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(54) Benævnelse: **Apparat til måling af deformationer i et rotorblad til et vindkraftanlæg**

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The invention concerns a device for detecting deformations of a rotor blade of a wind turbine according to Claim 1.

Rotor blades of wind turbines are subjected to diverse forces, which naturally result in deformations of the rotor blades and stimulate the rotor blades to oscillate. The weight alone of a rotating rotor blade produces a periodic deformation of the rotor blade involved. Said deformations are overlaid by further deformations, which inter alia result from the aerodynamic loads. For example, the aerodynamic loads depend on the altitude profile of the wind speed in combination with gusts of wind or wind turbulences. Likewise, with each revolution a pulsating force is introduced into the rotor blade by the reduction of wind speed in front of the tower. The extent of the deformations of rotor blades of a wind turbine can only be predicted with difficulty in any case, for which reason efforts have been made to record said deformations as actual values.

Regarding the prediction of damage due to fatigue, it can be advantageous to produce information looking back at an accumulated load on the rotor blade at a desired point in time based on the measured deformations or loadings. The availability of such load values is thus important in relation to short-term maximum loads or damage due to fatigue that is to be expected. Moreover, with knowledge of the actual deformations or actual loads, control of the wind turbine can be optimised, for example by adjusting the pitch angle.

PRIOR ART

From DE 19847982 A1, a device for detecting the oscillations of a rotor blade of a wind turbine is known, by which a deformation of the rotor blade can be determined using a distance sensor as a linear element.

From CH 127 311 A, a device for detecting deformations of an object is known, comprising an angle measuring device and an arm. The angle measuring device comprises a first component assembly and a second component assembly, wherein the first component assembly is disposed so as to be rotatable about an axis relative to the second component assembly. The relative angular position between the first component assembly and the second component assembly can be measured by means of the angle measuring device. The second component assembly comprises an attachment point that is designed so as to be connectable to the object. The arm comprises a connecting point that is disposed at a distance from the attachment point of the second component assembly and that is designed such that the arm can be connected to the object at said connecting point, wherein the distance is oriented orthogonally to the axis. The arm is mechanically coupled to the first component assembly at a radial distance, so that when the distance changes a relative pivotal movement can be produced between the first component assembly and the second component assembly.

SUMMARY OF THE INVENTION

It is the object of the invention to provide a device for detecting deformations of a rotor blade of a wind turbine that is robust, reliable and operates with high accuracy. Likewise, a rotor blade is provided by the invention, the deformations of which can be determined robustly, reliably and with high accuracy.

This object is achieved according to the invention by then device with the features of Claim 1.

Therefore, the device for detecting deformations of a rotor blade of a wind turbine comprises an angle measuring device, which comprises a first component assembly and a second component assembly, and an arm. The first component assembly of the angle measuring device is disposed so as to be pivotable about an axis relative to the second component assembly, wherein the relative angular position between the first component assembly and the second component assembly can be measured by the angle measuring device. The second component assembly of the angle measuring device is designed so as to be fixedly connectable to the rotor blade. The arm comprises a (first) connecting point that is designed such that the arm can be connected to the rotor blade at said connecting point. Furthermore, the connecting point is disposed at a distance from the attachment point of the second component assembly, wherein the distance is oriented orthogonally to the axis. The arm is mechanically coupled to the first component assembly at a radial distance from the axis, so that when the distance between the connecting point and the attachment point changes, a relative pivotal movement can be produced between the first component assembly and the second component assembly.

Even if a connecting line between the connecting point and the attachment point does not run strictly orthogonally to the axis, a distance orthogonal to the axis can still be determined if the connecting line between the connecting point and the attachment point is not exactly parallel to the axis. Accordingly, it is to be understood in relation to the formulation by which the distance is orthogonal to the axis, that a connecting line between the connecting point and the attachment point has a directional component (corresponding to the distance perpendicular to the axial direction), that is oriented orthogonally to the axis.

