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(71) Applicant: **ABB Power Grids Switzerland AG**
5400 Baden (CH)

(72) Inventors:
- **Galletti, Bernardo**
  5415 Nussbaumen (CH)
- **Herrmann, Lorenz**
  5300 Turgi (CH)
- **Gotti, Manuel**
  5300 Turgi (CH)
- **Doiron, Charles**
  4052 Basel (CH)
- **Costyson, Johan Karl Filip**
  5430 Wettingen (CH)
- **Dhotre, Mahesh**
  5200 Brugg (CH)
- **Karrer, Reto**
  8712 Stäfa (CH)

(74) Representative: **Michalski Hüttermann & Partner Patentanwälte mbB**
Speditionstraße 21
40221 Düsseldorf (DE)

(54) NOZZLE FOR A CIRCUIT BREAKER, CIRCUIT BREAKER, AND METHOD OF 3D PRINTING A NOZZLE FOR A CIRCUIT BREAKER

(57) A nozzle (100) for a circuit breaker (1000), the circuit breaker (1000) having at least two contact elements (210, 220) and a gas reservoir (310) is provided. The nozzle (100) is manufactured by 3D printing as a single piece and is configured to surround the at least two contact elements (210, 220). The nozzle includes an arcing zone (330) formed along a central axis (CA) of the nozzle (100), and a gas channel (320) formed within the nozzle (100), the gas channel (320) configured to fluidly connect the gas reservoir (310) and the arcing zone (330). At least one of the contact elements (210, 220) is configured to be movable.

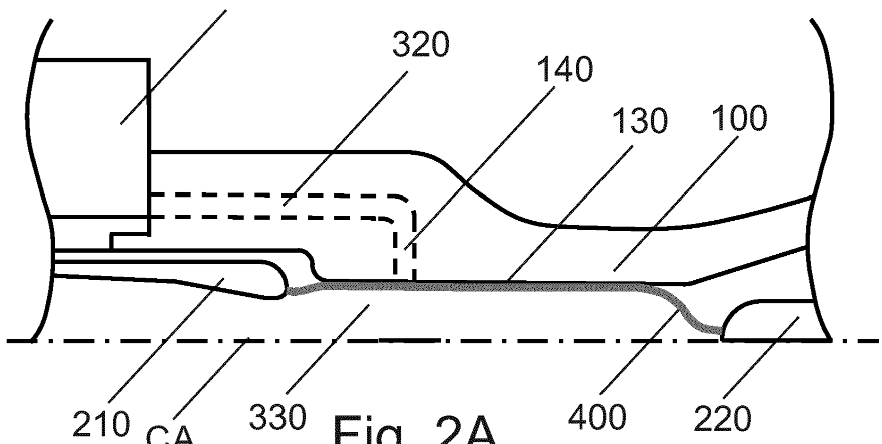

Fig. 2A

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Description

[0001] Aspects of the invention relate to a nozzle for a circuit breaker, in particular nozzle for a circuit breaker being manufactured by 3D printing as a single piece. Further aspects relate to circuit breaker including the nozzle. Further aspects relate to a method of 3D printing a nozzle for a circuit breaker.

Technical background:

[0002] Circuit breakers are known. Circuit breakers may have two contact elements which may move relative to each other along a central axis of the circuit breaker. An arc may form when the circuit breaker is opened, that is when the two contact elements are separated from each other. There may be an arcing zone between the two contact elements in which the arc is generated when the circuit breaker is opened or switched. The arc may be extinguished using an extinguishing gas.

[0003] Fig. 1 shows a cross-sectional representation of a part of a circuit-breaker. This circuit-breaker has two opposing contact elements 210, 220 which are movable relative to each other along a central axis CA of the circuit-breaker by means of a drive. Contact element 210 is a metal contact tulip, contact element 220 is a metal contact pin. An arc area 330 is provided between the two contact elements 210, 220, in which, for example, an arc is formed when the circuit-breaker is opened, in which the two contact elements are separated from each other. Furthermore, the circuit-breaker shown in Fig. 1 has a cylindrical auxiliary nozzle 100b which at least partially encloses the contact element 210. The inner jacket of the auxiliary nozzle faces the arc area 330. Furthermore, the circuit breaker shown has a main nozzle 100a which at least partially encloses the auxiliary nozzle 100b. A channel 320 is formed between the auxiliary nozzle 100b and the main nozzle 100a, which connects the arc area 330 with a gas reservoir 310, an upstream reservoir where the gas is temporarily stored with high pressure. The gas reservoir 310 is arranged circumferentially outside the auxiliary nozzle 100b. After the zero crossing of the current at which the current is meant to be interrupted during the switching operations of such a circuit-breaker, arc restrikes can occur due to the rise of the transient recovery voltage across the breaker terminals. These restrikes can run at least partially through channel 320 between the auxiliary nozzle 100b and the main nozzle 100a in an undesirable manner. Such an arc is indicated by the reference number 400 in Fig. 1. It extends from the contact element 220 along the inner jacket of the main nozzle 100a to the end region of the main nozzle 100a forming a side wall of the channel 320 and then continues in the channel region at its upper boundary wall in Fig. 1 until it is finally deflected in the direction of the contact element 210.

