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(54) Benævnelse: **Vindenergianlæg med mindst en elastisk deformerbar konstruktionsdel og fremgangsmåde til bestemmelse af begyndelsen af en slidbetinget restudnyttelsesperiode for konstruktionsdelen i vindenergianlægget**

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[0001] The invention relates to a wind turbine with a rotor and with at least one elastically deformable component as a structural part and/or bearing part according to the preamble of claim 1 and a method for determining the beginning of a wear-related remaining life of a component in a wind turbine according to the preamble of claim 10.

[0002] Wind energy is a regenerative energy source available worldwide which is being used with increasing tendency for power generation by wind turbines on land (onshore) and at sea (offshore wind parks). Wind turbines already have a high status of technical development, wherein their safe operation with the lowest possible operating and maintenance costs is a continuous challenge. A problem here is the estimation of the time of use of deformable components and their replacement, since these are usually only accessible with difficulty and/or cannot be examined by appearance.

[0003] In wind turbines, various deformation forces act on elastically deformable components as structural parts and/or bearing parts during operation depending on changing wind conditions, which forces ultimately lead to component wear which limits the time of use of the component. Such elastically deformable components are, in particular, rubber-metal bearings as shaft bearings and/or generator bearings and/or transmission bearings and/or elastic couplings and/or a nacelle mounting and/or components thereof. Furthermore, these are structural parts made of plastic, in particular fibre-reinforced materials, for example, rotor blades.

[0004] The term used “rubber-metal bearing” is, as is usual in technical circles, to be understood generally and interpreted broadly, wherein “rubber” stands as a synonym for “elastomer material” and “metal” for a deformation-resistant bearing component, which in particular can consist of plastic.

[0005] Such rubber-metal bearings and/or plastic parts, in particular fibre composite parts, when designed correctly, are known to be reliable over a long time of use even under high oscillating loads and in principle free from wear. A criterion for the function of such a component is the deformation under the action of wind or the corresponding component stiffness.

[0006] The time of use for sample components and for control components of one batch is measured in a known manner on a test rig under clearly defined conditions. To this end, for example, a rubber-metal bearing is exposed to oscillating loads. The load change or repeating load blocks are counted and at the same time force and deformation are measured, wherein one of the two values is predefined. A diagram is produced from this as a measurement curve in which a decreasing stiffness can be identified over the number of load changes. The number of load changes can be interpreted directly as the time of use. In each case, in the course of the time of use, an increase in the deformation according to a decrease in the stiffness can be identified from such a diagram in characteristic three stages. In the first stage, the stiffness decreases very rapidly, for example, by about 30%, which is designated as flowing and setting. Then, over a comparatively very long time of use, only a very small decrease in stiffness is measured according to a plateau behaviour with linear and/or slight decrease in stiffness. This is followed by a measurable comparatively rapid progressive decrease in the stiffness, which marks the near end of the component function with a possible failure and therefore the end of the time of use.

[0007] The reason for this measurable behaviour in particular of a rubber-metal bearing lies in that under permanent high oscillating loads caused by applied force moments or by forced deformations, molecular chains are broken, which then can no longer regenerate as a result of the applied alternating loads. In particular, in the third stage these processes increase and result in optically identifiable cracks and damage, which with a rapid decrease in component stiffness lead to an incipient end of the usage function and ultimately to a failure. Starting from measurements of the time of use on a test rig, a time of use for series parts in the installed state is then estimated and specified with safety margins for production-dependent tolerances and differing real component loads. Usual typical times of use according to the first and second stage of the above-mentioned diagram lie in the order of magnitude of 6 to 10 years. When the third diagram stage is reached, a rubber-metal bearing must certainly be replaced promptly but can still be further used over several weeks, possibly months until it fails completely.

[0008] A plastic component, in particular a fibre composite component in which the fibre composite loosens and disintegrates as a result of the oscillating loads and forced deformations usually also behaves similarly to the stiffness profile explained hereinbefore in connection with a rubber-metal bearing under corresponding loads.

[0009] In many applications of such components, the incipient end of the time of use according to the third diagram stage can be identified relatively easily, for example, by a changed noise evolution or in the case of a vehicle, by a changed driving behaviour. In easily accessible installation situations, an incipient damage according to the third diagram stage can possibly also be identified optically. However, since this is not usually possible in wind turbines, damage to a component can result in a safety risk and/or in expensive subsequent damage and operating failures.

Specifically for this reason, where possible relevant components are conventionally tested in advance and using measured load data, a maximum run time is specified after which, taking into account a normal scatter and using safety margins, they are usually replaced long before a possible lifetime, long before any damage is far advanced. A further development of this principle is known from US 2011/0125419. Disadvantageously a wind turbine must be put out of operation for such a preventative replacement of a component at regular maintenance intervals. In order to eliminate any safety risk and subsequent damage, a component must be replaced significantly before an average possible time of use. This results in high outage, component and maintenance costs which were not yet required due to the current and still reliable component state. Since usually a plurality of such components, for example, rubber-metal bearings are installed in wind turbine, the costs are multiplied accordingly.