Advantageously, the arm is made of a material containing plastic. The plastic can in particular be fibre-reinforced, for example by glass fibres and/or carbon fibres.

In a farther embodiment of the invention, the first component assembly is linked to the arm, in particular by means of a flexible component that can be designed as a solid body link or as a one-piece link.

Furthermore, the (first) connecting point of the arm can be designed as an adhesive surface.

Advantageously, the angle measuring device comprises a roller bearing or a plurality of roller bearings for pivotable support of the first component assembly relative to the second component assembly. A bearing of this type is also used to guide the arm. Alternatively, a slide bearing or a solid body link can also be used for pivotable support of the first component assembly relative to the second component assembly.

In an advantageous design, the second component assembly of the angle measuring device comprises an attachment point that is designed so as to be non-displaceably connectable to the inside of the rotor blade, in particular in the region of the root of the rotor blade.

According to the invention, the angle measuring device comprises a measuring scale and an element for scanning the measuring scale. The measuring scale can be of an annular design and from the geometrical viewpoint is a hollow cylinder with peripheral casing sides. The casing sides can comprise a small height, so that the measuring scale is designed as an annular disc with annular, mutually parallel end faces, which can also be referred to as bottom or top surfaces. The angular scale or angle encoding can be applied to one of the end faces.

Especially when the measuring scale is designed so that the sides of the casing have a relatively greater height, i.e. in the case of a drum-shaped measuring scale, the angular scale can be applied to the side of the casing. The measuring scale can however also be designed as a measuring band, which is attached to the side of the casing of a cylindrical body on the outside thereof or on the inside thereof for example.

In addition, the measuring scale can be designed so as to only have a scale over a limited angular range, i.e. to not extend over 360°, but only to have an angle segment as the measurement range. The angular extent of the measuring scale can be matched to the maximum measurement range or pivot angle.

Advantageously, the element for sampling the measuring scale is designed to be photosensitive or light sensitive. Accordingly, sampling of this type is thus based on an optical principle.

Alternatively, the sampling can be based on an inductive or magnetic principle.

Furthermore, the invention comprises a rotor blade of a wind turbine with a device for detecting deformations. For its part, said device comprises an angle measuring device and an arm. In this case, the angle measuring device comprises a first component assembly and a second component assembly. The first component assembly is disposed so as to be pivotable about an axis relative to the second component assembly, wherein the relative angular position between the first component assembly and the second component assembly can be measured by the angle measuring device. The second component assembly comprises an attachment point that is connected to the rotor blade. For its part, the arm comprises a (first) connecting point that is connected to the rotor blade, wherein the connecting point is disposed at a distance from the attachment point of the second component assembly, wherein the distance is oriented orthogonally to the axis. The arm is mechanically coupled to the first component assembly at a radial distance, so that when the distance between the connecting point and the attachment point changes, a relative pivotal movement can be produced between the first component assembly and the second component assembly.

In a further design of the rotor blade, the arm is oriented in the longitudinal direction of the rotor blade, wherein the rotor blade (at least in the region of the root thereof) comprises a central longitudinal axis extending in the longitudinal direction. The (pivot) axis of the angle measuring device is essentially oriented orthogonally to the longitudinal direction of the rotor blade. In this case, the angle measuring device can be disposed so that the axis is oriented essentially parallel to the inner wall of the rotor blade, or can be disposed so that the axis is oriented essentially orthogonally to the inner wall of the rotor blade. Therefore, the arm is oriented in the longitudinal direction of the rotor blade and the (pivot) axis of the angle measuring device is oriented tangentially or radially relative to the longitudinal axis of the rotor blade.

The tangential or radial orientation relates in particular to an arc of a circle, the centre point of which comes to lie on the longitudinal axis of the rotor blade.