[0004] DE 20 2017 103 766 U1 describes an auxiliary nozzle which at least partially encloses one of the contact elements, a main nozzle which at least partially encloses the auxiliary nozzle, and a channel between the auxiliary nozzle and the main nozzle. During separation of contact elements when a circuit breaker is opened, a breakdown of insulating gas may initiate in the region around a contact element such as a plug tip. The breakdown of insulating gas may lead to a formation of a highly conductive plasma channel or a leader. The leader may have a tendency to stick to a nearby wall such as a nozzle surface. The leader may travel towards the other contact element such as a tulip under the drive of the electric field generated by the recovery voltage. Once the leader gets in proximity of the gap or gas channel between the main nozzle and the auxiliary nozzle, the leader may either bridge over the gap or gas channel and reach the tulip or remain attached to the surface of the nozzle, enter the gap and travel along a surface of the gas channel. The leader may travel until it is discharged on a metal part having the same potential as the other contact element or tulip.

[0005] Flashover traces may form when the latter situation, wherein the leader does not bridge the gap but enters the gap, occurs during a breaking operation. The flashover traces may form on the nozzle surfaces. Punctures or holes through the nozzle body may also form.

[0006] While performing a breaking sequence in a certification test, it is expected that the breaker fails to interrupt the current at the confirmation of minimum arcing time. The IEC standard prescribes that such failed breaking operations must not result in flashover traces. If flashover traces are revealed during an inspection of the breaker, the certification test might be considered to be failed even though the breaker has cleared the IEC sequence.

[0007] Thus, flashover in the gas channel that separates the auxiliary nozzle and main nozzle should be avoided. That is, propagation of a leader along a surface of the gas channel or gap between the auxiliary nozzle and main nozzle should be avoided.

[0008] DE 20 2017 103 766 U1 describes a configuration to guide a plasma channel or a leader from one contact element to the other contact element, along the inner jacket of the main nozzle and the auxiliary nozzle, such that the leader does not enter the gas channel or gap between the main nozzle and the auxiliary nozzle. DE 20 2017 103 766 U1 describes a configuration where one of the auxiliary nozzle or the main nozzle has an extension section bridging the channel in a direction parallel to the central axis such that the inner casing or inner jacket or inner surface of the auxiliary nozzle and the inner casing of the main nozzle adjoin one another in a direction parallel to the central axis of the nozzle without interruption or substantially without interruption. "Substantially without interruption" may include a configuration where a narrow gap between the auxiliary nozzle and the main nozzle, for example, a gap of less than 1 mm, is formed such that a leader travelling from one contact element to the other contact element bridges the gap and does not propagate through this gap into the channel. Openings or fluid ducts in the extension region connect the arc region to the gas reservoir and allow gas, such as extinguishing gas, to flow between them.

[0009] DE 20 2017 103 766 U1 describes that the auxiliary nozzle and the main nozzle are manufactured independently of each other. The openings or fluid ducts on the auxiliary nozzle or the main nozzle are selected such that the openings may be easily machined into the extension section during manufacture. The main nozzle and the auxiliary nozzle are then assembled.

[0010] The manufacture of a main nozzle and an auxiliary nozzle, and their assembly involve production tolerances and/or clearance between the auxiliary nozzle and the main nozzle. The tolerance and/or clearance between the auxiliary nozzle and the main nozzle plays a role in preventing an arc formed from propagating through the gap into the channel. The tolerance and/or clearance must not be so large as to impair the prevention of arc propagation into the channel between the auxiliary nozzle and the main nozzle. The tolerance and/or clearance between the auxiliary nozzle and the main nozzle also plays a role in the correct assembly of the circuit breaker. The clearance must not be so small as to cause difficulties during assembly of the auxiliary nozzle and the main nozzle.

[0011] Furthermore there is also a complication of mechanical coupling between the auxiliary nozzle and the main nozzle. A threaded connection between the auxiliary nozzle and main nozzle would encapsulate air and undermine dielectric recovery.

[0012] Additionally, the openings or fluid ducts on the extension sections on the auxiliary nozzle or the main nozzle connecting the arcing zone to the gas channel are selected with considerations of the associated machining and/or manufacturing process. Thus, the design and/or other processing of the openings such as finishing and/or material considerations may impose some requirements or limitations. That is, manufacturing and/or machining considerations may mean that the openings may not be completely optimized with respect to the performance of the nozzle or circuit breaker such as the gas flow between the gas reservoir and the arcing zone.

[0013] Thus, there is a need to improve the design and/or production method of the nozzles as well as a need to improve the mechanical stability of the nozzles while maintaining the prevention of leader propagation into the gas channel between the auxiliary nozzle and the main nozzle.

