the external sheath to thereby directly preheat the cylinder interior of a diesel engine or the like.

[0011] US2010/0133252 discloses a reduced diameter (in particular taper-shaped) distal tip portion of the rod-like insulating core so as to reach a distal position of the taper-shaped reduced diameter of the distal end of the coil, and prevent inconsistent deformation of this distal end of the coil during the swaging step.

[0012] However the inventors have now found that such a taper-shaped or reduced diameter distal tip of the internal insulating core is not optimal as regards:

- the shape of the distal end of the distal heating coil, 5
- the position taken by the distal tip of the core when inserted in the external sheath,
- the stability and the position of this distal tip during the swaging step,
- the filling of the space between this distal tip of the internal insulating core and the distal end of the external sheath and the distal end of the distal heating coil, by the electrically insulating powder, when the heating rod also includes such an electrically insulating powder; it turns out that the powder does not completely and/or uniformly fill this space, and that the density of the powder at the tip of the rod is not uniform and is less than along the main cylindrical part of the core, leading to thermal conductivity gradients, to undesirable heating heterogeneities, or even to disconnections or failures at an early stage as mentioned by US2010/0133252; 10 15 20
- the use of an internal ceramic sleeve interposed between the heating coil(s) and the external sheath, which needs the heating coil to be precisely placed with regards to the external sheath and to the core, in close vicinity with the core. 25

[0013] The invention is thus aimed at overcoming these disadvantages of the prior art.

[0014] Another object of the invention is to reduce the cumbersome of the glow plug, by proposing a more compact and thinner heating rod, and so a quicker responding heating rod.

[0015] The invention is also aimed at allowing an optimally filling of the heating rod and thus at providing a better hold of the heating rod pieces during a swaging step.

[0016] The invention is, in particular, aimed at further increasing the thermal conductivity of the heating rod and the glow plug efficiency.

[0017] The invention is also aimed at increasing the life time of the glow plug.

[0018] Additionally, the invention is aimed at overcoming manufacturing problems of the heating rod and of the glow plug, by proposing an easier and cheaper process for manufacturing the heating rod.

[0019] The invention is in particular aimed at avoiding any positioning troubles of the various pieces of the heating rod, in particular the internal core relative to the external sheath and to the heating coil(s). 50

[0020] The invention is also aimed at making the manufacturing process of the heating rod faster by allowing an easy filling of several heating rods at the same time.

[0021] To this end, the invention concerns a heating rod comprising: 55

(i) an external sheath:

- axially extending along a longitudinal axis,
- comprising a closed distal end,

(ii) a distal heating coil:

- made of a resistance wire,
- located in the external sheath,
- having an outer coil dimension and an inner coil dimension,
- having a thinned distal end portion shaped so as to extend in said closed distal end of the external sheath,

(iii) an electrically insulating distal core:

- radially located inside said distal heating coil,
- having a thinned distal tip configured to be inserted into said thinned distal end of said distal heating coil, characterized in that said thinned distal tip of said distal core is shaped so as to have a peripheral outer surface trace, in any axial longitudinal plane and on each side of said longitudinal axis, having at least one distally thinning continuously curved concave portion having a radially outward oriented concavity.

[0022] The inventors have surprisingly noticed that such a continuously curved concave shape of the thinned distal tip of the core, without any sharp edge or rib, provides with numerous advantages when compared to other shapes, in particular:

- it is much better adapted to accommodate the thinned distal end portion of the heating coil, and in particular decreases the risk of deformation and damage of the coiled wire during the swaging step; 35
- it facilitates the introduction of the distal tip of the core in the external sheath, in particular when it is previously inserted inside the heating coil; 40
- it provides with a better stability and position of the distal tip during the swaging step;
- when the heating rod also includes an electrically insulating powder, the filling of this powder inside the external sheath is much more easier and improved in the vicinity of the distal tip of the internal insulating core, where the concave portion increases the space available for this powder, and better accommodates the powder which more uniformly fills the space between the heating coil and the distal tip of the core; 45
- it facilitates the use of an internal ceramic sleeve interposed between the heating coil and the external shapes, for which the above-mentioned advantages are even more important.

[0023] Said distally thinning continuously curved concave portion is thinning from a proximal end thereof toward a distal end thereof, i.e. when axially going toward

the distal end of said distal tip. The concavity of said distally thinning continuously curved concave portion is radially outward oriented i.e. any straight line normal to said trace oriented toward the concavity is oriented outwardly and at least partially radially with regard to the longitudinal axis of the external sheath.

[0024] Advantageously and according to the invention, said peripheral outer surface trace of thinned distal tip comprises a fully rounded curve between a junction proximal end of said peripheral outer surface trace and a distal extreme end of said peripheral outer surface trace. In embodiments where the electrically insulating distal core is made of a cylindrical rod-like piece, said junction proximal end joins the distal tip to a main cylindrical portion of said core. In some embodiments of the invention, the distal extreme end of the thinned distal tip of the core may not be itself entirely rounded, but the peripheral outer surface trace is made of a fully rounded curve. In other embodiments according to the invention, the distal extreme end of the thinned distal tip of the core is also itself fully rounded.

[0025] In some embodiments according to the invention, said peripheral outer surface trace may comprise several continuously curved concave portions extending in the continuation of each other, either directly and/or being two by two joined by convex portions, the latter also preferably being continuously curved. Advantageously and according to the invention, said peripheral outer surface trace of said thinned distal tip comprises only one concave portion between a junction proximal end of said peripheral outer surface trace and a distal extreme end of said peripheral outer surface trace. Advantageously and according to the invention, said distally thinning continuously curved concave portion has a proximal end joined by an inflection point to a continuously curved proximal convex portion of said peripheral outer surface trace, and a distal end joined by an inflection point to a continuously curved distal convex portion of said peripheral outer surface trace.

[0026] Said distally thinning continuously curved concave portion may have various shapes and dimensions. In some embodiments according to the invention, said peripheral outer surface trace of said thinned distal tip comprises, as concave portion, at least one curved portion chosen in the group comprising an arc of a circle, an arc of an ellipse, an arc of a parabola, and an arc of a hyperbola. An arc of a circle is preferred as it is simpler, in particular as regards the manufacturing process.

[0027] In a more particular embodiment, advantageously and according to the invention, said peripheral outer surface trace of thinned distal tip is formed of a concave arc of a circle having a proximal end joined by an inflection point to a continuously curved proximal convex portion and a distal end joined by an inflection point to a continuously curved distal convex portion. In this embodiment, preferably and according to the invention, at least one of the proximal convex portion and said distal convex portion is (at least substantially) an arc of a circle.

[0028] Advantageously and according to the invention, said concave arc of a circle has a radius comprised between 5 mm and 100 mm. Other dimensions are possible.

[0029] More preferably and according to the invention, said peripheral outer surface of thinned distal tip is fully rounded around said longitudinal axis.

[0030] Furthermore, said distal core also has a proximal tip, and this proximal tip is also preferably shaped similarly to the distal tip. Thus, advantageously and according to the invention, said distal core has a thinned proximal tip shaped so as to have a peripheral outer surface trace, in any axial longitudinal plane, having at least one proximally thinning continuously curved concave portion having a radially outward oriented concavity.

[0031] In preferred embodiments according to the invention, both said thinned distal tip and said thinned proximal tip of said distal core have similar shapes and dimensions. Thus, said distal core is easier to manufacture, and can be used in any orientation when inserted into heating coil and/or in the external sheath.

[0032] Furthermore, advantageously and according to the invention, said distal core is made of a thermally conductive and electrically insulating material -notably a ceramic molded rod-like piece-. This material can be chosen for example in the group of ceramic non-metallic inorganic and/or mineral materials made from compounds of at least one metal and at least one non-metal, in particular in the group comprising electro-melted magnesium oxide MgO, aluminum oxide Al_2O_3 , aluminum nitride AlN, a mixture of AlN and MgO, zirconium oxide ZrO_2 , silicon nitride Si_3N_4 ... Such ceramic materials sustain high temperature, and have high mechanical and oxidation resistances and good electrically insulating properties. Also, they have good thermally conductive properties. The distal core is pre-sintered in the meaning of being sintered before its use for manufacturing a heating rod, i.e. before being inserted in the external sheath.

[0033] A heating rod according to the invention may include only one electrically insulating core, i.e. only one core which constitutes said distal core.

[0034] In other embodiments the heating rod according to the invention may include several electrically insulating cores axially extending in the continuation of each other. Advantageously and according to the invention, each electrically insulating core is made of the same ceramic material. Furthermore, two axially adjacent electrically insulating cores are connected to one another by their tips having conjugated shapes, i.e. one of those tips is a male tip as above described, and the other one is a corresponding female tip configured to receive said male tip.

