(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 August 2020 (20.08.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/165689 A1

(51) International Patent Classification:
F04C 18/16 (2006.01) *F04C 29/00* (2006.01)

(21) International Application Number:
PCT/IB2020/050861

(22) International Filing Date:
04 February 2020 (04.02.2020)

(25) Filing Language: Dutch

(26) Publication Language: English

(30) Priority Data:
2019/5087 12 February 2019 (12.02.2019) BE

(71) Applicant: **ATLAS COPCO AIRPOWER, NAAMLOZE VENNOOTSCHAP** [BE/BE]; Boomsesteenweg 957, 2610 Wilrijk (BE).

(72) Inventors: **MARIËN, Karen Anna Leon**; c/o Atlas Copco Airpower, NV, Boomsesteenweg 957, 2610 Wilrijk (BE). **MICHEL, Peter**; c/o Fraunhofer-Institut für Mikrostruktur von Werkstoffen und Systemen IMWS, Walter-Hülse-Strasse 1, 06120 Halle (Saale) (DE). **HIRSCH, Patrick**; c/o Fraunhofer-Institute für Mikrostructur von Werkstoffen und Systemen IMWS, Walter-Hülse-Strasse 1, 06120 Halle (Saale) (DE).

(74) Agent: **VAN VARENBERG, Patrick** et al.; Arenbergstraat 13, 2000 Antwerpen (BE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: SCREW ROTOR AND METHOD FOR MANUFACTURING SUCH SCREW ROTOR

(57) Abstract: Screw rotor, characterized in that the screw rotor (1) is made out of polymer, wherein the screw rotor (1) consists of a shaft (2) with a rotor body (3) on it, wherein the polymer of the shaft (2) is reinforced with fibers (4), wherein the shaft (2) features elements (5a, 5b) that engage the rotor body (3) or corresponding elements (5c) on the rotor body (3), such that the elements (5a, 5b, 5c) prevent an axial and/or rotational movement of the shaft (2) with respect to the rotor body (3),

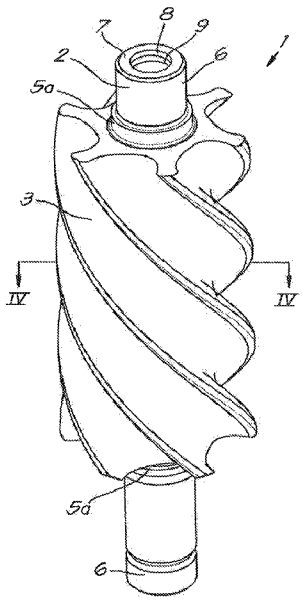


Fig. 1

WO 2020/165689 A1

[Continued on next page]

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

Screw Rotor and Method for Manufacturing Such Screw Rotor

The present invention relates to a screw rotor.

More specifically, the screw rotor according to the invention is meant for fluid-injected compressors, expanders, and vacuum pumps.

It is known that such screw rotors are traditionally manufactured from cast iron or steel, cast in a crude screw form or forged in a crude cylindrical form, which is then finished by way of coarse and fine grinding, filing, milling, and other cutting operations of the shaft as well as of the body of the screw rotor (with the screw profile) and its final finished screw form is obtained.

This finish is necessary because the casting process does not allow for obtaining a form within the very fine tolerances that are necessary for allowing the final machine to function properly.

Even though such conventional screw rotors function properly, the finishing by means of grinding, filing, milling and other such processes is very labor- and time-intensive.

Moreover, all this causes the cost to be driven up.

Another disadvantage is that much material is machined away during the finishing process, which constitutes a loss or a waste of raw materials.

Another disadvantage is the weight of such conventional screw rotors due to the use of cast iron or steel.

The task of the present invention is to offer a solution to at least one of the aforementioned and other disadvantages.

The subject of the present invention is a screw rotor, characterized in that the screw rotor is made from a polymer, wherein the screw rotor consists of a shaft with a rotor body on it, wherein the polymer of the shaft is reinforced with fibers, wherein the shaft features elements that engage the rotor body or corresponding elements in the rotor body, such that the elements prevent an axial and/or rotational movement of the shaft with respect to the rotor body.

By using a polymer, the screw rotor will not only be lighter than the traditional conventional metal screw rotors; it will furthermore be more resistant to corrosion, and it is easier to manufacture in complex forms.

