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Description

[0001] The invention relates to a method for checking the structural condition of wind turbines in the form of wind turbines with multiple rotor blades, whereby the wind turbines or rotor blades consist of one or more thermographic recording devices installed on or in a mobile location. The measurements they collect will then be evaluated in terms of damage rotor blades.

[0002] As part of the growing importance of renewable energies, in recent years the building of wind turbines has increased across the globe. Due to the fact that the prevailing strong winds that exist over water and in particular the sea will become more frequent and more offshore wind turbines will be built. This brings with it the decisive advantage that they are built in less attractive locations and do not affect the landscape. Like any other industrial plant, wind turbines must also have maintenance checks at regular intervals. This is particularly important for wind turbines as they are more exposed to higher dynamic stresses for example. Checks on the structural condition of all of the rotor blades must be carried out in a comparatively short space of time.

[0003] These inspections are particularly problematic especially for offshore wind turbines because the employees must travel by boat to each wind turbine. Considerable acrobatic skills are required to carry out the inspections work as the workers must have completed high altitude mountain training or industrial climbing training similar to mountain climbers. Aside from this, a prerequisite for the inspection is that each rotor blade must be approximately in the six o'clock position. Once the inspection on the first rotor blade is completed the wind turbine must be rotated and the next rotor blade to be checked must be brought into the six o'clock position. It is obvious that this requires a great deal of effort. DE 10 2010 048 400.8 or WO 2011/113402 A1 specifies the procedure and equipment to be used to check the structural conditions of wind turbines consisting of multiple rotor blades. In this case aircraft, usually helicopters, are used. Using the appropriate equipment, for example on-board thermal imaging cameras, these will collect the data necessary for the inspection. Through this, it has emerged that the measurements taken for the rotor blades – completely independent of damages - are in part grossly distorted for example. This in turn is particularly relevant to the thermal stresses on the rotor blades, which go hand in hand with their operation. This means that due to the friction created with the air on rotation, the rotor blades are subject to thermal stresses; they warm up or rather they heat up and the stresses are distributed unevenly across the rotor blades. In addition, they also have dynamic issues such

as the stresses caused by the rotation of the rotor blades. A similar procedure for the use of drones is laid out in 2010/013260 A1 in the USA.

[0004] Thus the following invention has the task of creating a method for checking the structural conditions of wind turbines by means of thermographic receptors, where the measurements determined are as exact as possible.

[0005] This objective is achieved by the fact that the measurements taken are calculated by taking into account the thermal/dynamic stresses on the rotor blades at the time of measurement.

[0006] During the normal rotational operation of the rotor blades and the movement of other building sections with dynamic stresses acting upon them, notable thermal stresses are present. These depend on the friction between the rotor blades and the air during rotation. Due to an acceleration error, which can be caused by the rotation, false deviations can occur. The consequent measurement errors significantly influence the measurement results of the thermographic receptors. Therefore, the measurements taken are first evaluated or output when the thermal stresses caused through the rotational operation of the rotor blades are taken into consideration accordingly. In doing so the stresses present at the time of measurement are effectively turned off. In taking these stresses into consideration we achieve a workable, spatial and precise evaluation and documentation.

[0007] Specifically, this means that the data regarding the thermal and/or dynamic stresses present at the time of measurement is placed in relation to the measurements determined. This means that on one hand there are the absolute measurements taken by the thermal receptors. However, these must then be used in relation to data where the thermal stresses on the rotor blades at the time of the measurements have been taken into account. In other words, the data must be calculated down from the thermographically determined measurements, that are subject to external influences such as air friction, atmospheric conditions, for example. The actual measurements are then left over which indicate the actual damage to the rotor blades.

[0008] Eventually, this then leads to the fact that the measured values taking into account the data that was set in relation to them, are released. This means that after working on the temperature measurement error using special software and the associated correction is performed, the analysis and output of the data set in relation, i.e. the revised or corrected measurements, can follow. The raw data is significantly effected by the rotational operation

of the rotor blades, which warm up or heat up due to the air friction. In terms of the invention, we plan to take into account the thermal stresses caused by friction during operation of the rotor blades. The same applies to other forms of thermal stress such as sunlight, external temperature etc.