[0035] Advantageously a heating rod according to the invention further includes an electrically insulating powder:

- filling said heating rod,
- blocking said distal heating coil and/or said distal core relative to said external sheath.

Advantageously and according to the invention, said insulating powder is made of a ceramic material, preferably the same one as the distal core ceramic material. Thus, said insulating powder can be advantageously made of a material chosen for example in the group of ceramic non-metallic inorganic and/or mineral materials made from compounds of at least one metal and at least one non-metal, in particular in the group comprising electro-melted magnesium oxide MgO, aluminum oxide Al₂O₃, aluminum nitride AlN, a mixture of AlN and MgO, zirconium oxide ZrO₂, silicon nitride Si₃N₄... Such ceramic materials sustain high temperature, and have high mechanical and oxidation resistances and good electrically insulating properties. Also, they have good thermally conductive properties.

[0036] Advantageously a heating rod according to the invention further comprises:

- a glow resistor forming said distal heating coil and having a distal end electrically connected to said external sheath closed distal end,
- a regulation resistor proximal coil having a proximal end electrically connected to an electric supply connection,
- a proximal end of said distal heating coil and a distal end of said regulation resistor proximal coil being electrically connected to one another.

[0037] Advantageously a heating rod according to the invention further includes at least one internal sleeve made of an electrically insulating molded piece located between said external sheath and said distal heating coil, said at least one internal sleeve:

- having an inner dimension corresponding to said outer coil dimension so that said distal heating coil is housed in it,
- having an outer dimension corresponding to said external sheath inner dimension so that it is housed in said external sheath,
- longitudinally extending in said external sheath at least along at least a part of said distal heating coil.

In those embodiments, said internal sleeve preferably longitudinally and distally extends as far as possible in the external sheath. However, it cannot extend in the closed distal end of the external sheath, and thus does not radially cover said thinned distal tip of said distal core. In other words, said internal sleeve has a distal extreme end which is proximally remote from the distal extreme end of said distal tip, and is in particular radially facing the proximal extreme end of said distal tip, i.e. its proximal end joined to the main cylindrical portion of said distal core.

[0038] The invention also concerns a glow plug including:

- (i) a plug body comprising:

- an external fixation thread,
- a receiving housing for a heating rod,

- (ii) a heating rod including at least one heating coil,
- (iii) an electric supply connection for said heating coil,

characterized in that said heating rod is a heating rod according to the invention. A glow plug according to the invention may be used for example as a (pre-)heating glow plug in a diesel engine.

[0039] The invention also concerns a heating rod and a glow plug characterized in combination by all or some of the features mentioned above or below.

[0040] Other features, objectives and advantages of the invention will be appreciated from the following description of non-limiting embodiments of the invention, with reference to the accompanying drawings in which:

- figure 1 is a schematic view of a glow plug according to the invention,
- figure 2 is a schematic axial section view of a glow plug according to the invention, with partial cutaways,
- figure 3 is a schematic axial section view of a heating rod according to a first embodiment of the invention,
- figure 4 is a schematic cross-section view of the heating rod of figure 3,
- figure 5 is a schematic axial section view of a heating rod according to a second embodiment of the invention,
- figure 6 is a schematic cross-section view of the heating rod of figure 5,
- figure 7 is a schematic view of a distal tip of a distal core of a heating rod according to a preferred embodiment of the invention,
- figure 8 is a schematic bottom view of figure 7.

[0041] A glow plug illustrated in figures 1 and 2 comprises a plug body 51 and a heating rod 52. A proximal connecting part of the plug body 51 includes an electrical connector 53. The connector 53 receives an electric supply voltage in order to supply electrical coiled heating wires 59, 60 of the heating rod 52. The distal side of the connector 53 is connected to an electrode 56 which is a round steel rod. The electrode 56 axially extends into the plug body, is connected to the connector 53 at its proximal end and to the heating wires 59, 60 at its distal end. A current flows from the connector 53 to the electrode 56 and then flows through the heating wire 59, 60. The current is adapted to supply the heating wires 59, 60 with electric power, so that said heating wires 59, 60 generate heat at the heating rod distal end by Joule effect.

[0042] The plug body 51 is formed of a metallic shell used as a receiving housing 55 for the heating rod 52. The housing 55 comprises a proximal open end across which the electrode 56 proximal end connects to the connector 53, and a distal open end across which the heating rod 52 is inserted. The heating rod 52 includes an external

sheath 58 axially extending along a main axis 50 of the glow plug and from the distal end of the electrode 56 to the distal end of the heating rod 52. The external sheath 58 and the housing 55 are both in contact and made of an electrically conductive material, preferably a metallic material. This contact forms a seal between the heating rod 52 and the plug body 51.

[0043] Said external sheath 58 comprises an open proximal end 71 and a closed distal end 72. The closed distal end 72 is thinned. In the embodiment illustrated on the drawings, the distal end 72 is rounded and has a substantially hemispherical shape. Other shapes are possible.

[0044] The heating wires 59, 60 comprise a glow resistor 59 forming a distal heating coil, and a regulation resistor 60 forming a proximal heating coil. The glow resistor 59 extends between the distal closed end 72 of the external sheath 58 and the distal end of the regulation resistor 60. The proximal end of the regulation resistor 60 is fastened by welding to the distal end of the electrode 56. The distal end of the regulation resistor 60 is fastened by welding to the proximal end of the glow resistor 59. The distal end of the glow resistor 59 is fastened by welding to the internal surface of the distal closed end 72 of the external sheath 58.

[0045] In such a glow plug numerous elements are electrically conductive. Thus insulator pieces are needed to prevent contacts there between. An insulating washer 54 is inserted between the connector 53 and the housing 55 to electrically insulate them. Moreover an electrically insulating separating material 65 is located between the housing 55 and the electrode 56. Additionally, an insulating gasket 57 is inserted at the heating rod proximal end 71, between the external sheath 58 and the electrode 56 in order to electrically insulate them and to sealingly close the heating rod 52.

[0046] An electrically insulating (and preferably thermally conductive) powder 62 is filling the external sheath 58. In some embodiments (in the first embodiment of figures 2, 3 and 4), at least one electrically insulating internal sleeve 63 is inserted between the heating wires 59, 60 and the external sheath 58. The heating wires 59, 60 forming the glow resistor 59 and the regulation resistor 60, are relatively soft, so they may bend or become eccentric during a rotation forging (swaging) step. Said internal sleeve 63 prevents contacts between the external sheath 58 and the heating wires 59, 60.

[0047] Additionally the heating rod 52 comprises an electrically insulating internal core 61 inserted into the heating coils which helically extend around said core 61. The core 61 longitudinally extends, along the longitudinal axis 50, in said external sheath 58. Thus the core 61 maintains the heating wires 59, 60 in position, in particular during a rotation forging (swaging) process.

[0048] The plug body 51, its housing 55, the external sheath 58, the internal sleeve 63 and the core 61 are preferably globally cylindrical and symmetrical around said main axis 50, but other forms could be considered.

[0049] The external sheath 58 holds all the pieces of the heating rod, transmits the electric current from the glow resistor 59 to the housing 55, and also transmits the heat outside of the heating rod 52. Metallic alloys sustaining high temperatures and devoid of transformation phases are used as material for the external sheath 58.

[0050] The glow resistor 59 is a helically coiled filament (heating wire), whose distal end is welded in a bore-hole to the distal end 72 of the external sheath 58, and whose proximal end is welded to the regulation resistor 60 distal end. Thanks to the bore-hole and to its tight closure, good electrical conductivity is achieved from the glow resistor 59 to the external sheath 58. The wire forming the glow resistor 59 is advantageously made of ferrite steel that contains chromium and aluminum apart from iron. Optimal mechanical and thermal properties are achieved through the following composition: 22% of Cr, 5.3% of Al and 72.7% of Fe. Such alloy is for instance Kanthal AF® (trademark of Sandvik Heating Technology).

[0051] The distal heating coil made by the glow resistor 59 has a thinned distal end portion 76 adapted to extend in the thinned closed end 72 of the external sheath 58.

[0052] The regulation resistor 60 is advantageously made of a helically coiled pure nickel wire since nickel has a positive temperature regulation coefficient. The resistor value of the regulation resistor 60 varies with the temperature unlike the glow resistor 59 which resistance value does not depend on the temperature. Therefore the regulation resistor 60 prevents the temperature from rising over a predetermined level.

[0053] The core 61 located inside said heating wires 59, 60, has an outer dimension corresponding to the helically wound wire inner dimension, that is to say the internal diameter of the smaller heating wire spires, so that the core 61 is housed in the heating wires winding. Said outer dimension of the core 61 is substantially the same than said helically wound wire inner dimension, so that there is a contact between an inner surface of the wires and an outer surface of the core. A mounting clearance may exist between said helically wound wire inner dimension and said outer dimension of the core 61. This clearance is defined by the ratio of the outer dimension of the core 61 on the helically wound wire inner dimension. Said ratio is preferably comprised between 0.95 and 1.