It is the object of the invention to determine more accurately than is possible by test rig measurements and estimates the possible time of use of components in a wind turbine with at least one elastically deformable component as structural part and/or bearing part. It is a further object of the invention to provide a method for determining the beginning of a wear-related remaining life of an elastically deformable component in a wind turbine.

[0010] These objects are solved by the features of the independent patent claims. Advantageous embodiments are the subject matter of the subclaims which relate back to these.

[0011] According to claim 1, in a wind turbine a wind condition that recurs at time intervals and is the same in each case is predetermined and is assigned a specific deformation force that is the same in each case. Such a wind condition can be detected and can be recorded by a recording unit in each case when it occurs. Preferably a wind conditions which occurs relatively frequently with a significantly measurable component deformation is selected and determined, so that a relative large number of evaluable measurement results can be obtained. Preferably, with the selected wind condition, load levels with a relatively high damage component, especially ongoing, high oscillating loads, should occur at the component. In this case, it is assumed that, with largely the same wind conditions and accordingly the same operating states of the wind turbine, the deformation forces which occur as a result at the component are also largely the same. In principle, a plurality of different wind conditions can also be predetermined for a plurality of parallel evaluations or for evaluations at a plurality of components installed in the wind turbine.

[0012] When such a predetermined wind condition is detected and recorded, a measuring operation is automatically carried out by a starting signal, wherein, for component monitoring, a component deformation is measured as a characteristic variable for a current component stiffness by at least one component-assigned sensor and a downstream measuring and evaluation unit and the measured value is stored. The deformation force acting on the component must here advantageously not be measured absolutely. Equally little is it necessary to measure the component deformation or its inverse value as component stiffness absolutely since in the further evaluation only relative values and tendential behaviours between successive measured values are used. In addition, it is not absolutely necessary to determine completely exactly a wind condition for the starting signal and the measurement. The predetermination of a narrow “wind window” which yields readily usable results for the evaluation of tendential behaviours should also be included here. A measurement curve of the measured values should be averaged and smoothed to compensate for measurement tolerances.

[0013] With a comparator unit of the measuring and evaluation unit, a comparison of a current measured deformation value is carried out with respect to previous, stored measured deformation values, wherein two different results can be shown: the measured deformation values stored over a relatively long time of use, or corresponding characteristic variables for the component stiffness, are approximately the same. When creating the measurement curve, a plateau region is obtained with, in the course of this long time of use of usually several years, only a relatively small slope incline for the component deformation or a small slope decline for the component stiffness. With such a comparison result, a further dependable functioning of the component is established. This plateau region corresponds to the initially mentioned second stage of the stiffness diagram mentioned there.

[0014] If however, measured deformation values recorded one after the other over a relatively short time of use of usually a few days/weeks in comparison with the time of use of the plateau region become successively and progressively greater, the uncritical plateau region is clearly left with a strong ascending incline of a measurement curve with respect to the component deformation or a strong slope decline of a measurement curve with respect to the component stiffness. When such an ascending incline or slope decline that is prescribed as a threshold value is established, the beginning of a wear-related predeterminable remaining component life is thereby established. In addition, corresponding warning information, for example as a visual or audible signal, is output which indicates that it is necessary to replace the component. This second result exists when the third stage is reached in the stiffness diagram described initially.

[0015] If a steep region of the measurement curve is established at the beginning of a component usage over a relatively short time interval in comparison to the time of use of the plateau region, this corresponds to the first stage in the previously explained stiffness diagram. This decreasing stiffness due to flow and setting at the beginning of use is not critical, and the corresponding measured values are removed and not used in the evaluation for the beginning of a remaining life.

[0016] The essence of the invention is therefore a qualitative determination of the stiffness of the deformable component which in the installed state in the wind turbine cannot be monitored and measured directly. The stiffness can only be determined absolutely by knowing a force and deformation, as for example on a test rig. In a technical application, it is not possible to measure the force applied to an installed component with reasonable expenditure. On the other hand, distances or deformations are relatively easy to measure in a manner known per se. The determination of the component lifetime is advantageously carried out according to the invention only by evaluations of changes in measured values which can be carried out easily.

[0017] To this end, a measurement of the component deformation is initiated in each case at different time points. The time point corresponding to the occurrence of a predetermined wind speed is selected so that load levels with clearly measurable deformations and preferably with a high damage component occur. Preferably the damage component is achieved in this case by a frequent occurrence of this load level and not by high loads with low frequency in order to obtain a large number of measurement results, the scatters of which, which necessarily occur, can thus be better evaluated as scatter and not as component damage which appears.

