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(54) **METHOD AND ASSEMBLY FOR CONTROLLING THE POSITIONING OF AT LEAST ONE ROTOR DISC ABOUT A TIE-ROD OF A PARTIALLY ASSEMBLED ROTOR**

(57) A method for controlling the positioning of at least one rotor disc (2) about a tie-rod (3) of a partially assembled rotor (1) of a gas turbine comprises:
• positioning the tie-rod (3) so as its longitudinal axis (A) extends substantially vertically;
• detecting the eccentricity of the rotor disc (2) with respect to the longitudinal axis (A) of the tie-rod by means of an assembly (23) comprising a main device (24) coupled to a free face (13a) of the rotor disc (2) and at least one first reference device (25, 26) coupled to the tie-rod (3); the assembly (23) further comprising at least three lasers emitters (28) coupled to one between the main device (24) and the at least one first reference device (25, 26) and at least three respective photosensitive sensors (30) coupled to the other between the main device (24) and the at least one first reference device (25, 26); the photosensitive sensors (30) being arranged so as to intercept laser beams (B) emitted by respective lasers emitters (28).

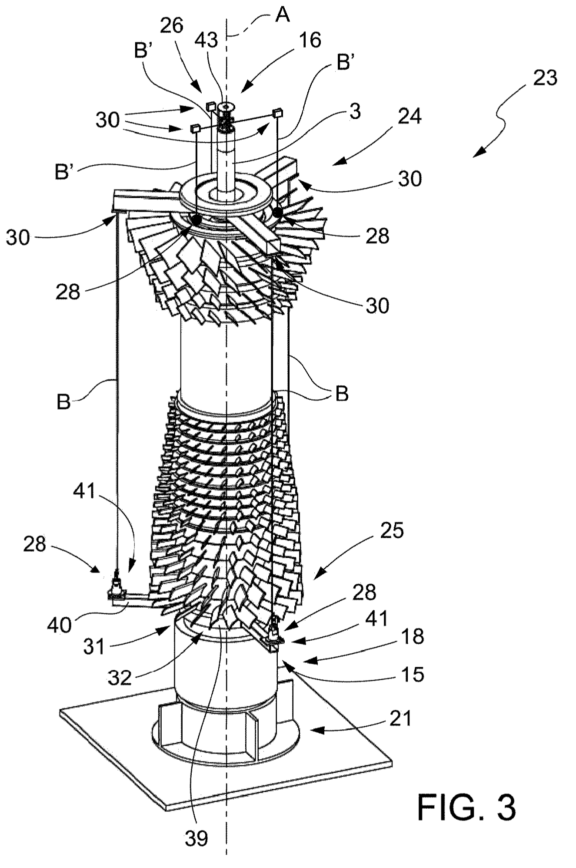

FIG. 3

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Description

TECHNICAL FIELD

[0001] The invention relates to a method and an assembly for controlling the positioning of a rotor disc about a tie-rod of a partially assembled rotor of a gas turbine.

BACKGROUND

[0002] A gas turbine rotor of a plant for the production of electrical energy usually comprises a plurality of bladed rotor discs, which are centred on an axis and are coupled one another. The coupling between adjacent rotor discs is obtained by means of Hirth joints.

[0003] Therefore, each rotor disc is provided with two respective annuli provided with radial teeth, the so-called Hirth teeth sets, one on each face. The annuli are coupled to annuli of adjacent discs so as to build the so-called Hirth joints.

[0004] The rotors discs are provided with respective blade sets and are bound into packs by a central tie-rod, which engages respective central holes of the rotor discs.

[0005] Each bladed disc defines a compressor rotor stage or a turbine rotor stage.

[0006] Gas turbine rotors must be produced and assembled with utmost precision, so as to ensure a nearly perfect balancing. Given the masses and the high rotation speeds (the rotor usually rotates at 3000 rpm or 3600 rpm, depending on the standards of the different countries), even the smallest defects can cause dangerous vibrations exceeding the allowed limits, thus forcing the plant to be stopped in order to carry out corrective interventions aimed at bringing the vibrations back to the allowed limits.

[0007] Assembling a rotor currently involves stacking the rotor discs about a central tie-rod arranged in a vertical position. The rotor discs automatically center themselves, thanks to the fact that the contact between the discs occurs through the Hirth toothing described above.

[0008] Assembling the rotor usually requires stacking a large number of rotor discs (e.g. about twenty). Therefore, having a lack of homogeneity in just one of these discs (for example, due to the fact that the disc has non-parallel faces) is enough to obtain, at the end of the stacking step, an inclined stack, namely a stack where the center of the last disc is not vertically aligned with the one of the first disc.

[0009] The compliance of the discs is usually controlled when the rotor is already clamped. In particular, the rotor compliance of the discs is usually controlled on a rotor tilted horizontally and transported to a lathe machine, where it is possible to measure the "run-out" eccentricity of each disc with respect to the axis formed by the bearings. Possible corrective actions may require the rotor to be disassembled.

[0010] Moreover, the tools and the methods currently available need infrastructures (cranes, tower cranes, etc.) and take a long time to assess and correct the stacking.

[0011] Control method for controlling the compliance of the discs before the stacking are known. However, they do not ensure the detection of all non-compliances of the discs, as operators need to carry out manual activities and personal assessments. Therefore, the accuracy and the times needed for the checks and the corrections cannot be considered as satisfying.

[0012] Another control method is disclosed in patent application no. EP3330484A1, filed by the current applicant. Said method detects the inclination of the rotor disc with respect to a horizontal plane and/or the eccentricity of the rotor disc with respect to the tie-rod by means of a ring shaped device. However, according to said solution, the reference for measuring the eccentricity of the single disc is the external surface of the tie-rod.

[0013] Said solution cannot be adopted for already exercised rotors (for example for service activities).

[0014] In overhauled rotors, in fact, the central tie-rod cannot be used as a valid reference for axial symmetry, as it is usually deformed by the long time and thermomechanical stresses to which it has been subjected during operation.

[0015] In other words, the external surface of the central tie-rod cannot be considered as a valid geometric reference for eccentricity measurements.

SUMMARY

[0016] Hence, it is an object of the present invention to provide a method for controlling the positioning of rotor discs about a tie-rod of a gas turbine rotor that is precise and reliable and avoids, or minimizes, the occurrence of balancing errors.

[0017] By so doing, assessment and correction operations to be carried on an already clamped rotor are minimized.

[0018] In accordance with these objects, the invention relates to a method for controlling the positioning of rotor discs about a tie-rod of a partially assembled rotor of a gas turbine; the tie-rod extending along a longitudinal axis;
the method comprising:

- positioning the tie-rod so as the longitudinal axis extends substantially vertically;
- detecting the eccentricity of the rotor disc with respect to the longitudinal axis of the tie-rod by means of an assembly comprising a main device coupled to a free face of the rotor disc and at least one first reference device coupled to the tie-rod; the assembly further comprising at least three lasers emitters coupled to one between the main device and the at least one first reference device and at least three respective photosensitive sensors coupled to the other between the main device and the at least one first reference device; the photosensitive sensors being ar-

ranged so as to intercept laser beams emitted by respective lasers emitters.

[0019] A further object is to provide an assembly for controlling the positioning of a rotor disc about a tie-rod of a partially assembled rotor of a gas turbine, which is precise, reliable and capable of easing the operations to be carried out in order to check the compliance of the discs, thus minimizing operators' manual activities and personal assessments.

