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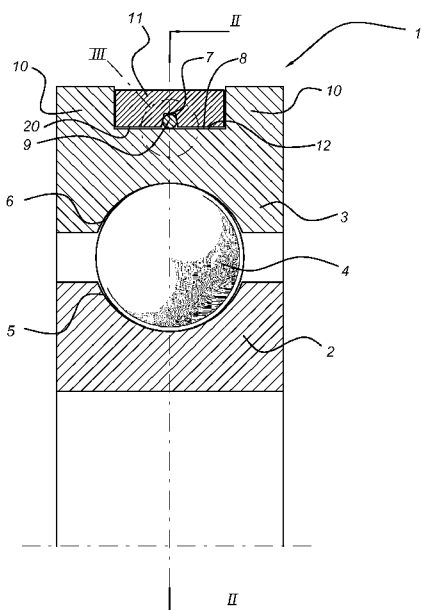
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(54) Title: OPTICAL FIBRE SENSOR ASSEMBLY

Fig. 1



(57) Abstract: A sensor assembly comprises a clamping ring for clamp-
ing engagement of a shaft or bearing and an optical fibre. The clamping
ring has an inner surface for engagement with an outer surface of the
shaft or bearing and a groove around a circumference of the inner sur-
face. The optical fibre is retained within the groove and extends from
the groove for connection to an interrogation unit. The optical fibre may
be a fibre Bragg grating sensor.

OPTICAL FIBRE SENSOR ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

5 The invention relates to a sensor assembly for condition monitoring of bearings and the like. In particular, the invention concerns a clamping ring and fibre assembly for connection to a mechanical system and a method for implementations thereof.

2. Description of the Related Art

10 Bearings are a very important component in rotating machinery. If a bearing fails, then the functionality of the machinery can break down. In some applications it can be very difficult or extremely expensive to replace a failed bearing outside regular scheduled maintenance. Such applications include deep sea applications, ships or continuous manufacturing lines. In an attempt to predict when a bearing needs to be
15 replaced before failure, condition monitoring is done. If the machinery and bearings are in a location that is easily accessible, then the condition of a bearing can be assessed by, for example, vibration measurement. For equipment which is not easily accessible, such as deep sea applications, other means are needed to assess the condition of a bearing to be able to determine when maintenance and/or replacement is required.

20 For diagnosis of the state of bearing rings and for detecting load states and stresses of the bearing, it is helpful to dynamically detect the deformation of the bearing. Similar measurements may be required for other mechanical systems such as shafts, journals, cams and the like. One way of dynamic detection is the use of fibreoptic sensors. The use of such sensors is described in American patent application
25 US2010/0158434. The fibreoptic sensor comprises a glass fibre, which is fixed in or to the periphery of the bearing ring. The sensor is attached in a groove around the bearing ring by means of a cement connection. Alternatively, the sensor can be attached by a glue connection. One disadvantage of such connections is that the fibreoptic sensor does not directly contact the surface of the bearing ring being monitored, which may
30 reduce measurement accuracy. Using a cement connection may require the use of high temperature treatment to establish a firm connection between the bearing ring and the fibre sensor. However, the use of high temperatures may cause thermal damage to the fibre sensor.

It would therefore be desirable to provide an alternative sensor arrangement that alleviated at least some of the perceived inconveniences of the prior art.

BRIEF SUMMARY OF THE INVENTION

5 According to the invention there is provided a sensor assembly comprising a clamping ring for clamping engagement of a shaft or bearing and having an inner surface for engagement with an outer surface of the shaft or bearing and a groove around a circumference of the inner surface; an optical fibre retained within the groove and extending from the groove for connection to an interrogation unit. Due to the force
10 applied by the clamping ring, relative movement of the fibre with respect to the outer surface may be reduced. Preferably, clamping occurs with direct contact to the outer surface, i.e. without an additional layer between the fibre and the outer surface. This can increase the accuracy of subsequent deformation measurements. Furthermore, the presence of a clamping force obviates the necessity for a connection layer during use of
15 the sensor. Such a connection layer can deteriorate during use, thereby influencing the quality of the deformation measurements in an adverse way. Additionally, the use of a groove and a clamping ring provides easy implementation of mass production of the clip and sensor, since the size of the groove may be predefined by the diameter of the fibre and the manufacturing process can be standardized. Although reference is given to
20 a shaft or bearing, this is not intended to be limiting and is to be interpreted in the broadest sense to also include mechanical systems such as journals, cams and the like capable of benefiting from such a sensor.