Such a screw rotor may, for instance, be made by means of an injection molding process, which allows for the manufacturing of a rough screw shape that already closely approximates the final finished screw shape, such that finishing it by means of the cutting operations needed to bring this rough screw within the required tolerances will be of a much more limited scope, or possibly not be necessary at all.

Moreover, the processing of the composite screw rotor is much simpler and easier than processing a cast iron or steel screw rotor.

This implies that much less work and time are needed for the finishing process, which will bring about considerable savings in cost.

Furthermore, less material will be lost, because the point of departure will be a crude screw form that already closely approximates the final form.

Even though for the invention, it is only necessary that polymer reinforced with fibers be used for the shaft, it is not excluded that the rotor body be manufactured from a fiber-reinforced polymer as well.

The elements of the shaft are deviations of the shaft into or from its surface, meaning deviations towards the center line of the shaft or away from the center line of the shaft.

The elements of the shaft and the corresponding or matching elements on or in the rotor body will cause a mechanical blockage between the shaft and the rotor body, as a result of which axial forces and torque may be transmitted from the shaft to the rotor body, and vice versa. Even though the elements may be arranged on the shaft itself, it is also possible for the elements of the shaft to be formed by means of an intermediate body or a key, arranged on the shaft in a designated recess.

Preferably, the fibers in the shaft extend primarily in the axial direction. This will provide the shaft with the necessary rigidity and strength.

It is known that in screw rotors in a screw compressor, for instance, very strong axial forces and gas forces are exerted on the screw rotor, for which reason it is crucially important for the shaft to have the necessary rigidity.

It is possible for the rotor body to consist of two or more concentric layers, wherein an inner layer features elements engaging the following layer, such that the elements prevent an axial and/or rotational movement of the one layer relative to the following layer.

This will be used in particular for manufacturing larger screw rotors by means of injection molding, such that the maximum thickness of each layer is eight millimeters.

By injection molding the rotor body in multiple steps or stages, the volume of the material added in each step or stage can be limited, allowing for an easier monitoring of the injection molding process and the subsequent cooling process. This will help optimize the final mechanical properties of the screw rotor. The elements are analogous to, and have the same function as, the aforementioned elements of the shaft.

The invention also has a method as its subject, for manufacturing a screw rotor consisting of a shaft and a rotor body, characterized in that the screw rotor is made

from a polymer and in that the method comprises the following steps:

A) providing a shaft;

B) the injection molding of the rotor body using a designated mould, wherein the aforementioned shaft is used as an insert into the mould.

By executing the process in at least two steps, the injection molding process of step B will be much easier as compared to an injection molding process in which the screw rotor is injection molded in a single step, among other things in terms of the shrinking of the material, the dimensions, and the mechanical properties, which are easier to monitor in a multistage process such as according to the invention.

Another advantage is that by using the shaft as an insert in the mould of the rotor body, the rotor body is cast onto or around the shaft, as a result of which the casting of the rotor body generates a thermal bond between the shaft and the rotor body.

This will ensure that the shaft cannot move relative to the rotor body, since with the injection molding of the rotor body, the surface of the shaft will heat up again due to its contact with the hot molten fiber-reinforced polymer that is injected into the mould, thus allowing it to create a thermal bond with the material of the rotor body that is cast around it.

With the understanding to better demonstrate the features of the invention, in the following, without these descriptions

having any restrictive character, some examples of preferred variants are described of a method according to the invention for manufacturing a screw rotor, with reference to the enclosed drawings, in which:

Figure 1 shows a schematic and perspective view of a possible embodiment of a screw rotor according to the invention;

Figure 2 shows the shaft of the screw rotor of Figure 1;

Figure 3 schematically shows a cross section along the line III-III in Figure 2;

Figure 4 schematically shows a cross section along the line IV-IV in Figure 1;

Figures 5 through 7 schematic show variant embodiments of Figure 2.

The screw rotor 1 according to the invention schematically shown in Figure 1 consists of a shaft 2 with a rotor body 3 on it.

The screw rotor 1 may be used in a fluid-injected compressor, expander, or vacuum pump.

In the example shown, the rotor body 3 is cylindrical in form. However, it is not excluded that the rotor body 3 have a conical form. Using a conical rotor has the advantage that the forces are better distributed, and that the compression can be increased.

In Figure 2, the shaft 2 is shown separately.

According to the invention, the screw rotor 1 is made out of a polymer.

