(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 047 178 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.08.2022 Bulletin 2022/34

(21) Application number: **21157645.9**

(22) Date of filing: **17.02.2021**

(51) International Patent Classification (IPC):
E21B 17/03 *(2006.01)* ***E21B 17/04*** *(2006.01)*
E21B 17/042 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E21B 17/03; E21B 17/042

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Sandvik Mining and Construction Tools AB**
81181 Sandviken (SE)

(72) Inventors:
- **JANSSON, Tomas**
  81181 Sandviken (SE)
- **KRAFT, Conny**
  81181 Sandviken (SE)

(74) Representative: **Sandvik**
Sandvik Intellectual Property AB
811 81 Sandviken (SE)

(54) **ELLIPTICAL DESIGN FOR HEXAGONAL SHANKS**

(57) A rock drill component to form part of a drilling assembly, the rock drill component comprising: a main body; a hexagonal shank provided at one end of the rock drill component; a radially projecting shoulder positioned axially between the main body and the hexagonal shank; wherein there is a transition section increases in diameter in a direction from the hexagonal shank to the shoulder; wherein the cross-sectional shape profile of the outer surface of the transition section in the plane of the longitudinal axis comprises a segment of an ellipse having semi-major axis (a); a semi-minor axis (b) and an exponential factor (n) according to the equation:

$$\left|\frac{x}{a}\right|^n + \left|\frac{y}{b}\right|^n = 1$$

characterised in that the ratio of the semi-major to semi-minor axes (a:b) is within the range 2b<a<8b.

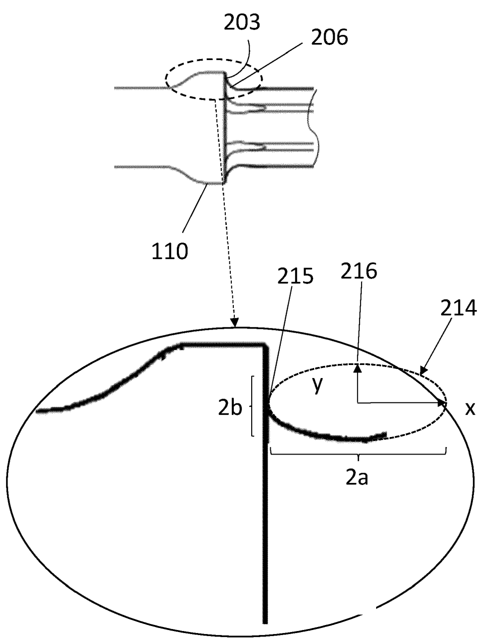


Fig 3

EP 4 047 178 A1

Description

Field of invention

[0001] The present invention relates to a hexagonal shank for rock drill components in particular, although not exclusively, to a hexagonal shank configured to minimise stress concentrations.

Background art

[0002] Percussion drilling is used to create a long borehole via a plurality of elongate drill string rods. The well-established technique breaks rock by hammering impacts transferred from the rock drill bit, mounted or forged at one end of the drill string, to the rock at the bottom of the borehole. Typically, the energy required to break the rock is generated by a hydraulically or pneumatically driven piston that contacts the end of the drill string to create a stress (or shock) wave that propagates through the drill string and ultimately to the base rock level.

[0003] Rock drill components having a hexagonal shank are commonly used in less powerful rock drills and in particular for drilling smaller holes. However, these rock tools are typically subjected to bending moments during drilling. These bending moments fatigue the rock tools and may lead to breakage within the joint.

[0004] In particular, the transition between the different diameters of shoulder on the rock drill component and the hexagonal shank provides a region for potentially high stress concentrations due to bending moments and tensile loads. Conventionally, the outside diameter of the rock drill component at the transition axially between the hexagonal shank and the shoulder is flared radially outward with a curved shape profile having a single radius curvature that is as large as can be accommodated between the two regions. The problem is with this profile is that high levels of stress can build up in this region. Fatigue and possible breakage are therefore very likely which causes significant disruption to a drilling operation. There is therefore a need for a hexagonal shank design that addresses these problems.

Summary of the Invention

[0005] It is an objective of the present invention to provide a rock drill component having a hexagonal shank that is optimised to minimise the likelihood of stress concentrations at the transition region between the shoulder and the hexagonal shank to extend the operational lifetime of the rock drill component and minimise fatigue and the risk of breakage in use. It is a further specific objective to provide a rock drill component that is compatible with existing drilling apparatus and methods that comprises an enhanced capacity to withstand large bending moments and tensile loads.

[0006] The objectives are achieved by specifically configuring the transition region that is positioned axially at the interface between the annular shoulder and the hexagonal shank. The present invention provides a rock drill component that has a hexagonal shank that exhibits reduced stress concentrations compared to known designs at the junction of the shoulder and the hexagonal shank resultant from incident bending moments or tensile loads.

[0007] According to a first aspect of the present invention there is a rock drill component to form part of a drilling assembly, the rock drill component comprising: a main body; a hexagonal shank provided at one end of the rock drill component; a radially projecting shoulder positioned axially between the main body and the hexagonal shank; wherein the transition section has an outside diameter that increases in diameter in a direction from the hexagonal shank to the shoulder; wherein the cross-sectional shape profile of the outer surface of the transition section in the plane of the longitudinal axis comprises a segment of an ellipse having semi-major axis (a); a semi-minor axis (b) and an exponential factor (n) according to the equation:

$$\left|\frac{x}{a}\right|^{n} + \left|\frac{y}{b}\right|^{n} = 1$$

characterised in that the ratio of the semi-major to semi-minor axes (a:b) is within the range 2b<a<8b.