The angle measuring device can in particular provide digital position signals and/or signals that have been produced by single or multiple differentiation of the position signals against time. The transmission of the signals involved can be carried out purely digitally and serially, so that relatively simple processing of the signals is possible, for example for incorporation in highly dynamic control.

The angle measuring device advantageously comprises a measuring scale with absolute encoding, so that the relative angular position between the first component assembly and the second component assembly can be measured as an absolute variable by the angle measuring device (in contrast to an incremental measurement). This enables the absolute deformation of the rotor blade to be measured at any points in time. This is in particular advantageous for testing settling processes in the structure of the rotor blade. For testing of this type, the rotor blade involved is driven into a horizontal position outside of the actual operation. Then the deformation is measured in said position. If an angle measuring device operating in an absolute manner is used, the absolute measurement value can be directly compared with preceding (also absolute) measurements.

Furthermore, the device for detecting deformations can be mounted at the root of the rotor blade, i.e. close to the joint of the rotor blade with the hub of the wind turbine. The second component assembly can thus be attached to a hub in the region of the blade joint. Alternatively, the attachment point can be disposed on an inner surface of the hub of the wind turbine involved.

In a farther embodiment of the invention, the arm or the material from which the arm is manufactured comprises the same coefficient of thermal expansion as the rotor blade or the material thereof.

Advantageously, the rotor blade comprises a plurality of devices for detecting deformations. Using the signals of the individual devices that are produced thereby, a spatial deformation of the rotor blade can be determined after combining or processing the respective signals.

Further advantageous designs of the invention are to be found in the dependent claims. Further features and advantages of the invention are made clear in the following description of an exemplary embodiment using the figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a side view of a device for detecting deformations of a rotor blade,

Figure 2 shows a perspective view of the device for detecting deformations of a rotor blade,

Figure 3 shows a sectional view of the device for detecting deformations of a rotor blade,

Figure 4 shows a rear view of the device for detecting deformations of a rotor blade,

Figure 5 shows a schematic view of a rotor blade with devices for detecting deformations.

DESCRIPTION OF THE EMBODIMENTS

A device for detecting deformations of a rotor blade 3 of a wind turbine is shown in Figures 1 and 2. In the exemplary embodiment presented, the corresponding rotor blade 3 is a component of a wind turbine with a horizontal axle, which in particular comprises a total of three rotor blades 3. The device involved for detecting deformations of the rotor blade 3 comprises an angle measuring device 1 and an arm 2.

The angle measuring device 1 shown in particular in Figures 3 and 4 comprises a first component assembly 1.1 and a second component assembly 1.2. The first component assembly 1.1 comprises a shaft 1.11 with a part to which a measuring scale 1.14 is fixedly and centrally connected relative to an axis A, for example with glue, and only with small tolerance deviations. The axis A extends in the y-direction. In the proposed exemplary embodiment, the measuring scale 1.14 consists of glass and is of annular design. It naturally comprises two end faces, wherein an angular scale is attached to one of the end faces. The angular scale can for example be designed as an incremental division with radially oriented scale marks, but wherein additionally or alternatively an absolute code can also be provided.

A drive element 1.12 (see also Figures 1 and 2) is rotationally fixedly attached to the shaft 1.11 by clamping, so that movement of the drive element 1.12 can produce a pivotal movement of the shaft 1.11. The drive element 1.12 can be associated with the first component assembly 1.1 and comprises a machined surface and an internal thread, so that a component 1.13 can be fixed precisely thereon. The component 1.13 is used as a solid body link and is of a suitably flexible design. In particular, the component 1.13 can be designed as a small, thin-walled steel plate.

According to Figure 3, the shaft 1.11 is rotatably supported by two roller bearings 1.3 within a body 1.25 that is associated with the second component assembly 1.2. Furthermore, a light source that is not shown in the figures, which for example comprises a LED and a collimator lens, is associated with the second component assembly 1.2, so that collimated light is emitted by the light source. Said light passes through the measuring scale 1.14 or the angular scale thereof and is modulated according to the angular position between the first component assembly 1.1 and the second component assembly 1.2 or the shaft 1.11 and the body 1.25.