Most preferably, the groove is sized to grip the optical fibre at its periphery such that the inner surface of the clamping ring is tangential to the periphery of the optical
25 fibre. In this context, tangential is intended to mean that the innermost surface of the fibre is flush with the inner surface of the clamping ring when clamped into engagement with the outer surface of the shaft or bearing. It will be understood that in order to press the fibre against the outer surface, it may initially need to be slightly proud of the groove and tangential to the periphery is intended to include this situation.
30 Nevertheless, the skilled person will understand it may be possible to provide a ridge on the engaging outer surface of the bearing or shaft in order to engage with the fibre within the groove. It is also not excluded that both surfaces have a partial groove and that the fibre is held between the opposing grooves. Most preferably, the groove and

the clamping element are sized with respect to the fibre to ensure a close fit with a predefined pressure applied to the fibre.

Preferably, the groove has an opening or entry with a width equal or greater than the diameter of the fibre, whereby the width of the groove decreases with depth. In this manner, a radial clamping force relative to the fibre may be obtained. The groove can comprise sidewalls defining the width of the groove. These sidewalls can be formed such that the width of the groove decreases with increasing distance from the inner surface of the clamping ring. The groove is thus tapered in cross-section. In order that the fibre can be clamped against the sidewalls of the groove, the mouth of the groove may have a width equal or greater than the diameter of the fibre and a base of the groove has a width smaller than the diameter of the fibre.

According to a further aspect of the invention, the fibre may be permanently engaged in the groove. This may take place in a manufacturing process of the sensor assembly. The clamping ring may then be applied to a shaft or bearing as required, without risk of the fibre becoming separated from the groove. The fibre may be engaged in the groove using an adhesive or similar potting composition. The adhesive may be a flexible adhesive, as its location between the fibre and the clamping ring will not be detrimental to the sensitivity of the sensor when the fibre is directly engaged against the outer surface of the system being measured.

The clamping ring may be engaged against the outer surface of the bearing or shaft in various ways. In one embodiment, it may be clamped by an external bearing housing or the like. Preferably, the clamping ring itself comprises a tightening arrangement, for tightening it around the shaft or bearing. Various tightening arrangements will be familiar to the skilled person, including spring clips, screw clips, hose clips, circlips, cable ties or the like. In general the clamping ring will be made of metal, as will the tightening arrangement. Nevertheless, it is not excluded that other materials may be used both for the clamping ring and for the tightening arrangement. It may also be desirable to provide appropriate friction increasing surfaces between the clamping ring and the shaft or bearing. These may be provided on the outer surface of the latter or may be provided on the clamping ring, or both.

According to a further alternative embodiment, the clamping ring may comprise an engagement arrangement for engaging with a channel provided in the outer surface of the shaft or bearing. The engagement arrangement may itself ensure the requisite

clamping force or may act together with a tightening arrangement. In one configuration, the clamping ring may have a form-fit engagement with the shaft or bearing to which it is applied, e.g. by an interference fit within such a channel.

The fibre may be any suitable optical fibre capable of measuring the state of the mechanical system to which it is applied. The skilled person will be familiar with various forms of sensor, working on the basis of strain, stress, elongation, temperature and the like. Preferably, the fibre is a fibre Bragg grating (FBG) sensor, operating in combination with a suitable interrogation unit. A light signal generated by a light source is input to the optical fibre and a returning light signal is detected by a detector after passing through the optical fibre. When the optical fibre is longitudinally deformed, this can be determined by a change of at least one parameter of the detected light signal passed through the optical fibre. A deformation of the outer surface against which the fibre engages can then also be deduced. Spatial resolution in the longitudinal direction of the sensor is achieved by a corresponding variation of the grating period, resulting in different Bragg wavelengths due to the variation of the grating period over the length of the sensor. The actual operation of such sensors is well known to the skilled person and will not be further discussed here.

