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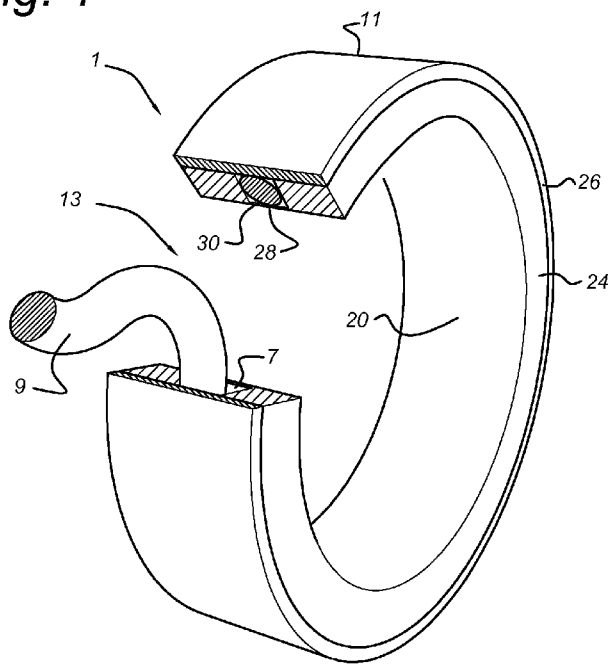
(54) Title: FIBREOPTIC SENSOR CLIP

Fig. 1



(57) Abstract: A fibreoptic sensor clip comprising a clamping ring for clamping engagement of a shaft or bearing, has a sensing region at an inner surface for engagement with an outer surface of the shaft or bearing and a cavity, extending around a circumference of the clamping ring. The cavity is adjacent to the sensing region and an optical fibre is retained within the cavity and extends from the cavity for connection to an interrogation unit. The clip may be a pre-fabricated element having the fibre embedded within it during a fabrication procedure.

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FIBREOPTIC SENSOR CLIP

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a sensor assembly for condition monitoring of bearings and the like. In particular, the invention concerns a fibreoptic sensor clip for connection to such a mechanical system.

2. Description of the Related Art

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 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.

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 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 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. Furthermore, the optical fibres used in such sensors are extremely fine and great care is required in handling them.

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

According to the invention there is provided a fibreoptic sensor clip comprising a clamping ring for clamping engagement of a shaft or bearing, having a sensing region at an inner surface for engagement with an outer surface of the shaft or bearing and a cavity extending around a circumference of the clamping ring adjacent to the sensing region and an optical fibre retained within the cavity and extending from the cavity for connection to an interrogation unit. The clip may thus be a pre-fabricated element having the fibre embedded within during a fabrication procedure. Thereafter, the clip may be applied to a mechanical system of choice without risk of damage to the optical fibre. Preferably, the fibre is reinforced or supported at the location where it exits from the clamping ring.

Due to the force applied by the clamping engagement, relative movement of the fibre or the sensing region with respect to the outer surface to which it engages may be reduced. Preferably, clamping occurs with direct contact to the outer surface, i.e. without an additional layer between the sensing region 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 the sensor. Such a connection layer can deteriorate during use, thereby influencing the quality of the deformation measurements in an adverse way. 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. Although reference is given to 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 sensing region comprises a thin membrane separating the cavity from the inner surface and the fibre is biased against the membrane. The cavity may be sized in order to cause such a bias. In this sense, the cavity may be a hollow

cavity within the clamping ring having a dimension greater than the fibre. Alternatively, the fibre may be simple embedded in the clamping ring. The membrane may have a thickness of less than 1 mm, preferably less than 0.5 mm or more preferably less than 0.3 mm. By making the sensing region very thin, the sensitivity of the sensor is optimised and the effect of the membrane may be minimised. Preferably, the clamping ring comprises an inner ring and an outer ring and the cavity is formed between the inner ring and the outer ring. The inner and outer ring may be separate items of manufacture, joined together after inserting the fibre into the cavity. The method of joining may be any appropriate means and may be permanent or non-permanent. In a preferred embodiment, both inner and outer rings are formed of metal and welded together. Nevertheless, other material and constructions such as screw engagement may be considered.

According to a most preferred configuration, the clamping ring is made of metal, at least at its inner surface. The sensing region in particular should preferably be made of metal as this is believed to maximise the sensitivity of the sensor to strain in 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 tightening arrangement will be made of metal. Nevertheless, it is not excluded that other materials may be used both for the clamping ring and for the tightening arrangement. In a most preferred embodiment, the clamping ring is a split ring, meaning that it does not extend a full 360 degrees but has a small gap or opening for tightening purposes.