[0018] In order to create a measurement curve, it is expedient to plot the number of measured values obtained on the X axis of a diagram, which can be interpreted as time of use. The deformation can be plotted on the Y axis. However, it is visually more understandable to plot its inverse value, one over the deformation, with the result that a measurement curve similar to the behaviour of the stiffness is obtained. Thus in a first stage at the beginning of the time of use of the component, a strong decrease in stiffness is observed due to flow and setting, which is followed in a second stage by a plateau region with slightly linearly decreasing stiffness over the lifetime and at the end of the time of use, in a third stage, a strongly progressive decrease. For the evaluation, a straight line is determined as the measurement curve, which readily maps the behaviour of the described plateau, wherein this is already possible after a few measured values in the plateau region. Each further measured value is then evaluated as to how it changes the characteristic of the previously determined straight line or differs therefrom. Preferably a change in the slope of this line is used as the criterion for an evaluation. If after the plateau region, the magnitude of the slope increases significantly above the value of the scatter over several measured values, the region of the progressive decline in stiffness begins as the signal to replace the component. In principle, the differential of the averaged measurement curve is thus evaluated.

[0019] According to the invention, the wear state of a deformable component is thus advantageously established immediately and directly during the time of use of the component. Thus, a component can be used over its actual lifetime up to the beginning of its progressive decline in stiffness.

[0020] In particular, due to estimates of time of use, predefined preventative exchange measures can thus be omitted before the actual possible end of use, with the result that maintenance and operating costs can be saved. In addition, the component safety is increased by the direct measurement on the component and the risk of any subsequent costs in the event of an unidentified component failure is reduced.

[0021] The predetermined wind condition can be recorded simply as a predetermined wind speed with the rotor turned transversely to the wind. An indirect recording of the wind condition by means of the rotor speed is also possible. Measurement signals for the wind speed and for the rotor speed are generated in any case in the wind turbine and can be used according to the invention.

[0022] In the event of every occurrence of a predetermined wind condition, a single measuring operation can be started and carried out in each case. Alternatively and/or additionally, when such a wind condition persists for a long time, after a predetermined waiting time a further measuring operation can in each case be automatically started and carried out.

[0023] The initially mentioned elastically deformable components of wind turbine as rubber-metal bearings and as structural parts are particularly suitable for the monitoring according to the invention.

[0024] Since the deformation of a component is also temperature-dependent, a temperature window of 6°C should be maintained as a further condition for the starting of a measuring operation and/or for the evaluation of a measured value, wherein this temperature window can be selected in a temperature range from 0°C to 35°C. In this case, it is taken into account that temperature influences at temperatures below 0°C and above 35°C result in strong unfavourable fluctuations of the measured values. The temperature influence on the measured values in a temperature window of 6°C within the temperature range from 0°C to 35°C is on the other hand negligible for the evaluation according to the invention.

[0025] Should a measuring operation not take place on account of established unfavourable temperatures or be carried out and/or not used but the other starting conditions, in particular the predetermined operating state are met, a measured value counter is nevertheless incremented according to a time of use in order not to distort the measurement curve, in particular the stiffness behaviour.

[0026] From the beginning of the progressive stiffness decline, a further time of use given as a remaining life of 10% of the time of use of the component so far can usually be assumed. This information can additionally be given to the signal for exchanging the component.

[0027] Specifically a sensor system for measuring a displacement and/or a speed and/or an acceleration can be used as the sensor for measuring the component deformation. A deformation can be measured directly or indirectly between component elements and/or attachment parts. In this case, the sensor system can be integrated in the deformable component, in particular in an elastomer and/or it can be arranged on adjacent/neighbouring attachment parts. For example, a distance can be measured directly as the deformation of a component whereby a signal generator sits on the inside of a rubber-metal bearing and a receiver on the outside. It is also possible to measure the accelerations in the elements, integrate twice and add so that the relative distance is obtained. Depending on the conditions, simple inductive displacement transducers known per se, magnetoresistive sensors, Hall probes, acceleration sensors or other sensors can also be used by means of which a displacement, a speed, an acceleration or another displacement-equivalent signal can be measured.

[0028] Expediently the recording unit and the measuring and evaluation unit are fully or partially integrated with their elements in a central electronic system which is usually provided in the wind turbine, wherein optionally measured values provided in any case for other purposes, for example measured wind speed values or measured rotor speed values, can also be used.

[0029] To sum up, the advantages of the invention are shown particularly in a wind turbine as a wind wheel for power generation, since shaft bearings, generator bearings, gear bearings, elastic couplings or nacelle bearings used here usually cannot simply be examined and can only be replaced with difficulty so that in any case it is worth using the possible full time of use according to the invention and not carrying out preventative earlier bearing exchange. A corresponding situation is found with structural parts made of plastic, in particular of fibre-reinforced composite materials, which can also be monitored with regard to their end of use according to the invention, in particular the rotor blades can advantageously be monitored.

[0030] The object of the invention is solved with regard to the method by the features of claim 10.

[0031] The invention is further explained with reference to a drawing.