[0008] Advantageously, this provides a coupling to hexagonal shank exhibiting enhanced stiffness and that is more resilient to bending moments and tensile forces. The transition section is configured to eliminate or at least minimise stress concentrations at the section where spigot projects axially from shoulder. If the ratio of the lengths of the semi-major to semi-minor axes are above or below this the stress concentrations increase. Consequently, the risk of breakage is reduced and so the operation lifetime of the rock drill component is increased. Optionally, the transition section may also comprise segments wherein the shape profile is straight and / or different curved profile.

[0009] Preferably, the ratio of the semi-major to semi-minor axes (a:b) is within the range 2.5b<a<6b, even more preferably 2.5<a<4b. Advantageously, within the narrowed ratio range the stress concentrations at the section where the hexagonal shank projects axially from the shoulder are further reduced meaning that there is enhanced capacity to withstand large bending moments and tensile stresses.

[0010] Preferably, the exponential factor (n) is in the range $1 \le n \le 3$. Advantageously, this provides a transition section having an elliptical profile with the lowest stress concentration.

[0011] Optionally, a vertex of the ellipse is positioned at a tangent with the annular side surface of the shoulder. Alternatively, the vertex of the ellipse undercuts the annular side surface of the shoulder. Different load cases may benefit from different forms of the ellipse.

[0012] Optionally, the x-axis of the ellipse is parallel to the longitudinal axis. Alternatively, the x-axis of the ellipse is tilted with respect to the longitudinal axis. Different load cases may benefit from different forms of the ellipse.

[0013] Optionally, the profile of the outer surface of the transition section in the plane of the longitudinal axis comprises a quarter segment of an ellipse. Alternatively, the cross-sectional shape profile of the outer surface of the transition section in the plane of the longitudinal axis comprises greater than a quarter segment of an ellipse. Alternatively, the cross-sectional shape profile of the outer surface of the transition section in the plane of the longitudinal axis comprises a less than quarter segment of an ellipse. Different load cases may benefit from different forms of the ellipse.

[0014] Within the specification, reference to '*curvature*' encompasses a smooth or gradual change in surface profile and a plurality of sequential linear increases (or decreases) in diameter that collectively may be regarded as a '*curved*' shape profile. For example, the term '*curvature*' encompasses relatively small linear step changes such that an edge or middle region of each step may be considered to collectively define a curve.

[0015] Preferably, the rock drill component comprises a shoulder projecting radially from the main length section wherein an outside diameter of the shoulder is greater than an outside diameter of the main length section and the transition section of the shank. Such a configuration allows for the conventional '*shoulder contact*' coupling between the male spigot and the female sleeve that is preferred over the alternative '*bottom contact*' due to the larger diameter and surface area contact between the male and female parts.

[0016] Preferably, a side surface of the shoulder that is in contact with the transition section comprises an annular radially outer region that is aligned substantially perpendicular to the longitudinal axis. The curved transition section therefore does not continue over the full radial length of the annular side surface to provide a flat annular surface for contact by the annular end face of the female sleeve.

[0017] In one embodiment, the rock drill component is a shank rod.

[0018] In another embodiment, the rock drill component is a taper rod.

[0019] In another embodiment, the rock drill component is an integral drill steel (IDS).

[0020] According to a second aspect of the present invention there is provided a drilling assembly comprising a rock drill component as claimed herein.

Brief description of drawings

[0021] A specific implementation of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is an external view of a rock drill component having a hexagonal shank.

Figure 2a is an external side view of one end of the rock drill component of Figure 1 showing the transition region between the shoulder and the hexagonal shank wherein the main body has a cylindrical external surface.

Figure 2b is an external side view of one end of the rock drill component of Figure 1 showing the transition region between the shoulder and the hexagonal shank wherein the main body has a hexagonal external surface.

Figure 3 is a magnified view of a rock drill component in the region of the transition section according to one embodiment of the invention wherein the vertex of the elliptical profile of the transition section is at a tangent to the shoulder;

Figure 4 is a magnified view of a rock drill component in the region of the transition section according to an alternative embodiment of the invention wherein the elliptical profile of the transition section undercuts the annular side surface of the shoulder.

Figure 5 is a magnified view of a rock drill component in the region of the transition section according to an alternative embodiment of the invention wherein the elliptical profile of the transition section is tilted.

Figure 6 is an example wherein the rock drill component is a shank rod.

Figure 7 is an example wherein the rock drill component is a taper rod.

Figure 8 is an example wherein the rock drill component is an integral drill steel (IDS)

Figure 9 is an example wherein the rock drill component is a plug hole IDS.

Figures 10a-c are von Mises effective stress images.

Detailed description of preferred embodiment of the invention

[0022] Figure 1 shows a rock drill component 100 having a hexagonal shank 102. The hexagonal shank 102 is positioned between a trailing end 103 and a shoulder 110 (or collar). The hexagonal shank 102 has a hexagonally shaped cross section. The hexagonal shank 102 is mounted in a percussive hammer (not shown) such that the hammer engages with the hexagonal shank 102 and the shoulder 102. The hammer is operated and rotates the rock drill component whilst simultaneously applying axial percussive loads to the trailing end 103 of the rock drill component.

