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(54) Title: LOAD SENSING ARRANGEMENT ON A BEARING COMPONENT, METHOD AND COMPUTER PROGRAM PRODUCT

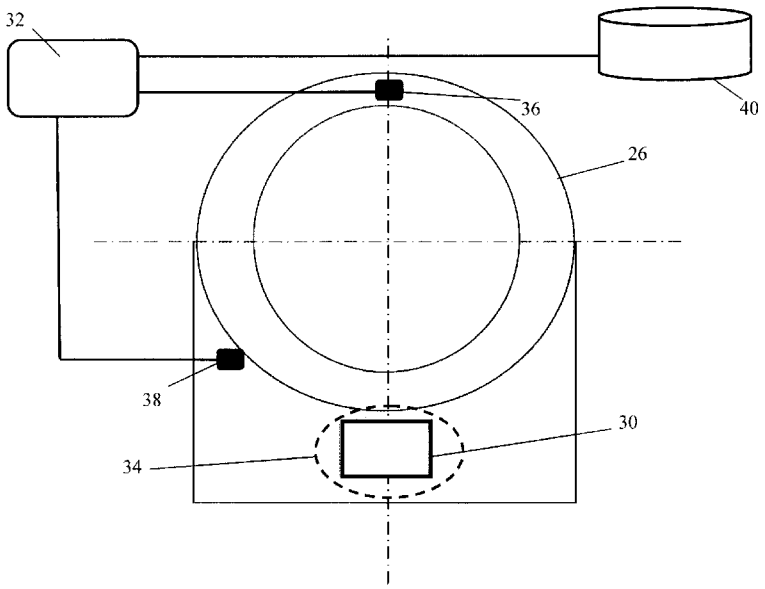


Fig. 4

(57) Abstract: Load sensing arrangement comprising at least one strain gauge (30) at a strain gauge location (34), the at least one strain gauge (30) being configured to measure the load on a bearing component (26), whereby said load sensing arrangement comprises temperature compensation means (32) arranged to compensate for the influence of temperature on measurements made by said at least one strain gauge (30). The temperature compensation means (32) is configured to receive data and determine a variable indicative of the influence of said data on measurements made by said at least one strain gauge (30).

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Load sensing arrangement on a bearing component, method and computer program product.

TECHNICAL FIELD

The present invention concerns a load sensing arrangement comprising at least one strain gauge configured to measure the load on a bearing component. The present invention also concerns a method for monitoring and/or optimizing a process in which such a load sensing arrangement is used. The present invention further concerns a computer program product that comprises a computer program containing computer program code means arranged to cause a computer or a processor to execute the steps of such a method.

BACKGROUND OF THE INVENTION

There are a number of applications in which sensing the loads and types of loads placed on a bearing in operation can provide useful and significant information about the bearing and objects supported by the bearing.

Most load sensing arrangements comprise at least one strain gauge that is affixed to the bearing. A common type of strain gauge comprises of an insulating flexible backing which supports a metallic foil pattern. As the bearing is deformed, the metallic foil is deformed, causing its electrical resistance to change. This change in electrical resistance, which is usually measured using a Wheatstone bridge, may be used to determine the load on the bearing.

If a bearing is subjected to variations in temperature or a temperature gradient during its use, thermal expansion will cause the bearing to change in size, which will be detected as a strain by the gauge. Many strain gauges are therefore provided with temperature compensation means in order to compensate for, or offset changes in the electrical resistance of the strain gauge which are due to the expansion/contraction of the bearing caused by temperature fluctuations or a temperature gradient.

For example, PCT-publication no. WO 01/23862 describes a system for monitoring the operating conditions of a tapered roller bearing which comprises a plurality of strain sensors located in a groove in the fixed race of the tapered roller bearing. A temperature

sensor is located in the groove to counteract and offset the changes in electrical resistance of the strain sensor which are produced by temperature variations.