[0032] In the figures:

Fig. 1 shows a schematic diagram of a wind turbine with components to produce a start pulse for a measuring operation,
Fig. 2 shows a flow diagram for the determination according to the invention of the beginning of a wear-related remaining time of use and
Fig. 3 shows a typical diagram of a measurement curve.

[0033] In Fig. 1 a wind turbine 25 is shown schematically with Fig. 1a in a front view and with Fig. 1b in a side view. A vertically rotatable nacelle 27 is arranged on a tower 26 with a horizontally aligned hub 28 for a rotor 29 with rotor blades 30.

[0034] In Fig. 1b the wind direction with a specific wind speed is additionally indicated by wind arrows 31. The nacelle 27 is already turned in the wind in a controlled manner or the rotor 29 is aligned transversely to the wind, whereby the rotor 29 is rotates in a rotationally driven manner (arrow 32). In addition, the generation of a start pulse for a measuring operation is given schematically: A wind speed signal is supplied by a control line 33 to a comparator module 34 in which a wind window 35 is defined. If the wind window 35 is reached by the established wind speed, a switching unit generates a trigger pulse as start pulse for a deformation measurement on a component by the measuring and evaluation unit 37 (control line 38). Recorded measured values are supplied via the measurement lines 39 of the measuring and evaluation unit 37 and processed according to the flow diagram according to Fig. 2.

[0035] Fig. 2 shows the process sequence by means of status/process rectangles and decision diamonds:
According to the first rectangle 1, the system for determining the time of use of the component is ready for measurement. For example, a rubber-metal bearing of the wind turbine in the installed state is assumed as the component.

[0036] According to the two following rectangles 2 and 3, a predetermined operating state for starting a measuring operation is reached, whereupon the command to perform a deformation measurement is given.

[0037] Such a trigger signal for starting a measurement is output according to Fig. 1 when the predetermined wind speed is reached and a nacelle of the system is aligned into the wind.

[0038] In the decision diamond 4 it is additionally checked whether a predetermined temperature window is satisfied for the measurement. Depending on the case of application, further boundary conditions can optionally also be redefined, for example a rotor speed as an indicator that the system is not at a standstill.

[0039] If the ambient conditions/boundary conditions for the measurement are not satisfied, the measured value counter is nevertheless incremented in order to thereby largely reduce otherwise given distortions of the measurement curve (rectangle 5).

[0040] If the ambient conditions/boundary conditions for the measurement are satisfied, a measured value is recorded and the measured value counter is incremented (rectangle 6).

[0041] In the following decision diamond 7, it is established whether values for the deformation are present, if this is not the case the current measuring and evaluation cycle is ended.

[0042] If measured values are present, these are stored and compared with preceding measured values (rectangle 9).

[0043] This comparison is then evaluated (decision diamond 10) and it is established in which region of the stiffness behaviour the component is located. A typical stiffness behaviour is shown and explained subsequently with reference to the diagram in Fig. 2.

[0044] If the first region 16 with relatively rapidly decreasing stiffness at the beginning of use caused by flow and setting of the elastomer material is established, this is not an indication of the beginning of a prompt end of use so that the current measuring and evaluation cycle is ended (rectangle 8).

[0045] If a stiffness profile is determined in such a manner that the second region 17 is continued as a plateau region through the current measurement, the straight line is continued to described the plateau region (rectangle 11). This is also no indication for the beginning of the end of use so that for this case also the current measuring and evaluation cycle is ended (rectangle 8).

[0046] If on the other hand, following a plateau region in a third region 19 of the stiffness behaviour a progressive decline in stiffness is established in the evaluation, the system outputs a warning that the monitored component must be replaced (rectangle 12). With this warning relating to the monitored component the process is ended (rectangle 13).

[0047] Fig. 3 shows in a diagram a typical measurement curve 14 for a component use of an elastically deformable component, here for example for a rubber-metal bearing of the wind turbine under successive loads which are the same within narrow limits and occur at time intervals.

[0048] For this purpose the characteristic determined in each case for the stiffness is plotted on the Y axis at the top as 1 divided by the deformation. The number of measured values is plotted on the X axis of the diagram, which can be interpreted as the time of use, wherein with the same intervals for each predetermined wind condition, a measured value provided for this is plotted in the diagram as measurement point 15.

[0049] As a result of the wind conditions which cannot be recorded exactly and measurement tolerances, however the measurement points 15 clearly show a scatter in only a small extent which is unimportant for the prediction to be made regarding the time of use. In the evaluation an interpolation is therefore made with the following result:
In the first stiffness region 16 the stiffness decreases relatively rapidly due to flow and setting. In the second stiffness region 17 which can be given by a straight line 18 by centring the measured value scatter, a plateau region is characterized by only a very small decrease in stiffness. In the diagram this stiffness region is shown with a relatively large slope of the straight line 18 for better illustration. In addition, the second stiffness region 17 as plateau region is actually substantially larger/longer with many measured values 15 compared to the first and third stiffness region 16, 19 and is shown here as shortened for better illustration of the fundamental behaviour of the measurement curve. Following the plateau region 17, in the third stiffness region 19 a rapid progressive decrease in stiffness is established as an indication for a soon-required replacement of the component according to the rectangle 12 from Fig. 1. This progressive decrease in stiffness as a clear deviation from the lengthening 20 of the straight line 18 can be established rapidly and easily shortly after its beginning (for example with measured value 21).