[0020] In accordance with these objects, the invention relates to an assembly for controlling the positioning of at least one rotor disc about a tie-rod of a partially assembled rotor of a gas turbine; the tie-rod extending along a longitudinal axis;
the assembly comprising:

- a main device coupled, in use, to a free face of the rotor disc; and
- at least one first reference device coupled, in use, to the tie-rod;
- at least three lasers emitters coupled to one between the main device and the at least one first reference device; and
- at least three respective photosensitive sensors coupled to the other between the main device and the at least one first reference device; the photosensitive sensors being arranged so as to intercept laser beams emitted by respective lasers emitters.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The invention will now be described with reference to the accompanying drawings, which show a non-limiting embodiment thereof, wherein:

- figure 1 is a side view of a gas turbine rotor with a section along a vertical axial plane;
- figure 2 is a perspective view of a detail of the gas turbine rotor of figure 1;
- figure 3 is a side view of the rotor of figure 1 partially assembled during a step of the method according to the invention;
- figure 3a is a perspective view of a first detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1;
- figure 4 is a bottom perspective view of a second detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1;
- figure 5 is a top perspective view of the second detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1;
- figure 6 is a perspective view of a third detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1 in a first operative configuration;
- figure 7 is a perspective view of the third detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1 in a second operative configuration;
- figure 8 is a schematic representation of a fourth detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1;
- figure 9 is a schematic representation of a fifth detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1 according to a variant of the present invention;
- Figure 10 is a schematic block diagram of a sixth detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1;
- Figure 11 is a schematic top view of a seventh detail of the assembly for controlling the positioning of a rotor disc about a tie-rod of the gas turbine rotor of figure 1.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0022] In figure 1, reference number 1 indicates a gas turbine rotor of a plant for the production of electrical energy comprising a plurality of discs 2 aligned along an axis A and bound into packs by means of a central tie-rod 3. The central tie-rod 3 extends along the longitudinal axis A. A first group of discs 2, provided with respective first rotor blades 5, defines a compressor section 1a of the rotor 1, whereas a second group of discs 2, provided with respective second rotor blades 6, defines a turbine section 1b of the rotor 1. The compressor section 1a and the turbine section 1b are separated from one another by a spacer disc 7 without blades, which basically acts as a spacer element and is substantially shaped like a cylinder. In use, a combustion chamber (not shown) of the gas turbine is arranged around the spacer disc 7.

[0023] With reference to figure 2, each rotor disc 2 is provided with a central through hole 8 and with a peripheral edge 9 provided with a plurality of seats 10 properly shaped so as to be engaged by respective first rotor blades 5 or to respective second rotor blades 6.

[0024] The central hole 8 will be engaged, in use, by the tie-rod 3 of the rotor 1.

[0025] Each rotor disc 2 is further provided with a radial teeth annulus 12, commonly named as Hirth toothing, on each face 13a, 13b of the rotor disc 2 (in figure 2 only face 13a of the rotor disc 2 is well visible).

[0026] Preferably, the radial teeth annulus 12 is arranged along the respective face close to the peripheral edge 9 of the rotor disc 2.

[0027] The radial teeth annuli 12 are positioned and shaped to be coupled to the respective annuli of the adjacent rotor discs 2 in order to build the so-called Hirth joint and to ensure a stable coupling of the rotor discs 2.

[0028] Figure 3 shows a partially assembled rotor 1, in which the tie-rod 3 is arranged and supported in a vertical position. In other words, the tie-rod 3 is positioned so as the longitudinal axis A is substantially vertical.

[0029] With reference to figure 1 and figure 3, the tie-rod 3 is provided with one first end 15 and with a second end 16 axially opposite to the first end 15.

[0030] In use, the first end 15 is coupled to a front shaft 18 (figure 1 and 3) and the second end 16 protrudes from a rear hollow shaft 19 (visible only in figure 1).

[0031] Preferably, the front shaft 18 is housed in a stacking pit 21, which ensures a correct and stable vertical positioning of the tie-rod 3.

[0032] The configuration shown in figure 3 can occur both during the assembling of the rotor 1 (when the rotor discs 2 are stacked on top of one another, so that the radial teeth annuli 12 of the adjacent rotor discs 2 can be coupled to one another in order to build the Hirth joints) and during the disassembling of the rotor 1 (when the rotor discs 2 are removed one by one).

[0033] The method for controlling the positioning of at least one rotor disc 2 about a tie-rod 3 according to the invention is applied to a partially assembled rotor 1 like the one shown in the configuration of figure 3.

[0034] The method comprises detecting at least one parameter correlated to the position of at least one rotor disc 2 with respect to one or more references.

[0035] In particular, the method comprises detecting the eccentricity of the rotor disc 2 with respect to the longitudinal axis A with an assembly 23 for controlling the positioning of the rotor disc 2 comprising a main device 24 coupled to a free face 13a of the rotor disc 2 and at least one reference device 25 26 coupled to the tie-rod 3.

[0036] Preferably, the detection of the eccentricity of the rotor disc 2 is obtained by at least three lasers emitters 28 coupled to one between the main device 24 or the at least one reference device 25 and at least three respective photosensitive sensors 30 coupled to the other between the main device 24 and the at least one reference device 25.

[0037] The three lasers emitters 28 are preferably arranged at 120° from each other.

[0038] The photosensitive sensors 30 are arranged at 120° from each other too and are disposed to intercept the beams of the respective lasers emitters 28.

[0039] In the non-limitative example here disclosed and illustrated, the detection of the eccentricity is made by means of the main device 24 coupled to the free face 13a of the rotor disc 2 and two reference devices 25 26 coupled to the tie-rod 3.

[0040] Therefore, in the non-limitative example here disclosed and illustrated, a first measure of the eccentricity is made using the main device 24 and the reference device 25 and a second measure of eccentricity is obtained using the main device 24 and the reference device 26.

[0041] With reference to figure 3, the reference device 25 is coupled in the proximity of the first end 15 of the tie-rod 3, while the reference device 26 is coupled in the proximity of the second end 16 of the tie-rod 3. The main device 24, is coupled to the free face 13a of the rotor disc 2 whose position need to be controlled.

[0042] The reference device 25 is preferably fixed to the front shaft 18. More preferably, the reference device 25 is fixed to a portion 31 (see also figure 1) of the front shaft 18 comprised between the first rotor disc 2 and an annular seat 32 made in the front shaft 18 and configured to house, in use, a compressor collar bearing (not shown in the attached figures).

[0043] In the non-limitative example here disclosed and illustrated, the reference device 25 supports three laser emitters 28, each of which is configured to emit a laser beam B substantially along a vertical direction.

[0044] With reference to figure 3a, each laser emitter 28 is coupled to a base structure 35, which is provided with a positioning device 36. The positioning device 36 is configured to regulate the position of the laser emitter 28. In use, the positioning device 36 is regulated so as each laser emitter 28 of the reference device 25 emits a laser beam along a substantially vertical direction.

[0045] The positioning device 36 (see figure 3A) has a plurality of degrees of freedom. In particular, the positioning device 36 comprises at least two regulating elements 37a 37b which are rotatable about a respective axis of rotation O1, O2. The rotation axes O1, O2 are orthogonal one with respect to the other.

[0046] The angular adjustments (i.e. the rotation about axes 01 and 02) of each laser beam B emitted by the laser emitter 28 can be controlled manually or electronically. According to a variant not shown, the positioning device can be replaced by an orientation device similar to the ones that will described later and shown in figures 8 and 9.Preferably, the reference device 25 is provided with an annular base 39 from which at least three spokes 40 protrudes (only two of which are visible in figure 3). Each spoke 40 has a free end 41 to which a respective laser emitter 28 is coupled.

[0047] The free ends 41 of the spokes 40 are arranged at 120° one from another. Preferably, the spokes 40 are radially arranged about the annular base 39.

[0048] The length of the spokes 40 is sufficiently greater than the maximum height of the compressor blades 5 and turbine blades 6 so as the free ends 41 of the spokes 40 protrude over the compressor blades 5 and turbine blades 6 when the reference device 25 is fixed to the rotor 1.

[0049] Preferably, the annular base 30 can be opened and closed so as to allow its positioning and fixing about the portion 31 of the front shaft 18.