The modulated light is sampled by a sampling device 1.26 attached to the body 1.25. Suitable light sensitive or photosensitive detectors are disposed on the sampling device 1.26, which is embodied as a populated circuit board. Inter alia, the sampling device 1.26 also comprises electronic components for signal shaping - for example to amplify and digitise - the sampled signals provided by the detector.

A housing 1.21 is mounted around the sampling device 1.26, so that inter alia the light source, the measuring scale 1.14 and the sampling device 1.26 are protected against environmental influences. A holder 1.22 is fixed to the body 1.25. Said holder 1.22 comprises a connecting surface as an attachment point 1.23, here an adhesive surface.

An electrical connection is made between the angle measuring device 1 and downstream electronics by means of a connecting cable that is not shown in the figures and that is connected to a socket 1.24, so that electrical signals and electrical power can be transferred between the downstream electronics and the angle measuring device 1.

Thus, the relative angular position between the first component assembly 1.1 and the second component assembly 1.2 or between the shaft 1.11 and the body 1.25 can be determined by the angle measuring device 1. Angle measuring devices 1 of this type are also often referred to as rotary encoders.

Besides the angle measuring device 1, the device for detecting deformations comprises the arm 2. In the exemplary embodiment presented, said arm is made of fibreglass-reinforced plastic and comprises a first connecting point 2.1 and a second connecting point 2.2.

The first connecting point 2.1 of the arm 2 is designed as a surface, so that said surface can be glued to the rotor blade 3. As with the arm 2, the rotor blade 3 is made out of fibreglass-reinforced plastic.

In the exemplary embodiment, the second connecting point 2.2 is a stop surface on which the component 1.13 is mounted, for example by threaded connections.

During assembly of the device for detecting deformations of a rotor blade 3 of a wind turbine, the first connecting point 2.1 of the arm 2 and the attachment point 1.23 of the holder 1.22 are now glued onto the inside of the wall of the rotor blade in the region of the root of the rotor blade 3. The gaps between the attachment point 1.23 or between the connecting point 2.1 and the inside of the rotor blade 3 are therefore filled with an adhesive 4. As a result, there are non-displaceable connections between the holder 1.22 and the rotor blade 3 and between the arm 2 and the rotor blade 3. Following successful assembly, the arm 2 is oriented to extend in the x-direction, wherein the x-direction essentially corresponds to the longitudinal axis (Figure 5) of the rotor blade 3. The first connecting point is thus disposed at a distance X from the attachment point 1.23 of the second component assembly 1.2, wherein the distance X is oriented orthogonally to the axis A. The arm 2 is mechanically coupled, in particular linked, to the angle measuring device 1 at a radial distance R in relation to the axis A. This enables a relative pivotal movement to be produced between the first component assembly and the second component assembly 1.1, 1.2 by varying the distance X, for example by expansion or contraction of the rotor blade 3.

Owing to the design of the component 1.13 as a thin-walled steel plate, bending moments in the device can be reduced without adversely affecting the measurement accuracy. The component 1.13 is dimensioned such that the flexural softness thereof matches the required torque or section modulus of the angle measuring device.

In order to be able to give an indication of the deformation of the rotor blade 3 in all dimensions, it is advantageous if a plurality of, for example four, devices of this type for detecting deformations are mounted in the root of the rotor blade 3, as shown in Figure 5. The four devices for detecting deformations, preferably in the four main bending directions, are offset over the periphery of the root of a rotor blade 3 by 90° in each case.