[0023] Figures 2a and 2b shows that a main body 101 of the rock drill component comprises a cylindrical or hexagonal external surface 200 that is flared radially outward at the shoulder 110 to provide an annular concave region 201 that terminates at a cylindrical surface 202 located at the shoulder 110. The cylindrical external surface 200 is shown in figure 2a and the hexagonal external surface is shown in figure 2b. Subsequent drawings all shown the cylindrical option for the external surface 200, but it should be understood that in any embodiment the hexagonal external surface could be used instead. The shoulder 110, in particular the cylindrical surface 202 is terminated at the hexagonal shank side by an annular side surface 203 aligned perpendicular to the axis 204. The hexagonal shank projects axially from a radially inward region of the surface 203 and is aligned coaxial with the main body 101 and the annular shoulder 110. A curved transition section 206 is positioned axially between the side surface 203 and the main length of the hexagonal shank 102. The transition section 206 tapers radially outward in a direction from the hexagonal shank 102 to contact against the annular side surface 203

[0024] Figure 3 shows an expanded view of the transition section 206. The transition section 206 increases in diameter and cross-sectional area from hexagonal shank 102 to the shoulder 110, such that the external surface profile of the transition section 206 in a plane along axis 204 is curved according to a gradual curvature having a profile corresponding to quarter segment of a perimeter of an ellipse 214, or slightly more or slightly less than a quarter segment of an ellipse 214. The ellipse 214 has a semi-major axis (x) and a semi-minor axis (y). Preferably, there is no abrupt change along the length of the transition section 206 from a first radius to a second radius, instead there is a continuous and gradual change in the radius along the length of the transition section 206. Optionally, the transition section 206 may also comprise segments wherein the shape profile is straight and / or has a different curved profile, which could be positioned at either end of the elliptical profile or as an interruption part way along the elliptical profile.

[0025] The equation of an ellipse is defined by a Lame curve when n=2:

$$\left|\frac{x}{a}\right|^n + \left|\frac{y}{b}\right|^n = 1$$

Wherein:

x is the co-ordinate on the x axis;
y is the co-ordinate on the y axis;
a is the semi-major axis (x);
b is the semi-minor axis (y);
n determines the shape of the curve. n=2 defines an ordinary ellipse. n<2 a hypoellipse and n>2 a hyperellipse.

[0026] In the present invention the ratio of the major to minor axes, (a: b) is within the range $2b<a<8b$, preferably, $2b<a<6b$, more preferably $2.5b<a<6b$, even more preferably $2.5b<a<4b$.

[0027] Preferably, the semi-minor axis (b) is as large as possible.

[0028] Preferably, the exponential factor n is in the range $1 \le n \le 3$, preferably $1.8 \le n \le 2.2$, most preferably 2.

[0029] The equation of the elliptical profile of the transition section 206 can be measured using a contour measuring machine. The contour measuring machine drags a needle over the surface of the transition section 206, then the equipment will try to fit different geometries and then output the equation of shape profile measured.

[0030] At each endpoint of the semi-major axis (x) is a vertex 215 of the ellipse 214 and at each endpoint of the minor axis (y) there is a co-vertex 216 of the ellipse 214. Optionally, the vertex 215 of the ellipse is positioned at a tangent with the annular side surface 203 of the shoulder 110, as shown in Figure 3.

[0031] Figure 4 shows an alternative design, where the vertex 215 of the ellipse 214 undercuts the annular side surface 203 of the shoulder 110.

[0032] Optionally, the x-axis of the ellipse 214 is parallel to the longitudinal axis 204, as shown in Figure 3.

[0033] Figure 5 shows an alternative wherein the x-axis of the ellipse 214 is tilted with respect to the longitudinal axis of 204.

[0034] It should be appreciated that any combination of the position of the vertex 215 can be combined with any orientation of the x-axis with respect to the longitudinal axis 204 as described hereinabove.

[0035] The profile of the transition section 206 provides a male shank end exhibiting enhanced stiffness and that is more resilient to bending moments and tensile forces with respect to conventional hexagonal shank designs. Additionally, the transition section 206 is configured to eliminate or at least minimise stress concentrations at the section where hexagonal shank 102 projects axially from shoulder 110.

[0036] Figure 6 shows that in one embodiment, the rock drill component 100 is a shank rod 250 having a threaded section 251 at the axially opposite end compared to the hexagonal shank 102 for connection to a coupling or directly to a threaded drill bit (not shown).

[0037] Figure 7 shows that in another embodiment, the rock drill component 100 is a taper rod 260 having a tapered joint 261 at the axially opposite compared to the hexagonal shank 102 for connection to a drill bit (not shown).

[0038] Figure 8 shows that in another embodiment, the rock drill component 100 is an integral drill steel (IDS) 270 having a forged bit end 271 at the axially opposite end to the hexagonal shank for drilling into the rock.

[0039] Figure 9 shows that the IDS 270 could for example be a plug hole IDS.

[0040] The rock drill component 100 could also be any component that has a hexagonal shank 102 and a shoulder 110.

[0041] Figures 10a-c show the maximum value of the von Mises effective stress using rotating bending as the load case for different transition section 206 profiles as shown in Table 1:

Table 1: Description of transition section profiles used in the von Mises effective stress images.