[0050] With reference to the non-limitative example shown in figure 3 and in figures 4 and 5, the reference device 26 is coupled to the second end 16 of the tie-rod 3 and is retractable. In particular, the reference device 26 comprises one cage structure 43, which is fixed to the tie-rod 3 and at least three retractable arms 44 which are housed in the cage structure 43 and arranged at 120° one from another. Each arm 44 can move from an operative position, wherein the arm 44 is extended outside the cage structure 43 (configuration shown in figures 3 and 5), and one rest position, wherein the arm 44 is retracted and is completely housed in the cage structure 43 (configuration shown in figure 4). Each arm 44 is an articulated arm having one end 45 coupled to a movable bush 46 and one free end 47 coupled to a respective photosensitive sensor 30.

[0051] Each arm 44 is configured to have a length in the operative position so as each photosensitive sensors 30 is able to detect the laser beam B' emitted by respective laser emitter 28 supported by the main device 24 as can be detailed later. Obviously, the arms 44 are arranged at the same angular position of the laser beams B' emitted by the laser emitters 28. Preferably, the photosensitive sensors 30 coupled to the arms 44 are arranged at the same radial distance from the longitudinal axis A. The movable bush 46 is arranged about a shaft 49. When the bush 46 is in the upper position (configuration shown in figure 4), the arms 44 are in the rest position, while when the bush 46 is in the lower position (configuration shown in figure 5) the arms 44 are in the operative position.

[0052] The bush 46 is preferably moved by a remotely controlled tool (not illustrated).

[0053] With reference to figure 3, the main device 24 is coupled to a free face 13a of the rotor disc 2. By free face we here and hereinafter mean a face of the rotor disc 2 that is not coupled to a further face of the adjacent rotor disc 2.

[0054] As already stated before, the method according to the invention can be applied both during the assembling and during the disassembling of the rotor 1.

[0055] During the assembling, the detection of the position of the disc 2 takes place before a further rotor disc 2 is stacked on the rotor disc 2 being controlled, whereas, during the disassembling, the detection of the position of the rotor disc 2 takes place before the rotor disc 2 being controlled is removed.

[0056] As a consequence, the method according to the invention requires the main device 24 to be coupled to one rotor disc 2 at a time.

[0057] However, this does not imply that the positioning control must be carried out for each disc of the rotor 1. It is also possible to control the positioning of groups of coupled rotor discs 2 by means of the detection of the position of the rotor disc 2 belonging to the group that has a free face.

[0058] With reference to the non-limitative example illustrated figures 6 and 7, the main device 24 comprises a support 53, a centring system 54 configured to center the support 53 on the rotor disc 2 being controlled, and at least three laser emitter 28 and at least three photosensitive sensors 30 coupled to the support 53.

[0059] The support 53 comprises an annular frame 58 and at least three spokes 60 with protrudes radially from the annular frame 58 and are arranged at 120° one from another. Each spoke 60 supports a respective photosensitive sensor 30. Preferably, the photosensitive sensor 30 is coupled to the side of the spoke 60 facing the free face 13a of the rotor disc 2. In other words, the photosensitive sensor 30 is coupled to the side of the spoke 60 facing, in use, the reference device 25. Preferably, the photosensitive sensor 30 is coupled to the free end 61 of the respective spoke 60.

[0060] The length of the spokes 60 is sufficiently greater than the maximum height of the compressor blades 5 and turbine blades 6 so as the free ends 61 of the spokes 60 protrude over the compressor blades 5 and turbine blades 6 when the main device 24 is coupled to the rotor disc 2. The sensors 30 are placed on the spokes 60 at the same angular position and at the same radial distance from the longitudinal axis A of the laser beams B emitted by the laser emitters 28 on the reference device 25. For example, the sensors 30 are placed on the spokes 60 long a circumference having a diameter of about 3.5 m.

[0061] Preferably, the annular frame 58 has one coupling face 62 (visible in figure 6), which, in use, faces the rotor disc 2 being controlled, and one operating face 63 (visible in figure 7), which is opposite the coupling face 62.

[0062] The coupling face 62 is coupled to the centring system 54, while the operating face 63 supports the at least three laser emitter 28. The laser emitters 28 are configured to emit respective laser beams B' and are arranged at 120° at the same radial distance from the center of the annular frame 58 (in use coinciding with the longitudinal axis A).

[0063] For example, the laser emitters 28 are placed on the operating face 63 along a circumference having a diameter of about 0.6 m.The spokes 60 are preferably arranged on the operating face 63.

[0064] Preferably, the support 53 comprises a further annular element 65, which is configured to protect the electronic devices (batteries, tilting sensors, control electronics, laser emitters 28, etc.) during the movement of the main device 24. The further annular element 65 is also configured so as to provide hooking points for the lifting of the support 53, for example by means of an overhead crane (not shown).

[0065] In the non-limiting example described and shown herein, the support 53 has dimensions that are compatible with the dimensions of the tie-rod 3 and of the rotor discs 2 making up the rotor 1.

[0066] With reference to figure 6, the centring system 54 comprises at least two portions 67 of a Hirth toothing annulus couplable to a respective portion of the radial teeth (Hirth) annulus 12 arranged on the free face 13a of one of the rotor discs 2 making up the rotor 1.

[0067] In order to be coupled to the radial teeth annulus 12 of any rotor disc 2 of the rotor 1, the portions 67 of the Hirth toothing annulus must be shaped so as to have a minimum radius that is equal to the inner radius of the radial teeth annulus 12 of the smallest rotor disc 2 and a maximum radius that is equal to the outer radius of the radial teeth annulus 12 of the largest rotor disc 2.

[0068] Furthermore, the portions 67 of the Hirth toothing annulus must have teeth that are oriented like the teeth of the radial teeth annulus 12, namely towards the center of the rotor discs 2, preserving all other parameters thereof (inclination of the walls of the teeth, number of teeth, etc.), so as to ensure a correct and stable coupling between the portions 67 and the radial teeth annulus 12 of the rotor discs 2.

[0069] If there are two portions 67 of the Hirth toothing annulus, they are diametrically opposite.

[0070] In the non-limiting example described and shown herein, the centring system 54 comprises three portions 67 that are separate and arranged on a same plane, preferably at approximately 120° from one another.

[0071] The three portions 67 are substantially identical.

[0072] Each laser emitter 28 coupled to the operating face 63 of the annular frame 58 of the support 53 is preferably coupled to an orientation device 70 (figure 8), configured to regulate the position of the laser emitter 28 so as the laser beam B' emitted by the laser emitter 28 is substantially vertical.

[0073] With reference to the non-limitative example illustrated in figure 8, the orientation device 70 comprises a casing 71 containing a fluid 72. The fluid is, for example, mercury in liquid state. The casing is coupled to the operating face 63 of the annular frame 58.

[0074] The laser emitter 28 is arranged in the casing 71 floating on the fluid 72. As the free surface 73 of the fluid 72 is always substantially horizontal independently from the inclination of the surface 63 supporting the casing 71, the laser emitter 28 is able to emit a laser B' always substantially vertical.

[0075] The orientation device 70 of figure 8 works properly if the laser emitter 28 has to emit a laser beam upwards, i.e. towards the end 16 of the tie-rod 3.

[0076] According to a variant shown in figure 9, the laser emitters 28 are coupled to the surface 62 of the annular frame 58 of the support 53 in order to emit laser beams downwards, i.e. towards the end 15 of the tie-rod 3. In this case, each laser emitter 28 is coupled to an axial-symmetrical body 75, which is hinged to the surface 62 of the annular frame 58 of the support 53. The body 75, due to its structure and weight, will be oriented so as the laser beam B' emitted by the laser emitter 28 is always substantially vertical independently from the inclination of the surface 62 supporting the body.