In this case, for the invention, at least the shaft 2 is made out of a polymer reinforced with fibers 4, and the rotor body 3 may be made out of a polymer without fibers 4, but in the example shown here and described below, the rotor body 3 is made out of a polymer reinforced with fibers 4 as well.

The polymer may be a polyamide, for instance, or a polyimide. However, the invention is not limited to these. For instance, the polymer may also be polyether ether ketone (PEEK).

Possibly, the polymer may also be a thermo-setting polymer, for instance an epoxy, a vinyl ester, or an unsaturated polyester.

The fibers 4 preferably, but not necessarily, comprise carbon fibers or glass fibers. The fibers may also comprise an organic polymer such as aramid fibers, for instance. Carbon nanotubes are a possibility as well.

In a possible embodiment, the polymer reinforced with fibers 4 is a so-called self-reinforced polymer, in which the fibers are made out of the same polymer as the mould.

Preferably, it is polymer polyamide, polyimide, or PEEK reinforced with between 10 and 60 percent of fibers 4 by weight. Preferably, the weight percentage of the fibers is between 25 and 45 percent.

It is not excluded that the shaft 2 is made from a different polymer than the rotor body 3, wherein the rotor body 3 may be made out of a polymer that may or may not be reinforced with fibers 4.

Thus, for instance, the polymer reinforced with fibers 4 of the shaft 2 may have an identical or a higher softening temperature than the polymer reinforced with fibers 4 of the rotor body 3.

The difference in the softening temperature of different layers preferably varies between zero and twenty degrees Celsius.

This will lead to benefits in particular in terms of the production or manufacturing of the screw rotor 1, as will be clarified below.

In this case, without this being necessary for the invention, the fibers 4 in the shaft 2 extend primarily in the axial direction X-X'.

This is shown schematically in the cross section in Figure 3.

Due to this orientation of the fibers 4, the shaft 2 will have the necessary rigidity. It is well known that during the operation of the machine, the shaft 2 is exposed to strong axial forces and gas forces at the location where the screw rotor 1 is mounted.

As can be seen in Figure 3, the shaft 2 is a full shaft 2. It is not excluded that the shaft 2 is hollow, meaning that there a longitudinal cavity extends through the shaft 2. This will prevent so-called flow problems in the production of the shaft 2.

In this case, but not necessarily, the fibers 4 in the rotor body 3 are oriented arbitrarily or randomly.

According to the invention, and as can be seen clearly in Figures 2, 3, and 4, the shaft 2 features elements 5a, 5b.

Some of these elements 5a may engage the rotor body 3, some of these elements 5b may engage corresponding elements 5c in the rotor body 3, all this being designed such that the elements 5a, 5b, 5c prevent an axial and/or a rotational movement of the shaft 2 relative to the rotor body 3.

This will be explained via the figures.

As can be seen in Figures 2 and 3, the shaft 2 features two elements 5a in the form of an ring shaped protrusion, wherein the projection onto the shaft 2 according to the axial direction X-X' is cyclically symmetrical and coaxial with the center line X-X' of the shaft 2.

Cyclically symmetrical means: sections or segments that repeat rotationally around the center line.

Even though these elements 5a pertain in this case to a ring shaped protrusion, these elements 5a may also comprise a differently shaped protrusion, groove, or ring.

These elements 5a may engage the rotor body 3 itself, as shown in Figure 1.

Such elements 5a will be able to transmit axial forces from the shaft 2 to the rotor body 3, and vice versa.

Effectively, they constitute a stop for the rotor body 3 on the shaft 2 and vice versa, such that when an axial force is exerted onto the rotor body 3, it can be transmitted via this stop to the shaft 2.

It is not excluded that these elements 5a are arranged at a different location, farther away from the end 6 of the shaft 2. In that case, these elements 5a will not engage the rotor body 3 itself, but corresponding elements 5c of the rotor body 3.

Furthermore, the shaft 2 also features a number of elements 5b that may engage corresponding elements 5c of the rotor body 3.

In that case, these elements 5b pertain to protrusions along the axial direction X-X' of the shaft 2, which cause the cross section of the shaft 2 to be hexagonal.

These elements 5b are located at a place on the shaft 2 above which the rotor body 3 is arranged, such as follows from the comparisons of Figures 1 and 2.

As can be seen in Figure 4, the rotor body 3 features corresponding elements 5c, which engage the elements 5b of the shaft 2.

