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(54) **CONCENTRIC CAMSHAFT AXIAL POSITION CONTROL**

(57) A concentric camshaft for an internal combustion engine is disclosed that comprises an outer tube (12), an inner shaft (24), and two groups of cam lobes (14;22). The first group (14) is fixed for rotation with the outer tube (12) and the second group (22) is rotatably mounted on the outer tube (12) and connected for rotation with the inner shaft (24). One or more bearing rings (16,17) are mounted to the outer tube (12) providing a bearing surface for supporting the camshaft in the engine, a bearing ring (16) secured to an axial end of the outer tube (12) serving to apply drive torque to the outer tube (12). In the invention, a sleeve (30) is secured to the outer surface of the inner shaft (24) for setting the axial position of the inner shaft (24) relative to the outer tube (12), the axial length of the sleeve (30) serving to limit the axial movement of the inner shaft (24) relative to the outer tube (12); a first axial end face of the sleeve (30) serving to limit the movement of the inner shaft (24) in one axial direction, and a second axial end face of the sleeve (30) serving to limit movement of the inner shaft (24) in the opposite axial direction.

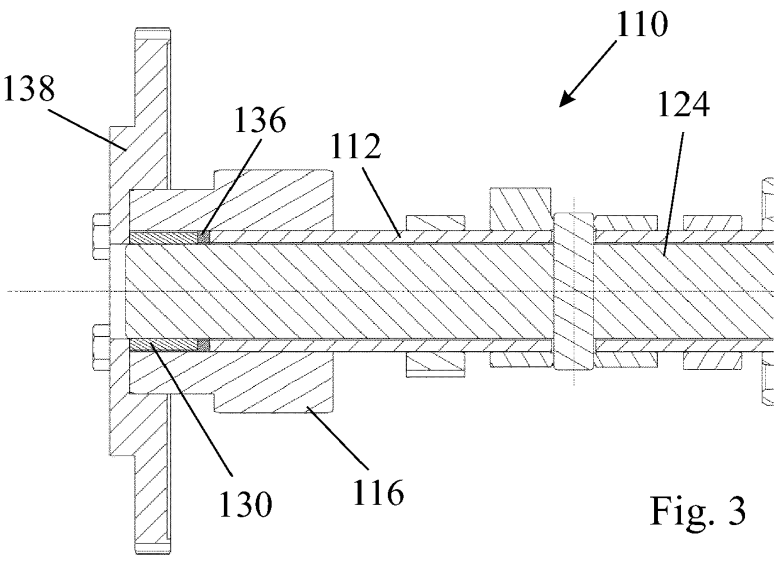

Fig. 3

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a valvetrain system for an internal combustion engine, and in particular to an adjustable camshaft, known as a concentric camshaft, having two groups of cam lobes which can be phased relative to each other. When combined with a phasing system, the concentric camshaft allows the phase of one or both of the groups of lobes to be controlled independently relative to the phase of the engine crankshaft. In a single camshaft engine, for example, this could allow independent control of intake and/or exhaust valve timing.

BACKGROUND

[0002] Concentric camshafts that allow the relative timing of two sets of cam lobes to be adjusted are well known. Typically, concentric camshafts comprise an outer tube having a first set of cam lobes affixed to its outer diameter and a second set of cam lobes mounted for rotation on the outer surface of the tube. Each of the second set of cam lobes is connected via a connecting pin for rotation with an inner shaft passing through the bore of the tube. The connecting pins pass with clearance through slots in the wall of the outer tube, so as to allow rotation of the second set of cam lobes through a limited angle when the inner shaft is rotated relative to the outer tube.

[0003] In many applications, the axial location of the inner shaft with respect to the outer tube of the concentric camshaft is determined by their respective drive connections to the camshaft phaser. In such cases, no provision is made in the design of the concentric camshaft for providing an axial bearing to set the relative position of the inner shaft with respect to the outer tube.

[0004] Some designs of phasing system, however, utilise form fitting drive interfaces such as splines, driving keys or pins in the torque transmission path from the input drive to one or both sets of camshaft lobes mounted to the concentric camshaft. In these cases, it is not convenient to use the phasing system to define the axial location of the inner shaft with respect to the outer tube. It can therefore be advantageous to incorporate an axial bearing into the concentric camshaft to set the position of the inner shaft with respect to the outer tube.