Summary of the invention

[0014] In view of the above, a nozzle for a circuit breaker according to claim 1, a circuit breaker according to claim 14, and a method of 3D printing a nozzle for a circuit breaker according to claim 15 are provided.

[0015] According to an aspect, there is provided a nozzle for a circuit breaker, the circuit breaker having at least two contact elements and a gas reservoir, wherein the nozzle is manufactured by 3D printing as a single piece and configured to surround the at least two contact elements of the circuit breaker at least partially, the nozzle having an arcing zone formed along a central axis of the nozzle; and a gas channel formed within the nozzle and configured to fluidly connect the gas reservoir to the arcing zone, wherein at least one of the contact elements is configured to be movable.

[0016] An advantage is that the issues of manufacturing tolerances and mechanical coupling associated with having two separate nozzles may be eliminated. A nozzle made of a single piece obtained with 3D printing manufacturing may replace the combination of two nozzle parts such as an auxiliary nozzle and a main nozzle or an auxiliary nozzle and an insulating nozzle. Another advantage may be that flashovers in a channel or gas channel or propagation of a leader into a channel or gas channel may as effectively be avoided or prevented as, or be avoided or prevented better than a combination of two nozzle parts such as an auxiliary nozzle and a main nozzle, or an auxiliary nozzle and an insulating nozzle.

[0017] According to embodiments, the arcing zone is configured to be between two or more contact elements of the circuit breaker. Specifically, the arcing zone can be configured to be between the two or more contact elements of the circuit breaker when the nozzle is mounted in the circuit breaker.

[0018] According to embodiments, the gas channel is formed in a direction substantially parallel to the arcing zone.

[0019] According to embodiments, the nozzle further includes a plurality of fluid ducts formed within the nozzle and configured to fluidly connect the gas channel to the arcing zone.

[0020] An advantage may be that fluid ducts or openings may be designed or selected with 3D printing tools so as to optimise the flow of gas, such as extinguishing gas, or optimise for other circuit breaker performance considerations.

[0021] For example, an advantage is that the fluid ducts or openings on the nozzle may be designed or selected with 3D printing tools to optimise the performance of the nozzle such as improved gas flow between the gas channel and the arcing zone.

[0022] Additionally, 3D printing may provide improved freedom in the design and/or manufacture of the gas channel and/or fluid ducts.

[0023] According to embodiments, each fluid duct of the plurality of fluid ducts adjoins the gas channel at one end and adjoins the arcing zone at the other end.

[0024] According to embodiments, each fluid duct of the plurality of fluid ducts is formed in a direction substantially perpendicular to the central axis of the nozzle or in a direction at an angle to a radial axis, and wherein the radial axis is perpendicular to the central axis of the nozzle.

[0025] According to embodiments, each fluid duct of a plurality of fluid ducts is rotationally asymmetric about a radial axis, and wherein the radial axis is perpendicular to a central axis of the nozzle.

[0026] According to embodiments, the plurality of fluid ducts are distributed in a circumferential direction of the nozzle and/or the plurality of fluid ducts are arranged spatially with n-fold rotational symmetry about a central axis of the nozzle.

[0027] According to embodiments, the plurality of fluid ducts span an entire gas channel length or a part of a gas channel length.

[0028] According to embodiments, the nozzle further includes a continuity of nozzle material configured to direct the propagation of a leader from a first contact element of the circuit breaker to a second contact element of the circuit breaker along at least a first surface of the nozzle, wherein the leader is highly conductive plasma.

[0029] An advantage may be that flashovers in a channel or gas channel or propagation of a leader into a channel or gas channel may be avoided or prevented.

[0030] According to embodiments, the first surface continuously abuts the arcing zone and/or the first surface is a surface of a throat of the nozzle.

[0031] According to embodiments, the first surface spans the nozzle.

[0032] According to embodiments, the nozzle is of a material composition, for example, including PTFE (polytetrafluoroethylene), FEP (fluorinated ethylene propylene), PFA (perfluoroalkoxy alkane), TFM (modified PTFE), MOS2 (molybdenum disulfide), BN (boron nitride), combinations thereof, or any fillings of one of these materials with another one.

[0033] According to another aspect, there is provided a circuit breaker having a nozzle.

[0034] Another aspect is directed to a method of 3D printing a nozzle for a circuit breaker, the circuit breaker having at least two contact elements and a gas reservoir, wherein the nozzle is manufactured as a single piece and configured to surround the at least two contact elements of the circuit breaker at least partially, the nozzle having an arcing zone formed along a central axis of the nozzle; and a gas channel formed within the nozzle and configured to fluidly connect the gas reservoir to the arcing zone, wherein at least one of the contact elements is configured to be movable.

[0035] Further advantages, features, aspects and details that can be combined with embodiments described herein are evident from the dependent claims, the description and the drawings.