[0054] The heating rod 52 preferably comprises one core 61 (figures 2 and 3); however, in some embodiments the heating rod 52 comprises several smaller cores, or a smaller core with some electrically insulating powder completing the space left by this smaller core, as shown for example on figure 5.

[0055] The core 61 can be made from various materials that must be electrically insulating and sustain high temperature of the operating conditions. It is preferably made of a ceramic material such as aluminum oxide Al_2O_3 . The core 61 is an injection molded ceramic piece, preferably sintered, for example at a temperature between 900°C and 1300°C, before being inserted into the heating rod

52.

[0056] The core 61 is rod-like ceramic piece with a main cylindrical central portion 78, and has a distal tip 74 and a proximal tip 75. The distal tip is a thinned distal tip 74 so as to accommodate the shape of the thinned distal end portion 76 of the distal heating coil (glow resistor 59) and the thinned distal closed end 72 of the external sheath 58.

[0057] The thinned distal tip 74 of core 61 is best illustrated on figures 7 and 8. It is shaped so as to have a peripheral outer surface which is a surface of revolution about the longitudinal axis 50, and has a distally thinning continuously curved concave surface portion 77 having a radially outward oriented concavity.

[0058] Thus, the peripheral outer surface of the thinned distal tip 74 of core 61 has a trace, in any axial longitudinal plane and on each side of the longitudinal axis 50, which has (as shown on figure 7) a distally thinning continuously curved concave portion 79 having a radially outward oriented concavity. Any line normal to this concave portion and extending in the concavity is oriented relative to axis 50 outwardly and at least partially radially (i.e. not entirely axially).

[0059] The distally thinning continuously curved concave surface portion 77 is a surface of revolution theoretically generated by rotation of said trace about the longitudinal axis 50. It is distally thinning, i.e. its diameter decreases from a proximal junction end 80 of said distal tip 74 (where it is joined to its main cylindrical central portion 78) toward a distal extreme end 81 of said distal tip 74.

[0060] The proximal junction end 80 of said distal tip 74 is also continuously curved (rounded) and convex. The distal extreme end 81 of said distal tip 74 is also continuously curved (rounded) and convex. Other shapes are possible, for example a flat transverse plate, or even a hollow axial recess, as distal extreme end.

[0061] The thinned distal tip 74 of core 61 is thus shaped like a continuously curved (fully rounded) concave stud or nipple easily inserted in the thinned distal end 76 of the distal heating coil 59.

[0062] Said trace of the peripheral outer surface of the thinned distal tip 74 is continuously curved, fully rounded and concave enough to form a recess accommodating the distal end portion 76 of the distal heating coil, and the insulating powder 62 there between in the closed distal end 72 of the external sheath 58. It may have several concave portions with different curvatures, extending from each other or continuously linked by convex portions, without any sharp edge or rib.

[0063] In the illustrated embodiments, said trace is formed of said distally thinning continuously curved concave portion 79; of a continuously curved proximal convex portion 82 linking said concave portion 79 to a straight line (which is the trace of said main cylindrical central portion 78 in the same plane) parallel to the axis 50; and of a continuously curved distal convex portion 83 linking said concave portion 79 to said distal extreme end 81 of

said distal tip 74. The proximal convex portion 82 is linked to said concave portion 79 by an inflexion point 84. The distal convex portion 83 is linked to said concave portion 79 by an inflexion point 85.

[0064] Each of the concave and convex portions 79, 82, 83 is continuously curved without any sharp edge or rib, and can have any appropriate exact shape, for example chosen in the group comprising an arc of a circle, an arc of an ellipse, an arc of a parabola, and an arc of a hyperbola, combination thereof or other (or even an unremarkable curve).

[0065] In the illustrated embodiments given as examples, said concave portion 79 is an arc of a circle with a radius R_c , said proximal convex portion 82 is an arc of a circle with a radius R_1 , and said distal convex portion 83 is an arc of a circle with a radius R_2 . The distal tip 74 has an axial height h and a rounded distal extreme end 81 having a diameter Φ at its junction (inflexion point 85) with said concave surface portion 77.

[0066] For example, the following values may be used:

- R_1 and R_2 may vary from 0.1mm to 5mm, and are for example about 2.5mm;
- R_c may vary from 5mm to 100mm, more preferably between 10mm and 60mm, and good results have been obtained when R_c is about 11mm, about 30mm, and about 60mm;
- h may vary from 5mm to 30mm and decreases with R_c , more preferably h is about 10mm when R_c is about 11mm, and h is about 25mm when R_c is about 60mm;
- Φ is less than the diameter Φ_m of said main cylindrical central portion 78, and may vary from $\Phi_m/1.5$ to $\Phi_m/20$; Φ may vary from 1mm to 10mm, for example about 5mm or 8mm.

[0067] The proximal tip 75 of the distal core 61 is a flat transverse plate in the first embodiment of figures 2, 3 and 4. On the second embodiment of figures 5 and 6 the proximal tip 75 of the distal core 61 is similar to the distal tip 74, i.e. it is also shaped like a concave stud or nipple. More preferably both proximal 75 and distal 74 tips of the distal core 61 are identical (same shapes and dimensions), so that the distal core 61 can be used in either orientation when manufacturing the heating rod 52, which makes it much easier.

[0068] The second embodiment of figures 5 and 6 also differs from the first one by the fact that no internal sleeve is provided in the heating rod 52, the external sheath being only filled with insulating ceramic powder 62.

[0069] In the first embodiment of figures 2, 3, 4, the glow resistor 59 and the regulation resistor 60 are electrically insulated from the external sheath 58 by an internal sleeve 63. The internal sleeve 63 has not only good electrical insulation properties but also good thermal conductivity at high temperatures and thus provides an improved transfer of heat generated by an electrical current flowing through the heating wires 59, 60. The internal

sleeve 63 is preferably made of a ceramic insulating material as for instance electro-melted magnesium oxide MgO.

[0070] The internal sleeve 63 axially extends in the external sheath 58 at least along at least a part of the heating wires 59, 60. However, there is no impediment to have several internal sleeves 63. In particular, a heating rod according to the invention may have several internal sleeves 63 axially placed in the extension of each other and/or laterally placed in the extension of each other around main axis 50 and/or concentrically placed around each other between a part of the external sheath 58 and the heating wires 59, 60. Thus several heating rod configurations according to the invention are possible, in particular the following ones:

- preferably, only one internal sleeve axially extending into the external sheath 58 along at least the whole axial length of the heating wires 59, 60,
- only one internal sleeve axially extending in the external sheath 58 along only an axial part of the heating wires 59, 60 and powder to axially complete the axial remaining part of the external sheath 58 and of the heating wires 59, 60 not covered by this internal sleeve,
- several internal sleeves axially extending on top of each other and/or laterally placed in the extension of each other around main axis 50 and/or concentrically placed around each other in the external sheath 58 all along the heating wires 59, 60,
- several internal sleeves axially extending on top of each other and/or laterally placed in the extension of each other around main axis 50 and/or concentrically placed around each other in the external sheath 58 along only a part of the heating wires 59, 60, and powder to axially complete the axial remaining part of the external sheath 58 and of the heating wires 59, 60 not covered by the internal sleeves.

[0071] Additionally in some embodiments at least one internal sleeve 63 may also extend along at least a part of the electrode 56.

[0072] Moreover, each internal sleeve 63 is a ceramic block, which is also preferably pre-sintered for example at a temperature between 900°C and 1300°C.

[0073] The inner dimension of the internal sleeve 63 corresponds to the helically wound wire outer dimension, that is to say the external diameter of the larger heating wire spires, so that the heating wires 59, 60 are housed in said internal sleeve 63. The term "larger" covers as well "larger or equal", and "strictly larger", that is to say this term encompasses the case where the inner dimension of the internal sleeve 63 is strictly larger than the helically wound wire outer dimension, and also the case where the inner dimension of the internal sleeve 63 is substantially the same than the helically wound wire outer dimension. Preferably the inner dimension of the internal sleeve 63 is substantially the same than the helically

wound wire outer dimension, advantageously with a mounting clearance between said inner dimension of the internal sleeve 63 and said helically wound wire outer dimension. This mounting clearance is defined by the ratio of the helically wound wire outer dimension on the inner dimension of the internal sleeve 63. Said ratio is preferably comprised between 0.95 and 1.