[0005] The closest prior art to the invention is believed to be EP1725745, which shows a concentric camshaft having a method of maintaining both the concentricity and the axial position of an inner shaft to an outer tube using two components fitted to opposing ends of the inner shaft.

SUMMARY OF THE INVENTION

[0006] In accordance with a first aspect of the invention, there is provided a concentric camshaft as hereinafter set forth in Claim 1 of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1A is a perspective view of a concentric camshaft connected to a camshaft phaser,

Figure 1B is a section of the camshaft and phaser of Figure 1A,

Figure 1C is a view of the end of the camshaft of Figure 1B drawn to an enlarged scale,

Figures 2A and 2B are perspective views of an inner shaft and a sleeve depicting alternative ways of providing a high friction surface,

Figure 3 is a section, similar to that of Figure 1C, of a second embodiment of a concentric camshaft connected to a drive sprocket,

Figure 4 is a similar section of a third embodiment of a concentric camshaft connected to a camshaft phaser,

Figure 5 is a perspective view of the inner shaft and the sleeve of the third embodiment,

Figure 6A is a section view of the inner shaft and the sleeve of a further embodiment,

Figure 6B is a perspective view of the embodiment of Figure 6A.

DETAILED DESCRIPTION OF THE DRAWINGS

[0008] Figures 1A, 1B and 1C illustrate the construction of a concentric camshaft **10** in a first embodiment, having an outer tube **12** with a first set of cam lobes **14** non-rotatably fitted to its outer surface together with additional bearing rings **16, 17** that support the camshaft **10** in the engine (not shown). Drive torque is transmitted to the outer tube **12** by a camshaft phaser **18** secured via four bolts **20** to the first bearing ring **16** secured to the end of the outer tube **12**. A second set of cam lobes **22** mounted to the outer tube **12** are free to rotate about the outer tube **12**, and are connected to an inner shaft **24** via connecting pins **26** that pass through arcuate slots in the outer tube **12**, such that the second set of cam lobes **22** are able to rotate relative to the first set **14** through an angular range defined by the circumferential length of the slots.

[0009] The phaser **18**, the internal construction of which is well known and therefore not shown in detail in the drawings, may for example be a hydraulic phaser having a stator driven by the engine crankshaft and two output driving connections of which at least one is rotated with a phase that is adjustable relative to the phase of the stator.

[0010] In the first embodiment, the drive connection between the camshaft phaser **18** and the inner shaft **24** is via a splined interface **28** and so the drive connection itself is unable to set the axial position of the inner shaft **24**. A sleeve **30** is secured to the outer surface of the inner shaft **24** to control its axial position, the sleeve **30** being positioned inside the first bearing ring **16** with a clearance around its outer surface, its axial location being defined by the axial end face of the outer tube **12** and the adjacent face of the camshaft phaser **18**. The axial clearance of the sleeve **30** is defined by the length of the sleeve **30** and the assembled distance of the outer tube **12** from the end face of the first bearing ring **16** against which the camshaft phaser **18** is secured.

[0011] A plug **32** is fitted the opposite end of the bore of the outer tube **12** from the camshaft phaser **18** in order to define a closed volume between the inner shaft **24** and the outer tube **12** that can be used to provide oil, either for lubrication of the camshaft **10** and phaser **18**, or for actuating the camshaft phaser **18**. Oil can be supplied to this cavity from the camshaft bearings of the engine via drillings in one or more of the bearing rings **17**. Oil pressure in the cavity will exert an axial force on the inner shaft **24** in the direction of the camshaft phaser **18**, hence generating an axial force between the sleeve **30** mounted to the inner shaft **24** and its mating face on the camshaft phaser **18**. Thus, the sleeve **30** also acts as a seal to prevent leakage of oil from the cavity between the inner shaft **24** and outer tube **12**.

[0012] To increase the axial load capacity in the joint between the inner shaft **24** and the sleeve **30**, a high friction surface texture can be used rather than a high interference fit. A high friction texture **34** could be applied to either the outer surface of the inner shaft **24,** as depicted in Figure 2A, or could be applied to the bore of the sleeve **30** prior to assembly, as designated **35** in Figure 2B.