Via such elements 5b, 5c the torque may be transmitted from the shaft 2 to the rotor body 3. This will be relevant in particular for the driving of the screw rotor 1 by a motor via the shaft 2.

Instead of protrusions extending in the axial direction X-X', a groove, ring, or similar may be used by way of elements 5b, 5c as well.

As can be seen in Figures 1 and 2, in this case, the shaft 2 is featured at its face 7 a coupling piece 8, which features a screw thread 9 in which a bolt can be arranged.

By means of this bolt, the shaft 2 may be connected to a drive shaft of a motor, for instance, or something similar.

Even though in the example shown, the screw rotor 1 consists of a shaft 2 with a rotor body 3, it is not excluded that the rotor body 3 itself consist of two or more concentric layers, wherein an inner layer features elements 5b, 5c engaging the following layer, such that the elements 5b, 5c prevent an axial and/or rotational movement of the one layer relative to the following layer.

In other words, the principle is very similar in nature to the principle of the shaft 2 and the rotor body 3 as explained above.

In the case of a large screw rotor 1, this will be advantageous in particular during the production process, as will be explained below.

The screw rotor of Figures 1 through 4 can be manufactured according to a method according to the invention.

The method for producing the screw rotor 1, made out of a polymer reinforced with fibers 4, by way of injection molding, essentially comprises two steps:

A) providing a shaft;

B) the injection molding of the rotor body 3 using a designated mould, wherein the aforementioned shaft 2 is used as an insert into the mould.

Preferably, but not necessarily, the aforementioned step A comprises the injection molding of the shaft 2 of the screw rotor 1, using a designated mould.

This is not necessary for the invention, however. The shaft 2 may also be extruded, for instance.

In step A, for the injection molding of the shaft 2, a mould will be used here with elements 5a, 5b, such that the aforementioned elements 5a, 5b are created on the shaft 2.

In order to ensure that the fibers 4 extend in the shaft 2 in the axial direction X-X', the polymer reinforced with fibers 4 may be injected into the mould in the axial direction X-X'.

By then using the shaft 2 as an insert in the mould of the rotor body 3, corresponding elements 5c will effectively be created automatically in the rotor body 3.

By using a different polymer reinforced with fibers 4 for the shaft 2 than the polymer reinforced with fibers 4 used for the rotor body 3, such that the polymer reinforced with fibers 4 used for the shaft 2 has an identical or a higher softening temperature than the polymer used for the rotor body 3, the shaft 2 as a whole will not melt or soften when the rotor body 3 is cast around it. This way, the mechanical properties of the shaft 2 remain intact, and the fibers 4 of the shaft 2 may be prevented from losing their orientation if the polymer of the shaft 2 were to soften somewhat.

It is not excluded for step B, the injection molding of the rotor body 3, to be executed in two or more steps, in each of which more material is added to the rotor body 3 through the use of successive matrices, wherein the rotor body part manufactured in the previous step is used as an insert in the following mould.

Thus, the rotor body 3 itself can be made out of two or more concentric layers, wherein the use of matrices with elements 5c may cause elements 5c to be provided on an inner layer to engage the following layer cast around it.

This approach is particularly advantageous with large screw rotors 1, because this may provide for the material added to be more limited with each step, so that the cooling can be monitored, such that no or much fewer mechanical tensions are created.

If the rotor body 3 has a conical form, this has the advantage that it can be demolded, i.e. removed from the mold, much more easily.

In order to insert the aforementioned coupling piece 8 into the face 7 of the shaft 2, the coupling piece 8 is arranged in the mould of the shaft 2 at the location of the respective face 7 of the shaft 2.

Thus, the coupling piece 8 can be integrated into the shaft 2 during the casting process.

Alternatively, after step B, the aforementioned coupling piece 8 may be arranged through self-tapping in a designated cavity in a face 7 of the shaft 2.

It should be clear that in the examples shown and described in Figures 1 through 5, only some possible examples of possible embodiments of elements 5a, 5b are shown.

Another possible embodiment is shown in Figure 5, in which the elements 5a, 5b comprise at least one protrusion 5b, having the form of a helix or a spiral around the shaft 2.

Instead of a protrusion, this may also be a helix- or spiral-shaped groove.

The protrusion, or element 5b, is situated at a location of the shaft 2 above which the rotor body 3 is arranged, so that during the injection molding process, corresponding elements are formed in the rotor body 3.