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 sensing region 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 cavity may extend around the clamping ring over a length sufficient to provide the desired sensing function. The cavity may extend once around the full circumference or may extend only over part of the circumference. The cavity 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 a clip as described above, engaged around the outer surface such that the sensing region 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 clip may be engaged with another outer surface of the bearing, including regions of an inner bearing ring. Preferably, the sensing region 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 sensing region 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 sensing region is preferably attached directly opposite the raceway along which the rolling bodies move. The clip 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 provides for a clip or bearing as described above in combination with an interrogation unit for applying a light signal to the fibre and analysing the response. The interrogation unit may also be an on chip logging device provided on the clip.

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 having a sensing region for engagement with the outer surface of the shaft or bearing and a cavity extending around a circumference of the clamping ring adjacent to the sensing region; locating an optical fibre within the cavity having a portion extending from the cavity for connection to an interrogation unit; and engaging the clamping ring with the shaft or bearing, such that the sensing region 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. The clip may also be easily removed or exchanged.

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 a perspective view of a clip according to the present invention;

Figure 2 shows an axial cross-section through a bearing and clip according to the invention;

Figure 3 shows a radial cross-section through the bearing and clip of Figure 2 along line III-III;

Figure 4 shows an axial cross-section through a clip according to the invention applied to a shaft;

Figure 5 shows a bearing with a clip according to an alternative embodiment of the invention; and

Figure 6 shows a number of different clips according to the invention in perspective view.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Figure 1 shows a perspective view of a clip 1 according to the present invention. The clip comprises a clamping ring 11 having a cavity 7 within its interior extending circumferentially. The ring 11 is not a full annulus, being split at a gap 13. Within the cavity 7 is located an optical fibre 9. It is noted that the figure is schematic and not to scale. In actual fact, the optical fibre may have a diameter of around 0.1 mm while the diameter of the clamping ring 11 may be a number of centimetres.

The clamping ring 11 is constructed in two parts, an inner ring 24 and an outer ring 26, with the cavity 7 being formed between them. Both parts are formed of steel, welded together after introduction of the fibre 7. The inner ring has an inner surface 20 provided with a sensing region 28 underlying the cavity. The material of the inner ring 24 in the sensing region 28 is very thin, forming a membrane 30. The size of the cavity 7 and the fibre 9 are such that in the assembled condition shown in Figure 1, the fibre is biased against the membrane 30.

Figure 2 shows an axial cross-section through a bearing 100 according to an aspect of the invention, on which the clip 1 of Figure 1 has been applied. The bearing 100 comprises 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. 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 the clamping ring 11 with the sensing region 28 at its inner surface 20 engaged with the outer surface 8.

Figure 3 shows a radial cross-section through the bearing 100 and clamping ring 11 along line III-III of Figure 2. As can be seen, 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 gap 13, which is used for placing the clamping ring 11 over outer bearing ring 3 and into the channel 12. The cavity 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 40.

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 40. 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 located within the cavity 7.

Figure 4 shows an axial cross-section through a clip 1 applied to a shaft 42. The clip 1 is held within a portion of a journal 44 with the sensing region 28 engaged against the shaft 42.

Figure 5 shows a bearing 200 with an alternative clip 201 according to an alternative embodiment of the invention. According to Figure 4, clamping ring 211 is distinguished from that of the first embodiment by a pair of engagement ribs 226 extending laterally. The channel 212 provided in the outer bearing ring 203 has sidewalls 210 provided with corresponding detent elements 227 for receipt of the engagement ribs 226. As can be seen in Figure 4, the ribs 226 and elements 227 are

located at a position to ensure the correct degree of clamping of the sensing region 228 against the outer surface 208. It will be understood that other shapes of engagement elements and ribs may be provided to achieve the same effect.

Figure 6 shows a number of different clamping rings in perspective view. Clamping ring 211 is as shown in Figure 5. Clamping ring 311 is of a screw clamp type, having a pair of flanges 314, that can be drawn to each other by a screw 315. Clamping ring 411 is of a hose clamp type, having a captive screw 415 that engages with thread sections 414 formed along the ring 411. The skilled person will recognise that many other alternative forms of clamping ring may be implemented.