[0013] A second embodiment of the invention is shown in Figure 3. The second embodiment is identical in function to the first, however a sealing ring **136** is used to retain oil in the cavity between the outer tube **112** and the inner shaft **124**, the seal **136** being located between the end face of the outer tube **112** and the adjacent end face of the sleeve **130** fitted to the inner shaft **124**. Instead of a phaser **18**, a drive sprocket **138** may be fitted to the first bearing **116**. In this case, a phasing system (not shown) to control the phasing of the inner shaft **124** relative to the tube **112** could be fitted to the opposite end of the camshaft **110**. The additional seal **136** of the second embodiment could, however, equally be used with the phasing system location of the first embodiment.

[0014] The sealing ring **136** also acts to define the axial position of the inner shaft **124** if it is forced in the direction away from the input drive sprocket **138**.

[0015] In a third embodiment of the invention, shown in Figure 4, the drive connection between a first output of the camshaft phaser **218** and the outer tube **212** is via a splined interface **220** between the phaser **218** and the first bearing ring **216**, whilst a second output of the phaser **218** is connected to the inner shaft **224** via a bolt **235**. As in other embodiments, the connections to the cam phaser **218** are unable to set the relative axial positions of the inner shaft **224** and the outer tube **212**. The sleeve **230** is secured to the outer surface of the inner shaft **224** to control its axial position, which in this case is defined by the end face of the outer tube **212** and an additional retaining ring **238** pressed into the bore of the first bearing ring **216**. Whilst in principle the same result could be achieved by using a stepped bore in the first bearing ring **216**, it would hinder assembly of the first bearing ring **216** to the outer tube **212** to the correct axial position when the inner shaft 224 is already in place.

[0016] The inner shaft **224** has a uniform outer diameter in the region of the sleeve **230**, and the inner shaft **224** passes completely through the sleeve **230** such that the fixed connection to the sleeve **230** and the concentric location between the inner shaft **224** and the phasing system **218** can utilise predominantly the same shaft diameter.

[0017] The third embodiment also illustrates how the outer surface of the sleeve **230** can be used to provide a bearing surface to maintain concentricity between the inner shaft **224** and the first bearing ring **216**. Figures 4 and 5 illustrate the sleeve **230** with an exaggerated outer profile form **237** to avoid any jamming of the shaft in the case where there is a slight misalignment of the sleeve **230** in the first bearing ring **216**. The use of the sleeve **230** as a support bearing would equally be possible in the previous embodiments.

[0018] Figure 5 additionally illustrates a method of transmitting oil past the sleeve **230** to lubricate the phaser **218** or to provide actuation pressure. In this case, the sleeve **230** has a profiled inner surface that defines oil passages when the sleeve is fitted to the inner shaft **224**. Figures 6A and 6B show that a similar result could also be achieved in the first embodiment by allowing the splines of the inner shaft **24** to pass under the sleeve **30**.

Claims

1. A concentric camshaft for an internal combustion engine comprising:

an outer tube (12);
an inner shaft (24);
two groups of cam lobes (14;22), the first group (14) being fixed for rotation with the outer tube (12) and the second group (22) being rotatably mounted on the outer tube (12) and connected for rotation with the inner shaft (24); and
one or more bearing rings (16,17) mounted to the outer tube (12) providing a bearing surface

for supporting the camshaft in the engine, a bearing ring (16) secured to an axial end of the outer tube (12) serving to apply drive torque to the outer tube (12);
characterised in that
a sleeve (30) is secured to the outer surface of the inner shaft (24) for setting the axial position of the inner shaft (24) relative to the outer tube (12), the axial length of the sleeve (30) serving to limit the axial movement of the inner shaft (24) relative to the outer tube (12);
a first axial end face (31) of the sleeve (30) serving to limit the movement of the inner shaft (24) in one axial direction, and
a second axial end face (33) of the sleeve (30) serving to limit movement of the inner shaft (24) in the opposite axial direction.

2. A concentric camshaft according to claim 1, wherein the second axial end face of the sleeve (230) is located by a component (238) secured to the bearing ring (216) that drives the outer tube.

3. A concentric camshaft according to claim 2, wherein a drive sprocket (138) is mounted to the bearing ring (116) driving the outer tube (112) and serves to locate the second axial end face of the sleeve (130).

4. A concentric camshaft according to claim 2, wherein a phasing system (18; 218) is mounted to the bearing ring (16,216) driving the outer tube and serves to locate the second axial end face of the sleeve (30,230).