US patent 4 118 933 discloses a bearing load indicator comprising pairs of strain gauges wherein one strain gauge (a "dummy strain gauge") in each pair is mounted so as not to respond to the strain, but to serve as a temperature compensator. The temperature compensating strain gauge in each pair of strain gauges is not completely affixed to the support yoke of a bearing but is attached thereto so as to be subjected solely to the temperature at that location, while the other strain gauge in each pair is normally affixed to the support yoke of the bearing and is subjected to both the load on the support yoke and the temperature thereof.

SUMMARY OF THE INVENTION

An object of the invention is to provide an improved load sensing arrangement comprising at least one strain gauge at a strain gauge location, the at least one strain gauge being configured to measure the load on a bearing component, and temperature compensation means arranged to compensate for the influence of temperature on measurements made by the at least one strain gauge.

This object is achieved by a load sensing arrangement comprising temperature compensation means configured to receive data and determine (i.e. calculate, estimate or predict, and not directly measure) a variable indicative of the influence of said data on measurements made by said at least one strain gauge.

Such a load sensing arrangement does not therefore require any apparatus for measuring data, such as the temperature, at the at least one strain gauge location, such as a temperature sensor or a dummy strain gauge, to be placed at the at least one strain gauge location together with the at least one strain gauge. The influence of temperature at the strain gauge location is instead determined using other data received by the temperature compensation means.

The temperature at the strain gauge location need not necessarily be determined. Only the influence of temperature in some part of a bearing component on the measurements made by the strain gauge needs to be determined. For example, if the top of a bearing

housing is subjected to a high temperature, the top of the bearing housing may expand. This may give rise to strain within the bearing housing, which must be compensated for in order to obtain accurate strain gauge measurements.

For example, according to an embodiment of the invention the temperature compensation means comprises at least one temperature sensor that is arranged to measure at least one temperature at at least one location remote from the at least one strain gauge and use the measured remote temperature data to determine the variable indicative of the influence of the at least one measured temperature on measurements made by the at least one strain gauge.

Additionally, or alternatively the temperature compensation means is arranged to determine the variable using process parameter data. The at least one strain gauge may namely be configured to measure the load on a bearing component of at least one of the following: continuous casting apparatus, apparatus used in mining, or an application in which the bearing component is at least temporarily exposed to temperatures over 50-60°C, over 100°C, over 200°C, over 300°C, over 500°C or over 700°C when in use.

In such a case, no temperature measurement needs to be made at all. For example, process parameters that are measured or determined while the at least one strain gauge is making measurements, or process parameters that have been measured or determined previously for the same or similar apparatus and/or during the same or a similar process and/or under similar conditions may be used to determine the variable. Process parameters may be measured directly, and/or determined using a process simulation model or a Finite Element Method (FEM).

The process parameter data may be any data that allows a variable indicative of the influence of said data on measurements made by said at least one strain gauge to be determined directly or indirectly therefrom. In a continuous casting process, such process parameter data may include at least one of the following: strand temperature data, strand position data, strand size data, pressure data, vibration data, casting speed data, molten metal temperature data, room temperature data.

The load sensing arrangement according to the present invention may be used to monitor and/or optimize a system and/or a process in which at least one bearing component is

used. For example, the useful lifetime of a bearing component used in a certain system and/or a certain process and/or under certain conditions may be more accurately determined using a load sensing arrangement according to the present invention.

It should be noted that the at least one strain gauge of the load sensing means according to the present invention need not necessarily be arranged to measure electrical resistance but can be any type of strain gauge whose measurements are adversely affected if it is at least temporarily subjected to temperature fluctuations, or a temperature gradient during its use, especially but not exclusively when subjected to temperature fluctuations of 50-60°C or more.

According to an embodiment of the invention the measured temperature data and/or process parameter data is used in a temperature compensation algorithm that determines the amount of temperature compensation required.

The expression "temperature compensation" as used in this document is intended to mean that a strain gauge measurement is changed, corrected, calibrated, offset or manipulated in some way in order to reduce or eliminate the effect of expansion or contraction of a bearing component caused by temperature fluctuations. Temperature compensation thereby decreases the sensitivity of a strain gauge to strains caused by temperature fluctuations or temperature gradients and consequently increases the accuracy of measurements made by the strain gauge. This temperature compensation may be arranged to take place while measurements are being made by at least one strain gauge (so that changes to a process may be made while a process is taking place), or after measurements have been made (so that changes can be made subsequently).