The length of the groove may be any length sufficient to provide the desired sensing function. The groove may extend once around the full circumference of the outer surface or may extend only over part of the circumference. The groove may also make more than a single turn and may be serpentine or doubled-back on itself. Most preferably, the optical fibre extends around at least three-quarters of the circumference of the clamping ring.

The present invention also relates to a bearing having an outer surface and comprising an assembly of a clamping ring and optical fibre as described above, engaged around the outer surface such that the optical fibre is held in intimate contact therewith. The outer surface is preferably a radially outer surface of an outer bearing ring of the bearing. Nevertheless, it is not excluded that the fibre may be engaged with another outer surface of the bearing, including regions of an inner bearing ring. Preferably, the fibre will be engaged at a position where strain in the bearing can best be measured.

In a preferred embodiment, the bearing comprises a channel formed in the outer surface and the clamping ring is engaged within the channel. In this manner, the fibre

may be located closer to a region of strain and greater sensitivity may be achieved. Additionally, the presence of a channel may assist in retaining the clamping ring in position.

In a further preferred embodiment, the channel may have engaging surfaces on its side walls for engaging and retaining the clamping ring within the channel as described above. The channel and clamping ring may be a form fit. Alternatively, other permanent connection may be provided between the clamping ring and the bearing, including welding or adhesives.

Preferably, the channel is at least as deep or deeper than the clamping ring, such that the clamping ring is contained entirely within the channel.

The bearing may include any suitable rolling elements, including ball bearings, roller bearings, needle bearings and the like. In general, the invention may be applicable to bearings having an inner and an outer bearing ring, with roller elements located between the inner and outer bearing rings, which may be provided with suitable raceways. The fibre is preferably attached directly opposite the raceway along which the rolling bodies move. The fibre will generally be provided on the stationary bearing ring. However, it is also possible to engage the fibre against the rotating bearing ring for rotation therewith. It will be understood that the invention may also be applicable to journal bearings and other devices in which rolling or even sliding contact with a bearing ring occurs.

The invention also encompasses a method for connecting a fibre sensor to a shaft or bearing having an outer surface, the method comprising: providing a clamping ring comprising an inner surface for engagement with the outer surface of the shaft or bearing and a groove around a circumference of the inner surface; locating an optical fibre within the groove, having a portion extending from the groove for connection to an interrogation unit; and engaging the clamping ring with the shaft or bearing, such that the fibre sensor intimately engages the outer surface thereof with a clamping force. Such a method can be easily implemented either during production or installation and can be performed without adhesive or the like.

30

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the invention will be appreciated upon reference to the following drawings of a number of exemplary embodiments, in which:

Figure 1 shows an axial cross-section of a bearing incorporating an embodiment of the present invention;

Figure 2 shows a radial cross-section of the bearing of Figure 1;

Figure 3 shows a detail of the bearing of Figure 1 indicated by III;

5 Figure 4 shows an alternative embodiment of the invention in axial cross-section; and

Figure 5 shows a bearing in perspective view with alternative clamping rings according to the invention.

10 DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Figure 1 shows an axial cross-section of a bearing 1 comprising an inner bearing ring 2 having an inner raceway 5, and an outer bearing ring 3 having an outer raceway 6. In between the inner and outer rings 2, 3, rolling elements 4 are provided such that the inner and outer bearing rings 2, 3 can rotate with respect to each other.

15 The rolling elements 4 are located in between the inner and outer raceways 5, 6.

A channel 12 is provided at an outer surface 8 of the outer bearing ring 3, shaped as a recess between two sidewalls 10. Within the channel 12 is located a clamping ring 11. The clamping ring 11 has a groove 7 at its inner surface 20 in which is located an optical fibre 9. The fibre 9 engages with the outer surface 8.

20 Figure 2 shows a radial cross-section through the bearing 1 and clamping ring 11 along line II-II of Figure 1. As can be seen, the groove 7 extends around the complete circumference of the clamping ring 11. The clamping ring 11 extends around a large part of the circumference of the outer bearing ring 3, except for a relatively small portion forming an opening 13, which is used for placing the clamping ring 11 over
25 outer bearing ring 3 and into the channel 12. The groove 7 extends around the complete extent of the clamping ring 11 although the fibre 9 stops short of the opening 13 at a first end 14 and extends outwards through the clamping ring at a second end 15 for attachment to a suitable interrogation device 30.