5. A concentric camshaft according to any preceding claim, wherein the sleeve (30) provides a sealing face to retain oil in the cavity between the inner shaft and the outer tube.

6. A concentric camshaft according to claim 5, wherein a sealing ring (136) is located between the first axial end face of the sleeve (130) and the end face of the outer tube (112) to retain oil in a cavity between the inner shaft and the outer tube.

7. A concentric camshaft according to any of claims 1 to 5, wherein the first axial end face of the sleeve (30) is located by the end face of the outer tube (12).

8. A concentric camshaft according to any of claims 1 to 4, wherein features are provided in the bore of the sleeve (30,230) and/or the outer surface of the inner shaft (24,224) to allow oil from a cavity between the inner shaft and the outer tube to pass from one side of the sleeve (30,230) to the other.

9. A concentric camshaft according to any preceding claim, wherein the outer surface of the sleeve (30) provides a bearing face to transmit radial force from the inner shaft (24) to the bearing ring (16) that drives the outer tube.

10. A concentric camshaft according to claim 9 , wherein the outer surface of the sleeve is profiled to compensate for small amounts of misalignment of the sleeve (30) within the bore of the bearing ring (16).

11. A concentric camshaft according to any preceding claim, wherein the inner shaft (24) has a constant outer diameter in the region where the sleeve (30) is mounted which region passes entirely through the sleeve (30) and provides a concentric location face for mounting a driving component (218) to the inner shaft (224).

12. A concentric camshaft according to any preceding claim, wherein a high friction surface (34,35) is provided between the inner shaft (24) of the camshaft and the sleeve (30).