The present invention also concerns a method for optimizing a process in which a load sensing arrangement comprising at least one strain gauge at a strain gauge location, the at least one strain gauge being used to measure the load on a bearing component. The method comprises the step of receiving data and determining a variable indicative of the influence of said data on measurements made by said at least one strain gauge in order to determine the amount of temperature compensation required to compensate for the influence of temperature on measurements made by the at least one strain gauge.

According to an embodiment of the invention the method comprises the steps of measuring at least one temperature at at least one location remote from the at least one strain gauge, and using the measured temperature data to determine the variable.

Additionally, or alternatively the method comprises the step of determining the variable using process parameter data.

According to another embodiment of the invention the method comprises the step of using the measured temperature data and/or process parameter data in a temperature compensation algorithm that determines the amount of temperature compensation required.

According to a further embodiment of the invention the method is used to monitor and/or optimize at least one of the following: a continuous casting process, a mining process or any process in which the bearing component is at least temporarily exposed to temperatures over 50-60°C when in use.

The present invention also concerns a computer program product that comprises a computer program containing computer program code means arranged to cause a computer or a processor to execute the steps of a method according to any of the embodiments of the invention, stored on a computer-readable medium or a carrier wave.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be further explained by means of non-limiting examples with reference to the appended schematic figures where;

Figure 1 shows a continuous casting apparatus,

Figures 2 & 3 shows roll lines of a continuous casting apparatus,

Figure 4 shows a load sensing arrangement according to an embodiment of the invention, and

Figure 5 shows the steps of a method according to an embodiment of the invention.

It should be noted that the drawings have not been drawn to scale and that the dimensions of certain features have been exaggerated for the sake of clarity.

DETAILED DESCRIPTION OF EMBODIMENTS

Any number of load sensing arrangements according to the present invention may be used to monitor and/or optimize a process in which a bearing component is used. A load sensing arrangement comprising a plurality of strain gauges, such as 20 to 50 strain gauges may for example be used to monitor and/or optimize a continuous casting process.

Figure 1 shows a continuous casting process in which molten metal 10 is tapped into a ladle 12. After undergoing any ladle treatments, such as alloying and degassing, and arriving at the correct temperature, molten metal 10 from the ladle 12 is transferred via a refractory shroud to a tundish 14. Metal is drained from the tundish 14 into the top of an open-base mould 16. The mould 16 is water-cooled to solidify the molten metal directly in contact with it. In the mould 16, a thin shell of metal next to the mould walls solidifies before the middle section, now called a strand, exits the base of the mould 16 into a cooling chamber 18; the bulk of metal within the walls of the strand is still molten. The strand is supported by closely spaced, water cooled roll lines 20 which act to support the walls of the strand against the ferrostatic pressure of the still-solidifying liquid within the strand.

The surface temperature of a strand may be 800-900°C as it passes over the roll lines 20, which will adversely affect the accuracy of measurements made by a strain gauge measuring the load on a bearing component of the roll lines 20. An inaccurate strain measurement may namely be made just after a strand has passed over a bearing component of a roll line 20.

To increase the rate of solidification, the strand is sprayed with large amounts of water as it passes through the cooling chamber 18. Final solidification of the strand may take place after the strand has exited the cooling chamber 18.

In the illustrated embodiment the strand exits the mould 16 vertically (or on a near vertical curved path) and as it travels through the cooling chamber 18, the roll lines 20 gradually curve the strand towards the horizontal. (In a vertical casting machine, the strand stays

vertical as it passes through the cooling chamber 18). After exiting the cooling chamber 18, the strand passes through straightening roll lines (if cast on other than a vertical machine) and withdrawal roll lines. Finally, the strand is cut into predetermined lengths by mechanical shears or by travelling oxyacetylene torches 22 and either taken to a stockpile or the next forming process. In many cases the strand may continue through additional roll lines and other mechanisms which might flatten, roll or extrude the metal into its final shape.