Figure	Transition section profile	Von Mises stress
10a (prior art)	Single radius = 4.5 mm	361 MPa
10b (invention)	Elliptical: a = 7.0 mm and b = 2.3 mm	327 MPa
10c (invention)	Elliptical: a = 10.0 mm and b = 3.5 mm	291 MPa

[0042] The risk for failure is increased as the value of the von Mises effective stress increases. Thus, darker colours mean higher risk for failure. By comparing figure 10a (prior art) to figures 10b-c (embodiments of the present invention) it can be seen that the von Mises effective stress has decreased for the inventive profiles. The stress images were captured using implicit analysis in LS-Dyna and the von Mises stress images are extracted using the Hyperview software. Table 1 also shows the maximum value of the von Mises effective stress measured from this equipment. It can be seen from the results in Table 1 that all the inventive samples have lower von Mises stress compared to the prior art version.

Claims

1. A rock drill component (100) to form part of a drilling assembly, the rock drill component (100) comprising:

a main body (101);
a hexagonal shank (102) provided at one end of the rock drill component (100);
a radially projecting shoulder (110) positioned axially between the main body (101) and the hexagonal shank (102);
wherein there is a transition section (206) increases in diameter in a direction from the hexagonal shank (108) to the shoulder (110);
wherein the cross-sectional shape profile of the outer surface of the transition section (206) in the plane of the longitudinal axis (204) comprises a segment of an ellipse (214) having semi-major axis (a); a semi-minor axis (b) and an exponential factor (n) according to the equation:

$$\left|\frac{x}{a}\right|^n + \left|\frac{y}{b}\right|^n = 1$$

characterised in that:
the ratio of the semi-maj or to semi-minor axes (a:b) is within the range 2b<a<8b.

2. The rock drill component (100) according to claim 1, wherein the ratio of the semi-major to semi-minor axes (a:b) is within the range 2.5b<a<6b.

3. The rock drill component (100) according to claim 1 or claim 2, wherein the exponential factor (n) is in the range $1 \leq n \leq 3$.

4. The rock drill component (100) according to any preceding claim, wherein a vertex (215) of the ellipse (214) is positioned at a tangent with the annular side surface (203) of the shoulder (110).

5. The rock drill component (100) according to any of claims 1-3, where the vertex (215) of the ellipse (214) undercuts the annular side surface (203) of the shoulder (110).

6. The rock drill component (100) according to any preceding claim, wherein the x-axis of the ellipse (214) is parallel to the longitudinal axis (204).

7. The rock drill component (100) according to any of claims 1-5, wherein the x-axis of the ellipse (214) is tilted with respect to the longitudinal axis (204).

8. The rock drill component (100) according to any of the preceding claims, wherein the cross-sectional shape profile of the outer surface of the transition section (206) in the plane of the longitudinal axis (204) comprises a quarter segment of an ellipse (214).

9. The rock drill component (100) according to any of claims 1-7, wherein the cross-sectional shape profile of the outer surface of the transition section (206) in the plane of the longitudinal axis (204) comprises greater than a quarter segment of an ellipse (214).

10. The rock drill component (100) according to any of claims 1-7, wherein the cross-sectional shape profile of the outer surface of the transition section (206) in the plane of the longitudinal axis (204) comprises less than a quarter segment of an ellipse (214).

11. The rock drill component (100) according to any of the preceding claims wherein the rock drill component (100) is a shank rod (250).

12. The rock drill component (100) according to any of the preceding claims wherein the rock drill component (100) is a taper rod (260).

13. The rock drill component (100) according to any of the preceding claims wherein the rock drill component (100) is an integrated rock drill (IDS) (270).