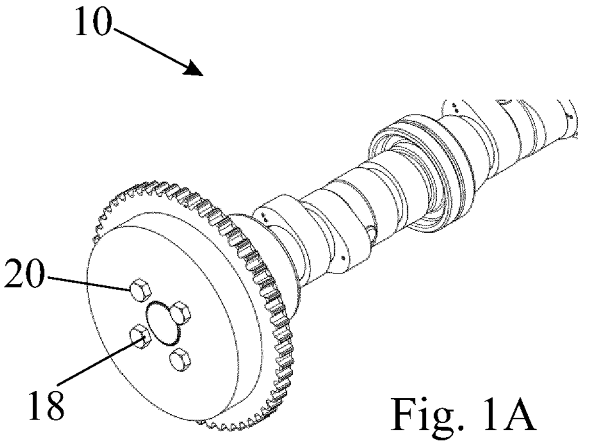

Fig. 1A

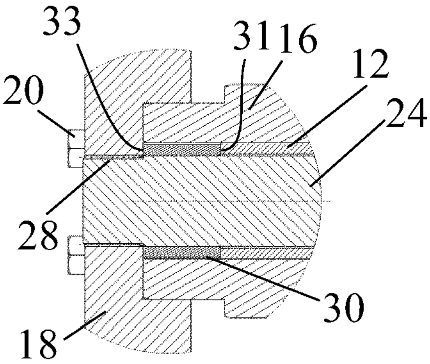

Fig. 1C

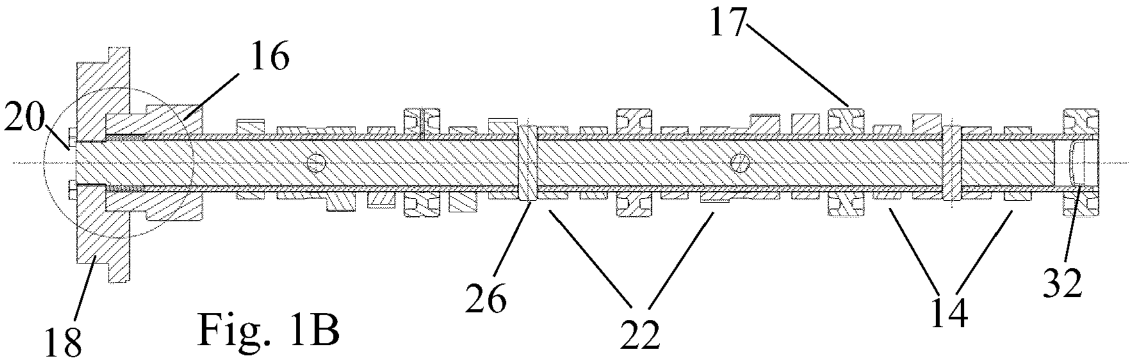

Fig. 1B

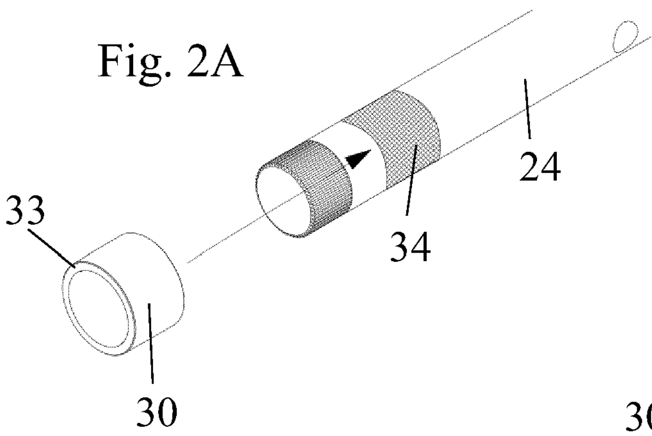

Fig. 2A

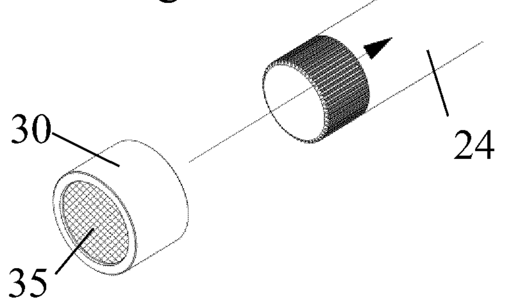

Fig. 2B

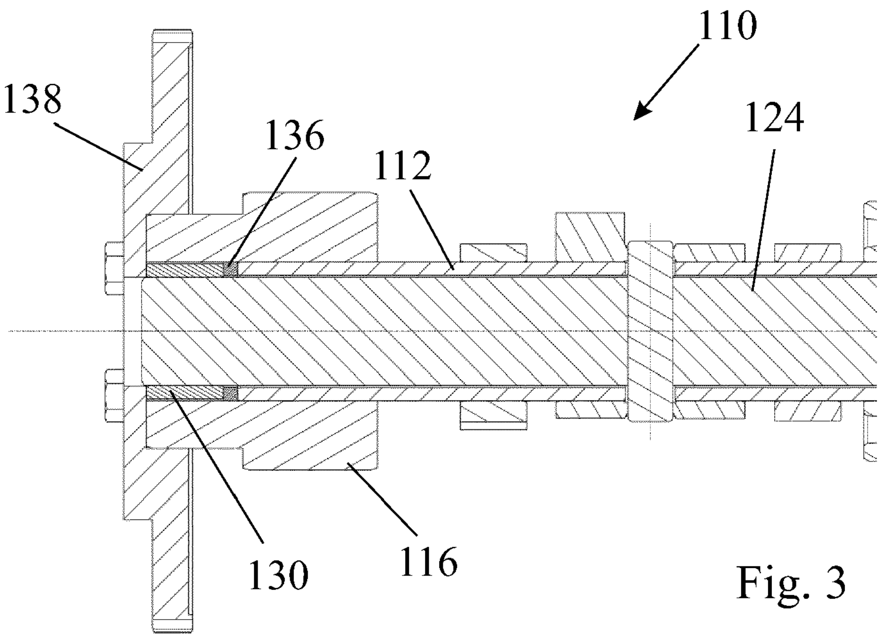
110
138
136
112
124
130
116

Fig. 3

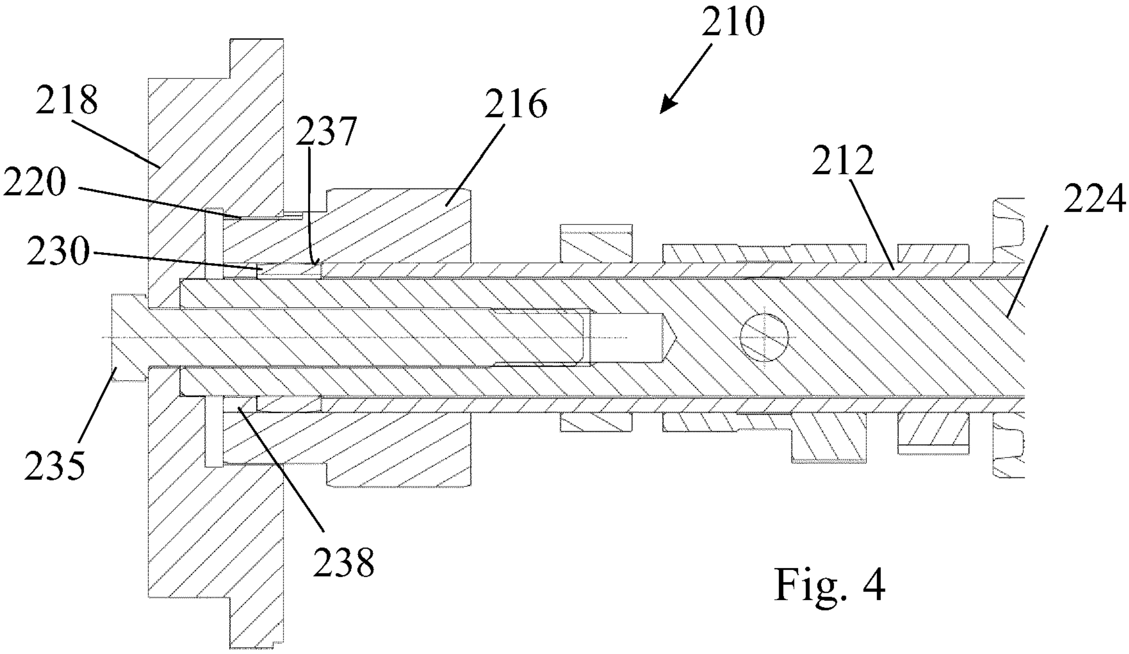
210
218
216
237
212
224
220
230
235
238

Fig. 4

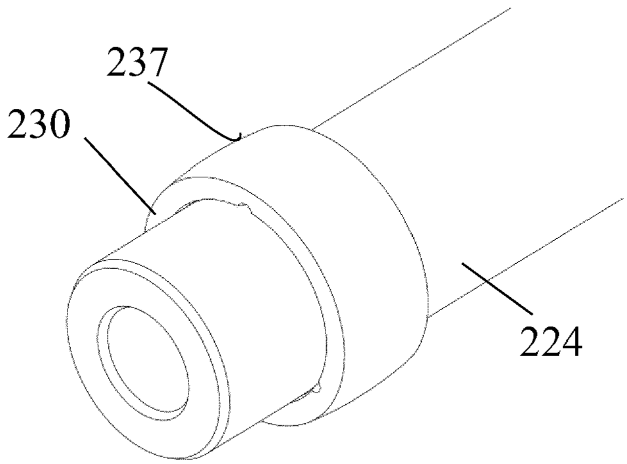