The helix-shaped elements 5b will be able to transmit a combination of rotational as well as axial forces in order to prevent an axial and rotational movement of the shaft 2 relative to the rotor body 3.

Figure 6 shows an additional embodiment, wherein the shaft 2 features an element 5b that may engage a corresponding element 5c of the rotor body 3.

In this case, this element 5b is a ring shaped protrusion around the shaft 2.

This element 5b is situated at a location on the shaft 2 above which the rotor body 3 is arranged. This element 5b will be able to transmit axial forces from the shaft 2 to the rotor body 3, and vice versa.

Figure 7 shows yet another variation, wherein the shaft 2 features multiple elements 5b in the form of elongated protrusions that extend in the axial direction along the shaft 2 and are dispersed around the shaft 2.

Based on the aforementioned variants, it is clear that the elements 5a, 5b may be embodied in various manners, and that the examples shown are not restrictive in any way.

The present invention is in no way limited to the exemplary embodiments described and shown in the figures. Rather, a method and a screw rotor according to the invention may be realized in different variants without exceeding the scope of the invention.

Claims.

1.- Screw rotor, characterized in that the screw rotor (1) is made out of polymer, wherein the screw rotor (1) consists of a shaft (2) with a rotor body (3) on it, wherein the polymer of the shaft (2) is reinforced with fibers (4), wherein the shaft (2) features elements (5a, 5b) that engage the rotor body (3) or corresponding elements (5c) in the rotor body (3), such that the elements (5a, 5b, 5c) prevent an axial and/or rotational movement of the shaft (2) with respect to the rotor body (3).

2.- Screw rotor according to the preceding claim 1, characterized in that the elements (5a, 5b) comprise at least one groove, ring, protrusion, or similar, wherein the projection on a surface perpendicular to the shaft (2) in the axial direction (X-X') is cyclically symmetrical and coaxial with the center line (X-X') of the shaft (2).

3.- Screw rotor according to claims 1 or 2, characterized in that the elements (5a, 5b) comprise at least one groove, ring, protrusion, or similar extending in the axial direction (X-X'), whereby this element (5a, 5b) is situated at a location on the shaft (2) upon which the rotor body (3) is arranged.

4.- Screw rotor according to any one of the preceding claims, characterized in that the shape of the rotor body (3) is cylindrical or conical.

5.- Screw rotor according to any one of the preceding claims, characterized in that the shaft (2) is hollow.

6.- Screw rotor according to any one of the preceding claims, characterized in that the elements (5a, 5b) comprise at least one groove, protrusion, or similar, having the shape of a helix around the shaft (2).

7.- Screw rotor according to any one of the preceding claims, characterized in that the fibers (4) in the shaft (2) primarily extend in the axial direction (X-X').

8.- Screw rotor according to any one of the preceding claims, characterized in that the rotor body (3) is at least partially made out of a polymer manufactured reinforced with fibers (4).

9.- Screw rotor according to claim 8, characterized in that the fibers (4) in the rotor body (3) are arbitrarily or randomly oriented.

10.- Screw rotor according to any one of the preceding claims, characterized in that the polymer is a polyamide, a polyimide, or PEEK.

11.- Screw rotor according to any one of the claims 1 through 9, characterized in that the polymer is a thermo-setting polymer, or more specifically, an epoxy, a vinyl ester or an unsaturated polyester.

12.- Screw rotor according to any one of the preceding claims, characterized in that the fibers (4) comprise carbon fibers or glass fibers.

13.- Screw rotor according to any one of the preceding claims, characterized in that the fibers (4) comprise an organic polymer.

14.- Screw rotor according to claim 13, characterized in that the fibers (4) made out of an organic polymer are aramid fibers.

15.- Screw rotor according to any one of the claims 1 through 9, characterized in that the polymer is a self-reinforced polymer of aramid fibers in an aramid polymer matrix.

16.- Screw rotor according to any one of the preceding claims, characterized in that the shaft (2) is made of a different polymer than the rotor body (3).

17.- Screw rotor according to the preceding claim 10, characterized in that the polymer of the shaft (2) has an identical or higher softening temperature than the polymer of the rotor body (3).

18.- Screw rotor according to any one of the preceding claims, characterized in that at the location of a face (7), the shaft (2) features a coupling piece (8) that features a screw thread (9) in which an bolt can be arranged.