30 The fibre 9 comprises Bragg gratings 19 distributed along its length. These are a type of distributed Bragg reflectors constructed in a short segment of the optical fibre that reflects particular wavelengths of light and transmits all others. Such gratings may be achieved by creating a periodic variation in the refractive index of the fibre core, which generates a wavelength specific dielectric mirror. The fibre Bragg grating thus

operates as an inline wavelength-specific reflector. Elongation of the fibre 9 due to strain in the outer bearing ring 3 may thus be detected by the interrogator 30. Operation of such a sensor is generally conventional and will not be discussed further in the present application. It will also be understood that other types of sensor may also be
5 located within the groove 7.

Figure 3 shows a detail of the sensor assembly indicated by III in Figure 1. The groove 7 can be seen to have a tapered shape in cross-section. The width of the entry 16 of the groove 7 is larger than the diameter D of the fibre 9, which in turn is wider than a base 21 of the groove 7. Due to the tapered shape, the sidewalls 17 of the groove 7 grip
10 the fibre 9 at its periphery 18. The groove 7 and fibre 9 are dimensioned specifically such that on insertion of the fibre 9 into the groove 7, the inner surface 20 of the clamping ring 11 is tangential to the periphery 18 of the fibre 9. In order to maintain the fibre 9 within the groove 7, adhesive 24 is provided at the base 21 of the groove 7.

Figure 4 shows a bearing 101 with an alternative clamping ring 111 according to
15 an alternative embodiment of the invention. According to Figure 4, clamping ring 111 is distinguished from that of the first embodiment by a pair of engagement ribs 126 extending laterally. The channel 112 provided in the outer bearing ring 103 has sidewalls 110 provided with corresponding detent elements 127 for receipt of the engagement ribs 126. As can be seen in Figure 4, the ribs 126 and elements 127 are
20 located at a position to ensure the correct degree of clamping of the fibre sensor 9. It will be understood that other shapes of engagement elements and ribs may be provided to achieve the same effect.

Figure 5 shows the bearing 1 of Figures 1 to 3 in perspective view with a number of different clamping rings. Clamping ring 11 as shown in Figure 5 corresponds to that
25 of Figures 1 to 3, with clamping taking place by the inherent spring properties of the ring 11, which is made of spring steel.

Clamping ring 211 is of a screw clamp type, having a pair of flanges 214, that can be drawn to each other by a screw 215. It will be understood that the clamping ring 211 and bearing 1 are shown schematically and that in reality, the flanges 214 will be of a
30 size that they fit within the channel 12.

Clamping ring 311 is of a hose clamp type, having a captive screw 315 that engages with thread sections 314 formed along the ring 311. The skilled person will recognise that many other alternative forms of clamping ring may be implemented. It is

also noted in this embodiment that fibre 309 and groove 307 do not extend around the full circumference of the clamping ring 311.

Thus, the invention has been described by reference to the embodiment discussed above. It will be recognized that this embodiment is susceptible to various

5 modifications and alternative forms well known to those of skill in the art without departing from the spirit and scope of the invention. In particular, it will be understood that although a single groove and fibre sensor has been described, multiple grooves and or multiple fibres could be incorporated. Accordingly, although specific embodiments have been described, these are examples only and are not limiting upon the scope of the
10 invention.