[0074] The outer dimension of the internal sleeve 63 corresponds to the external sheath inner dimension, that is to say both dimensions are substantially the same. Additionally said outer dimension of the internal sleeve 63 is smaller than said external sheath inner dimension so that the internal sleeve 63 is housed in said external sheath 58. The term "smaller" covers as well "smaller or equal", and "strictly smaller", that is to say this term encompasses both the case where the outer dimension of the internal sleeve 63 is strictly smaller than the external sheath inner dimension, and also the case where the outer dimension of the internal sleeve 63 is substantially the same than the external sheath inner dimension, advantageously with a mounting clearance between said outer dimension of the internal sleeve 63 and said external sheath inner dimension. This mounting clearance is defined by the ratio of the outer dimension of the internal sleeve 63 on the external sheath inner dimension. Said ratio is preferably comprised between 0.95 and 1.

[0075] The internal sleeve 63 has both open axial ends: a proximal open end allowing the passing of the electrode 56 and/ or of the proximal end of the regulation resistor 60; and a distal open end allowing the passing of the distal end of the glow resistor 59 and the thinned distal tip 74 of the internal core 61. At least one of those open axial ends may comprise a device to electrically insulate the different heating wires 59, 60 ends from each other at the passing through this open axial end.

[0076] One function of the internal sleeve 63 is to transfer the heat from the heating wires 59, 60 to the external sheath 58. Because the internal sleeve 63 is pre-sintered, a better level of strength is reached (compared to a ceramic powder) which is suited for handling and embedding the heating rod 52. In particular, the internal sleeve 63 allows manufacturing of a very slim heating rod 52 during a rotational forging step which reduces the heating rod radial size. Also having a thinner heating rod 52 increases the heat transfer efficiency by reducing the path between the heating wires 59, 60 and the external sheath 58, which decreases heat losses.

[0077] The manufacture of the internal sleeve 63 by a pre-sintering step contributes to an initial density of the internal sleeve 63 by 10% to 30% higher than the density of a ceramic powder, which leads to a better thermal conductivity of the heating rod 52.

[0078] A pre-sintered internal sleeve 63 with good electrical insulating and thermal conductivity properties, provides with an equal temperature distribution over the en-

tire volume of the heating rod 52 and prevents any local overheating.

[0079] Furthermore a higher initial density provides with a more equal final density of the internal sleeve 63 after a rotational forging reduction step, which results in a better thermal conductivity. In this way, a better redirection of the heat from the heating wires 59, 60 to the external sheath 58, and hence to the surface of the heating rod 52, is achieved. Improving the heat transfer decreases the temperature difference between the glow resistor 59 and the external sheath 58. Thus the level of continuous electrical current flowing through the heating wires 59, 60, in order to maintain the glow plug at a predetermined temperature, can be decreased. This also decreases the danger of breaking for the heating wires 59, 60 and therefore increases the durability of the heating rod 52.

[0080] The heating rod 52 also comprises the insulating powder 62 adapted to optimally fill the heating rod 52 and hence to hold together all the heating rod pieces. This powder 62 is made of a ceramic powder, preferably an electro-melted magnesium oxide MgO powder, but it could be made of other ceramic powder which is thermally conductive, electrically insulating and which sustains the predetermined operating conditions of the combustion chamber. The choice of the ceramic powder and also the choice of the materials of the core 61 and of the internal sleeve 63, influence the thermal conductivity of the heating rod.

[0081] The powder 62 is located into at least one groove (several grooves 64 on figure 5) or into at least one split of the internal sleeve 63, into the space between the internal sleeve 63 and the external sheath 58, and also into the space between the core 61 and the internal sleeve 63 comprising the heating wires 59, 60. In other words, the powder 62 is located anywhere where there is air to expel. The size of each groove 64, or the size of each split, must largely exceed the average size of the grains of the powder 62. Also the groove(s) 64, or the split(s), allow additional filling of the heating rod 52 by the powder 62.

[0082] The powder 62 is preferably filled into the heating rod 52 by a vibration process. By filling the external sheath 58, the powder 62 expels air, and thus prevents a subsequent burning of the heating wires during the glowing phase. Additionally, the powder 62 has also the function of holding the internal sleeve 63 and the core 61 in place in relation to the external sheath 58. In order to effectively provide with such a blocking, and also to ease the filling of the heating rod, the heating rod 52 also includes a rotation and/or translation blocking device adapted for rotatably and/or translational blocking said internal sleeve 63 with regard to the external sheath 58 around and/or along said glow plug main axis 50. Preferably, said blocking device is made of a particular structure of said internal sleeve 63 and/or of said external sheath 58. The above mentioned grooves 64, or the above mentioned split of the internal sleeve 63 constitute

such a blocking device.

[0083] In some embodiments, the internal sleeve 63 may thus have two or more grooves 64 axially and/or transversally extending along at least a part of the internal sleeve 63. Each groove 64 may have a depth and a width of at least 0.1mm, and preferably, of minimum 0.30 mm. Each groove 64 may have a cross-section with various shapes, such as a U-shape, a V-shape, a rectangular shape... Moreover grooves 64 are preferably disposed on both the outer and the inner surfaces of the internal sleeve 63. In some other embodiments, grooves 64 are disposed only on one of said surfaces. The grooves 64 on the outer surface and the grooves 64 on the inner surface are not radially in front of each others, in order to assure sufficient strength of the internal sleeve 63 during the assembly process.

[0084] Preferably, the internal sleeve 63 has four grooves 64, as represented on figure 4, distributed at the same distance from each other on each surface of the internal sleeve 63, with each groove 64 on the inner surface located substantially at the middle between two grooves 64 of the outer surface. They also preferably axially extend along the entire length of the internal sleeve 63. The shape of the cross-sections of the grooves is all the same, and may be an arc of circle or a U-shape. These selected preferential shape, size and distribution of the grooves 64 provide with an optimal strength of the internal sleeve 63 during the assembly process.

[0085] In some embodiments (not represented), the internal sleeve 63 may also have at least one split axially extending along at least a part of the internal sleeve 63. This split may have a width ranging from 0.1mm to 2mm, and preferably from 0.30mm to 1mm along the entire length of the internal sleeve 63. The cross-section of the split can have various shapes, like for instance a U-shape, a V-shape, a rectangular shape, a trapezium shape... In some embodiments (not represented), the internal sleeve 63 may have several splits (as soon as they do not separate the internal sleeve in several parts). Preferably, the internal sleeve 63 has one split axially extending along the entire length of the internal sleeve 63, having a double trapezium shape being wider at the inner and outer surfaces of the internal sleeve 63, thus forming a restricted width between said surfaces, substantially at the middle of its thickness. Also those selected preferential shape, size and distribution of the split provide with an optimal strength of the internal sleeve 63 during the assembly process.

[0086] In order to prevent the diffusion of the powder 62 and the intrusion of any foreign body into the heating rod 52, a gasket 57 is inserted between the proximal end of the heating rod 52 and the distal part of the electrode 56. The gasket 57 is preferably an O-ring and is made of material sustaining the predetermined operating conditions of the combustion chamber as for example a fluoro elastomere such as Viton® (trademark of DuPont Performance Elastomers L.L.C.).

[0087] An embodiment of a method for manufacturing

heating rod 52 and a glow plug according to the invention is described thereafter.

[0088] The core 61 is inserted into the regulation resistor 60 and the glow resistor 59. Both resistors are positioned in a way that the proximal end of the regulation resistor 59 and the distal end of the glow resistor 60 come in contact to be welded together by a method such as laser welded.

[0089] The proximal end of the regulation resistor 60 is fastened to the distal end of said electrode 56. This step can be done by various means such as mechanical and/or welding steps.

[0090] Said internal sleeve 63 is inserted into said external sheath 58.

[0091] The heating wires forming said glow resistor 59 and said regulation resistor 60 with the core 61 inserted inside, are inserted into the internal sleeve 63 and the external sheath 58. In this step, the concave distal tip 74 of the core 61 helps to place and maintain the distal end portion of the heating coil 59 in the closed distal end 72 of the external sheath 58 without any damage to the heating wire.

[0092] The distal end of the glow resistor 59 is welded to the distal closed end of the external sheath 58 by a welding step such as an arc welding step. The fastening of the glow resistor 59 and of the regulation resistor 60 in their correct position in the external sheath 58 prevents any short-circuit contact between the heating wires forming said glow resistor 59 and said regulation resistor 60 and the external sheath 58.

[0093] All the above described steps are in a preferably chronological order, but this chronological order can be modified without changing the final heating rod functioning.

[0094] The electrode 56 is slightly lifted at its proximal end to a predetermined height from the heating rod 52, which is fixed. This lifting height may be of several millimeters. This lifting step expands the regulation resistor 60 and the glow resistor 59. This lifting of the electrode 56 changes the temperature distribution in the heating rod. The global temperature of the heating rod 52 remains the same, as the heating wires 59, 60 length does not change; but the temperature per unit of surface of the heating rod 52 decreases as the length of the heating wires forming said glow resistor 59 and said regulation resistor 60 per unit of surface is decreased. Therefore this lifting step makes the temperature distribution more uniform along the heating rod 52. Also, with the lifting of the electrode 56, the total length of the glow resistor 59 and the regulation resistor 60 becomes longer. This step also allows an optimal and easier filling of several heating rods 52 simultaneously.