14. A drilling assembly comprising a rock drill component (100) according to any preceding claim.

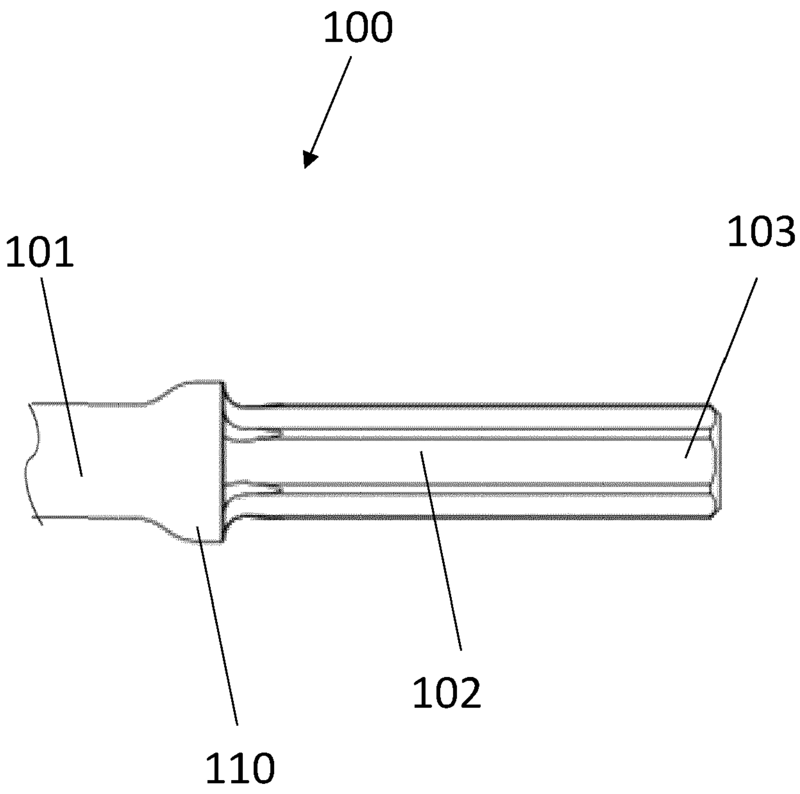


Fig 1

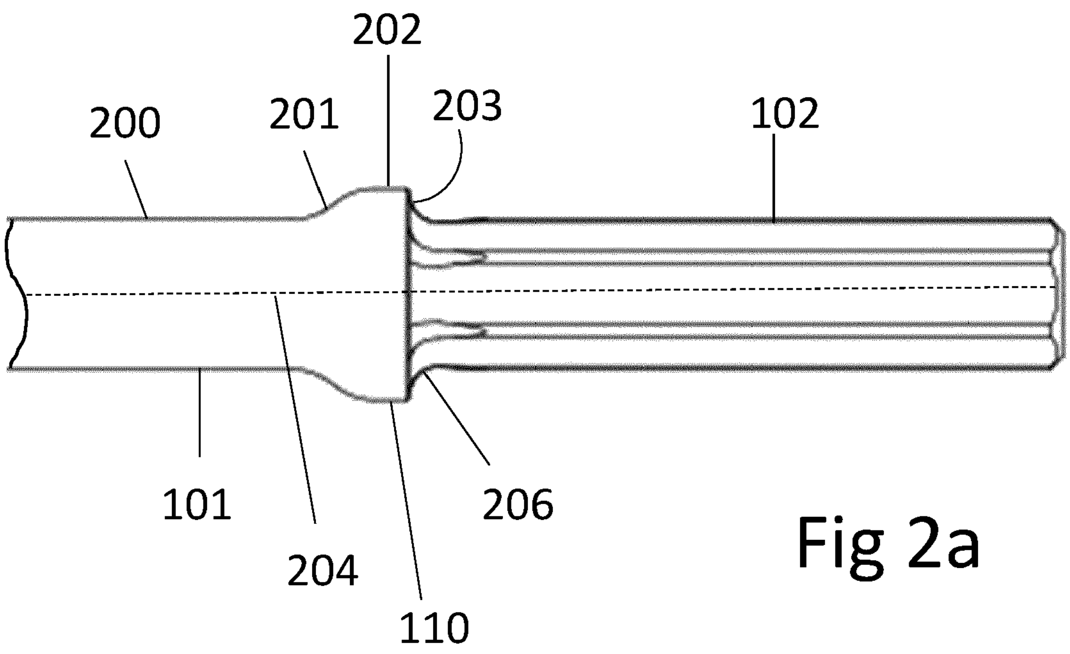

202
200
201
203
102
101
204
110
206

Fig 2a

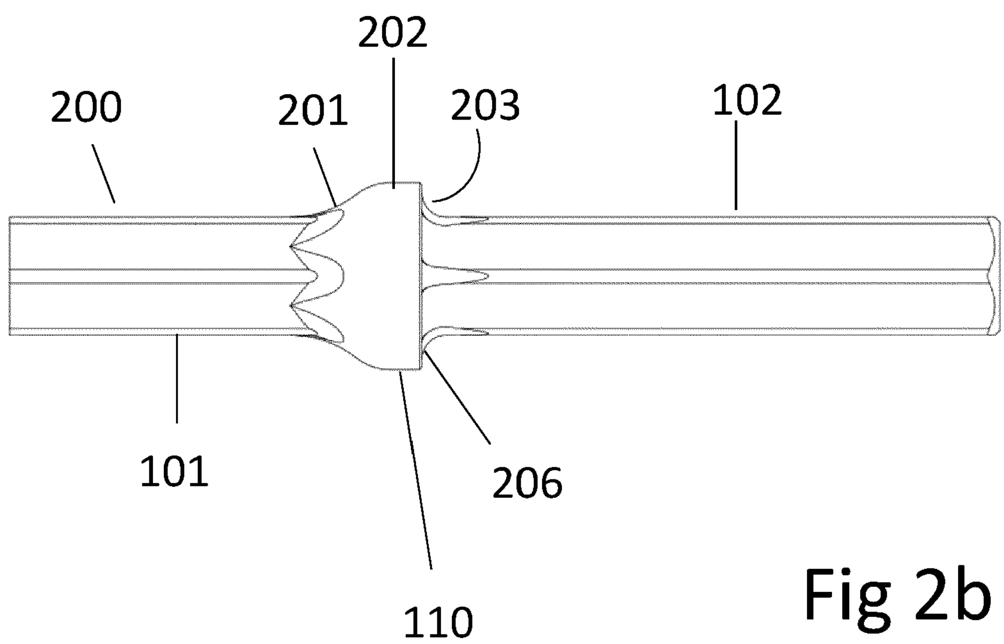

202
200
201
203
102
101
206
110

Fig 2b

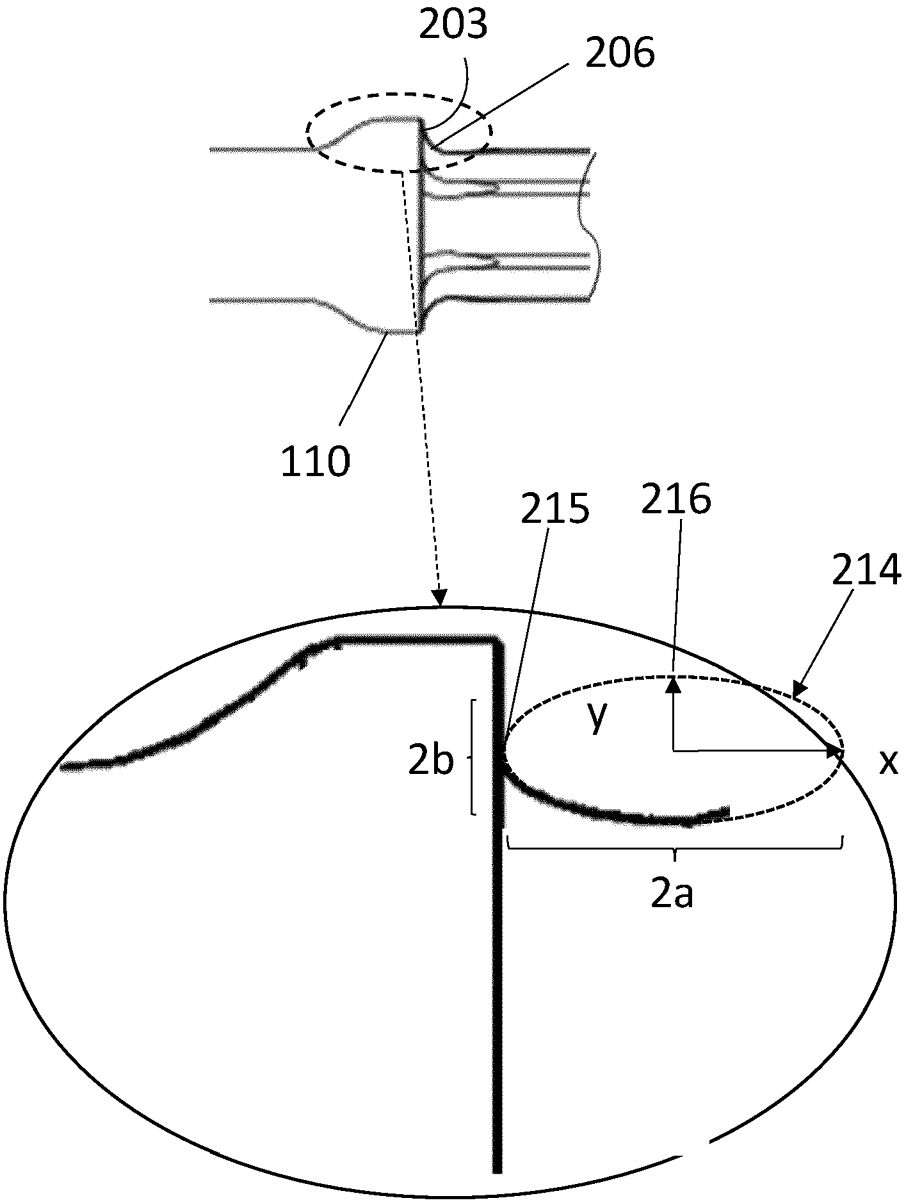


Fig 3

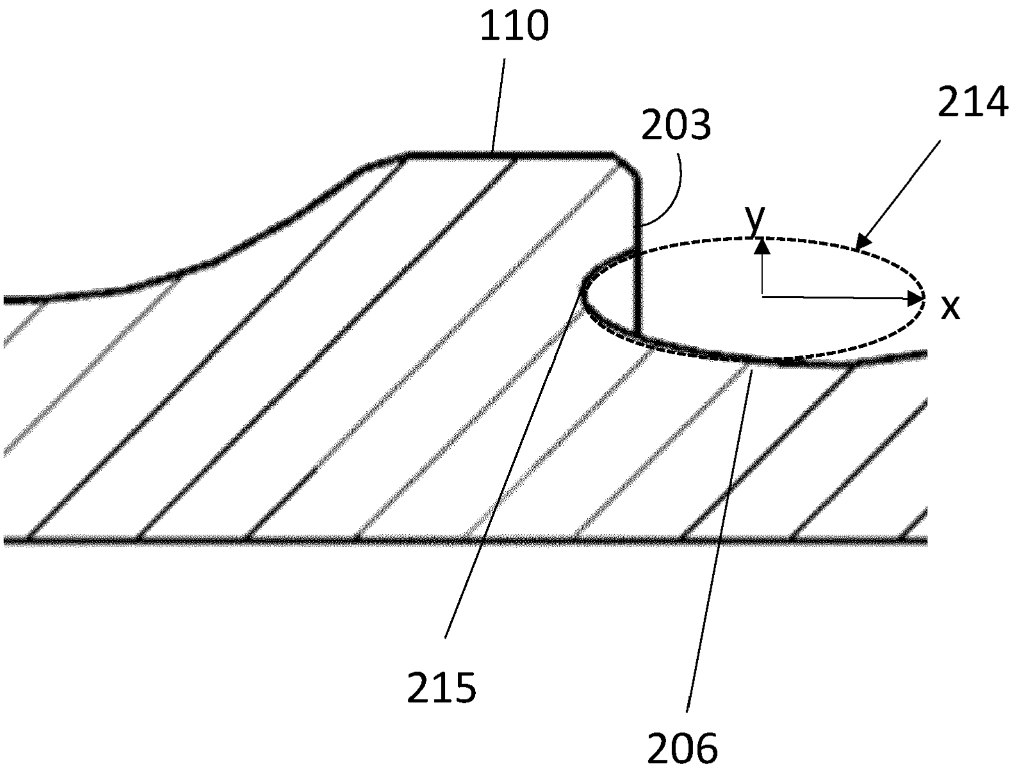


Fig 4

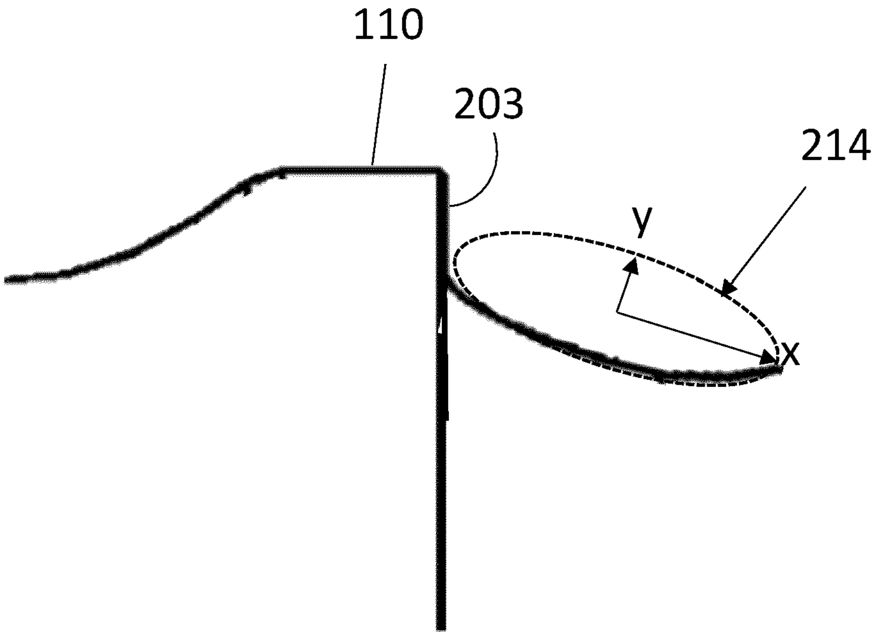


Fig 5

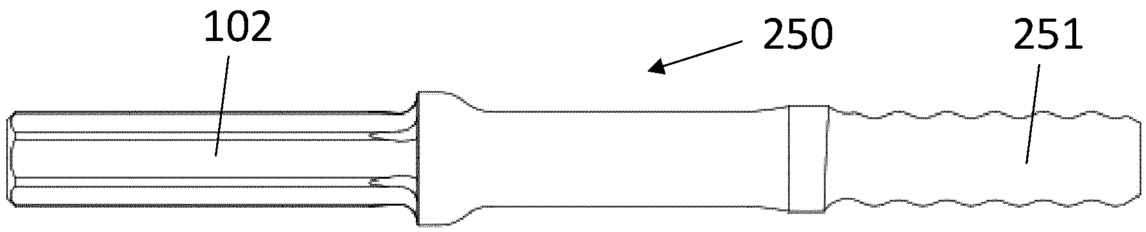


Fig 6

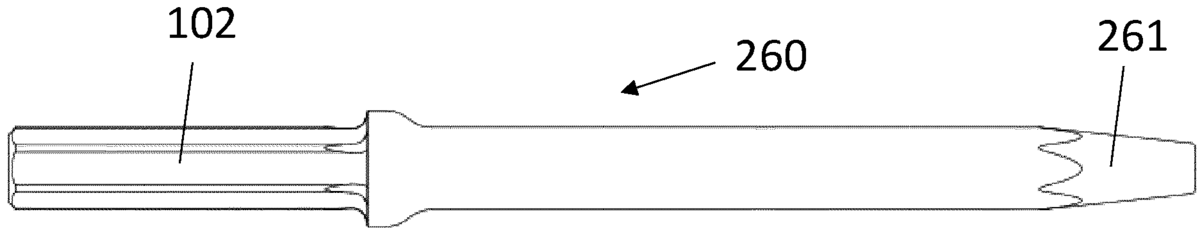


Fig 7