Patentkrav

1. Vindenergianlæg med en rotor og med mindst en elastisk deformerbar konstruktionsdel som strukturdel og/eller lejedel, hvorpå der under driften, afhængigt af vekslende vindtilstande, indvirker forskellige deformationskræfter, som fører til en konstruktionsslitage, der begrænser konstruktions-nytteperioden,
kendetegnet ved, at der forud fastlægges en tidsforskudt, sig gentagende ens vindtilstand, hvortil der knytter sig en bestemt deformationskraft, og at en sådan vindtilstand kan erkendes og registreres med en registreringsenhed (33, 34, 35), og at der ved konstatering og registrering af en sådan i forvejen bestemt vindtilstand (2) automatisk - ved et startsignal - startes og gennemføres en måleprocedure (3), og hvor der i forbindelse med en konstruktionsdel-overvågning med mindst en konstruktionsdel-tilforordnet føler og en efter-(ind)koblet måle- og evalueringsenhed (37) måles en konstruktionsdel-deformation som karakteristisk størrelse for en aktuel konstruktionsdel-stivhed, og at måleværdien lagres,
og at der med en sammenligningsenhed vedrørende måle- og evalueringsenheden (37) foretages en sammenligning mellem en aktuel deformationsmåleværdi og tidligere lagrede deformationsmåleværdier (9) med det resultat,
at de over en forholdsvis lang udnyttelsesperiode lagrede deformationsmåleværdier eller tilsvarende kernestørrelser vedrørende konstruktionsstivheden er nogenlunde ens, og at en af måleværdier opbygget målekurve (14) danner et plateau-område (17) med en i løbet af denne udnyttelsesperiode ringe hældningsstigning vedrørende konstruktionsdeformationen eller et ringe hældningsfald vedrørende konstruktionsdel-stivheden, hvorved der konstateres en yderligere, mere sikker konstruktionsdel-funktion, eller
at alternativt - ved hjælp af en i forhold til plateauområdets nyttevarighed - den korte nytteperiode af efter hinanden følgende deformationsmåleværdier successivt og progressivt bliver større, således at plateauområdet med en over for plateauområdet større stigningsforøgelse har en målekurve vedrørende konstruktions-deformation eller en i forhold til plateauområdets hældning stærkere hældningsfald for en målekurve (4) vedrørende konstruktionsstivheden, hvorved begyndelsen af et slidbetinget i forvejen givet konstruktionsdel restnytte-holdbarhe-

den konstateres, og en tilsvarende advarselsinformation afgives, især ved opnåelse af en tærskelværdi for en i forvejen stigningsforøgelse henholdsvis hældningsreduktion af målekurven (14).

2. Vindenergianlæg ifølge krav 1, **kendetegnet ved,** at et stigende eller faldende område (16) på målekurven (14), som er optegnet ved begyndelsen af levetiden for en konstruktionsdel, ikke er anvendt ved vurdering af anlæggets restudnyttelsestid.

3. Vindenergianlæg ifølge krav 1 eller 2, **kendetegnet ved,** at en forvejen bestemt vindtilstand er registreret direkte som en i forvejen bestemt vindhastighed (33), idet en rotor (29) er drejet på tværs af vinden og/eller er registreret indirekte som et i forvejen bestemt rotor-omdrejningstal, idet rotoren (29) er drejet på tværs i forhold til vinden.

4. Vindenergianlæg ifølge et af kravene 1 til 3, **kendetegnet ved,** at hvis efter påbegyndelse og udførelse af en måleprocedure den vindtilstand (33), som er blevet registreret i forbindelse med starten, stopper i en i forvejen bestemt tidsperiode - så vil efter en i forvejen bestemt ventetid en yderligere måleprocedure i det enkelte tilfælde automatisk blive påbegyndt og udført - ellers vil en enkel måleprocedure blive påbegyndt og udført i det enkelte tilfælde, når en sådan vindtilstand forekommer.

5. Vindenergianlæg ifølge et af kravene 1 til 4, **kendetegnet ved,** at en overvåget elastisk konstruktionsdel er et kautsjuk-metalleje, især et akselleje og/eller generatorleje og/eller tandhjulsleje og/eller elastiske koblingsorganer og/eller lejer til en gondol og/eller dennes komponenter, og/eller
at en overvåget elastisk konstruktionsdel er en strukturdel af plast, især af fiberkomposit-materiale, især et rotorblad til en rotor.