[0009] In order to take into account the dynamic stresses caused by the rotation of the rotor blades, another form of the invention is planned. This correction may be necessary if the acceleration error arising from the rotation of the rotor blades is having a distorting effect on the final results.

[0010] To a certain extent these stresses can be standardised as the thermal and dynamic loads of the rotor blades comply with certain laws, in particular those for thermal stresses caused by air friction and dynamic stresses caused by rotation. In this case, it is suggested that the thermal and/or dynamic stresses should be taken in to consideration separately for sections of the rotor blades.

[0011] For one embodiment of the invention it is planned that the rotor blades will be divided into their longitudinal or latitudinal parallel segments, sections or zones. Thus, on the one hand you can view the corresponding sections more expediently in a longitudinal direction. On the other hand, the latitudinal or parallel sections will also be shown. Subsequently, in the analysis the individual segments will be assigned to each rotor blade and as far as possible a complete picture or representative partial picture will be created.

[0012] The latitudinal direction of the rotor blades is of particular importance due to its high correctional needs with regard to the measurements collected by the thermographic receptors. Therefore, we plan to take into account at least the front edge, flat surface and back edge of the latitudinal direction of the rotor blades. During rotation the front edge of the rotor blades experiences a particularly high acceleration in air flow. Air particles and rotor blades in this area will also be particularly hot, which bring with it the need for a higher correction demand in terms of the measurement results. Through a reduction in the acceleration on the actual blade area, the temperature development in this area is usually low. It will then rise towards the back edge again, however, compared with the front edge to a lower degree. This standardised data for recording the temperature of the rotor blade during operation must be taken into account and calculated on the output of the final measurements, in order to avoid distorted measurement results.

[0013] In order to take the thermographic readings an approved or manned aircraft able to hold in a pattern is needed as a mobile location, such as a helicopter, a balloon, a Zeppelin, a kite or a drone. Model helicopters / Drones (unmanned aircraft) of less than 25 kg do not require airworthiness certification and would not be used to examine the structural condition.

[0014] The data will be collected from a preferred distance of approx. 0.01 to 10,000m between the rotor blades and the receptors.

[0015] The apparatus for carrying out the procedure according to the invention includes five components in the preferred design example. For this, an approved or manned aircraft that can hold in a pattern such as a helicopter, a balloon, a Zeppelin, a kite or a drone and one or more thermographic receptors are needed. These are to be used in parallel with other thermographic devices or other devices such as radar, ultrasonic, terahertz, laser technology or 3D scanning devices, whereby the latter will be set to take special three-dimensional recordings. In this manner data can be taken from different angles. All the pictures collected from these different techniques - E.g. thermal, terahertz, 3D scanning, laser, radar, ultrasonic and/or infrared technology, preferably dual-band infrared technology - can be superimposed on one another to create a result. In doing so the position of the object to be measured deep in the rotor blades can be precisely measured. Compact casings serve to house one or more of these recording devices. The helicopter flies over the rotor blades one at a time or altogether regardless of their position and their other status. Then, the individual rotor blade is scanned, preferably with terahertz waves, whereby the material density, for example, of the rotor blades is detected. In particular, this procedure can also provide good in depth information. An advantage is that the scan can take place even on dirty equipment, that has been affected by salt crystals for example. As a third component, the apparatus includes a (intermediate) storage unit for the data and as a fourth unit a means of taking into account the thermal and/or dynamic stresses acting on the rotor blades at the time of measurement due to their operational status. This quickly follows in a separate, automatic process step prior to the actual output of the measured results, through which, for example, the damage to the rotor blades can be determined. Finally the apparatus includes a unit for outputting the final, corrected results taking into account the specific thermal and/or dynamic stresses acting on the rotor blades due to their being in operation. The staff then evaluate the state of the measurements, in the truest sense of the word, and compile a picture of the state of the rotor blades that were checked.

[0016] A further embodiment of the invention plans to inspect the entire rotor blade and/or only the surface at a standstill or in operation, where among other things, an assessment can be carried out by scanning or laser measurements.

[0017] A further variation on the invention that has been considered is that data is compiled through scanning and thermographically or terahertz measurement can be determined in relation to one another. For the scanned item, such as a rotor blade, nacelle housing, tower or bridge the thermographic or terahertz measurements can be displayed in order to determine the position of individual damages.