[0077] According to variants not illustrated, the laser emitters can be coupled to other kind of devices able to regulate properly the orientation of the laser beams. For example, motorized device or other known laser levelling systems.

[0078] With reference to figure 7, preferably, the main device 24 comprises also a biaxial inclinometer 78, which is coupled to the support 53 and is configured to measure the inclination of the support 53 with respect to two orthogonal axes.

[0079] Since the support 53 is integral to the rotor disc 2 to which it is coupled, the biaxial inclinometer 78 measures the inclination of the rotor disc 2 to which the main device 24 is coupled.

[0080] Preferably, the biaxial inclinometer 78 is coupled to surface 63 of the annular frame 58 of the support 53.

[0081] The main device 24 comprises also at least two distance detectors 80, which are coupled to the support 53 and arranged in respective points belonging to a same circumference (represented with a broken line in figure 7). The distance detectors 80 are oriented towards the centre of the above referred circumference. In this way, in use, the distance detectors 80 detect a distance along a radial direction with respect to the tie-rod 3.

[0082] In the non-limiting example described and shown herein, the main device 24 comprises three distance detectors 80, which are preferably arranged at 0°-90°-225° along the circumference.

[0083] Preferably, the distance detectors 80 are coupled to the operative surface 63 of the annular frame 58 and are arranged at a radial distance from the centre of the annular frame 58 shorter than the radial distance of the laser emitters 28. In other words, the distance detectors 80 are arranged internally with respect to the laser emitters 28.

[0084] The distance detectors 80 preferably are contactless detectors, for example laser triangulation systems; the distance detectors 80 allow to measure also the eccentricity of the external surface of the tie-rod 3 (used and potentially deformed) with respect to a virtual cylinder that is coaxial with the longitudinal axis A of the rotor 1.

[0085] With reference to figure 3, in use, the laser emitters 28 on the reference device 25 emit laser beams B towards the photosensitive sensors 30 of the main device 24, while the laser emitters 28 of the main device 24 emit laser beams B' towards photosensitive sensors 30 of the reference device 26.

[0086] According to a variant not illustrated, the reference device 25 comprises photosensitive sensors and the main device 24 comprises laser emitters emitting laser beams towards the photosensitive sensors of the reference device.

[0087] According to a variant not illustrated, reference device 26 comprises laser emitters emitting laser beams towards respective photosensitive sensors 30 of the main device.

[0088] Each photosensitive sensor 30 is configured to detect the laser beam impacting on it and to provide the radial position of the impacting point with respect to the longitudinal axis A.

[0089] With reference to figure 10, the photosensitive sensors 30 on the main device 24 are able to provide respective radial distances R1, R2, R3 with respect to longitudinal axis A by detecting the laser beams B emitted by the laser emitters 28 on the reference device 25 (the lower one), while the photosensitive sensors 30 on the reference device 26 (the upper one) are able to provide respective radial distances R1', R2', R3' with respect to the longitudinal axis A by detecting the laser beams B' emitted by the laser emitters 28 on the main device 24.

[0090] Laser emitters 28 are preferably low power laser emitters to ensure the safety of operators. In order to avoid external light noise detected by the photosensitive sensors 30, the laser emitters 28 emits laser beam with a frequency modulation. In this way, the photosensitive sensors 30 can be provided with appropriate filters.

[0091] Said values are sent to a control device 85. The control device 8 comprises a first eccentricity calculator 86 and a second eccentricity calculator 87.

With reference to 11, the first eccentricity calculator 86 is configured to elaborate the radial distances R1, R2, R3, define a circumference passing through the points detected by the sensors 30 and calculate the eccentricity value Vecc of said circumference with respect to the centre of symmetry "O" of the main device 24.

[0092] In case of significative (but atypical) inclination of the reference device 25, the radial distances R1, R2, R3 have to be fitted using an ellipse (instead of a circle); that ellipse can be calculated by taking into account the data detected by the inclinometer 78 (that is an input of block 86).

[0093] The second eccentricity calculator 87, analogously, is configured to elaborate the radial distances R1', R2', R3', define a circumference (or a ellipse taking into account the data of the inclinometer 78) passing through the points detected by the sensors 30 and calculate the eccentricity value Vecc' of said circumference (or ellipse) with respect to the centre of symmetry "O" of the main device 24.

[0094] The eccentricity values Vecc Vecc' are sent to an evaluation module 90, wherein the data about the eccentricity of each disc 2 of the rotor 1 are memorized and an assessment of the positioning of each the rotor disc 2 can be elaborated.

[0095] According to a variant not illustrated, the control device 85 comprises only one eccentricity calculator.

[0096] According to an embodiment that is not shown herein, the control device 85 comprises a further module, which is configured to give indications on possible corrective actions to be carried out in the light of the eccentricity values detected.

[0097] Preferably, the data detected by the photosensitive sensors 30 are sent to the control device 85 by means of wi-fi communications.

[0098] Preferably, also laser emitters 28 are remotely controlled by means of wi-fi communications.

[0099] Preferably, the control device 85 is not coupled to the support 53 and is integrated in an external processor (e.g. a tablet) available to the operator who follows the assembling/disassembling of the rotor 1. By so doing, the tablet can give the operator information on the correct positioning of the disc on the stack, respecting all tolerances, and, in any case, store the information.

[0100] In use, for controlling the positioning of a rotor disc 2 about the tie-rod 3 the operators have to position the rotor 1 vertically by means of a crane (not shown). Preferably, the front shaft 18 of the rotor 1 is housed in the stacking pit 21 to ensures a correct and stable vertical positioning of the tie-rod 3.

[0101] Then the reference devices 25 and 26 are coupled to the rotor 1 respectively in the proximity of the end 15 and of the end 16 of the tie-rod 3. The reference devices 25 and 26 are moved by a crane.

[0102] After the reference devices 25 and 26 have been correctly positioned, the main device 24 is arranged on the free face 13a of the rotor disc 2.

[0103] The positioning of the main device 24 on the rotor disc 2 is regulated so as to ensure that laser emitters 28 are substantially vertically aligned with respective photosensitive sensors 30.

[0104] Also the main device 24 is moved by using a crane.

[0105] After the positioning of the main device 24 laser emitters 28 are activated and the eccentricity of the controlled disc is evaluated.

[0106] Preferably, also the inclinometer 78 and the distance detectors 80 are activated in order to improve the controlling of the positioning of the rotor disc 2.

[0107] Advantageously, the assembly 23 and the method for controlling the positioning of the rotor disc according to the invention allow the assembling of the rotor 1 to be improved and optimized, thus avoiding assembling an unbalanced rotor and avoiding, especially, the costs deriving from one or more corrective interventions to be carried out on an already assembled rotor.

[0108] The assembly 23 and the method for controlling the positioning of a rotor disc according to the invention can also be applied to already assembled rotors that were assembled with the preceding assembling techniques.

[0109] In case of already assembled rotors, the assembly 23 and the method according to the invention can be applied during the disassembling of the rotor 1 disc by disc.

[0110] During the disassembling, the rotor discs 2 are removed one at a time and the assembly is used to detect the position of each rotor disc 2 until the rotor disc (or the rotor discs) is (are) found that is (are) responsible for the unbalance of the rotor 1.

[0111] The application of the assembly 23 during the disassembling of the rotor 1 is advantageous compared to currently known solutions, as it gives objective indications on the positioning of each rotor disc 2, without introducing operators' personal assessment elements.

[0112] Furthermore, you do not have to completely disassemble the rotor 1, for example in the following cases:

- if the rotor disc 2 responsible for the unbalance is identified before all rotor discs are removed;
- if at least two discs or two group of discs (possibly, even non-adjacent ones) are identified, which have an inclination that is such as to be capable of being compensated by a proper corrective action (i.e. a

rotation with respect to the axis A of one of the discs or groups of discs), which takes the stack of rotor discs back to being aligned, as a whole, within the given tolerances.