19.- Screw rotor according to any one of the preceding claims, characterized in that the rotor body (2) consists of two or more concentric layers, wherein an inner layer features elements (5c) engaging the following layer, such that the elements (5c) prevent an axial and/or rotational movement of the one layer relative to the following layer.

20.- Method for manufacturing a screw rotor (1) consisting of a shaft (2) and a rotor body (3), **characterized in that** the screw rotor (1) is made out of a polymer **and in that** the method comprises the following steps:

A) providing a shaft (2);

B) the injection molding of the rotor body (3) using a designated mould, wherein the aforementioned shaft (1) is used as an insert into the mould.

21.- Method according to claim 20, characterized in that step B, the injection molding of the rotor body (1), is executed in two or more steps, in each of which more material is added to the rotor body (1) through the use of successive moulds, wherein the rotor body part manufactured in the previous step is used as an insert in the following mould.

22.- Method according to claim 20 or 21, characterized in that step A, the provision of a shaft (2), comprises the injection molding of the shaft (2) of the screw rotor (1), using a designated mould.

23.- Method according to claim 22, characterized in that for the injection molding of the shaft (2) the polymer

reinforced with fibers (4) is injected into the mould in the axial direction (X-X').

24.- Method according to claim 22 or 23, characterized in that in step A, a mould is used with elements (5a, 5b), such that the elements (5a, 5b) will prevent the thus manufactured shaft (2) and rotor body (3) from moving radially and/or axially with respect to one another.

25.- Method according to any one of the preceding claims 22 through 24, characterized in that in the mould for the shaft (2), at the location of a face (7) of the shaft, a coupling piece (8) is arranged as an insert in the mould, featuring a screw thread (9) in which a bolt can be arranged, or in that after the aforementioned step B, the aforementioned coupling piece (8) is arranged through self-tapping in a designated cavity in a face (7) of the shaft (2).