Thus, the invention has been described by reference to the embodiment discussed above. It will be recognized that this embodiment is susceptible to various 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 cavity and fibre have been described, multiple cavities 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 invention.

CLAIMS

1. A fibreoptic sensor clip comprising:

a clamping ring for clamping engagement of a shaft or bearing, having a sensing region at an inner surface for engagement with an outer surface of the shaft or bearing and a cavity extending around a circumference of the clamping ring adjacent to the sensing region;

an optical fibre retained within the cavity and extending from the cavity for connection to an interrogation unit.

2. Clip according to claim 1, wherein the sensing region comprises a thin membrane separating the cavity from the inner surface and the fibre is biased against the membrane.

3. Clip according to claim 1 or 2, wherein the clamping ring comprises an inner ring and an outer ring and the cavity is formed between the inner ring and the outer ring.

4. Clip according to any preceding claim, wherein the clamping ring is made of metal, at least at its inner surface.

5. Clip according to any preceding claim, wherein the clamping ring comprises a tightening arrangement, for tightening it around the shaft or bearing.

6. Clip according to any preceding claim, wherein the clamping ring comprises an engagement arrangement, for engaging with a channel provided in the outer surface of the shaft or bearing.

7. Clip according to any preceding claim, wherein the optical fibre comprises a fibre Bragg grating (FBG) sensor.

8. Clip according to any preceding claim, wherein the optical fibre extends around at least three-quarters of the circumference of the clamping ring.

9. Clip according to any preceding claim wherein the clamping ring is a split ring.

10. A bearing having an outer surface and comprising a clip according to any of the preceding claims engaged around the outer surface such that the sensing region of the clip is held in intimate contact therewith.

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

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

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

14. The bearing according to any of claims 10 to 13, the bearing being a rolling element bearing.

15. A fibreoptic sensor assembly comprising a clip according to any of claims 1 to 9 or a bearing according to any of claims 10 to 14 in combination with an interrogation unit for applying a light signal to the fibre and analysing the response.