[0113] Basically, the identification of an unbalance does not always lead to the replacement of the rotor disc 2. As a matter of fact, the unbalance can simply be corrected by means of proper rotations of the rotor discs. In this case, the device 16 has a crucial role in establishing whether the corrective actions were effective and sufficient to compensate the unbalance.

[0114] Finally, it is clear that the assembly and the method described herein can be subject to changes and variations, without for this reason going beyond the scope of protection of the appended claims.

Claims

1. Method for controlling the positioning of at least one rotor disc (2) about a tie-rod (3) of a partially assembled rotor (1) of a gas turbine; the tie-rod (3) extending along a longitudinal axis (A);
the method comprising:

- positioning the tie-rod (3) so as the longitudinal axis (A) extends substantially vertically;
- detecting the eccentricity of the rotor disc (2) with respect to the longitudinal axis (A) of the tie-rod by means of an assembly (23) comprising a main device (24) coupled to a free face (13a) of the rotor disc (2) and at least one first reference device (25, 26) coupled to the tie-rod (3); the assembly (23) further comprising at least three lasers emitters (28) coupled to one between the main device (24) and the at least one first reference device (25, 26) and at least three respective photosensitive sensors (30) coupled to the other between the main device (24) and the at least one first reference device (25, 26); the photosensitive sensors (30) being arranged so as to intercept laser beams (B) emitted by respective lasers emitters (28).

2. Method according to claim 1, wherein the step of detecting the eccentricity comprises measuring a radial distance (R1, R2, R3; R1', R2', R3') between the longitudinal axis (A) and each laser beam (B) emitted by the laser emitters (28) by means of the at least three photosensitive detectors (30) and signal an eccentricity occurrence (Vecc; Vecc') on the basis of the detected radial distances (R1, R2, R2; R1', R2', R3').

3. Method according to claim 1 or 2, wherein the tie-rod (3) has one first end (15), which is arranged close to the floor when the tie rod (3) is in vertical position, and one second end (16), axially opposite to the first end (15); the at least one first reference device (25, 26) being coupled in the proximity of the first end (15) and/or of the second end (16).

4. Method according to anyone of the foregoing claims, wherein the at least one reference device (25; 26) comprises at least three supporting elements (40; 44), each of which supports one between the laser emitter (28) and the photosensitive sensor (30).

5. Method according to claim 3 or 4, wherein the assembly (23) comprises a second reference device (26); the first reference device (25) being coupled in the proximity of the first end (15) and the second reference device being coupled to the second end (16).

6. Method according to claim 5, wherein the step of detecting the eccentricity of the rotor disc (2) comprises:

measuring a first radial distance (R1, R2, R2) between the longitudinal axis (A) and each laser beam (B) emitted by first laser emitters (28) arranged on the first reference device (25) by means of at least three first photosensitive detectors (30) arranged on the main device (24);
measuring a second radial distance (R1', R2', R3') between the longitudinal axis (A) and each laser beam (B') emitted by second laser emitters (28) arranged on the main device (24) by means of at least three second photosensitive detectors (30) arranged on the second reference device (26);
signalling a second eccentricity occurrence (Vecc') on the basis of the second radial distances (R1', R2', R3').

7. Method according to anyone of the foregoing claims, wherein at least one laser emitter (28) is coupled to an orientation device (70, 75) configured to regulate the position of the laser emitter (28) so as the laser beam (B) emitted by the laser emitter (28) is substantially vertical.

8. Method according to anyone of the foregoing claims, comprising also the step of measuring the inclination by means of an inclinometer (78) coupled to main device (24).

9. Assembly for controlling the positioning of at least one rotor disc (2) about a tie-rod (3) of a partially assembled rotor (1) of a gas turbine; the tie-rod (3) extending along a longitudinal axis (A);
the assembly comprising:

- a main device (24) coupled, in use, to a free face (13a) of the rotor disc (2); and

• at least one first reference device (25, 26) coupled, in use, to the tie-rod (3);

• at least three lasers emitters (28) coupled to one between the main device (24) and the at least one first reference device (25, 26); and

• at least three respective photosensitive sensors (30) coupled to the other between the main device (24) and the at least one first reference device (25, 26); the photosensitive sensors (30) being arranged so as to intercept laser beams (B) emitted by respective lasers emitters (28).

10. Assembly according to claim 9, wherein the at least three photosensitive detectors (30) are configured to measure a radial distance (R1, R2, R3; R1', R2', R3') between the longitudinal axis (A) and each laser beam (B) emitted by the laser emitters (28).

11. Assembly according to claim 10, comprising a control device (85) configured to signal an eccentricity occurrence (Vecc; Vecc') on the basis of the detected radial distances (R1, R2, R2; R1', R2', R3').

12. Assembly according to anyone of the claims from 9 to 11, wherein the at least one reference device (25; 26) comprises at least three supporting elements (40; 44), each of which supports one between the laser emitter (28) and the photosensitive sensor (30).

13. Assembly according to anyone of claims from 9 to 12, wherein the at least one first reference device (25, 26) is coupled, in use, in the proximity of a first end (15) and/or of a second end (16) of the tie-rod (3).

14. Assembly according to claim 13, comprising a second reference device (26); the first reference device (25) being coupled in the proximity of the first end (15) and the second reference device being coupled to the second end (16).

15. Assembly according to anyone of the claims from 9 to 14, wherein at least one laser emitter (28) is coupled to an orientation device (70; 75), configured to regulate the position of the laser emitter (28) so as the laser beam (B) emitted by the laser emitter (28) is substantially vertical.