CLAIMS

1. A sensor assembly comprising:
 - a clamping ring for clamping engagement of a shaft or bearing, comprising
 - 5 an inner surface for engagement with an outer surface of the shaft or bearing and a groove around a circumference of the inner surface;
 - an optical fibre retained within the groove and extending from the groove for connection to an interrogation unit.
- 10 2. Assembly according to claim 1, wherein the groove is sized to grip the optical fibre at its periphery such that the inner surface of the clamping ring is tangential to the periphery of the optical fibre.
3. Assembly according to claim 1 or 2, wherein the groove is tapered in cross-
- 15 section.
4. Assembly according to any preceding claim, wherein the fibre is permanently engaged in the groove, preferably using adhesive.
- 20 5. Assembly according to any preceding claim, wherein the clamping ring comprises a tightening arrangement, for tightening it around the shaft or bearing.
6. Assembly according to any preceding claim, wherein the clamping ring comprises an engagement arrangement, for engaging with a channel provided in the
- 25 outer surface of the shaft or bearing.
7. Assembly according to any preceding claim, wherein the optical fibre comprises a fibre Bragg grating (FBG) sensor.
- 30 8. Assembly according to any preceding claim, wherein the optical fibre extends around at least three-quarters of the circumference of the clamping ring.

9. A bearing having an outer surface and comprising an assembly according to any of the preceding claims engaged around the outer surface such that the optical fibre is held in intimate contact therewith.

5 10. The bearing according to claim 9, further comprising a channel formed in the outer surface and wherein the clamping ring is engaged within the channel.

11 The bearing according to claim 10, wherein the channel has engaging surfaces on its side walls for engaging and retaining the clamping ring within the channel.

10

12. The bearing according to claim 10 or claim 11, wherein the channel is deeper than the clamping ring, such that the clamping ring is contained entirely within the channel.

15 13. The bearing according to any of claims 9 to 12, the bearing being a sealed rolling element bearing.

14. A method for connecting a fibre sensor to a shaft or bearing having an outer surface, the method comprising:

20 - providing a clamping ring comprising an inner surface for engagement with the outer surface of the shaft or bearing and a groove around a circumference of the inner surface;

- locating an optical fibre within the groove, having a portion extending from the groove for connection to an interrogation unit;

25 - engaging the clamping ring with the shaft or bearing, such that the fibre sensor intimately engages the outer surface thereof with a clamping force.

15. Method according to claim 14, wherein the clamping ring is a clamping ring according to any of claims 1 to 8 or applied to a bearing according to any of claims 9 to

30 13.