Brief description of the figures:

[0036] The details will be described in the following with reference to the figures, wherein:

Fig. 1 is a cross-sectional representation of a part of a circuit-breaker, and

Figs. 2A and 2B are cross-sectional representations of a nozzle for a circuit breaker at different sections according to embodiments described herein.

Detailed description of the figures and embodiments:

[0037] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations.

[0038] Within the following description of the drawings, the same reference numbers refer to the same or to similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment applies to a corresponding part or aspect in another embodiment as well.

[0039] The reference numbers used in the figures are merely for illustration. The aspects described herein are not limited to any particular embodiment. Instead, any aspect described herein can be combined with any other aspect(s) or embodiment(s) described herein unless specified otherwise.

[0040] According to aspects or embodiments described herein, the problem of flashover traces in a channel or gas channel 320 in the nozzle 100 may be avoided. The problem of flashover traces may occur in case of an unsuccessful breaking operation. The breaking operation may be with a failure of dielectric type.

[0041] Figures 2A and 2B show cross-sectional views of a nozzle 100 for a circuit breaker 1000 according to embodiments described herein. Figures 2A and 2B are cross-sectional views at two different angles about the central axis CA of the nozzle 100, parallel to the central axis CA of the nozzle 100.

[0042] As shown in Figs. 2A and 2B, the nozzle 100 can be configured for a circuit breaker 1000 having at least two contact elements 210, 220. At least one of the contact elements 210, 220 may be configured to be movable.

[0043] According to embodiments described herein, the nozzle 100 may be manufactured as a single piece. The nozzle 100 may be manufactured by 3D printing. The nozzle 100 may be configured to surround the at least two contact elements 210, 220 of the circuit breaker 1000 at least partially. An arcing zone may be formed along a central axis CA of the nozzle 100. A gas channel 320 may be formed within the nozzle 100. The gas channel 320 may be configured to fluidly connect the gas reservoir 310 to the arcing zone 330.

[0044] According to embodiments described herein, the nozzle 100 may be made of a single piece. In particular, the nozzle 100 may be obtained with 3D printing manufacturing. A single piece nozzle may replace two or more nozzle parts such as an auxiliary nozzle and a main nozzle.

[0045] As shown in Fig. 2A, a single piece nozzle 100, a continuity of nozzle material may direct the propagation of a leader 400 from a first contact element 220 to a second contact element 210.

[0046] The leader 400 may be highly conductive plasma. The continuity of material may be of an insulating material.

[0047] The leader 400 may travel along a first surface 130 of the continuity of nozzle material. The first surface 130 may be continuously abutting the arcing zone 330. The first surface 130 may be a surface of a throat of the nozzle 100. The first surface 130 may span the nozzle 100.

[0048] The throat of the nozzle 100 may be section or portion of the nozzle 100 with the smallest cross-section or diameter. The throat of the nozzle 100 may have a constant cross-section or changing cross-section. The throat of the nozzle 100 may be a section or portion of the nozzle 100 surround the arcing zone 330. The throat of the nozzle 100 may be an inner surface of the nozzle 100. The throat of the nozzle 100 may be a section or portion of the nozzle 100 adjoining the arcing zone 330.

[0049] The leader 400 may travel until it discharges on a contact element 210. For example, the contact element 210 may be a tulip contact or pin contact configured for circuit breakers 1000. The leader 400 may travel from the first contact element 220 to the second contact element 210, vice versa, or between any two contact elements. Further, the contact element 220 may be the other one of the tulip contact or pin contact.

[0050] A nozzle 100 formed or manufactured as a single piece may have improved mechanical stability. A single piece nozzle 100 obtained with 3D printing may have improved mechanical stability.

[0051] Fig. 2B shows a cross-sectional view of a nozzle 100, where a plurality of fluid ducts 140 or openings 140 are formed. The plurality of fluid ducts 140 may be formed within the nozzle 100. The plurality of fluid ducts 140 may be configured to ensure gas flow is not hindered. Gas may flow between the gas reservoir 310 and the arcing zone 330 through at least one or more fluid duct 140 or opening 140. Alternatively or in addition, gas may flow between and/or the plurality of fluid ducts 140 may fluidly connect the gas channel 320 and the arcing zone 330. The gas reservoir 310 may be a reservoir or chamber containing gas for extinguishing or quenching an arc. The gas in the gas reservoir 310 may be at a pressure higher than the gas elsewhere in the circuit breaker 1000.

[0052] The plurality of fluid ducts 140 or openings 140 may be delimited by parts of the same insulating material that the nozzle 100 is made of. The continuity of material may be provided to make it easier for the leader 400 of plasma to discharge on a contact element 210 instead of travelling upstream in a channel or gas channel 320.

[0053] Possible complications arising from the mechanical coupling between two distinct or separate nozzles with extension sections or insulating bridges between said two distinct or separate nozzles, such as in DE 20 2017 103 766 U1, may be avoided by the nozzle 100 of the present disclosure.