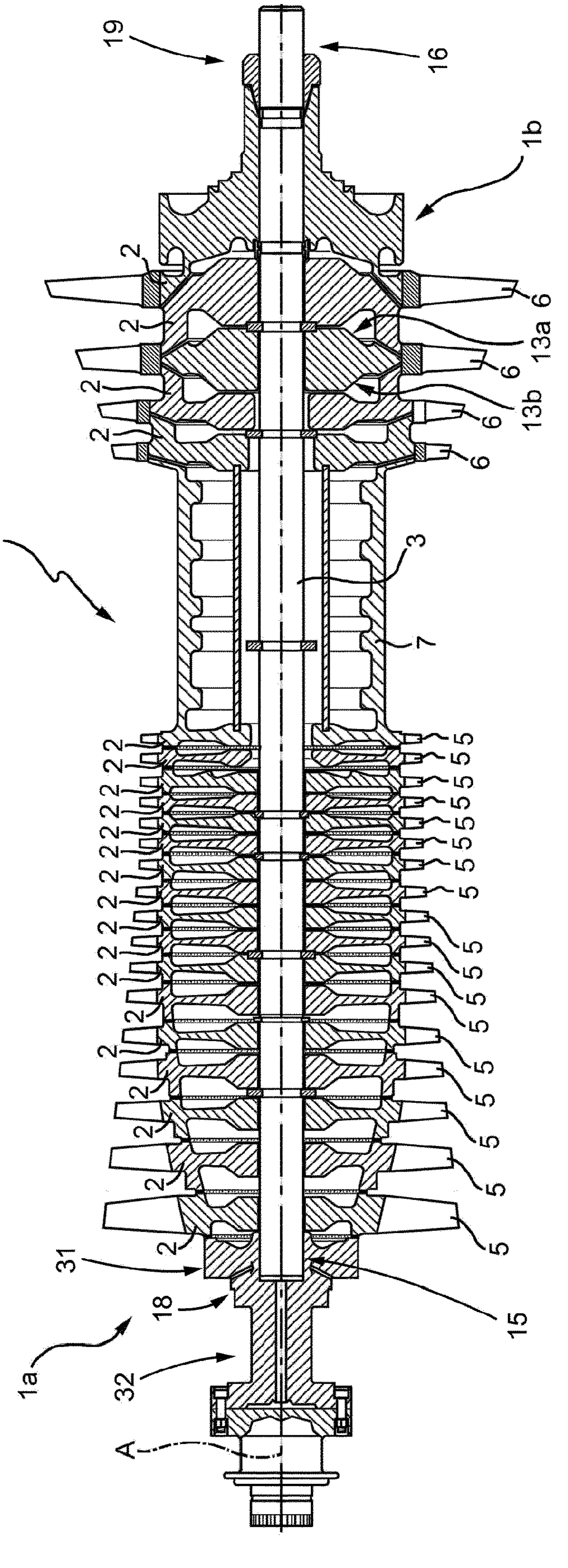

FIG. 1

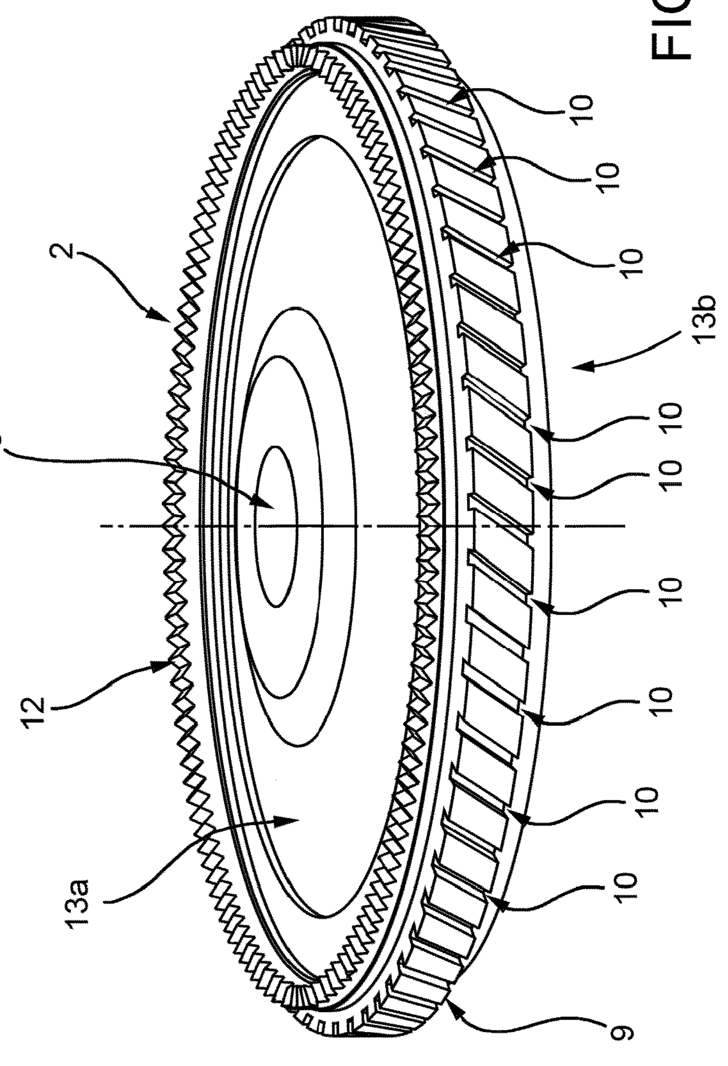

FIG. 2

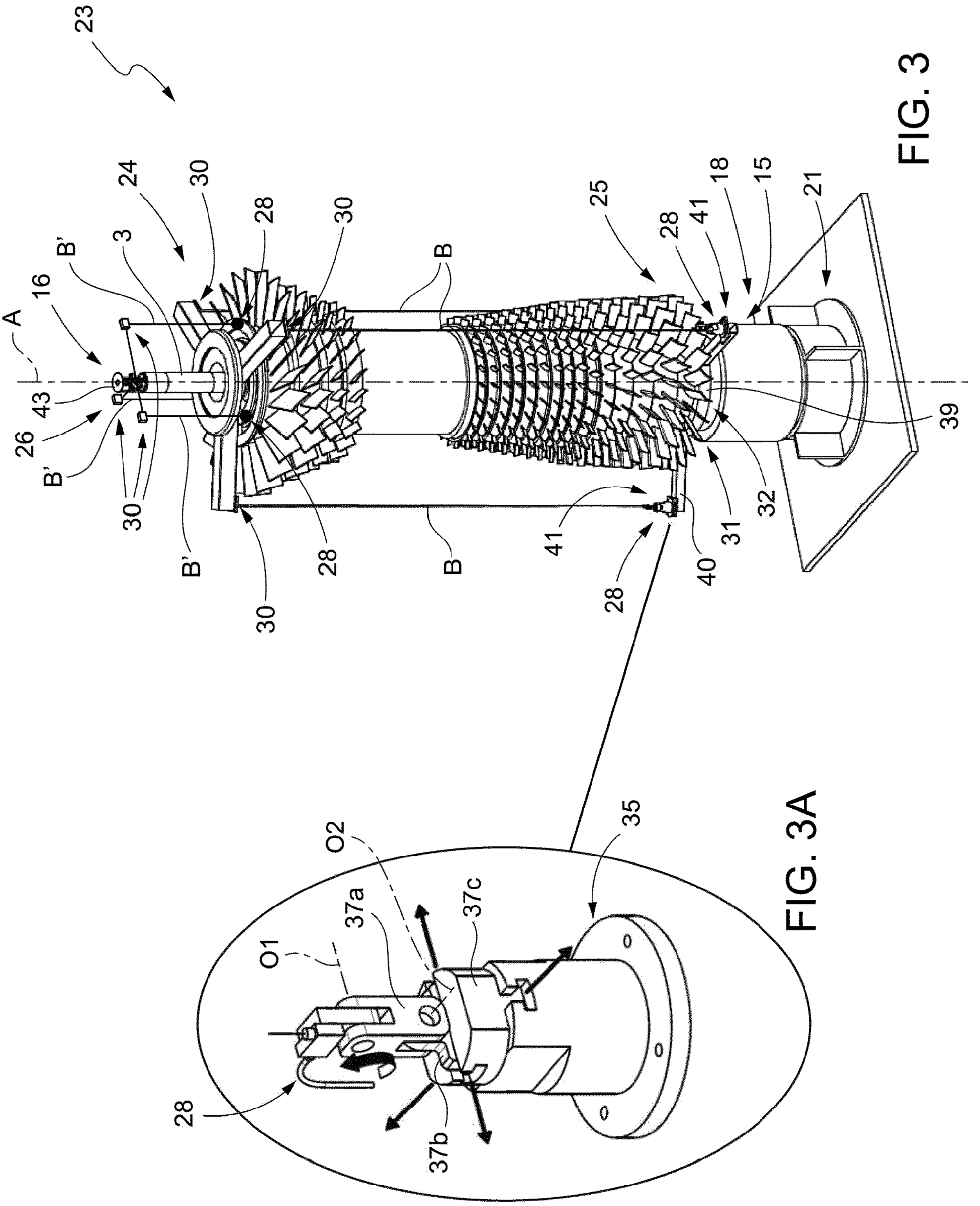
23
24
25
26
16
A
B'
B
3
28
30
43
41
40
31
32
39
18
15
21
35
37a
37b
37c
O1
O2