[0018] The invention is therefore characterised in particular by the fact that a procedure for inspecting the structural condition of structures such as buildings, towers, masts, bridges and in particular of wind turbines is created. In addition to the tower and nacelle housing of a wind turbine, the invention revolves around the wind turbines, especially offshore wind turbines where the measurements collected by a thermographic receptor can be corrected. Therefore, a workable, spatial and precise evaluation and documentation is possible. Corrections take place in the form of placing data in relation to the thermographic measurements, through which the thermal stresses, in particular those caused by air friction, and the dynamic stresses caused by the rotation of the rotor blades, that exist at the time of measurement can be taken into consideration. With the support of a helicopter, it has a flexible application in particular that it is not dependant on the form, type and size of the wind turbine to be inspected. It is also conceivable that it can be used on a rotor blade that rotates on a horizontal axis as well as one that rotates on a vertical axis.

[0019] Further details and advantages of the subject matter of the invention arise from the following description of the accompanying figures, in which a preferred design example with the necessary details and individual parts is shown.

[0020] It shows:

Figure 1 shows a helicopter in action at a wind turbine,

Figure 2 shows a rotor blade,

Figure 3 shows a section of the rotor blade.

[0021] Figure 1 shows a wind turbine 1 as part of a wind power station in a body of water, illustrated by the water level and is indicated by the reference symbol 15. Wind turbine 1 includes a seabed and/or floating anchored tower 5, on which the actual wind turbine is positioned. The reference symbols 3 and 4 show two rotatable rotor blades on a horizontal

axis 17, 7 is the hub and 8 the so-called nacelle, which rotates on the yaw control 9. Wind turbine 1, to be more precise rotor blade 4, the tower 5 or the nacelle 8, are recorded as represented in Figure 1, by a helicopter 2 or a camera installed on it 6 that is a thermographic recording device 11. It is conceivable that data collection can be made using terahertz waves, 3D scanning or laser technology. The positioning of rotor blades 3, 4 is also unimportant as is their state, in particular the rotor blades 3, 4 do not need to be cleaned before the data is collected as shown here.

[0022] In Figure 2 one such rotor blade 3 with segments extending on its longitudinal axis 17, is shown. Here, there are four segments 20 to 23.