During operation of the wind turbine, the rotor blades 3 are deformed by the own weight thereof and by aerodynamic loads. In particular, the loads result in expansion or compression of the rotor blade 3 in the x-direction. Accordingly, the distance between the attachment point 1.23 of the holder 1.22 and the first connecting point 2.1 of the arm 2 varies. If the distance X is about 500 mm, the distance between the attachment point 1.23 of the holder 1.22 and the first connecting point 2.1 changes by about 0.5 mm for customary loads. In the case of dimensioning of R at about 30 mm, this results in a pivotal movement of approximately 1° between the first component assembly 1.1 and the second component assembly 1.2. The angle measuring device 1 described above, which operates according to a precise optical principle, has for example a resolution of 25 bits for one revolution (360°), and with the mentioned geometric boundary conditions this corresponds to a resolution of 5.6 nm in relation to the changes in the length of the distance X between the attachment point 1.23 of the holder 1.22 and the first connecting point 2.1 of the arm 2.

The device for detecting deformations of a rotor blade 3 in a wind turbine is naturally subjected to large temperature fluctuations. Exceedingly high measurement accuracies can still be achieved by the device outlined above for detecting deformations, even under said adverse ambient conditions. This is because owing to detecting angular positions, the thermal expansion of the measuring scale 1.14 hardly has any effect (the distances between the scale markers and the width thereof vary with the temperature, but not the angular position). On the other hand, the arm 2 and the rotor blade 3 are made of the same material, so that both have the same thermal expansion behaviour. Finally, owing to the pot-shaped electrically conductive housing 1.21, optimal protection is guaranteed against overvoltages, for example during thunderstorms, especially for the sampling device 1.26 and associated electronics.

The signals that can be output via the socket 1.24 are advantageously fully digital, so that the aforementioned downstream electronics can process the signals of all devices for detecting deformations of the rotor blades without further digitisation. On the one hand, this guarantees signal transmission that is proof against external interference, and on the other hand the signals can be processed relatively simply, so that the measured deformations can be used in a control circuit, for example for (separate) control of the pitch angles for any rotor blade 3.

Patentkrav

1. Apparat til måling af deformationer i et rotorblad (3) til et vindkraftanlæg, og som omfatter:

- en vinkelmåleindretning (1), som har en første konstruktionsdel-gruppe (1.1, 1.2), hvor
den første konstruktionsdel-gruppe (1.1) er indrettet drejeligt i forhold til en anden konstruktionsdel-gruppe (1.2) omkring en akse (A), og hvor man ved hjælp af vinkelmåleindretningen, som har en skala (1.14) og et organ til aftastning (1.26) af skalaen (1.14), kan måle den relative vinkelposition mellem den første og anden bygningskonstruktionsdel-gruppe (1.1, 1.2), og hvor den anden konstruktionsdel-gruppe (1.2) har et fastgørelsessted (1.23), som er således udformet, at det kan forbindes med rotorbladet (3), og
- en arm (2), som har et forbindelsessted (2.1), som er således udformet, at armen (2) ved nævnte forbindelsessted kan forbindes med rotorbladet (3), idet forbindelsesstedet (2.1) er indrettet i en afstand (X) fra den anden konstruktionsdel-gruppes (1.2) fastgørelsessted (1.23), og hvor afstanden (X) er orienteret vinkelret på en akse (A), og hvor armen (2) i en radial afstand (R) er mekanisk koblet til den første konstruktionsdel-gruppe (1.1), så at man ved ændring af afstanden (X) kan tilvejebringe en relativ drejebevægelse mellem den første og anden konstruktionsdel-gruppe (1.1, 1.2).

2. Apparat ifølge krav 1, hvor armen (2) er fremstillet af et materiale, som omfatter plast.

3. Apparat ifølge krav 2, hvor plasten er fiberforstærket.

4. Apparat ifølge et af de foregående krav, hvor den første konstruktionsdel-gruppe (1.1) ved hjælp af led er forbundet med armen (2), især ved hjælp af et ret stift konstruktionsorgan (1.13).