[0054] According to embodiments described herein, the nozzle 100 is configured for a circuit breaker 1000 that has two opposing contact elements 210, 220 movable relative to one another along a central axis CA of the circuit breaker 1000. One or more contact element 210, 220 may be configured to be movable. Contact elements may be a metal contact tulip 210 or a metal contact pin 220.

[0055] According to embodiments described herein, an arcing zone 330 is provided. An arcing zone 330 may be formed between the two or more contact elements 210, 220. The arcing zone 330 may be formed along a central axis CA of the nozzle 100. The arcing zone 330 may be a zone where an arc is formed when the circuit breaker 1000 is opened or when two contact elements 210; 220 are separated from each other.

[0056] The nozzle 100 may be cylindrical or have any other suitable shape. The nozzle 100 may be formed of an insulating material. The nozzle 100 may be formed of a material composition suitable for use in circuit breakers. In particular, the material composition may be a result of the 3D printing. The material composition of the nozzle 100 may include, without being limited thereto, PTFE (polytetrafluoroethylene), FEP (fluorinated ethylene propylene), PFA (perfluoroalkoxy alkane), TFM (modified PTFE), MOS2 (molybdenum disulfide), BN (boron nitride), or any combination of at least two of these materials. For example, in one combination, one of these materials can be used as a matrix and another one can be used as a filler.

[0057] At least a part of the inner surface of the nozzle 100 may face, adjoin, delimit and/or abut the arcing zone 330.

[0058] According to aspects described herein, a channel or gas channel 320 may be provided. The channel 320 may be configured for gas flow. That is, the channel may be a gas channel 320. The gas channel 320 may be formed in a direction substantially parallel to the arcing zone 330. Alternatively or in addition, the gas channel 320 may be formed in a direction at an angle to a direction that is parallel to the arcing zone 330.

[0059] Additionally or alternatively, the gas channel 320 may be formed as a delimited channel, that is not spanning the entire circumference of the nozzle 100 or the gas channel 320 may be formed spanning substantially the entire circumference of the nozzle 100. A plurality of gas channels 320 may be provided instead of or in addition to an annular gas channel 320.

[0060] The gas channel 320 may extend parallel or substantially parallel to the central axis CA of the nozzle 100. The gas channel 320 may be configured to fluidly connect the gas reservoir 310 to the arcing zone 330. The gas channel 320 may be configured to fluidly connect the gas reservoir 310 to the plurality of fluid ducts 140. For example, the plurality of gas channels 320 may resemble a plurality of fluid ducts 140, e.g. in that the plurality of channels 320 connect to the plurality of fluid ducts 140.

[0061] In particular, the plurality of fluid ducts 140 may be formed in the nozzle 100. According to embodiments described herein, the fluid ducts 140 can be openings in the nozzle material. The plurality of fluid ducts 140 may be configured to fluidly connect the gas reservoir 310 to the arcing zone 330. Additionally or alternatively, the plurality of fluid ducts 140 may be configured to fluidly connect the gas channel 320 to the arcing zone 330. Additionally or alternatively, the plurality of fluid ducts 140 may be configured to adjoin the gas channel 320 at one end and adjoin the arcing zone 330 at the other end.

[0062] The plurality of fluid ducts 140 may be configured to allow the flow of gas such as extinguishing gas or insulating gas, in particular between the arcing zone 330 and the gas channel 320 and/or gas reservoir 310. The plurality of fluid ducts 140 may be configured to optimise the flow of gas, such as extinguishing gas or insulating gas between the arcing zone 330, and the gas channel 320 or gas reservoir 310. Alternatively, instead of an extinguishing gas, it may be a vacuum, or partial vacuum state.

[0063] The plurality of fluid ducts 140 may adjoin the arcing zone 330 and/or the gas channel 320. The plurality of fluid ducts 140 may extend at right angles or substantially at right angles to the central axis CA of the nozzle 100. Alternatively or in addition, the plurality of fluid ducts 140, or the axis of the plurality of fluid ducts 140 may be at an angle to a radial axis of the nozzle 100. The radial axis may be perpendicular to the central axis CA of the nozzle 100.

[0064] That is, at least one fluid duct 140 may be tilted with respect to the radial axis. The radial axis of the nozzle 100 is perpendicular to the central axis CA of the nozzle 100.

[0065] The plurality of fluid ducts 140 may be rotationally asymmetric about the radial axis. For example, the plurality of fluid ducts 140 may have an oval or a rectangular or a rounded rectangular cross-section or any other suitable cross-section. Alternatively, the plurality of fluid ducts 140 may be rotationally symmetric about a radial axis. For example, the plurality of fluid ducts 140 may have a circular cross-section, without being limited thereto. In particular, the plurality of fluid ducts 140 can have any cross-section. Further, the fluid ducts 140 may have different geometries or shapes or cross-sections from each other. In addition or alternatively, the fluid ducts may have changing cross-section along their length or axis.