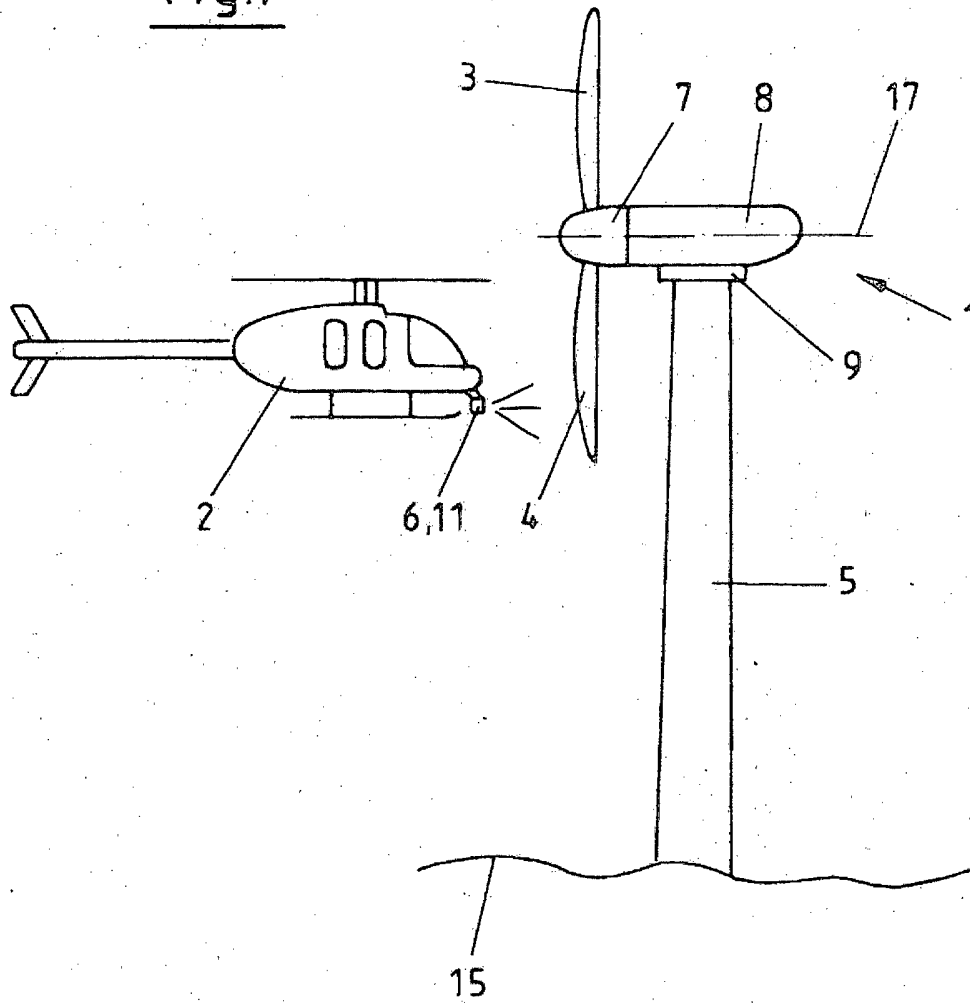
[0023] Finally, Figure 3 shows the segments provided in Figure 2 with the reference symbol 22 or the corresponding sections between the two lateral axes 18 'and 18' in an enlarged view. Thermal stresses or areas that warm up due to the friction caused by the rotation of the rotor blades are shown as peaks. These are located in particular at the front edge 24 of the rotor blade 3 and are shown as examples with the reference symbols 27, 28 and 29. Towards the flat surface 25 the thermal load decreases significantly; the acceleration is lower and accordingly the temperature increase is lower. The thermal stress then rises again toward back edge 26 of the rotor blade 3, symbolised by the peaks 30, 31, 32, however, in respect to peaks 27, 28 and 29 for the front edge 24 of the rotor blade 3 they are significantly lower. Using the method invented, the final measurement results will be adjusted correspondingly to the thermal stress data. The evaluation of damage to the rotor blades follows taking into consideration these thermal stresses, as exemplified in Figure 3.

Patentkrav

1. Fremgangsmåde til overvågning af strukturel tilstand af vindmøller i form af rotor (1) med flere rotorblade (4), idet vindmøllerne overvåges af en eller flere termografiske registreringsanordninger (6) installeret på og/eller i en mobil placering (2), og de målte værdier derved evalueres med hensyn til eventuelle tilfælde af skader, som er kendetegnet ved, at de målte, bestemte værdier evalueres, samtidig med der tages hensyn til de termiske og/eller dynamiske belastninger forårsaget af driften af rotorbladene (4) på tidspunktet for målingen.
2. Fremgangsmåde ifølge krav 1, kendetegnet ved at data om de termiske og/eller dynamiske belastninger forårsaget på tidspunktet for målingen er sat i forhold til de målte, bestemte værdier.
3. Fremgangsmåde ifølge krav 2, kendetegnet ved, at de målte værdier er output, mens der tages hensyn til de relativiserede data.
4. Fremgangsmåde ifølge krav 1, kendetegnet ved, at der tages hensyn til termiske belastninger som følge af friktion under driften af rotorbladene (4).
5. Fremgangsmåde ifølge krav 1, kendetegnet ved, at der tages hensyn til de dynamiske belastninger forårsaget af rotationen af rotorbladene (4).
6. Fremgangsmåde ifølge krav 1, kendetegnet ved, at der tages særskilt hensyn til termiske og/eller dynamiske belastninger på grundlag af rotorbladets segmenter (4).
7. Fremgangsmåde ifølge krav 6, kendetegnet ved, at tolerancen i det mindste er lavet for de segmenter, der er forkanten (24), bladets område (25) og bagkanten (26).
8. Fremgangsmåde ifølge krav 1, kendetegnet ved, at et typecertificeret luftfartøj og/eller bemandedt luftfartøj, som en helikopter (2), en ballon, en zeppelin, en drage eller en drone anvendes som den mobile placering.

9. Fremgangsmåde ifølge krav 1, kendetegnet ved, at de termografiske optagelser fremstilles ved hjælp af dual-band infrarød teknologi.
10. Fremgangsmåde ifølge krav 1, kendetegnet ved, at rotorbladet (4) i sin helhed og/eller kun overfladen deraf overvåges ved stilstand eller under drift.
11. Fremgangsmåde ifølge krav 1, kendetegnet ved, at registrerede data ved scanning og termografisk eller terahertz-måling er sat i forhold til hinanden.