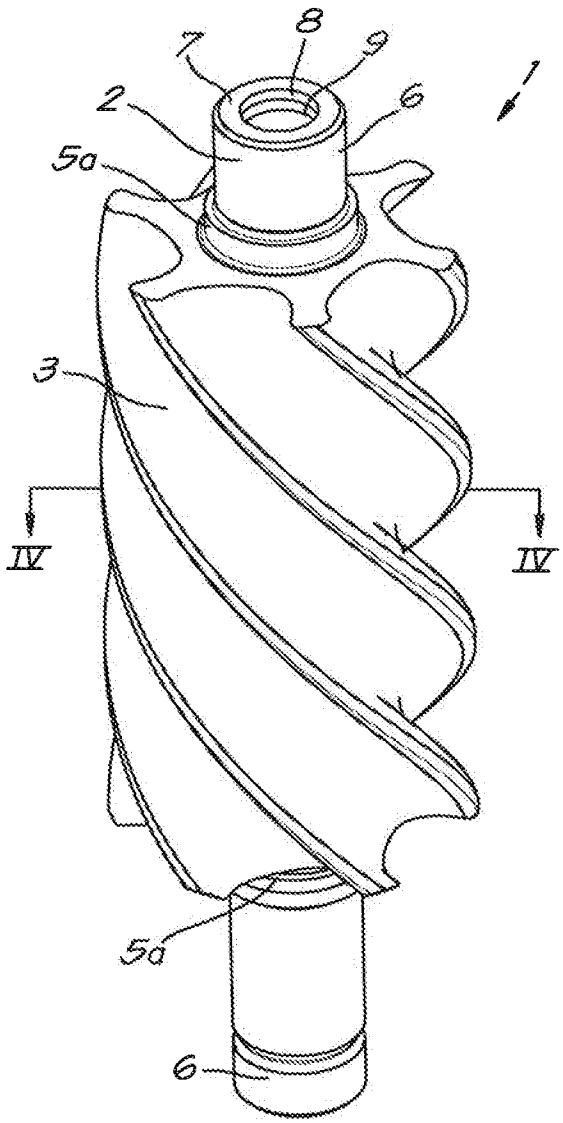


Fig. 1

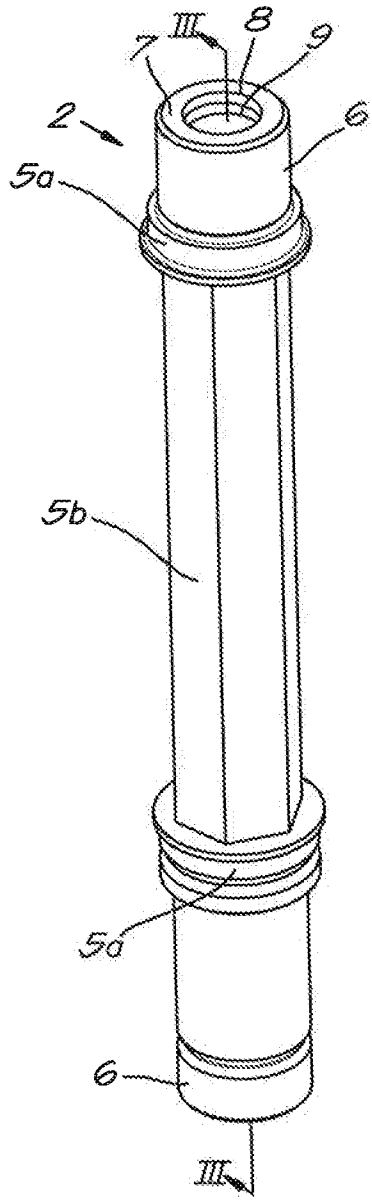


Fig. 2

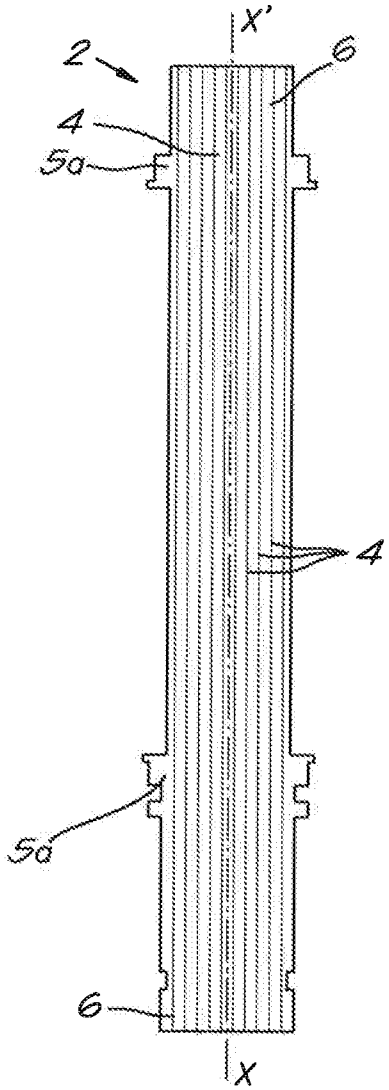


Fig.5

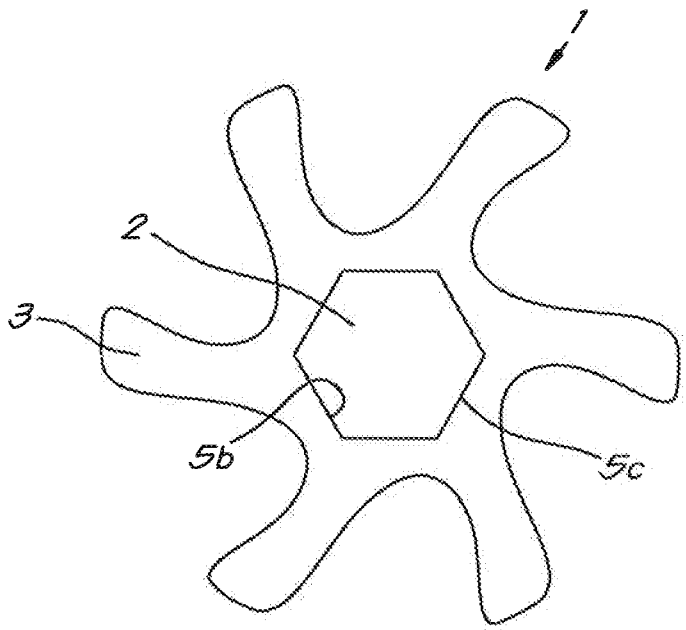


Fig.4

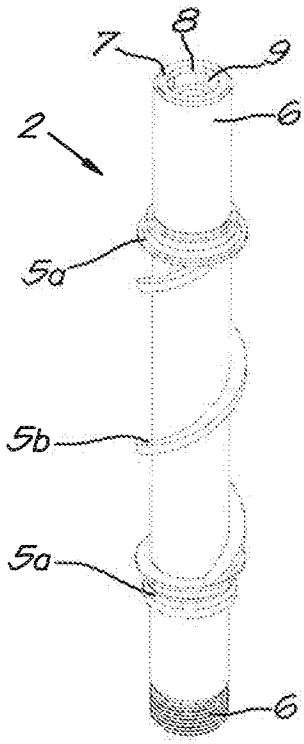


Fig.5

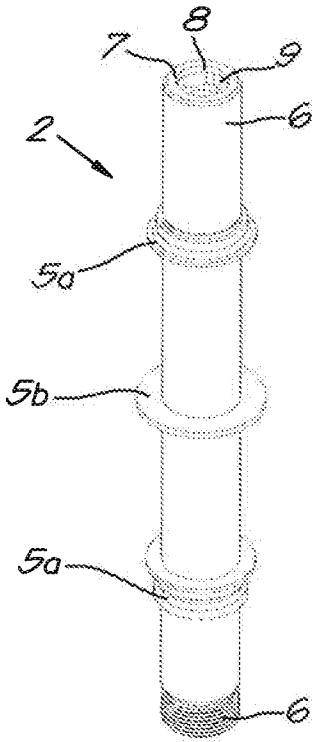


Fig.6

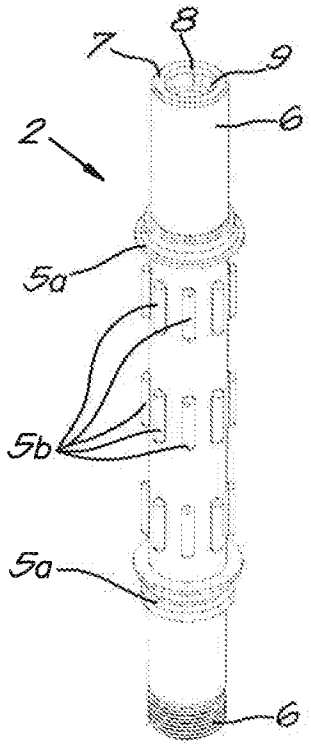


Fig.7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/050861

A. CLASSIFICATION OF SUBJECT MATTER
INV. F04C18/16 F04C29/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04C F16C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP H02 27180 A (EBARA CORP) 29 January 1990 (1990-01-29)	1-19
A	the whole document	20-25

X	JP S63 203310 A (ISHIKAWAJIMA HARIMA HEAVY IND) 23 August 1988 (1988-08-23)	20-25
A	abstract; figures	1-19

A	WO 2011/092674 A1 (AGILENT TECHNOLOGIES ITALIA S P A [IT]; GIORS SILVIO [IT] ET AL.) 4 August 2011 (2011-08-04) page 4, line 33 - page 8, line 3	1-25

A	CN 208 311 036 U (RIXIN ELECTRICAL CO LTD) 1 January 2019 (2019-01-01) abstract; figures	1-25

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 March 2020	19/03/2020