[0066] The plurality of fluid ducts 140 may be spatially arranged or distributed in a circumferential direction or rotational direction about the central axis CA of the nozzle 100. Additionally or alternatively, the plurality of fluid ducts 140 may be spatially arranged or distributed in the axial direction or in a direction parallel to the central axis CA of the nozzle 100. Alternatively or in addition, the plurality of fluid ducts 140 may be arranged spatially or distributed with n-fold rotational symmetry about the central axis CA of the nozzle 100. Alternatively or in addition, the plurality of fluid ducts 140 may span the entire gas channel 320 length or a part of the gas channel 320 length.

[0067] A continuity of nozzle material in the nozzle 100 may be configured to guide, direct or conduct the propagation of a leader 400, which may be highly conductive plasma. The continuity of nozzle material may be configured to direct a leader 400 from the first contact element 220 of the circuit breaker 1000 to the second contact element 210 of the circuit breaker 1000.

[0068] In particular, the continuity of nozzle material may guide a leader 400 along a first surface 130 of the nozzle 100. The first surface 130 of the nozzle 100 may continuously adjoin or abut the arcing zone 330. Alternatively or in addition, the first surface 130 may be a surface of a throat of the nozzle 100. Alternatively or in addition, the first surface 130 may span the nozzle. Alternatively or in addition, the first surface 130 may span from a first axial position to a second axial position. The first axial position may correspond to the axial position of the first contact element 220 and/or the second axial position may correspond to the axial position of the second contact element 210. The axial position may be a position in the direction parallel to the central axis CA of the nozzle 100.

[0069] The continuity of material or the first surface 130 may prevent, hinder or discourage a leader 400 or an arc from travelling, propagating or spreading into the gas channel 320 and/or the plurality of fluid ducts 140. In particular, the first surface 130 may provide or be formed by a continuity of material or insulating material or insulating surface to guide, direct or conduct a leader 400 to propagate from one contact element 220 to another contact element 210.

[0070] According to aspects described herein, a circuit breaker 1000 may be provided. The circuit breaker 1000 may include a nozzle 100. The circuit breaker 1000 may include a nozzle 100 according to embodiments described herein.

[0071] According to embodiments described herein, a method of 3D printing a nozzle 100 may be provided. The method may include 3D printing a nozzle 100 for a circuit breaker 1000. The circuit breaker 1000 may have at least two contact elements 210, 220. The circuit breaker 1000 may have a gas reservoir 310. The nozzle 100 may be manufactured or formed as a single piece. The nozzle 100 may be configured to surround the at least two contact elements 210, 220 of the circuit breaker 1000 at least partially. The nozzle 100 may comprise an arcing zone 330 formed along a central axis CA of the nozzle 100. The nozzle 100 may comprise a gas channel 320 formed within the nozzle 100. The nozzle 100 may comprise a gas channel configured to fluidly connect the gas reservoir 310 to the arcing zone 330. At least one of the contact elements 210, 220 may be configured to be movable.

[0072] According to embodiments described herein, the nozzle 100 can be configured for a circuit breaker 1000 having a rated voltage of > 36 kV.

Claims

1. Nozzle (100) for a circuit breaker, the circuit breaker having at least two contact elements (210; 220) and a gas reservoir (310), wherein the nozzle is manufactured by 3D printing as a single piece and configured to surround the at least two contact elements (210; 220) of the circuit breaker at least partially, the nozzle (100) comprising:

   an arcing zone (330) formed along a central axis (CA) of the nozzle (100); and
   a gas channel (320) formed within the nozzle (100) and configured to fluidly connect the gas reservoir (310) to the arcing zone (330),
   wherein at least one of the contact elements (210; 220) is configured to be movable.

2. Nozzle (100) of claim 1, wherein the arcing zone (330) is configured to be between the two or more contact elements (210; 220) of the circuit breaker.

3. Nozzle (100) of claim 1 or 2, wherein the gas channel (320) is formed in a direction substantially parallel to the arcing zone (330).

4. Nozzle (100) of any of the preceding claims, further comprising a plurality of fluid ducts (140) formed within the nozzle (100) and configured to fluidly connect the gas channel (320) to the arcing zone (330).

5. Nozzle (100) of claim 4, wherein each fluid duct of the plurality of fluid ducts (140) adjoins the gas channel (320) at one end and adjoins the arcing zone (330) at the other end.

6. Nozzle (100) of claim 4 or 5, wherein each fluid duct of the plurality of fluid ducts (140) is formed in a direction substantially perpendicular to the central axis (CA) of the nozzle (100) or in a direction at an angle to a radial axis (RA), and wherein the radial axis (RA) is perpendicular to the central axis (CA) of the nozzle (100).

7. Nozzle (100) of any claims 4 to 6, wherein each fluid duct of the plurality of fluid ducts (140) is rotationally asymmetric about a radial axis (RA), and wherein the radial axis (RA) is perpendicular to the central axis (CA) of the nozzle (100).