Fig. 5

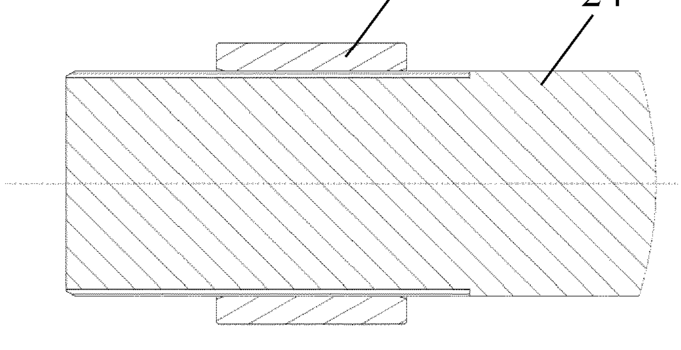

Fig. 6A

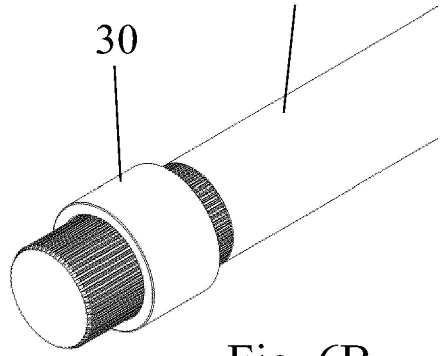

Fig. 6B

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EUROPEAN SEARCH REPORT

Application Number
EP 18 19 8581

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	18 March 2019	Klinger, Thierry

CATEGORY OF CITED DOCUMENTS

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

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