[0095] After that, the heating rod 52 is filled with said powder 62 on a vibration table. Vibration movements allow compact and optimal filling of the heating rod 52 by the powder 62. The continuously curved concave distal tip 74 of the core 61 facilitates a good and uniform filling of the distal end of the external sheath by the powder 62,

including a space between said concave distal tip 74 and the thinned distal end portion of the heating wire 59. The excess powder 62 is withdrawn by suction.

[0096] Then the gasket 57 is put inside the heating rod 52 between the distal part of the electrode 56 and the proximal part of the external sheath 58.

[0097] The external sheath 58 is then closed at its proximal end by rotation forging. In this way the gasket 57 and the powder 62 can not fall from the external sheath 58. This step allows an easier handling of the heating rod 52 in subsequent operations. The assembly of said heating rod is thus finished.

[0098] Thereafter follows a step of rotation forging, with which the required diameter and electric characteristics of the heating rod are achieved. The rotation forging step reduces the content of atmospheric air in pores of the heating rod 52, by firmly compressing the powder 62. This results in a low porosity and a reduced diameter, and increased the length of the heating rod 52. If necessary, the thinner distal end of the heating rod 52 is also shaped by additional rotation forging.

[0099] Once said heating rod 52 is manufactured, it is inserted into said housing 55 of a glow plug, force fit to a predetermined depth.

[0100] The internal sleeve 63 facilitates the manufacturing method of a heating rod 52 according to the invention. Indeed, the level of the rotation forging process can be decreased because the internal sleeve 63 and the core 61 are pre-sintered. Additionally, the heating wires 59, 60 with the core 61 inserted inside, are more easily inserted into the external sheath 58 thanks to that fact that the internal sleeve 63 constitutes a landmark; and there are less placement mistake risks for the heating wires 59, 60 with the core 61 inserted inside.

[0101] There are many other possible variations of heating rod, of a glow plug and of their manufacturing method, from the embodiments above described and illustrated in the figures. In particular, there is no impediment to design a glow plug comprising a heating rod with several internal sleeves 63 and/or several cores 61. It is also possible to design a glow plug comprising a heating rod with ceramic powder to at least partly replace the core 61. Also, it is possible to use a material different than a ceramic for the internal sleeve 63 as soon as this material is electrically insulating and sustains said predetermined operating conditions. In particular, the internal sleeve 63 and the core 61 could be formed with another method than by sintering, like casting or milling or other. Additionally, there is no impediment to use said glow plug and/or said heating rod in other applications than to preheating a diesel engine as for instance for preheating water.

Claims

1. A heating rod comprising:

- (i) an external sheath (58):
- axially extending along a longitudinal axis (50),
 - comprising a closed distal end (72),
- (ii) a distal heating coil (59):
- made of a resistance wire,
 - located in the external sheath (58),
 - having an outer coil dimension and an inner coil dimension,
 - having a thinned distal end portion (76) shaped so as to extend in said closed distal end (72) of the external sheath (58),
- (iii) an electrically insulating distal core (61):
- radially located inside said distal heating coil (59),
 - having a thinned distal tip (74) configured to be inserted into said thinned distal end (72) of said distal heating coil (59),
- characterized in that** said thinned distal tip (74) of said distal core (61) is shaped so as to have a peripheral outer surface trace, in any axial longitudinal plane and on each side of said longitudinal axis (50), having at least one distally thinning continuously curved concave portion (79) having a radially outward oriented concavity.
2. A heating rod according to claim 1, **characterized in that** said peripheral outer surface trace of thinned distal tip (74) comprises a fully rounded curve between a junction proximal end of said peripheral outer surface trace and a distal extreme end of said peripheral outer surface trace.
3. A heating rod according to any of claims 1 or 2, **characterized in that** said peripheral outer surface trace of said thinned distal tip (74) comprises only one concave portion between a junction proximal end of said peripheral outer surface trace and a distal extreme end of said peripheral outer surface trace.
4. A heating rod according to any of claims 1 to 3, **characterized in that** said peripheral outer surface trace of said thinned distal tip (74) comprises, as concave portion, at least one curved portion chosen in the group comprising an arc of a circle, an arc of an ellipse, an arc of a parabola, and an arc of a hyperbola.
5. A heating rod according to any of claims 1 to 4, **characterized in that** said peripheral outer surface trace of thinned distal tip (74) is formed of a concave arc of a circle (79) having a proximal end joined by an inflection point to a continuously curved proximal convex portion (82) and a distal end joined by an inflection point to a continuously curved distal convex portion (83).
6. A heating rod according to claim 5, **characterized in that** said at least one of said proximal convex portion (82) and said distal convex portion (83) is an arc of a circle.
7. A heating rod according to any of claims 5 or 6, **characterized in that** said concave arc of a circle (79) has a radius comprised between 5 mm and 100 mm.
8. A heating rod according to any of claims 1 to 7, **characterized in that** said peripheral outer surface of thinned distal tip (74) is fully rounded around said longitudinal axis (50).
9. A heating rod according to anyone of claims 1 to 8, **characterized in that** said distal core (61) has a thinned proximal tip (75) shaped so as to have a peripheral outer surface trace, in any axial longitudinal plane, having at least one proximally thinning continuously curved concave portion having a radially outward oriented concavity.
10. A heating rod according to claim 9, **characterized in that** both said thinned distal tip (74) and said thinned proximal tip (75) of said distal core have similar shapes and dimensions.
11. A heating rod according to anyone of claims 1 to 10, **characterized in that** said distal core (61) is made of a thermally conductive and electrically insulating material.
12. A heating rod according to anyone of claims 1 to 11, **characterized in that** it includes an electrically insulating powder (62):
- filling said heating rod (92),
 - blocking said distal heating coil (59) and/or said distal core (61) relative to said external sheath (58).
13. A heating rod according to anyone of claims 1 to 12, **characterized in that** it comprises:
- a glow resistor (59) forming said distal heating coil and having a distal end electrically connected to said external sheath closed distal end,
 - a regulation resistor (60) proximal coil having a proximal end electrically connected to an electric supply connection,
 - a proximal end of said distal heating coil and a distal end of said regulation resistor proximal coil being electrically connected to one another.

14. A heating rod according to anyone of claims 1 to 13, **characterized in that** it includes at least one internal sleeve (63) made of an electrically insulating molded piece located between said external sheath (58) and said distal heating coil (59), said at least one internal sleeve:

- having an inner dimension corresponding to said outer coil dimension so that said distal heating coil (59) is housed in it,
- having an outer dimension corresponding to said external sheath inner dimension so that it is housed in said external sheath (58),
- longitudinally extending in said external sheath (58) at least along at least a part of said distal heating coil (59).

15. A glow plug including:

- (i) a plug body (51) comprising:
 - an external fixation thread,
 - a receiving housing for a heating rod (52),
 - (ii) a heating rod (52) including at least one heating coil (59, 60),
 - (iii) an electric supply connection for said heating coil,
- characterized in that** said heating rod (52) is a heating rod according to anyone of claims 1 to 14.

Patentansprüche

1. Heizstab, Folgendes umfassend:

- (i) eine äußere Hülle (58):
 - die sich axial entlang einer Längsachse (50) erstreckt,
 - ein geschlossenes distales Ende (72) umfassend,
- (ii) eine distale Heizspule (59):
 - die aus einem Widerstandsdraht gefertigt ist,
 - die sich in der äußeren Hülle (58) befindet,
 - die eine äußere Spulenabmessung und eine innere Spulenabmessung aufweist,
 - die einen dünner werdenden distalen Endabschnitt (76) aufweist, der geformt ist, um sich ins besagte geschlossene distale Ende (72) der äußeren Hülle (58) zu erstrecken,
- (iii) einen elektrisch isolierenden distalen Kern (61):

- der sich radial innerhalb der besagten distalen Heizspule (59) befindet,
- der eine dünner werdende distale Spitze (74) aufweist, die konfiguriert ist, um in das besagte dünner werdende distale Ende (72) der besagten distalen Heizspule (59) eingeführt zu werden,

dadurch gekennzeichnet, dass die besagte dünner werdende distale Spitze (74) des besagten distalen Kerns (61) ausgeformt ist, um einen umlaufenden Außenflächenverlauf in irgendeiner axialen Längsebene und auf jeder Seite der besagten Längsachse (50) aufzuweisen, der zumindest einen distal dünner werdenden durchlaufend gekrümmten konkaven Abschnitt (79) aufweist, der eine radial nach außen orientierte Konkavität aufweist.