FIG. 3

FIG. 3A

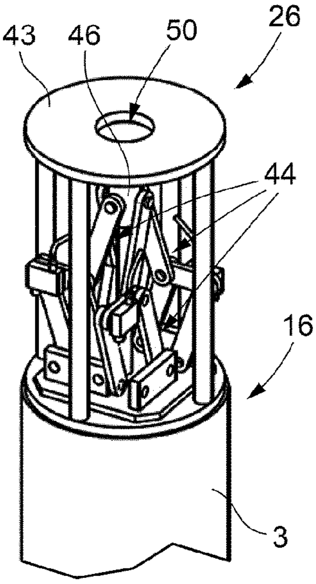

FIG. 4

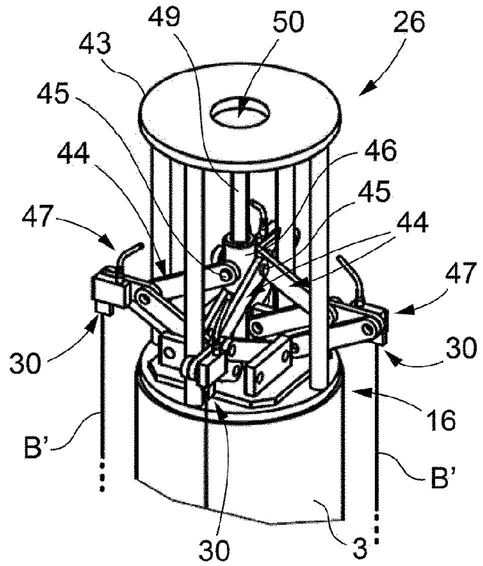

FIG. 5

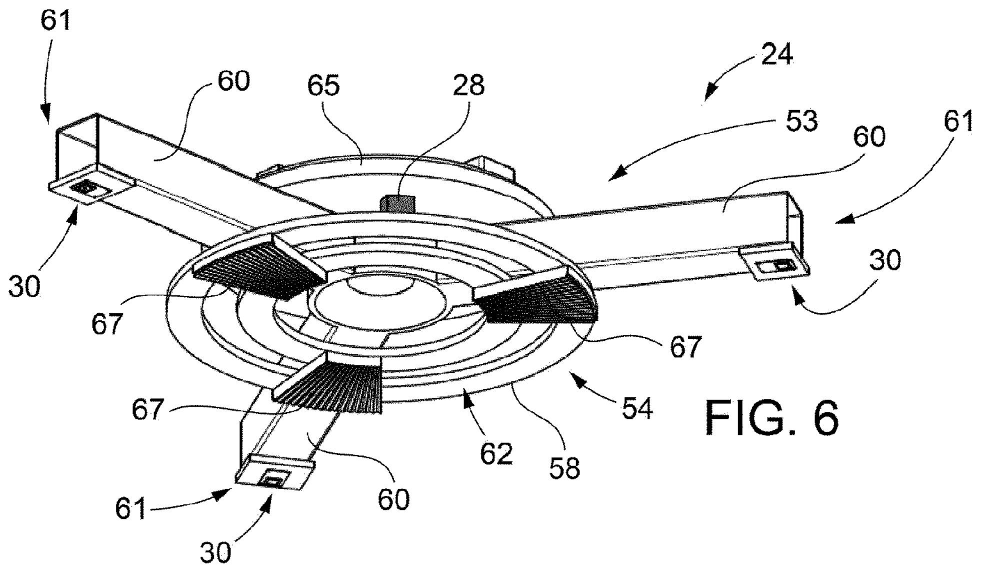

FIG. 6

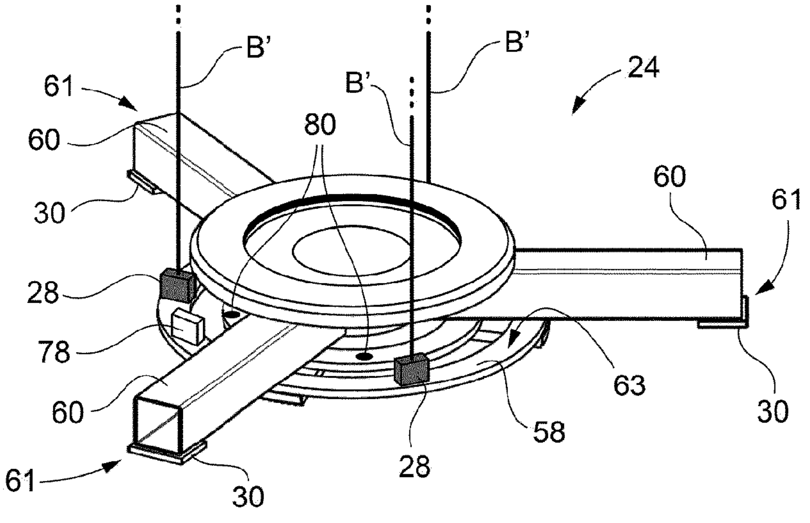

FIG. 7

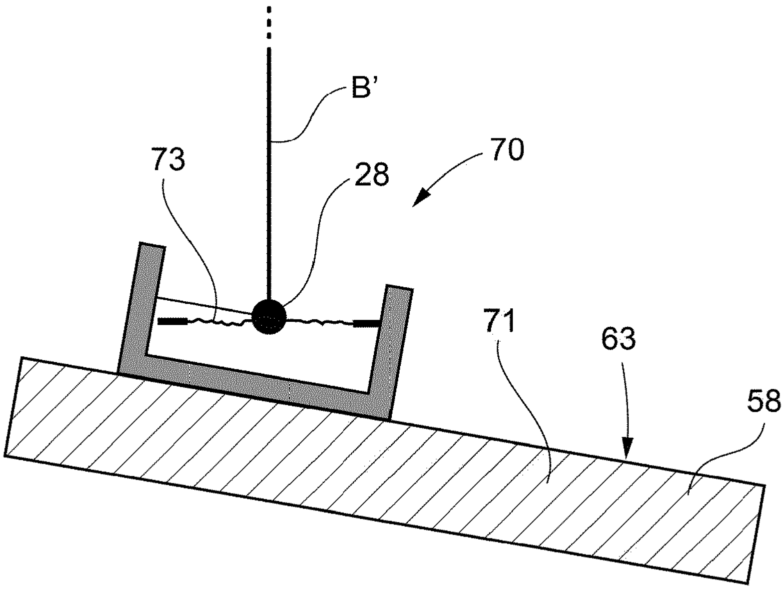

FIG. 8

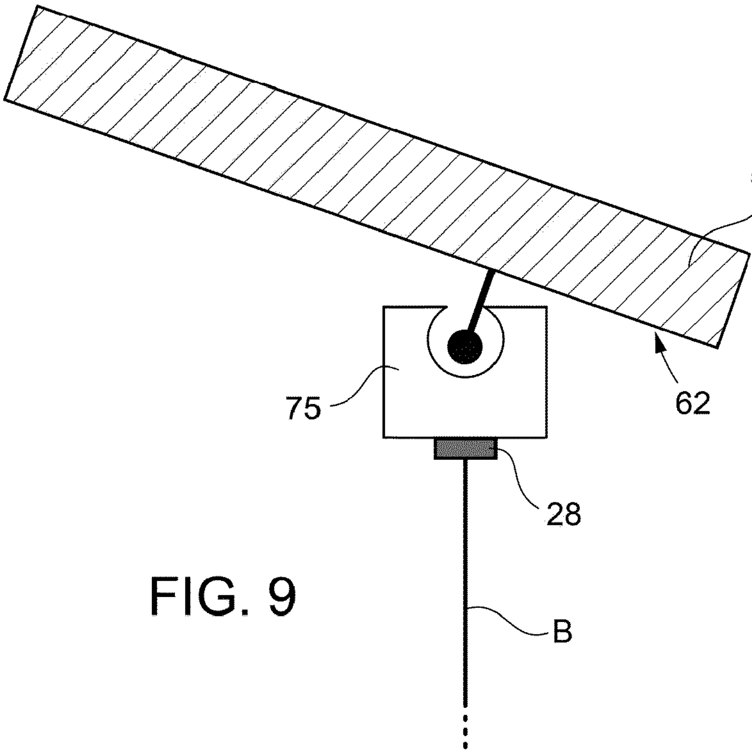

FIG. 9

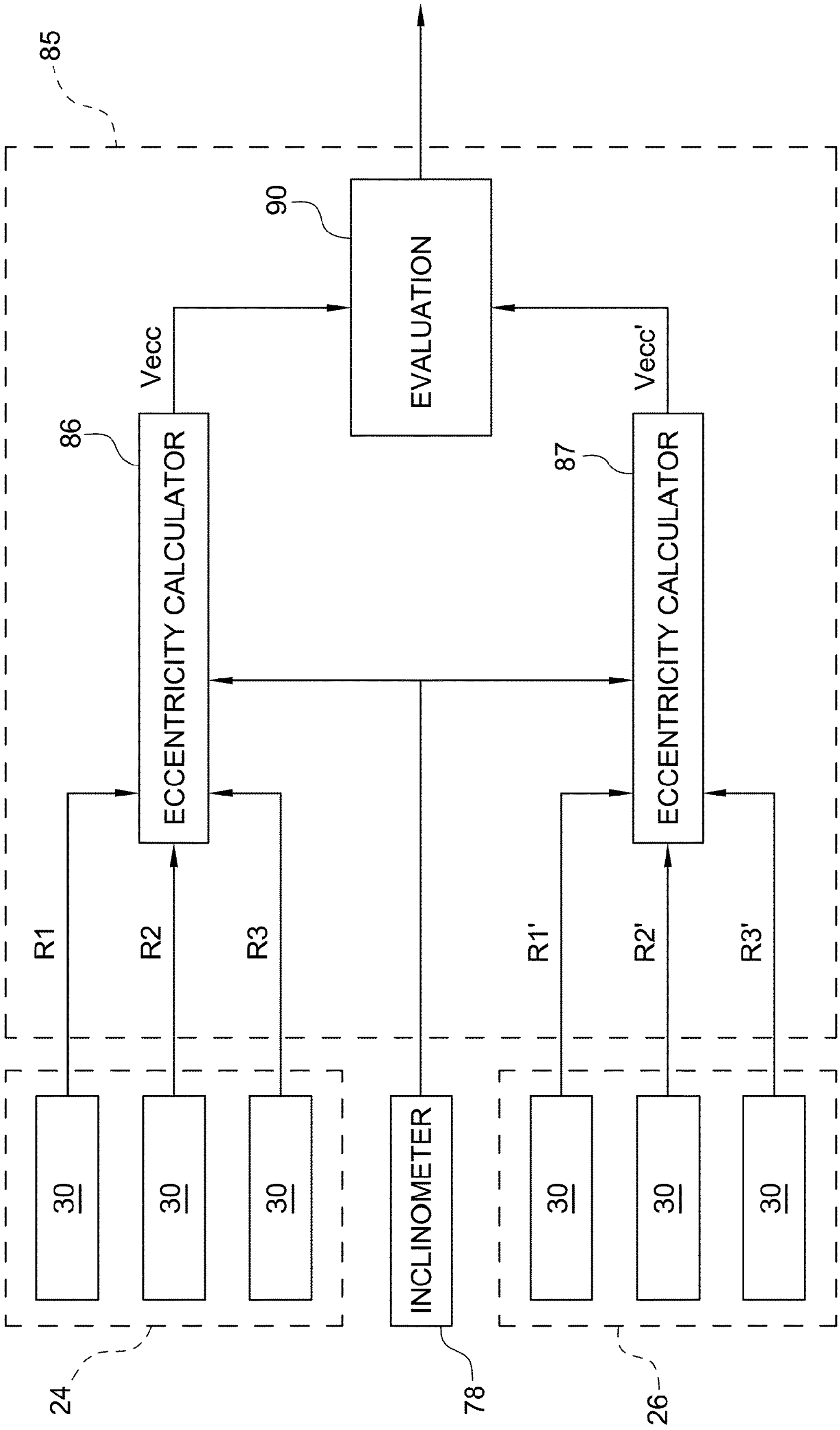
85
90
EVALUATION
Vecc
Vecc'
86
87
ECCENTRICITY CALCULATOR
ECCENTRICITY CALCULATOR
R1
R2
R3
R1'