Figures 2 and 3 shows examples of roll lines 20 for continuous casting apparatus in which load sensing arrangements according to the present invention may be used. The load sensing arrangement according to the present invention may however be used to monitor and/or optimize a bearing component located anywhere in a system, and/or used in any process.

Figure 2 shows a roll line 20 that comprises a shaft 24 supported by bearings housed in bearing housings 26, and three roll mantles 28 for transporting a metal strand along the outer surface 28a thereof, which are arranged to be fixedly supported on the shaft 24.

Figure 3 shows a roll line 20 according to another embodiment of the present invention. The roll line 20 comprises a non-rotating shaft 24 and three roll mantles 28 for transporting a metal strand along the outer surface 28a thereof, which are arranged to be rotatably supported on the shaft 24 by means of bearings 26 located inside the roll mantles 28.

Figure 4 shows a load sensing arrangement according to an embodiment of the present invention. The load sensing arrangement comprises a strain gauge 30 configured to measure the load on a bearing component, such as a bearing housing 26 at least temporarily subjected to a temperature gradient during its use, and temperature compensation means 32 arranged to compensate for the influence of temperature on measurements made by the strain gauge 30. The temperature compensation means 32 is configured to receive data and determine a variable indicative of the influence of said data on measurements made by the at least one strain gauge 30.

The temperature compensation means 32 comprises a plurality of temperature sensors 36, 38 arranged for example at the top of the bearing housing 26 and/or behind the raceway of one of the bearing's races. The temperature sensors 36, 38 are arranged to

measure the temperature at a location remote from the strain gauge 30 and send this information to the temperature compensation means 32 which then uses that measured temperature data to determine said variable.

Alternatively, or additionally, the temperature compensation means 32 is arranged to receive data concerning any number of process parameters and determine the variable using that process parameter data, namely any suitable data concerning a process, such as continuous casting, a mining process or any process in which the bearing component is at least temporarily exposed to temperatures over 50-60°C when in use. The load sensing arrangement may comprise a memory 40 and such process parameter data may be stored in a memory 40. The process parameter data may be collected and/or determined in real time or it may have been measured and/or determined during one or more previously run processes to be used in subsequent processes.

According to an embodiment of the invention measured temperature data from remote temperature sensors 36, 28 and/or process parameter data is used in a temperature compensation algorithm that determines the amount of temperature compensation required.

The components of the load sensing arrangement according to the present invention, namely the at least one strain gauge 30, the at least one remote temperature sensor 36, 38, the memory 40 and the temperature compensation means 32 may be connected wirelessly and/or in a wired manner. Furthermore, the components of the load sensing arrangement according to the present invention need not necessarily be separate components. The temperature compensation means 32 may for example be integrally formed with the memory 40 for example and/or at least one of the remote temperature sensor 36, 38. One or more parts of the load sensing arrangement according to the present invention may be integrally formed in a bearing component 26.

The bearing component may for example be any part of a bearing that is subjected to a load during its use, such as a bearing housing or a raceway. The bearing component may be at least one part of a roller, plain bearing, bushing, journal bearing, sleeve bearing, slewing bearing or a rolling element bearing, such as a ball bearing or roller bearing, a cylindrical roller bearing, a spherical roller bearing, a toroidal roller bearing, a taper roller bearing, a conical roller bearing or a needle roller bearing.

The temperature compensation means 32 may be located in the vicinity of one or more bearing components 26 that are to be monitored or remotely thereto. The temperature compensation means 32 may be constituted by a computer program product comprising a computer program containing computer program code means arranged to cause a computer or a processor to execute the steps of a method according to any of the embodiments of the present invention. It should be noted that a single temperature compensation means 32 may be used to make the required temperature compensation for any number of strain gauges 30 used in any number of systems or processes in which at least one bearing component 26 is used.

Figure 5 shows the steps of a method for optimizing a process in which a load sensing arrangement comprising at least one strain gauge 30 is used to measure the load on a bearing component 26. The method comprises the step of measuring the load on a bearing using a strain gauge, receiving data and determining a variable indicative of the influence of said data on measurements made by said at least one strain gauge 30 and making the required temperature compensation. It should be noted that the load on a bearing component 26 may optionally be measured only after a variable indicative of the temperature at the strain gauge location 34 has been determined.