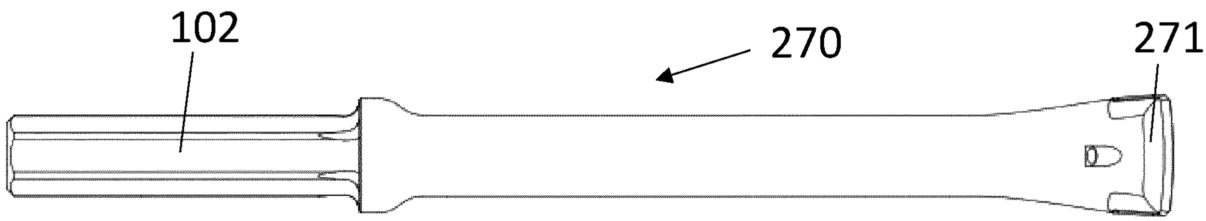


Fig 8

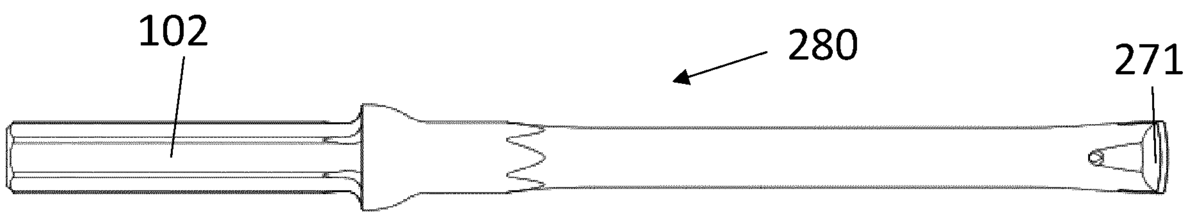
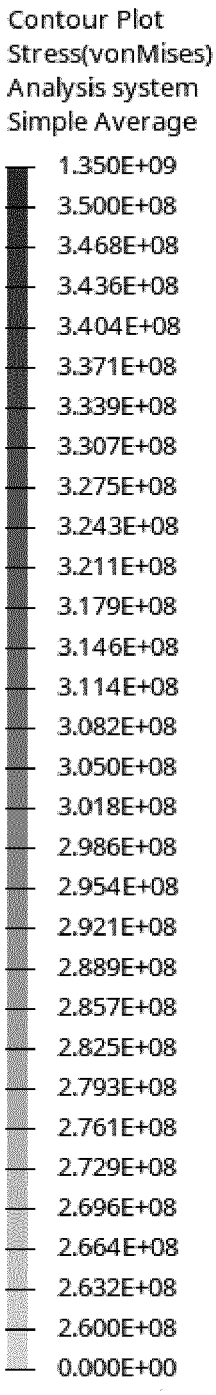


Fig 9



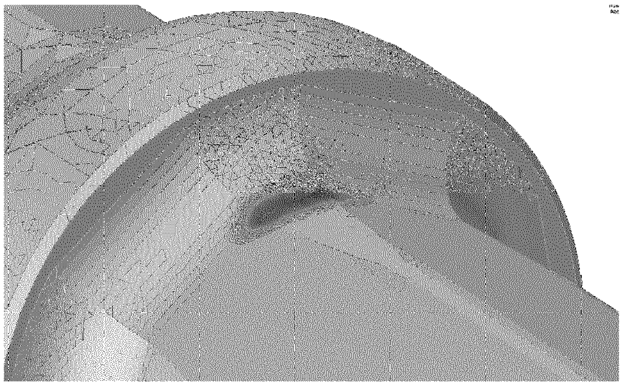


Fig 10a

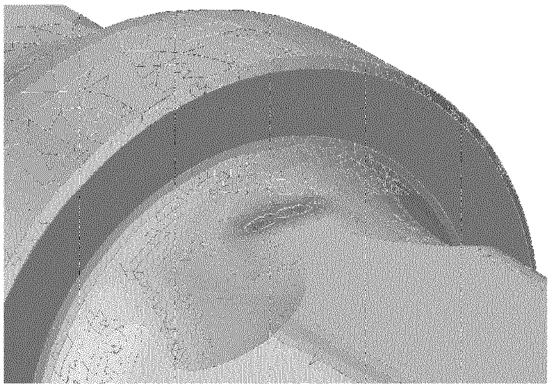


Fig 10b

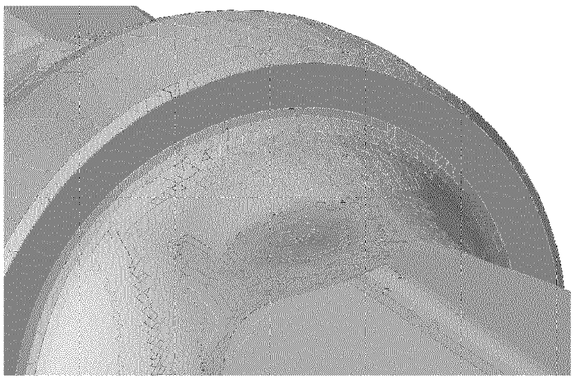


Fig 10c

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 15 7645

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 3 876 319 A (MEYER DIETER B) 8 April 1975 (1975-04-08) * the whole document *	1-14	INV. E21B17/03 E21B17/04 E21B17/042