8. Nozzle (100) of any of claims 4 to 7, wherein the plurality of fluid ducts (140) are distributed in a circumferential direction (CD) of the nozzle (100) and/or the plurality of fluid ducts (140) are arranged spatially with n-fold rotational symmetry about the central axis (CA) of the nozzle (100).

9. Nozzle (100) of any of claims 4 to 8, wherein the plurality of fluid ducts (140) span the entire gas channel (320) length or a part of the gas channel (320) length.

10. Nozzle (100) of any of the preceding claims, further comprising a continuity of nozzle material configured to direct the propagation of a leader (400) from a first contact element (210) of the circuit breaker to a second contact element (220) of the circuit breaker along at least a first surface (130) of the nozzle (100), wherein the leader (400) is highly conductive plasma.

11. Nozzle (100) of claim 10, wherein the first surface (130) continuously abuts the arcing zone (330) and/or the first surface (130) is a surface of a throat of the nozzle (100).

12. Nozzle (100) of claim 10 or 11 wherein the first surface (130) spans the nozzle (100).

13. Nozzle (100) of any of the preceding claims, wherein the nozzle (100) is of a material composition including for example PTFE, (polytetrafluoroethylene), FEP (fluorinated ethylene propylene), PFA (perfluoroalkoxy alkane), TFM (modified PTFE), MOS2 (molybdenum disulfide), BN (boron nitride), combinations thereof, or any fillings of one of these materials with another one.

14. Circuit breaker (1000) comprising a nozzle (100) of any one of the preceding claims.

15. Method of 3D printing a nozzle (100) for a circuit breaker, the circuit breaker having at least two contact elements (210; 220) and a gas reservoir (310), wherein the nozzle is manufactured as a single piece and configured to surround the at least two contact elements (210; 220) of the circuit breaker at least partially, the nozzle (100) comprising:

   an arcing zone (330) formed along a central axis (CA) of the nozzle (100); and
   a gas channel (320) formed within the nozzle (100) and configured to fluidly connect the gas reservoir (310) to the arcing zone (330),
   wherein at least one of the contact elements (210; 220) is configured to be movable.