5. Apparat ifølge et af de foregående krav, hvor forbindelsesstedet (2.1) er udformet som en klæbeflade.

6. Apparat ifølge et af de foregående krav, hvor vinkelmåleindretningen har et vuggeleje (1.3) til drejelig lejring af den første konstruktionsdel-gruppe (1.1) i forhold til den anden konstruktionsdel-gruppe (1.2).

7. Apparat ifølge et af de foregående krav, hvor organet (1.21) til aftastning af skalaen (1.11) er fotofølsom.

8. Rotorblad (3) til et vindkraftanlæg med et apparat til måling af deformationer ifølge krav 1, hvor et fastgørelsessted (1.23) er forbundet med rotorbladet (3), og forbindelsesstedet (2.1) er forbundet med rotorbladet (3).

9. Rotorblad (3) ifølge krav 8, hvor armen (2) er orienteret i rotorbladets (3) længderetning (x).

10. Rotorblad (3) ifølge krav 8 eller 9, hvor fastgørelsesstedet (1.23) vedrørende den anden konstruktionsdel-gruppe (1.2) er forbundet med indersiden af rotorbladet (3).

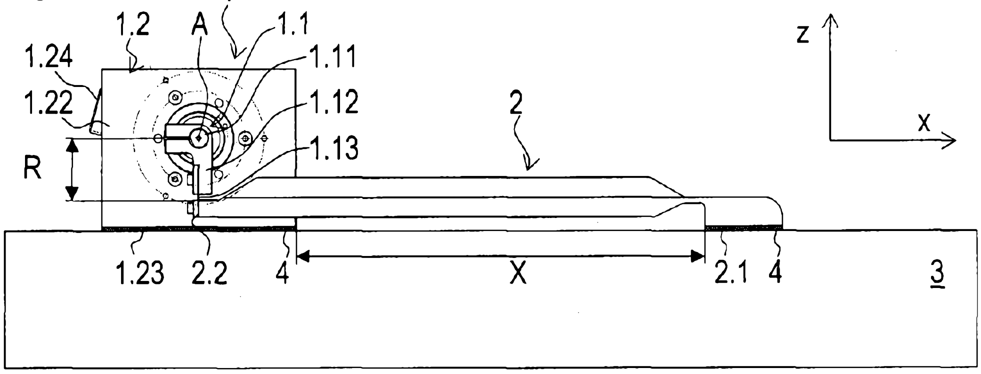
11. Rotorblad (3) ifølge krav 10, hvor armen (2) er orienteret i rotorbladets længderetning (x), og at aksen (A) i forhold til rotorbladets (3) længdeakse (ξ) er rettet tangentielt eller radialt.

12. Rotorblad (3) ifølge et af kravene 8 til 11, hvor apparatet til måling af deformationer er monteret ved roden af rotorbladet (3).

13. Rotorblad (3) ifølge et af kravene 8 til 12, hvor armen (2) har samme varmeudvidelseskoefficient som rotorbladet (3).

14. Rotorblad (3) ifølge et af kravene 8 til 13, hvor rotorbladet (3) har flere apparater til måling af deformationer.

Fig. 1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1.11
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4
X
2.1
4
3