According to an embodiment of the invention the method comprises the steps of measuring at least one temperature at at least one location remote from the strain gauge 30, and using the measured temperature data to determine the a variable indicative of the influence of said data on measurements made by said at least one strain gauge 30. Alternatively, the method comprises the step of determining the variable using process parameter data. Measured temperature data and/or process parameter data may be used in a temperature compensation algorithm that determines the amount of temperature compensation required.

Further modifications of the invention within the scope of the claims would be apparent to a skilled person.

CLAIMS

1. Load sensing arrangement comprising at least one strain gauge (30) at a strain gauge location (34), the at least one strain gauge (30) being configured to measure the load on a bearing component (26), whereby said load sensing arrangement comprises temperature compensation means (32) arranged to compensate for the influence of temperature on measurements made by said at least one strain gauge (30), **characterized in that** said temperature compensation means (32) is configured to receive data and to determine a variable indicative of the influence of said data on measurements made by said at least one strain gauge (30).

2. Load sensing arrangement according to claim 1, **characterized in that** said temperature compensation means (32) comprises at least one temperature sensor (36, 38) that is arranged to measure at least one temperature at at least one location remote from said at least one strain gauge (30) and use the measured data to determine said variable indicative of the influence of said at least one measured temperature on measurements made by said at least one strain gauge (30).

3. Load sensing arrangement according to claim 1 or 2, **characterized in that** said at least one strain gauge (30) is configured to measure the load on a bearing component (26) of at least one of the following: continuous casting apparatus, apparatus used in mining, or an application in which said bearing component (26) is at least temporarily exposed to temperatures over 50-60°C when in use.

4. Load sensing arrangement according to any of the preceding claims, **characterized in that** said temperature compensation means (32) is arranged to determine said variable using process parameter data.

5. Load sensing arrangement according to claim 2 or 3, **characterized in that** said measured temperature data and/or process parameter data is used in a temperature compensation algorithm that determines the amount of temperature compensation required.

6. Method for optimizing a process in which a load sensing arrangement comprising at least one strain gauge (30) at a strain gauge location (34), the at least one strain gauge (30) being used to measure the load on a bearing component (26), **characterized in that** the method comprises the step of receiving data and determining a variable indicative of the influence of said data on measurements made by said at least one strain gauge (30).

7. Method according to claim 6, **characterized in that** it comprises the steps of measuring at least one temperature at at least one location remote from said at least one strain gauge (30), and using the measured temperature data to determine said variable indicative of the influence of said at least one temperature on measurements made by said at least one strain gauge (30).

8. Method according to any of claim 6 or 7, **characterized in that** it is used to monitor and/or optimize at least one of the following: a continuous casting process, a mining process or any process in which said bearing component (26) is at least temporarily exposed to temperatures over 50-60°C when in use.

9. Method according to any of claims 6-8, **characterized in that** it comprises the step of determining said variable using process parameter data.

10. Method according to claim 7 or 8, **characterized in that** it comprises the step of using said measured temperature data and/or process parameter data in a temperature compensation algorithm that determines the amount of temperature compensation required.

11. Computer program product, **wherein** it comprises a computer program containing computer program code means arranged to cause a computer or a processor to execute the steps of a method according to any of claims 6-10, stored on a computer-readable medium or a carrier wave.