2. Heizstab nach Anspruch 1, **dadurch gekennzeichnet, dass** der besagte umlaufende Außenflächenverlauf der besagte dünner werdenden distalen Spitze (74) eine vollständig gerundete Krümmung zwischen einem proximalen Verbindungsende des besagten umlaufenden Außenflächenverlaufs und einem distalen extremen Ende des besagten umlaufenden Außenflächenverlaufs umfasst.

3. Heizstab nach einem der Ansprüche 1 oder 2, **dadurch gekennzeichnet, dass** der besagte umlaufende Außenflächenverlauf der besagten dünner werdenden distalen Spitze (74) lediglich einen konkaven Abschnitt zwischen einem proximalen Verbindungsende des besagten umlaufenden Außenflächenverlaufs und einem distalen extremen Ende des besagten umlaufenden Außenflächenverlaufs umfasst.

4. Heizstab nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** der besagte umlaufende Außenflächenverlauf der besagten dünner werdenden distalen Spitze (74) als konkaven Abschnitt zumindest einen gekrümmten Abschnitt umfasst, der aus der Gruppe ausgewählt wird, die einen Kreisbogen, einen Ellipsenbogen, einen Parabelbogen und einen Hyperbelbogen umfasst.

5. Heizstab nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet, dass** der besagte umlaufende Außenflächenverlauf der besagten dünner werdenden distalen Spitze (74) aus einem konkaven Kreisbogen (79) gebildet wird, der ein proximales Ende aufweist, an das ein Wendepunkt zu einem durchgehend gekrümmten proximalen konvexen Abschnitt (82) anschließt, und ein distales Ende, an das ein Wendepunkt zu einem durchgehend gekrümmten distalen konvexen Abschnitt (83) anschließt.

6. Heizstab nach Anspruch 5, **dadurch gekennzeichnet, dass** zumindest entweder der besagte proximale konvexe Abschnitt (82), oder der besagte distale konvexe Abschnitt (83) ein Kreisbogen ist. 5
7. Heizstab nach einem der Ansprüche 5 oder 6, **dadurch gekennzeichnet, dass** der besagte konkave Kreisbogen (79) einen Radius aufweist, der zwischen 5 mm und 100 mm beträgt. 10
8. Heizstab nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, dass** die besagte umlaufende Außenfläche der dünner werdenden distalen Spitze (74) voll um die besagte Längsachse (50) herum abgerundet ist. 15
9. Heizstab nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet, dass** der besagte distale Kern (61) eine dünner werdende proximale Spitze (75) aufweist, die ausgeformt ist, um einen umlaufenden Außenflächenverlauf in irgendeiner axialen Längsebene aufzuweisen, der zumindest einen distal dünner werdenden durchlaufend gekrümmten konkaven Abschnitt aufweist, der eine radial ach außen orientierte Konkavität aufweist. 20 25
10. Heizstab nach Anspruch 9, **dadurch gekennzeichnet, dass** sowohl die dünner werdende distale Spitze (74), als auch die dünner werdende proximale Spitze (75) des besagten distalen Kerns ähnliche Formen und Abmessungen aufweisen. 30
11. Heizstab nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet, dass** der besagte distale Kern (61) aus einem wärmeleitenden und elektrisch isolierenden Material gefertigt ist. 35
12. Heizstab nach einem der Ansprüche 1 bis 11, **dadurch gekennzeichnet, dass** er ein elektrisch isolierendes Pulver (62) enthält: 40
- mit dem der besagte Stab (92) gefüllt ist,
 - das die besagte distale Heizspule (59) und/oder den besagten distalen Kern (61) im Verhältnis zur besagten äußeren Hülle (58) blockiert. 45
13. Heizstab nach einem der Ansprüche 1 bis 12, **dadurch gekennzeichnet, dass** er Folgendes umfasst: 50
- einen Glühwiderstand (59), der die besagte distale Heizspule bildet und ein distales Ende aufweist, das elektrisch mit dem geschlossenen distalen Ende der besagten äußeren Hülle verbunden ist,
 - eine proximale Spule mit einem Regelungswiderstand (60), die ein proximales Ende aufweist,

das elektrisch mit einem elektrischen Versorgungsanschluss verbunden ist,

- wobei ein proximales Ende der besagten distalen Heizspule und ein distales Ende der besagten proximalen Spule mit einem Regelungswiderstand elektrisch miteinander verbunden sind.

14. Heizstab nach einem der Ansprüche 1 bis 13, **dadurch gekennzeichnet, dass** er zumindest eine innere Manschette (63) umfasst, die aus einem elektrisch isolierenden Formgussteil gefertigt ist, das sich zwischen der besagten äußeren Hülle (58) und der besagten distalen Heizspule (59) befindet, wobei die besagte zumindest eine innere Manschette:

- eine Innenabmessung aufweist, die der besagten äußeren Spulenabmessung entspricht, so dass die besagte distale Heizspule (59) darin untergebracht ist,
- eine Außenabmessung aufweist, die der besagten Innenabmessung der äußeren Hülle entspricht, sodass sie in der besagten äußeren Hülle (58) untergebracht ist,
- sich in Längsrichtung in der besagten äußeren Hülle (58), zumindest entlang eines Teils der besagten distalen Heizspule (59) erstreckt.

15. Glühkerze, Folgendes umfassend:

(i) ein Kerzengehäuse (51), Folgendes umfassend:

- ein äußeres Befestigungsgewinde,
- ein Aufnahmegehäuse für einen Heizstab (52),

(ii) einen Heizstab (52), der zumindest eine Heizspule (59, 60) enthält,

(iii) einen Stromversorgungsanschluss für die besagte Heizspule,

dadurch gekennzeichnet, dass der besagte Heizstab (52) ein Heizstab nach einem der Ansprüche 1 bis 14 ist.

Revendications

1. Tige de chauffage comprenant :

(i) une gaine externe (58) :

- s'étendant axialement le long d'un axe longitudinal (50),
- comprenant une extrémité distale (72) fermée,

(ii) une bobine de chauffage distale (59) :

- constituée d'un fil de résistance,
 - située dans la gaine externe (58),
 - présentant une dimension de bobine externe et une dimension de bobine interne,
 - présentant une partie d'extrémité distale amincie (76) formée de sorte à s'étendre dans ladite extrémité distale (72) fermée de la gaine externe (58),
- (iii) un coeur distal (61) électroisolant :
- situé radialement dans ladite bobine de chauffage distale (59),
 - présentant un bout distal aminci (74) configuré pour être inséré dans ladite extrémité distale (72) amincie de ladite bobine de chauffage distale (59), **caractérisée en ce que** ledit bout distal aminci (74) dudit coeur distal (61) est formé de sorte à avoir une trace de surface extérieure périphérique dans tout plan longitudinal axial et sur chaque côté dudit axe longitudinal (50), présentant au moins une partie concave courbée en continu s'amincissant distalement (79) présentant une concavité orientée vers l'extérieur radialement.
2. Tige de chauffage selon la revendication 1, **caractérisée en ce que** ladite trace de surface extérieure périphérique de bout distal aminci (74) comprend une courbe complètement arrondie entre une extrémité proximale de jonction de ladite trace de surface extérieure périphérique et une extrémité extrême distale de ladite trace de surface extérieure périphérique.
 3. Tige de chauffage selon l'une quelconque des revendications 1 ou 2, **caractérisée en ce que** ladite trace de surface extérieure périphérique dudit bout distal aminci (74) comprend une seule partie concave entre une extrémité proximale de jonction de ladite trace de surface extérieure périphérique et une extrémité extrême distale de ladite trace de surface extérieure périphérique.
 4. Tige de chauffage selon l'une quelconque des revendications 1 à 3, **caractérisée en ce que** ladite trace de surface extérieure périphérique dudit bout distal aminci (74) comprend, comme partie concave, au moins une partie courbée choisie dans le groupe comprenant un arc de cercle, un arc d'ellipse, un arc de parabole et un arc d'hyperbole.
 5. Tige de chauffage selon l'une quelconque des revendications 1 à 4, **caractérisée en ce que** ladite trace de surface extérieure périphérique dudit bout distal aminci (74) est formée d'un arc concave d'un cercle (79) présentant une extrémité proximale jointe par un point d'inflexion à une partie convexe proximale (82) courbée en continu et une extrémité distale jointe par un point d'inflexion à une partie convexe distale (83) courbée en continu.
 6. Tige de chauffage selon la revendication 5, **caractérisée en ce que** ladite au moins une de ladite partie convexe proximale (82) et ladite partie convexe distale (83) est un arc de cercle.
 7. Tige de chauffage selon l'une quelconque des revendications 5 ou 6, **caractérisée en ce que** ledit arc de cercle concave (79) a un rayon compris entre 5 et 100 mm.
 8. Tige de chauffage selon l'une quelconque des revendications 1 à 7, **caractérisée en ce que** ladite surface extérieure périphérique du bout distal aminci (74) est complètement arrondie autour dudit axe longitudinal (50).
 9. Tige de chauffage selon l'une quelconque des revendications 1 à 8, **caractérisée en ce que** ledit coeur distal (61) a un bout proximal aminci (75) formé de sorte à avoir une trace de surface extérieure périphérique, dans tout plan longitudinal axial, présentant au moins une partie concave courbée en continu s'amincissant de manière proximale présentant une concavité orientée radialement vers l'extérieur.
 10. Tige de chauffage selon la revendication 9, **caractérisée en ce qu'à la fois** ledit bout distal aminci (74) et ledit bout proximal aminci (75) dudit coeur distal ont des formes et dimensions similaires.
 11. Tige de chauffage selon l'une quelconque des revendications 1 à 10, **caractérisée en ce que** ledit coeur distal (61) est constitué d'un matériau thermconducteur et électroisolant.
 12. Tige de chauffage selon l'une quelconque des revendications 1 à 11, **caractérisée en ce qu'elle** comprend une poudre électroisolante (62) :
 - remplissant ladite tige de chauffage (92),
 - bloquant ladite bobine de chauffage distale (59) et/ou ledit coeur distal (61) par rapport à ladite gaine externe (58).
 13. Tige de chauffage selon l'une quelconque des revendications 1 à 12, **caractérisée en ce qu'elle** comprend :
 - une résistance à la chaleur rouge (59) formant ladite bobine de chauffage distale et présentant une extrémité distale reliée électriquement à ladite extrémité distale fermée de gaine externe,
 - une bobine proximale de résistance de régu-