Fig.1



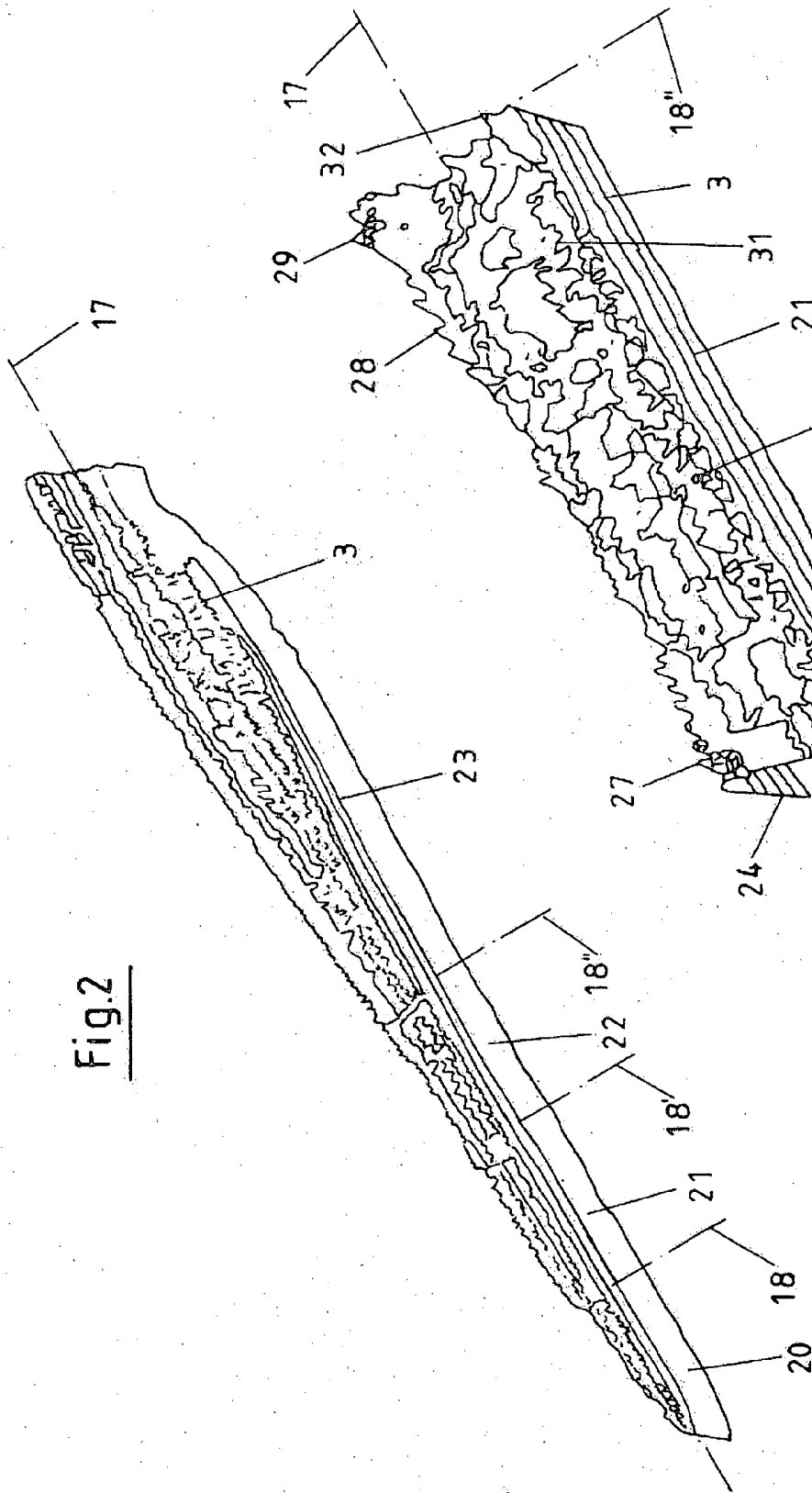


Fig. 2

Fig. 3