R2'
R3'
30
30
30
INCLINOMETER
30
30
30
24
78
26

FIG. 10

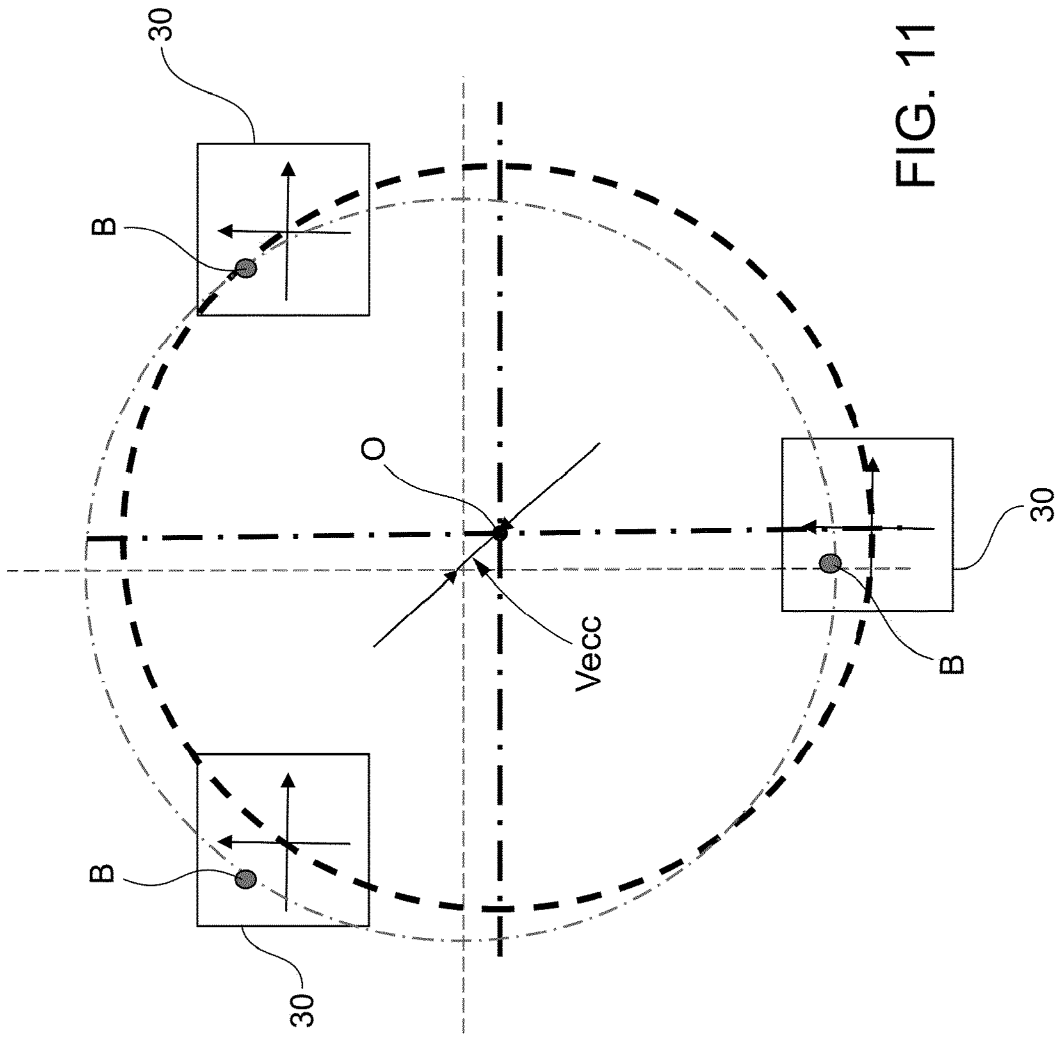

FIG. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 9754

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F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	15 September 2020	Pileri, Pierluigi

CATEGORY OF CITED DOCUMENTS

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15-09-2020

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