lation (60) présentant une extrémité proximale reliée électriquement à une connexion d'alimentation électrique,

- une extrémité proximale de ladite bobine de chauffage distale et une extrémité distale de ladite bobine proximale de résistance de régulation étant reliées électriquement l'une à l'autre.

14. Tige de chauffage selon l'une quelconque des revendications 1 à 13, **caractérisée en ce qu'elle** comprend au moins un manchon interne (63) constitué d'une pièce moulée électroisolante située entre ladite gaine externe (58) et ladite bobine de chauffage distale (59), ledit au moins un manchon interne :

- présentant une dimension intérieure correspondant à ladite dimension de bobine extérieure de sorte que ladite bobine de chauffage distale (59) soit logée en lui,
- présentant une dimension extérieure correspondant à ladite dimension intérieure de gaine externe de sorte qu'il soit logé dans ladite gaine externe (58),
- s'étendant longitudinalement dans ladite gaine externe (58) au moins le long d'au moins une partie de ladite bobine de chauffage distale (59).

15. Bougie de préchauffage comprenant :

- (i) un corps de bougie (51) comprenant :
- un filet de fixation externe,
 - un logement de réception pour une tige de chauffage (52),

- (ii) une tige de chauffage (52) comprenant au moins une bobine de chauffage (59, 60),
- (iii) une connexion d'alimentation électrique pour ladite bobine de chauffage,
- caractérisée en ce que** ladite tige de chauffage (52) est une tige de chauffage selon l'une quelconque des revendications 1 à 14.

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Fig 1

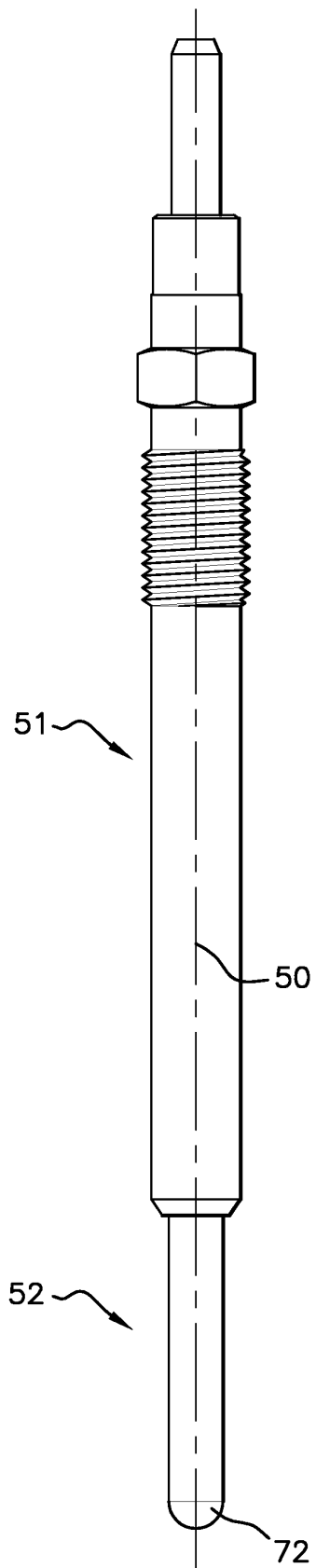
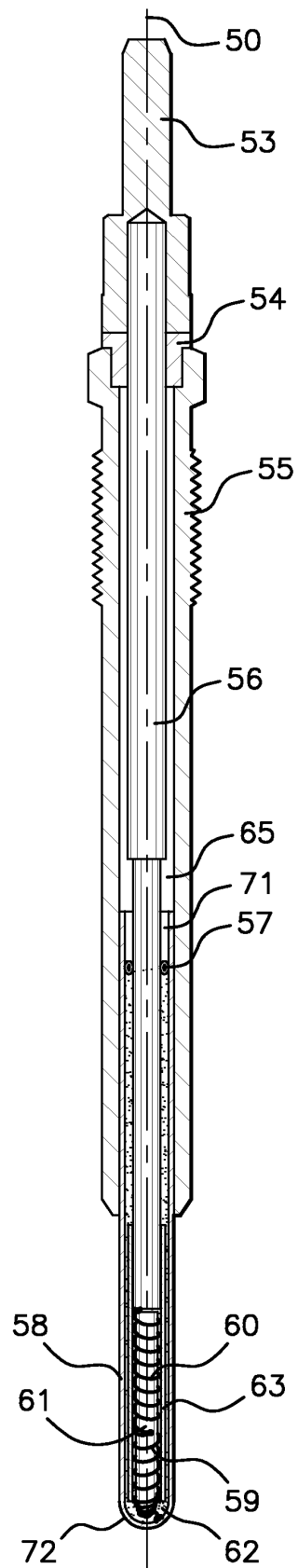