Fig. 2

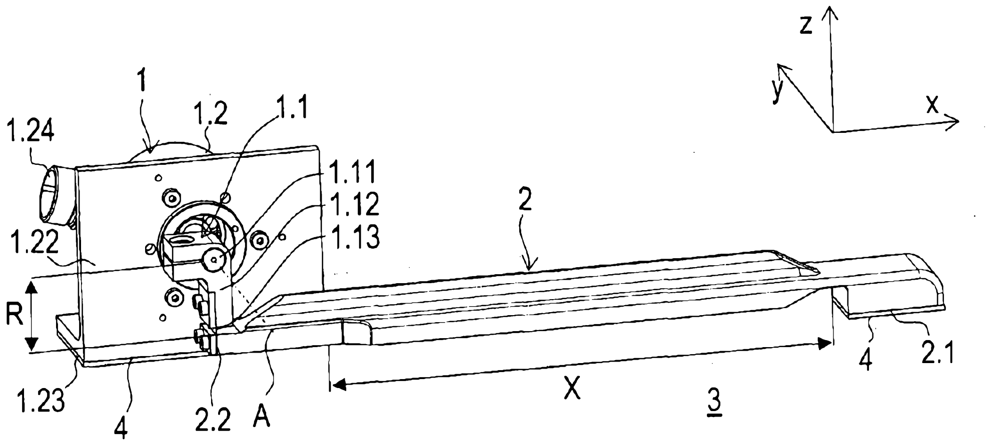
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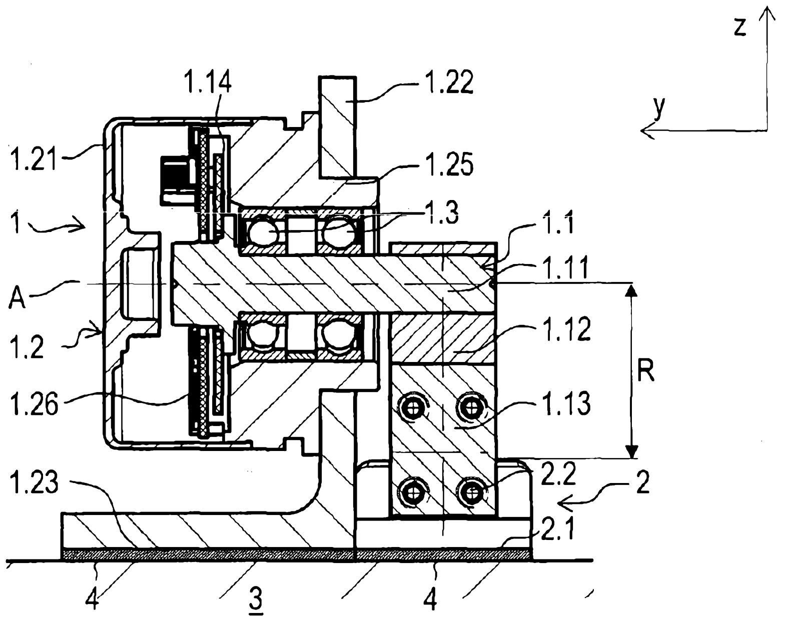
Fig. 3



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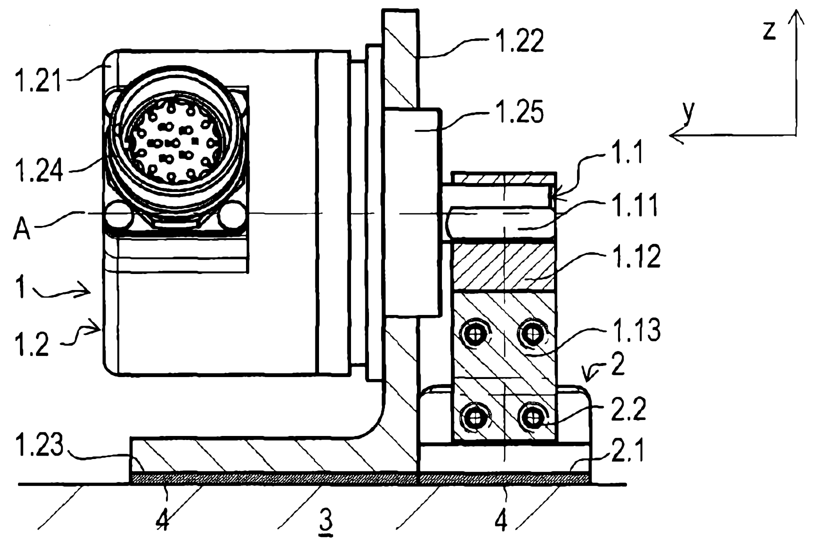
4

Fig. 4



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3
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Fig. 5