A	EP 2 845 991 A1 (SANDVIK INTELLECTUAL PROPERTY [SE]) 11 March 2015 (2015-03-11) * the whole document *	1-14	
A	EP 3 095 954 A1 (SANDVIK INTELLECTUAL PROPERTY [SE]) 23 November 2016 (2016-11-23) * the whole document *	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

E21B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	13 July 2021	Simunec, Duro

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 15 7645

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-07-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3876319 A	08-04-1975	JP S49122091 A	21-11-1974
		US 3876319 A	08-04-1975
EP 2845991 A1	11-03-2015	EP 2845991 A1	11-03-2015
		WO 2015032660 A1	12-03-2015
EP 3095954 A1	23-11-2016	AU 2016266604 A1	07-12-2017
		BR 112017024932 A2	31-07-2018
		CA 2986624 A1	01-12-2016
		CL 2017002940 A1	16-03-2018
		CN 107683363 A	09-02-2018
		EP 3095954 A1	23-11-2016
		EP 3298229 A1	28-03-2018
		PE 20180718 A1	26-04-2018
		PL 3298229 T3	08-02-2021
		PT 3298229 T	19-11-2020
		RU 2017144031 A	24-06-2019
		US 2018135782 A1	17-05-2018
		WO 2016188862 A1	01-12-2016
		ZA 201707459 B	26-05-2021

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82