6. Vindenergianlæg ifølge et af kravene 1 til 5, **kendetegnet ved,**

at omgivelsernes temperatur omkring konstruktionsdelen måles ved hjælp af en temperaturmåleenhed, og at begyndelsen af en måleprocedure og/eller vurderingen af en målt værdi kun kan godkendes (4), hvis omgivelsernes temperatur ved hver måleprocedure ligger i et i forvejen givet ens temperaturvindue, fortrinsvis i et temperaturområde på 6°C, hvor temperaturvinduet kan vælges i et temperaturområde fra 0°C til 35°C, og

at når de øvrige startbetingelser foreligger, en måleværditæller alligevel står ret højt, hvis blot temperaturbetingelsen og eventuelt yderligere specificerbare randbetingelser for frigivelse ikke er opfyldt.

7. Vindenergianlæg ifølge et af kravene 1 til 6, **kendetegnet ved,** at den tid, en konstruktionsdel kan udnyttes, indtil den afgiver en advarselsinformation, registreres, og at advarselsinformationen ledsages af information om en mulig ukritisk yderligere brug eller om en absolut nødvendig udskiftning af konstruktionsdelen, idet den så gives en yderligere restbrugstid på 10% af den hidtidige brugstid vedrørende konstruktionen.

8. Vindenergianlæg ifølge et af kravene 1 til 7,

kendetegnet ved,

at der som føler til måling af konstruktionsdel-deformation anvendes en følerindretning til måling af en forskydning og/eller en hastighed og/eller en acceleration, hvorved man direkte eller indirekte kan måle en deformation eller forskydning mellem konstruktionsdel-komponenterne og/eller tilsluttede dele, og

at følerindretningen i det mindste er delvis integreret i den deformerbare konstruktionsdel og/eller i tilgrænsende/ved siden af hinanden anbragte dele.

9. Vindenergianlæg ifølge et af kravene 1 til 8, **kendetegnet ved,** at registreringsenheden og måle- og evalueringsenheden med deres komponenter er helt eller delvis integreret i en centralelektronik i vindenergianlægget.

10. Fremgangsmåde til bestemmelse af begyndelsen af en slitagebetinget restnytteperiode for en elastisk deformerbar konstruktionsdel som strukturdel og/eller

lejedel i et vindenergianlæg, **kendetegnet ved** de træk, som er angivet i et af kravene 1 til 9.