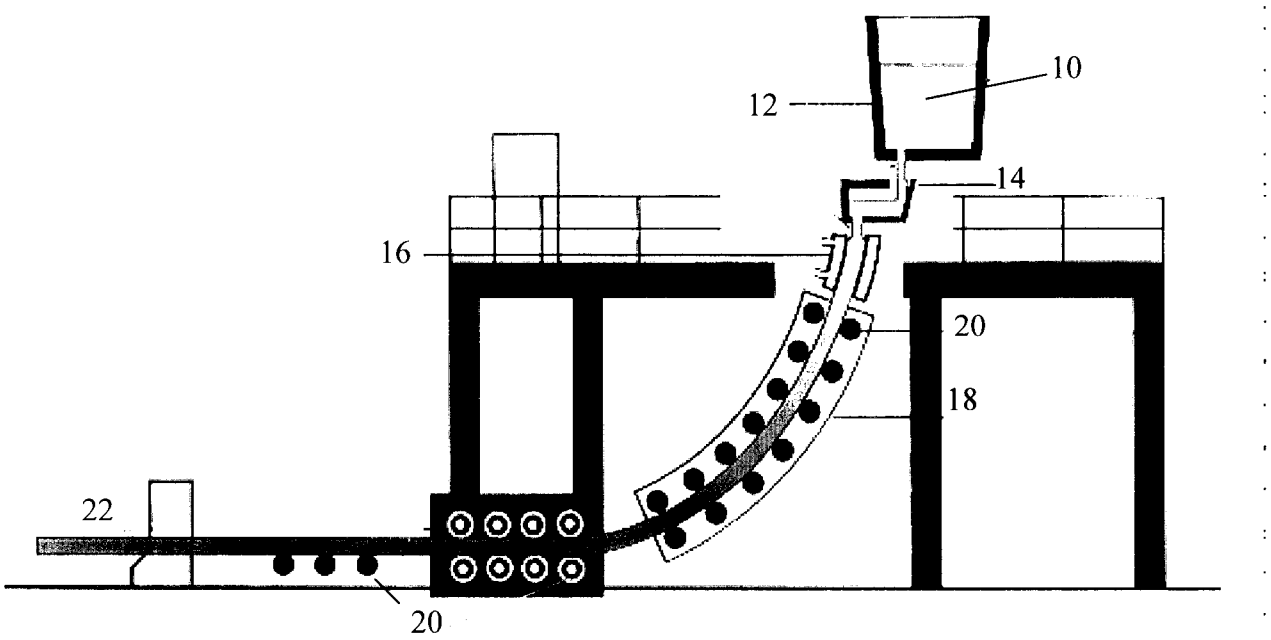


Fig. 1

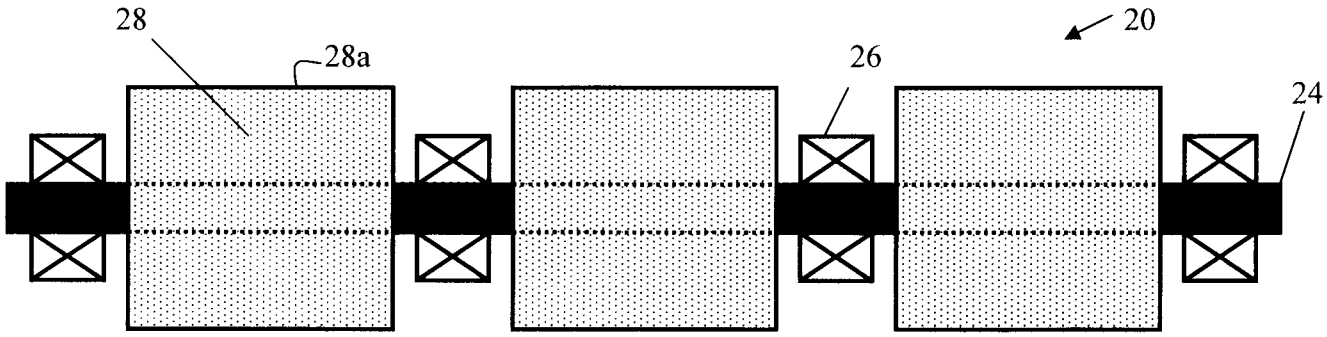


Fig. 2

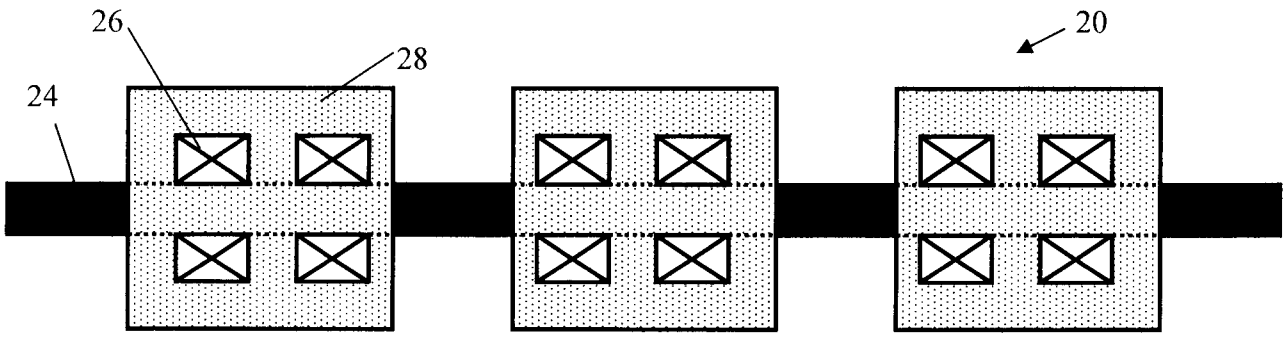


Fig. 3

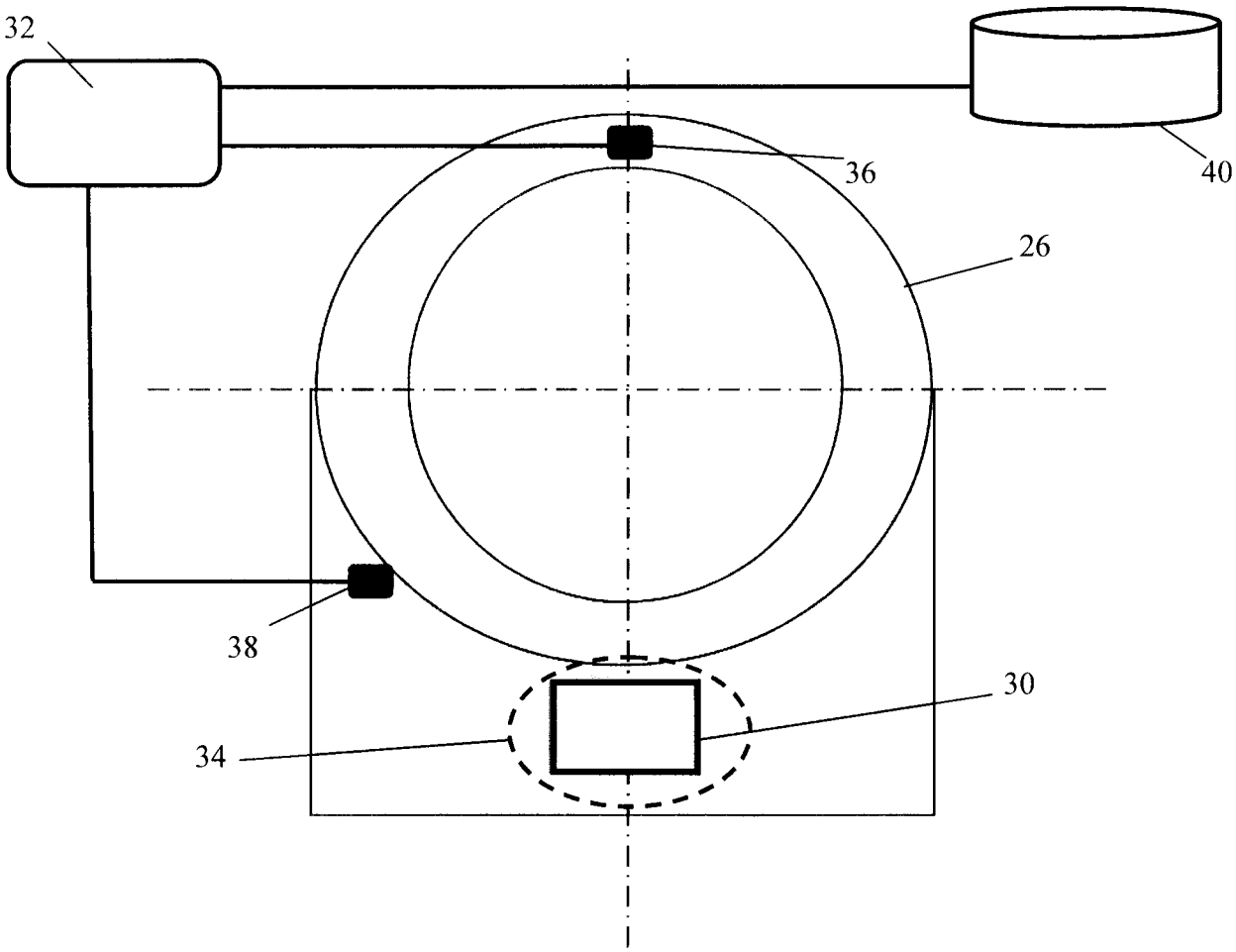

32
36
40
26
38
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34

Fig. 4

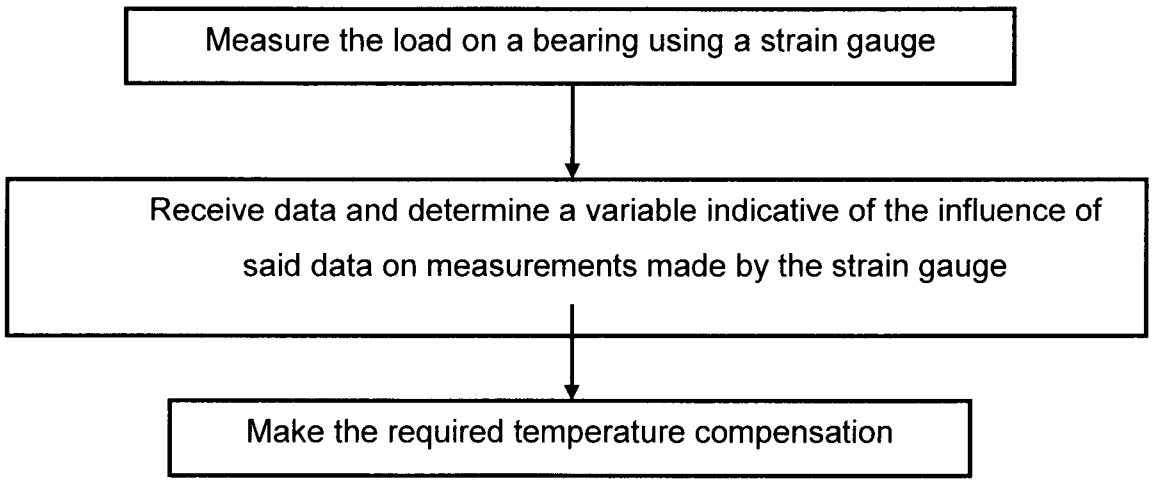

Measure the load on a bearing using a strain gauge
Receive data and determine a variable indicative of the influence of said data on measurements made by the strain gauge
Make the required temperature compensation

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/000104

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: G01L, G01M

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

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, 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	WO 0177634 A2 (TIMKEN CO), 18 October 2001 (2001-10-18); abstract; page 11, line 3 - line 20; figure 3 --	1-11
X	EP 1930708 A1 (NTN TOYO BEARING CO LTD), 11 June 2008 (2008-06-11); abstract; paragraphs [0031], [0032], [0093]-[0097]; figure 25 --	1-11
A	US 5140849 A (FUJITA KIYOSHI ET AL), 25 August 1992 (1992-08-25); abstract; column 4, line 33 - line 51; column 5, line 29 - line 36; figures 1-11 --	1-11

☒ 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	Date of mailing of the international search report
24-10-2013	24-10-2013

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2013/000104

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 4118933 A (COLEMAN WILLIAM H ET AL), 10 October 1978 (1978-10-10); abstract; figures 1-3	1-11

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International application No.
PCT/SE2013/000104

Continuation of: second sheet

International Patent Classification (IPC)

G01L 5/00 (2006.01)
G01M 13/04 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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