Fig. 1

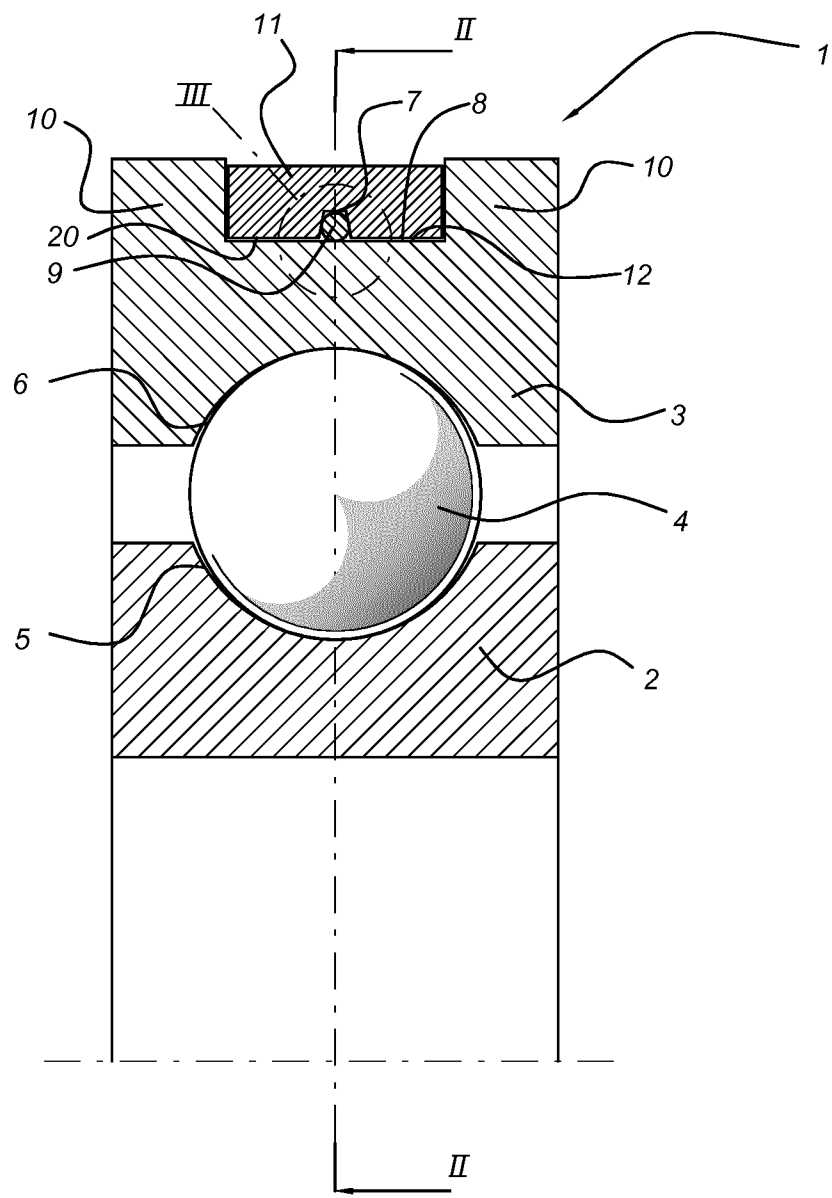


Fig. 2

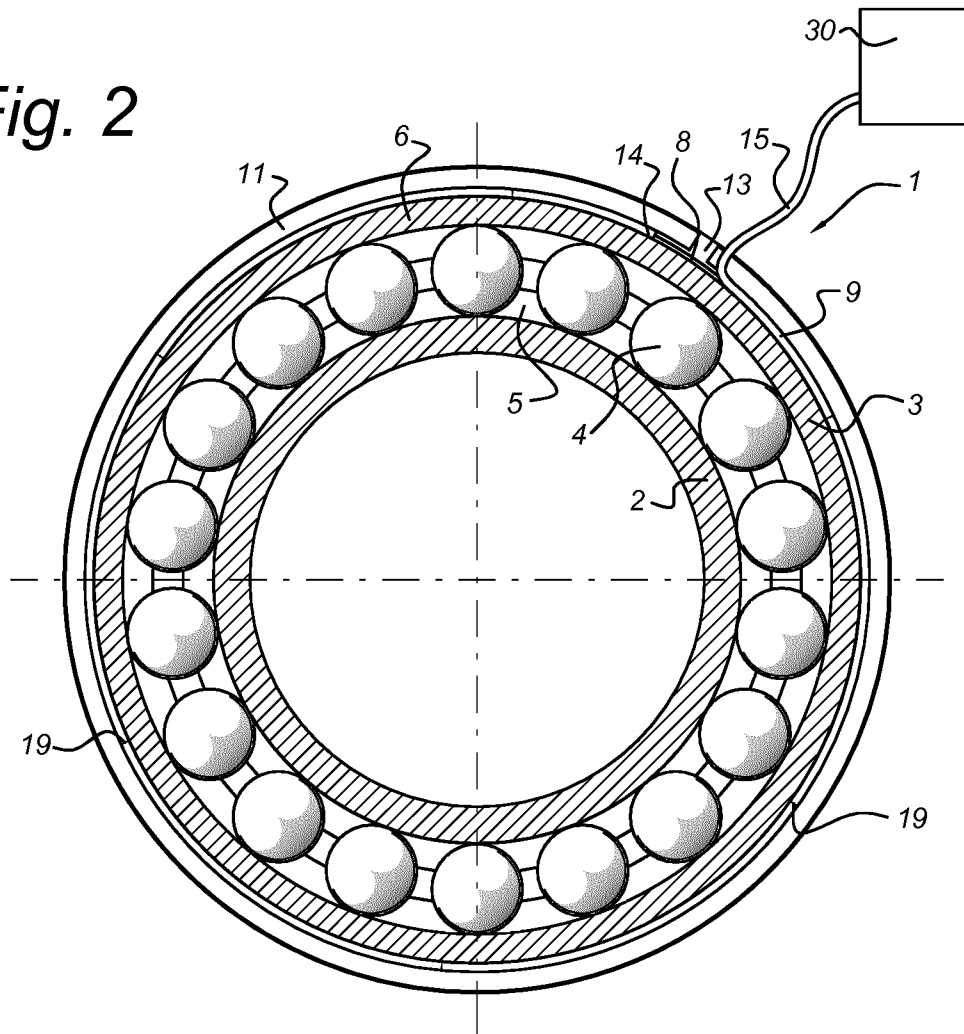