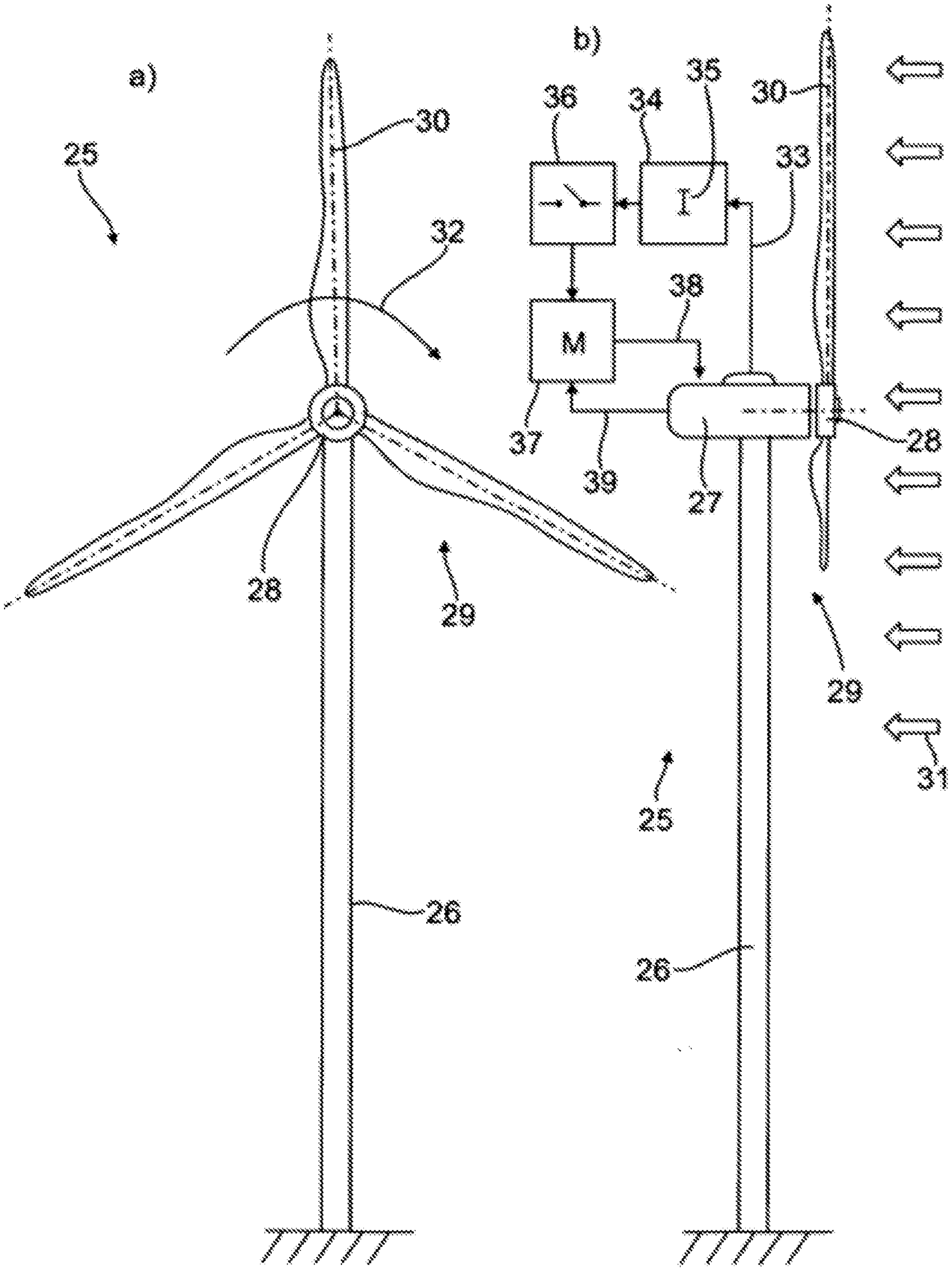
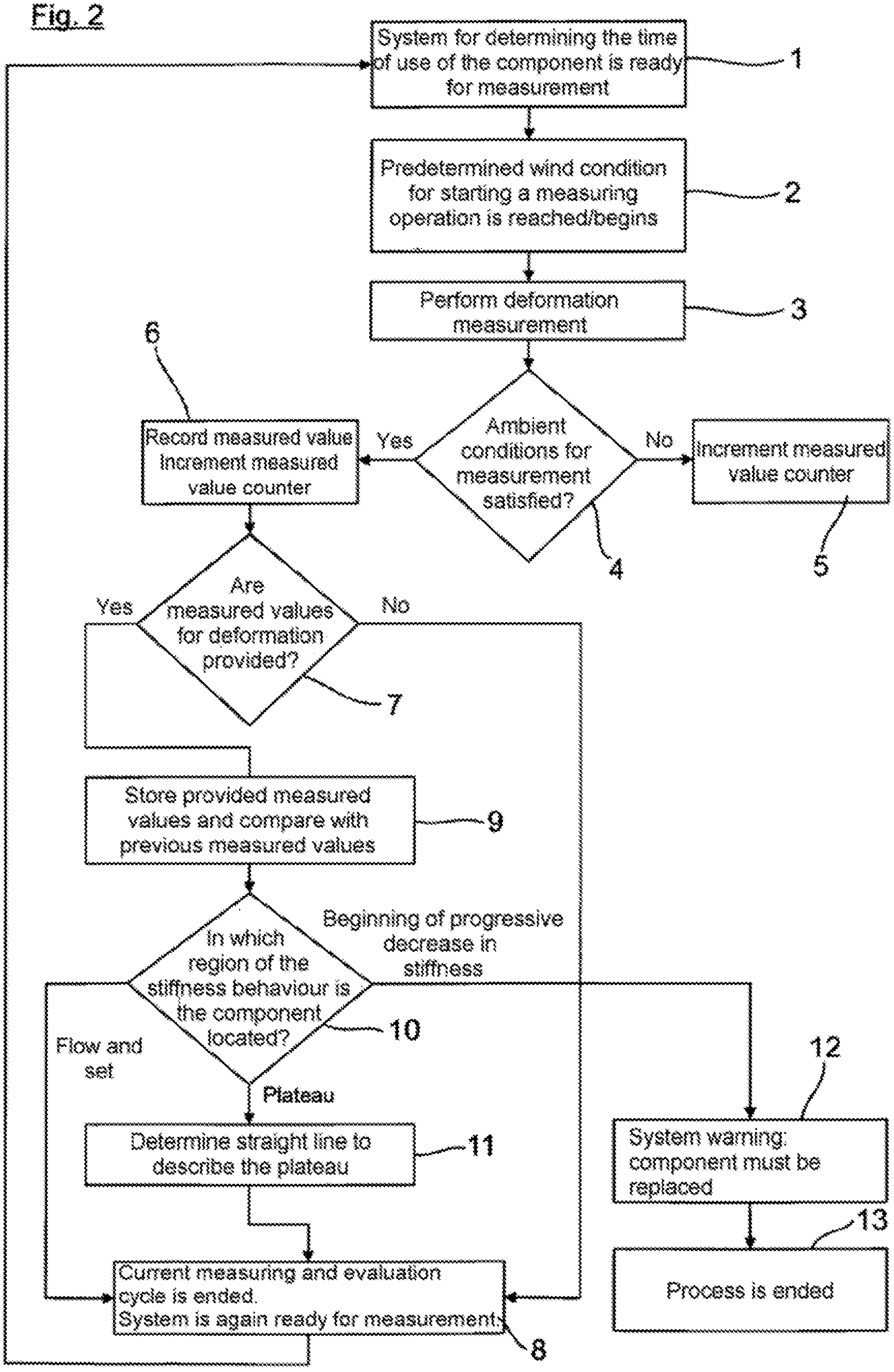