Fig 2



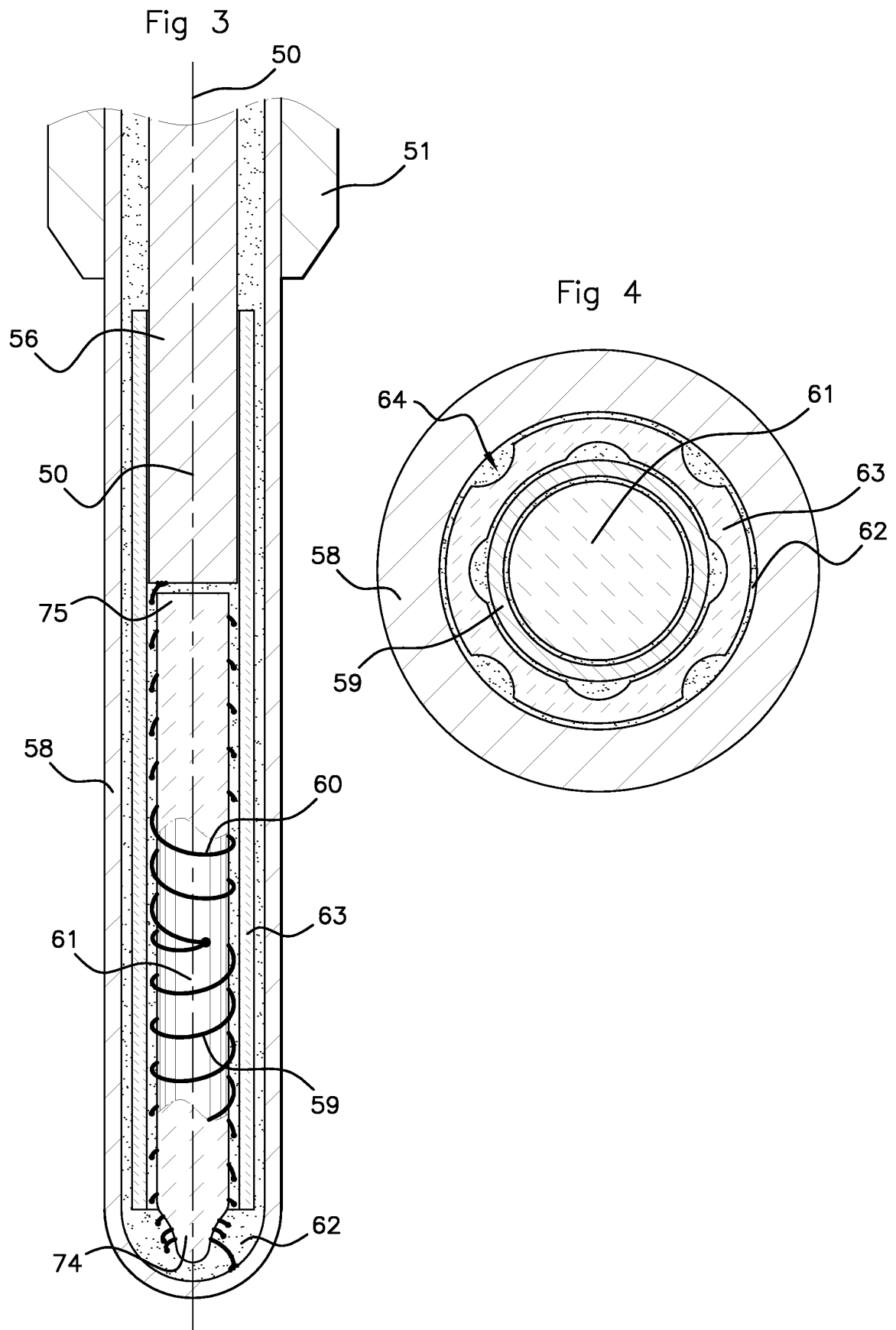


Fig 5

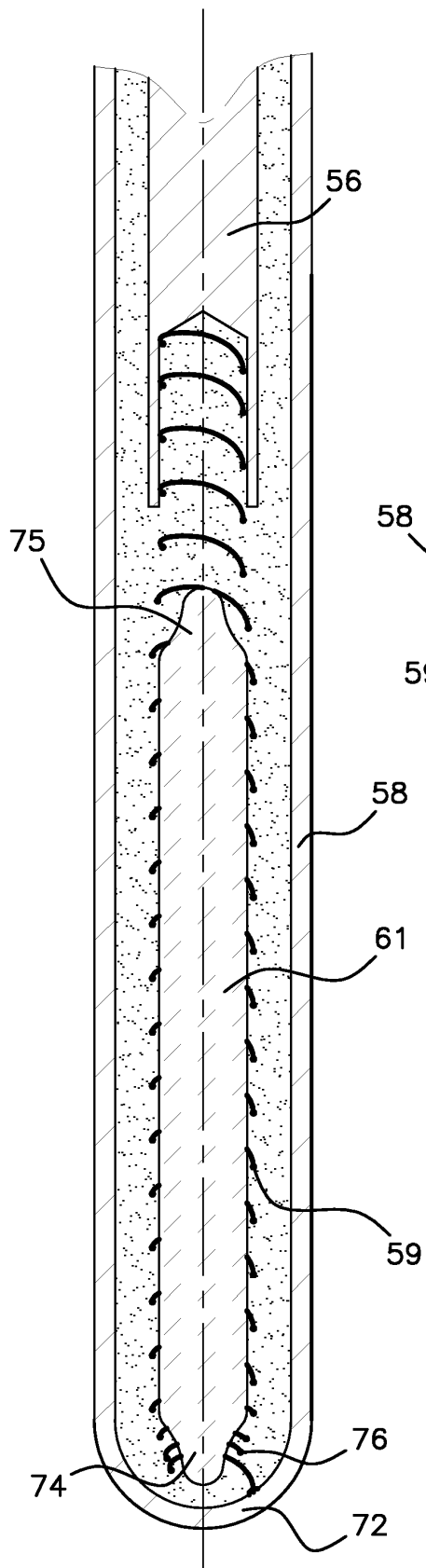


Fig 6

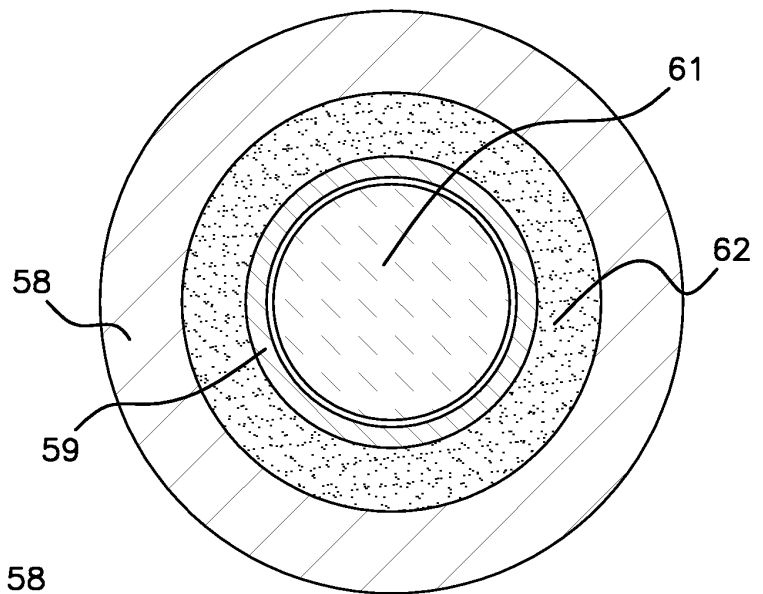


Fig 7

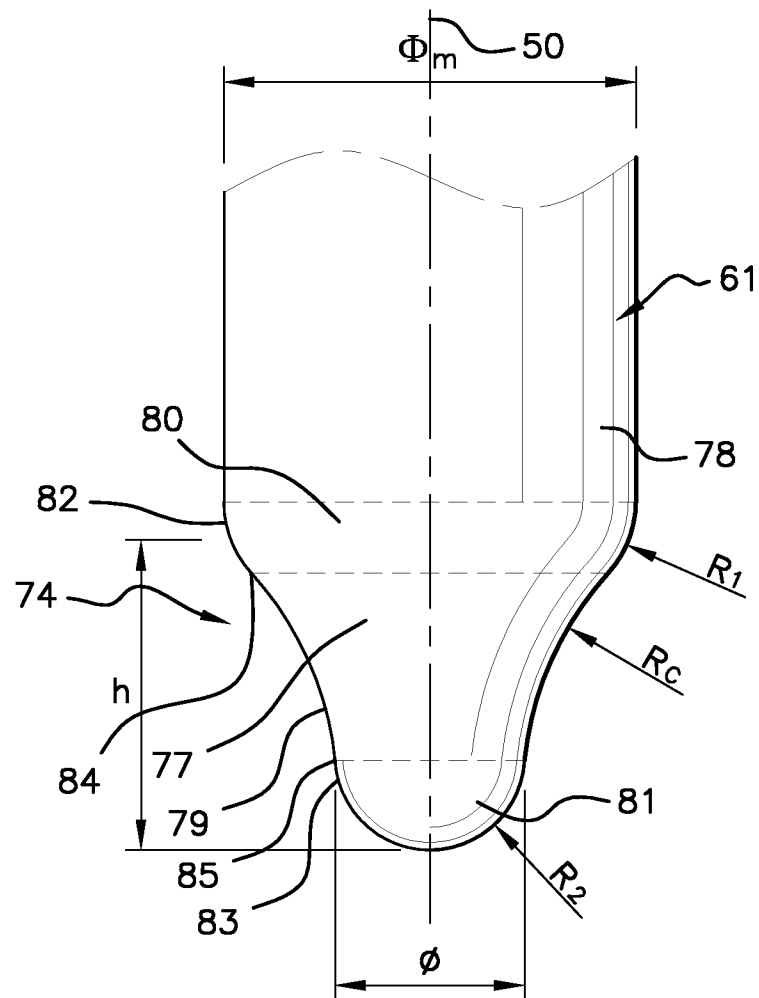
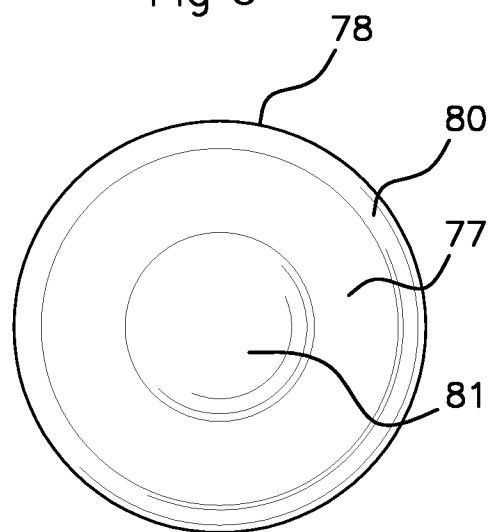


Fig 8



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20100133252 A [0007] [0011] [0012]