Fig. 3

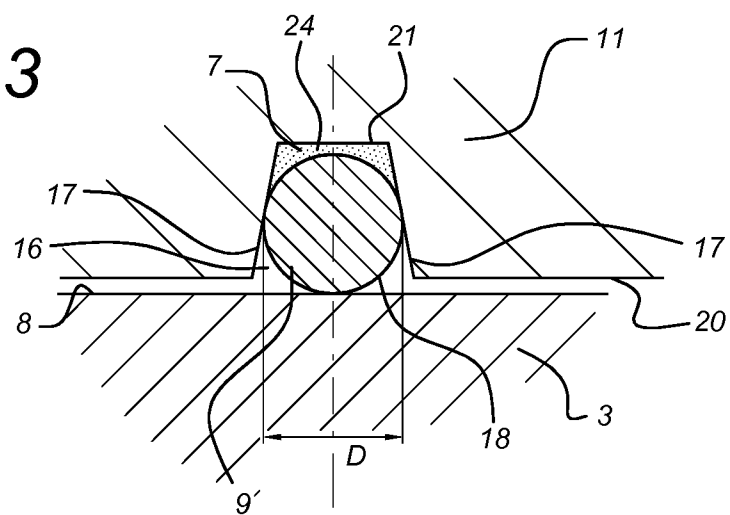
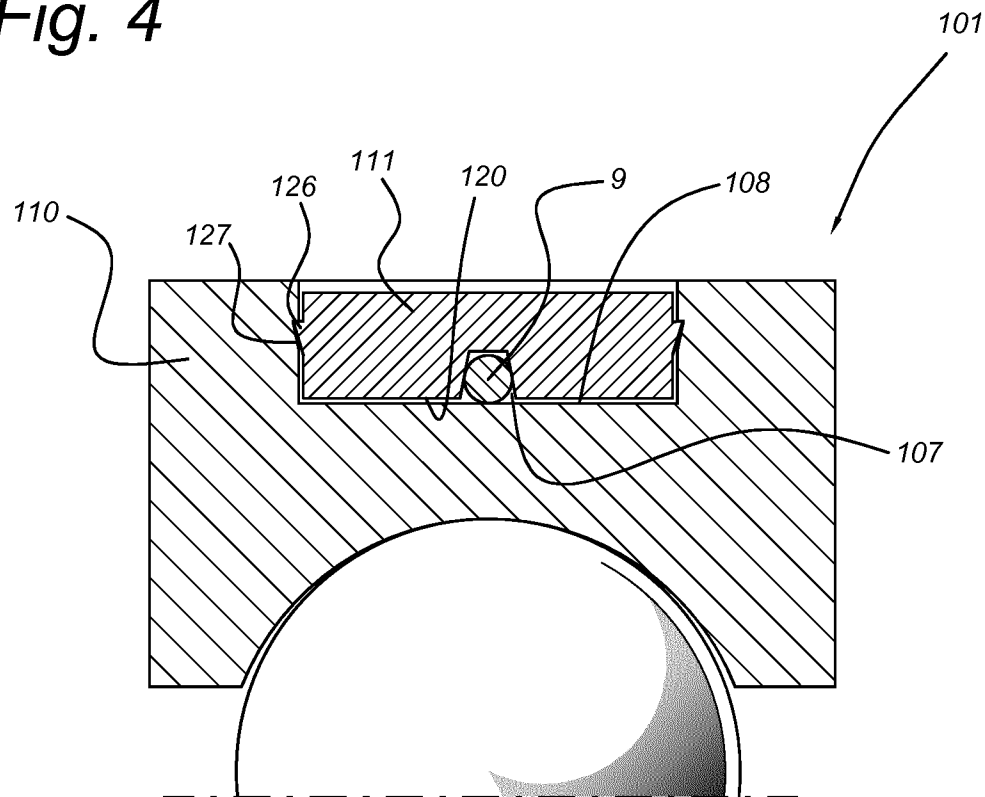