Fig. 1

Fig. 2


System for determining the time of use of the component is ready for measurement
1
Predetermined wind condition for starting a measuring operation is reached/begins
2
Perform deformation measurement
3
Ambient conditions for measurement satisfied?
4
Yes
No
Record measured value Increment measured value counter
6
Increment measured value counter
5
Are measured values for deformation provided?
7
Yes
No
Store provided measured values and compare with previous measured values
9
In which region of the stiffness behaviour is the component located?
10
Beginning of progressive decrease in stiffness
Flow and set
Plateau
Determine straight line to describe the plateau
11
System warning: component must be replaced
12
Process is ended
13
Current measuring and evaluation cycle is ended. System is again ready for measurement.
8

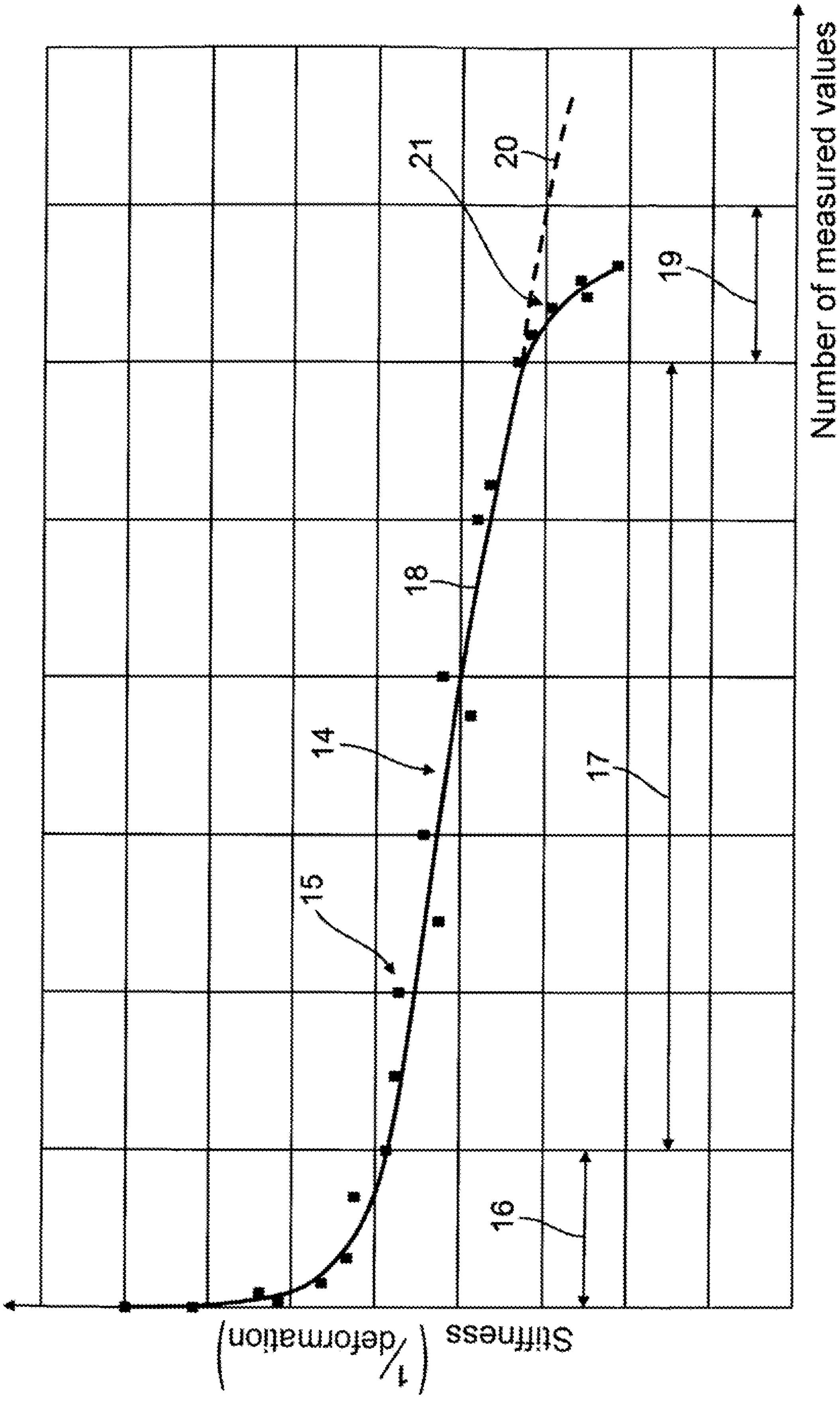

Number of measured values
Stiffness ($^1/_{deformation}$)
14
15
16
17
18
19
20
21

Fig. 3