Prior Art

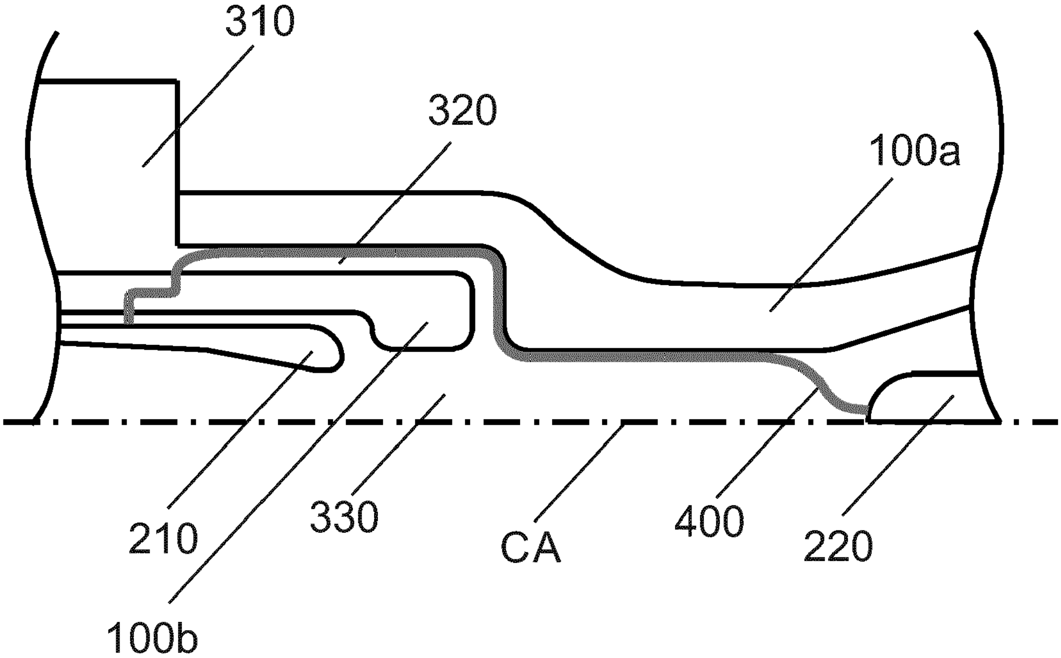

Fig. 1

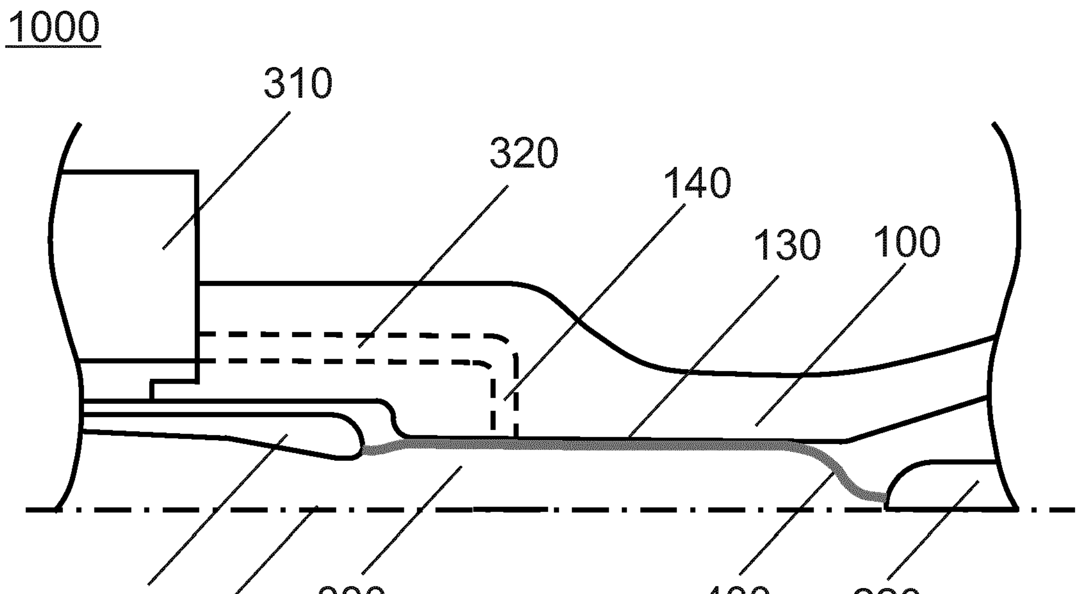
1000
310
320
140
130
100
210
CA
330
400
220

Fig. 2A

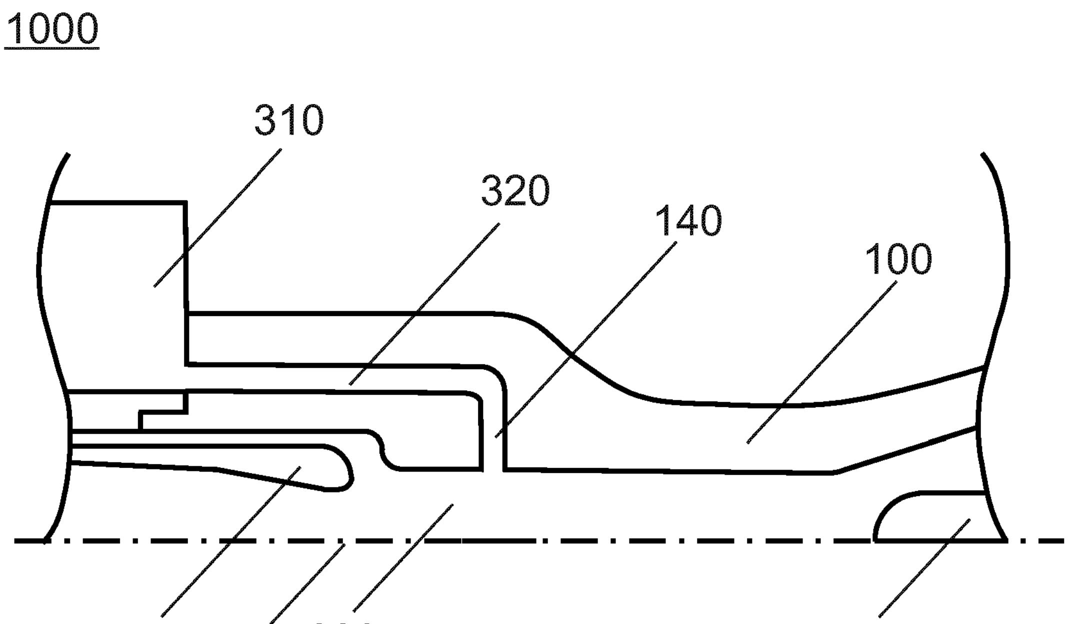
1000
310
320
140
100
210
CA
330
220

Fig. 2B

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EUROPEAN SEARCH REPORT

Application Number
EP 19 17 4447

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 2 827 353 A1 (ABB TECHNOLOGY AG [CH]) 21 January 2015 (2015-01-21) * page 3, paragraph 0021 - page 4, paragraph 0035; figures 1-3 *	1-15	INV. H01H11/00 H01H33/70 ADD. H01H33/90
Y,D	DE 20 2017 103766 U1 (ABB SCHWEIZ AG [CH]) 18 July 2017 (2017-07-18) * page 4, paragraph 0035 - page 6, paragraph 0054; figures 2,6-8 *	1-15	
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A	* page 10, line 15 - page 17, line 9; figure 1 *	4-12	
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TECHNICAL FIELDS SEARCHED (IPC)

H01H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	14 October 2019	Pavlov, Valeri

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CATEGORY OF CITED DOCUMENTS

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14-10-2019

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