Fig. 4



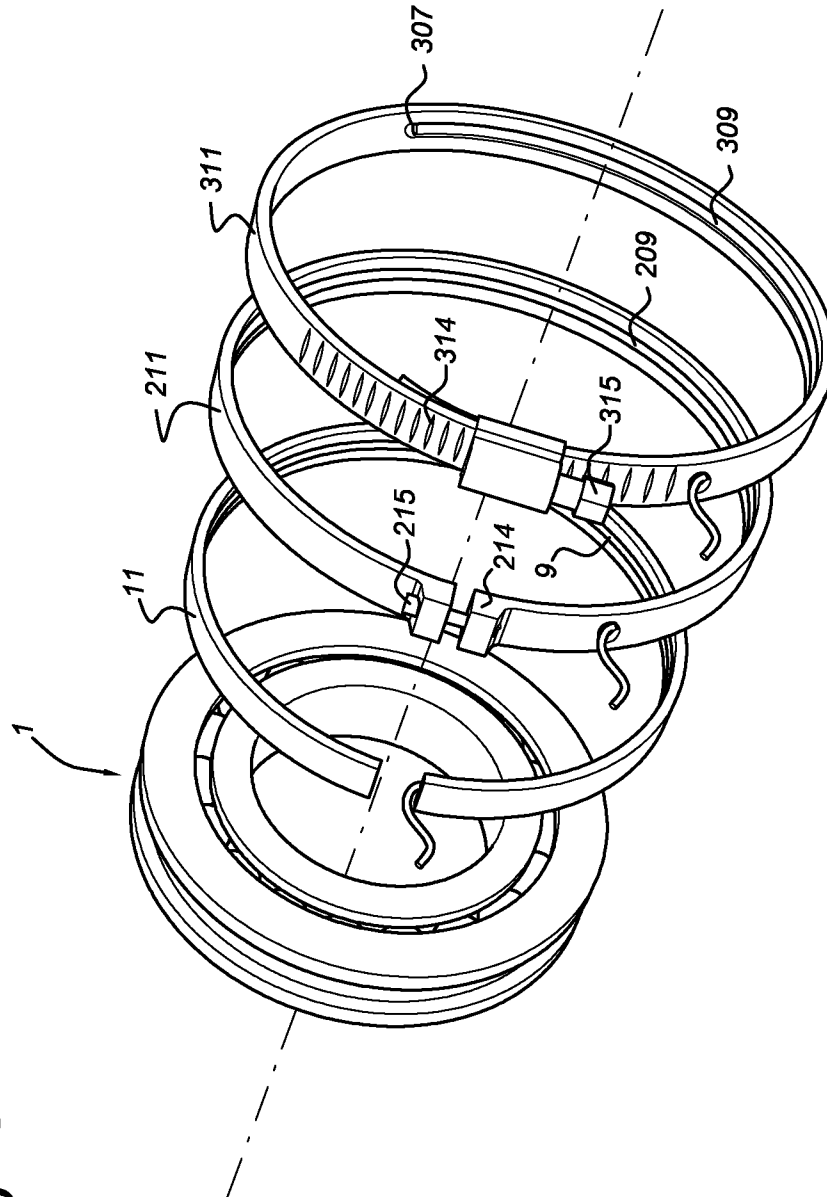


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/075507

A. CLASSIFICATION OF SUBJECT MATTER INV. G01D5/353 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) G01D F16C G01L G01M		
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.
Y	GB 2 457 277 A (SCHLUMBERGER HOLDINGS [VG]) 12 August 2009 (2009-08-12) paragraphs [0006] - [0010], [1625] - [0029]; figures 1,2 -----	1-15
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Y	US 6 080 982 A (COHEN EDWARD ISAAC [US]) 27 June 2000 (2000-06-27) column 2, line 1 - line 15; figures 1,2 column 6, line 8 - line 41 ----- -/-	1
☒ Further documents are listed in the continuation of Box C. ☒ 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 31 October 2013		Date of mailing of the international search report 11/11/2013
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Faber-Jurk, Sonja

INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

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