Fig. 1

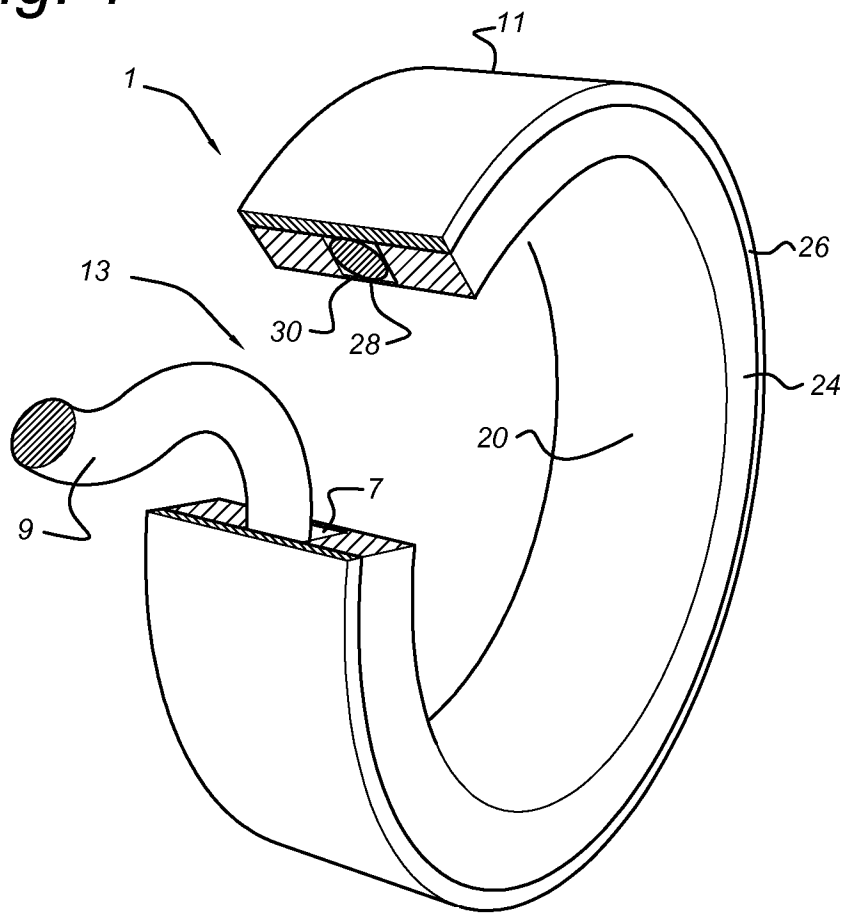


Fig. 2

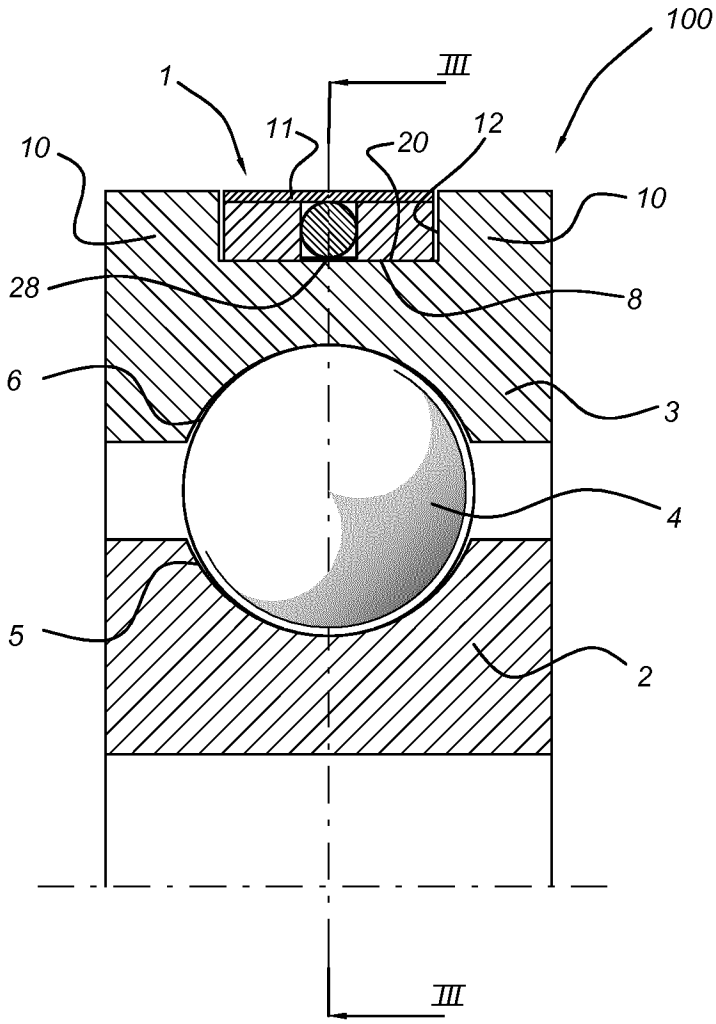


Fig. 3

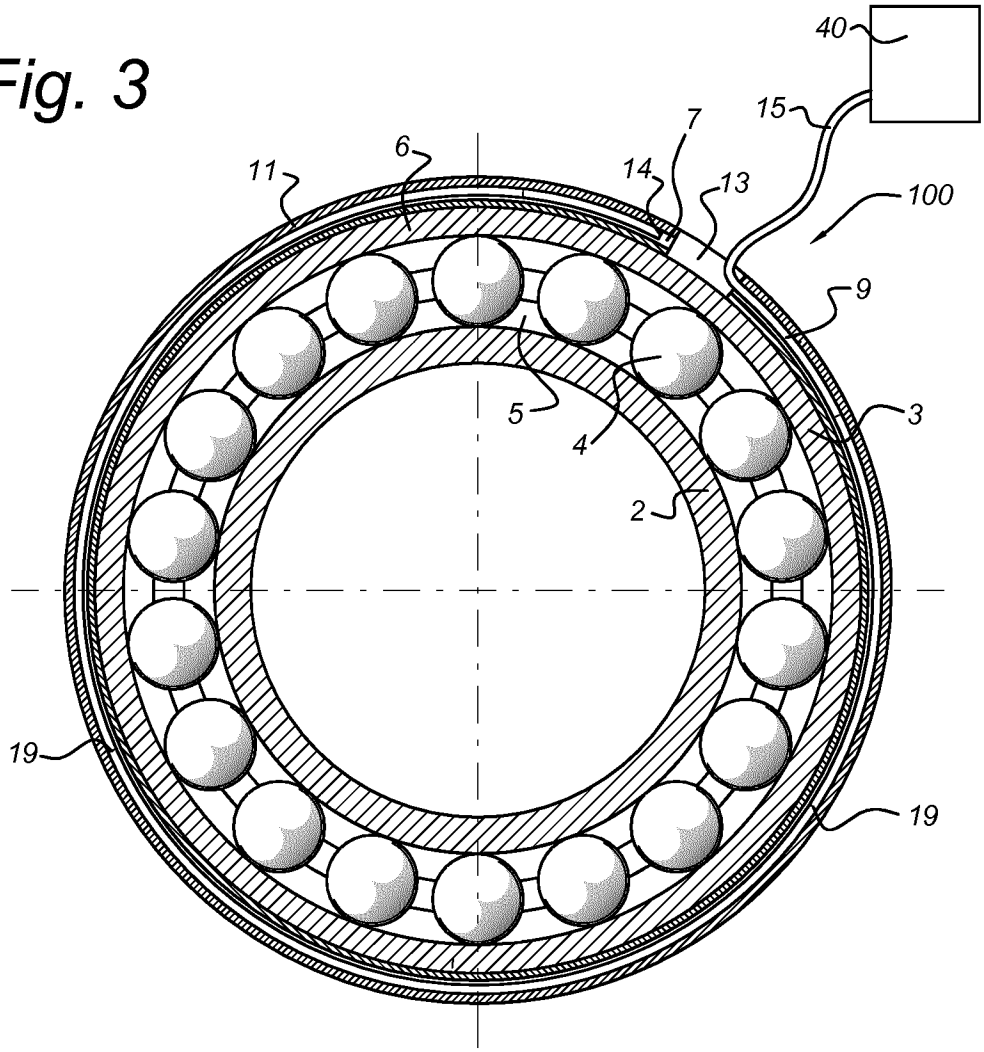


Fig. 4

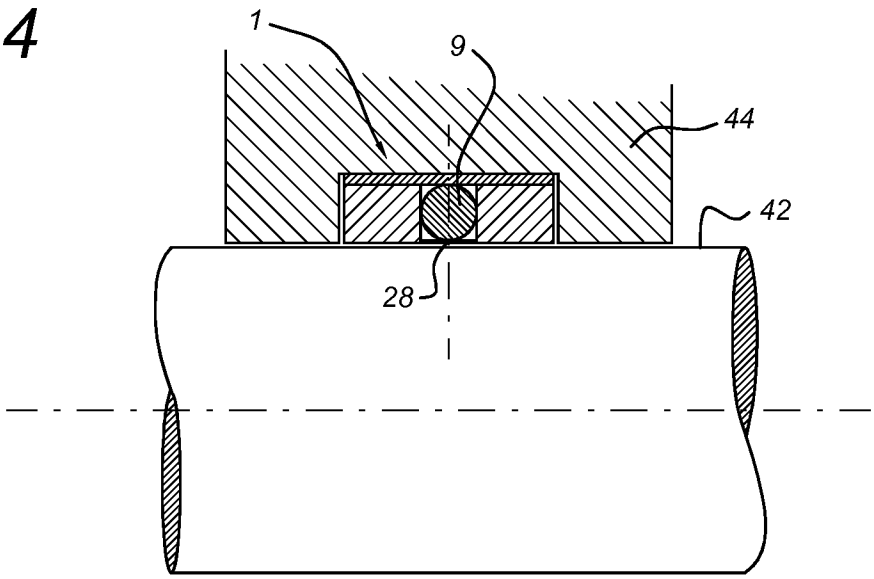


Fig. 5

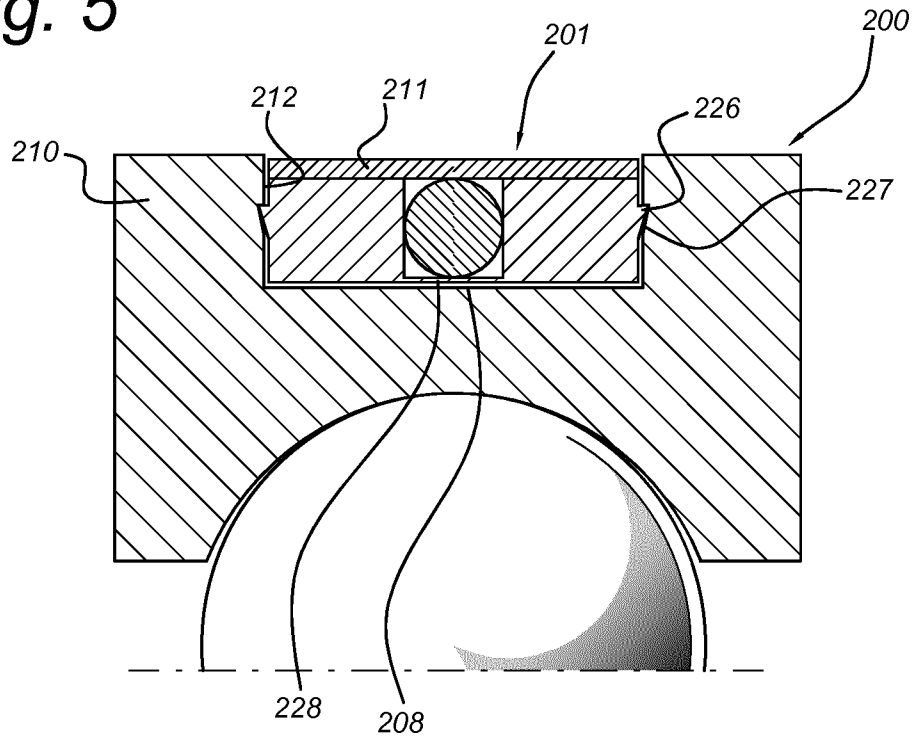
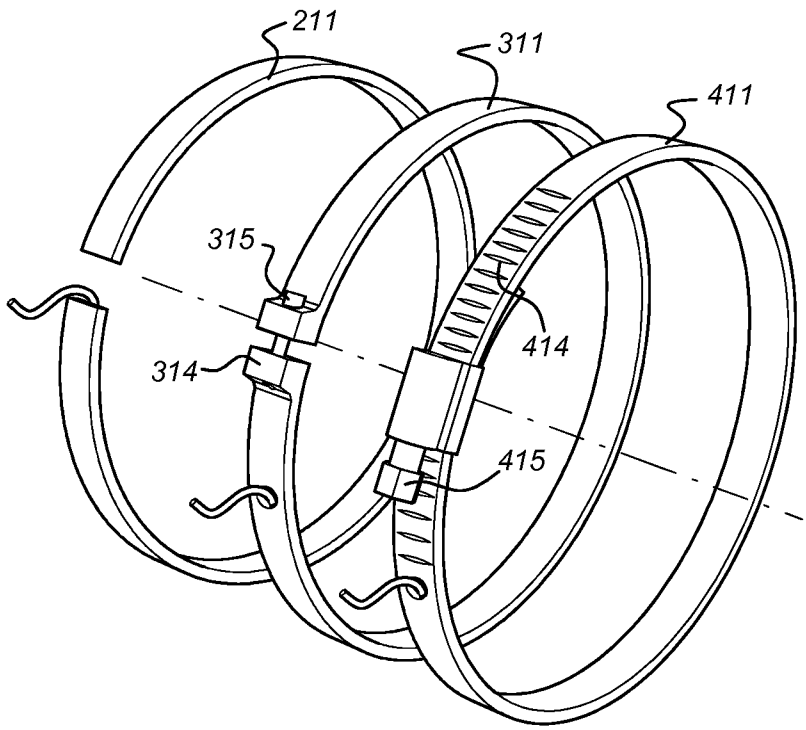


Fig. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/050209

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01M13/04 F16C19/52 G02B6/36 G01L5/00 F16B2/02
G01D5/353 G01K11/32 G01B11/16
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)
G01M F16C G02B G01L F16B G01D G01K G01B F16L

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/100084 A1 (SCHLUMBERGER CA LTD [CA]; SCHLUMBERGER TECHNOLOGY CORP [US]; SCHLUMBER) 13 August 2009 (2009-08-13)	1-9,15
Y	page 5; figures 1,2	10,11, 13,14
A		12

Y	WO 2011/066926 A1 (SKF AB [SE]; REEDMAN ADAM VICTOR CREYKE [NL]; YANG HONG YU [NL]) 9 June 2011 (2011-06-09) abstract; figures 1,4,5A	10,11, 13,14

A	US 2010/158434 A1 (BECKER EDWIN [DE]) 24 June 2010 (2010-06-24) cited in the application paragraph [0015]; figures 1-3	1-15

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

[X] See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 September 2013	17/09/2013

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/050209

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 10 2011 077495 A1 (SCHAEFFLER TECHNOLOGIES AG [DE]) 20 December 2012 (2012-12-20) paragraphs [0007], [0010], [0011], [0012]; figure 1 -----	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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