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

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2020/050861

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/183185 A1 (DIRSCHERL JUERGEN [DE] ET AL) 18 July 2013 (2013-07-18) paragraphs [0038], [0047], [0050], [0066] - [0073] figures	1-25
A	JP H02 276612 A (HITACHI LTD) 13 November 1990 (1990-11-13) abstract; figure 2	1-25
A	WO 2015/138557 A1 (EATON CORP [US]) 17 September 2015 (2015-09-17) abstract; figures 1,2,17	1-25

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2020/050861

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H0227180 A	29-01-1990	NONE	
JP S63203310 A	23-08-1988	NONE	
WO 2011092674 A1	04-08-2011	CN 102906427 A	30-01-2013
		DE 112011100402 T5	27-12-2012
		JP 2013519033 A	23-05-2013
		US 2013045094 A1	21-02-2013
		WO 2011092674 A1	04-08-2011
CN 208311036 U	01-01-2019	NONE	
US 2013183185 A1	18-07-2013	CN 103256224 A	21-08-2013
		EP 2615307 A1	17-07-2013
		US 2013183185 A1	18-07-2013
JP H02276612 A	13-11-1990	NONE	
WO 2015138557 A1	17-09-2015	CN 106103998 A	09-11-2016
		EP 3117102 A1	18-01-2017
		US 2017101989 A1	13-04-2017
		WO 2015138557 A1	17-09-2015