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(54) **SYSTEM AND METHOD FOR ALINGNING ROLLERS OF CONTINUOUS CASTING SEGMENTS OF SLABS**

(57) A measurement system (1) for measuring the position of the axes of the rollers of a containment and guide segment, adapted to contain and guide a cast product exiting from a crystallizer in a continuous casting process, the system comprising a robot (2) having an arm (4) provided at one end thereof with a reflector (5), said robot being adapted to move the reflector (5) in order to suc-

cessively put it in contact with a plurality of points of each roller of the containment and guide segment; and comprising a laser tracker (3) adapted to track the reflector (5) by means of a laser beam and to calculate the position in space of each of said points of the containment and guide segment so as to determine the position of the axis of each roller.

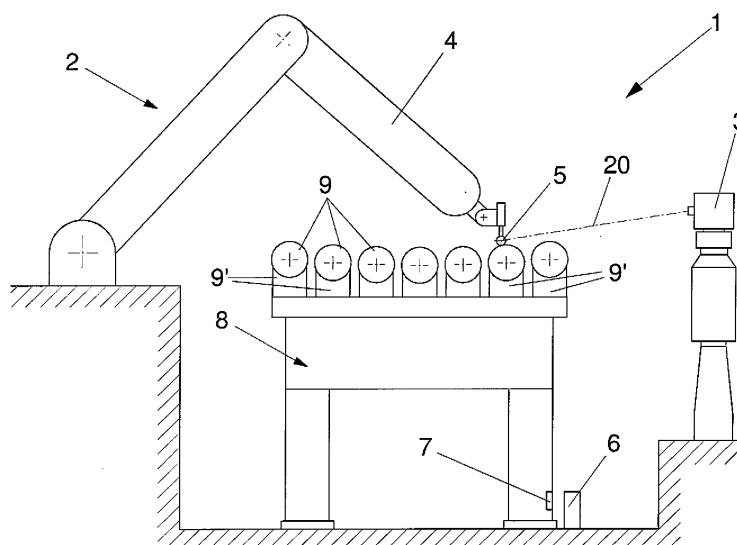


Fig. 1

Description

Field of the invention

[0001] The present invention relates to a system and to a method for aligning rollers of segments belonging to the continuous casting of slabs.

State of the art

[0002] The product exiting from a crystallizer needs to be contained and guided. This occurs initially by means of rollers at the foot of the mold in which the crystallizer is inserted, and then by means of a series of containment and guide segments or sectors, which accompany the product until it reaches the horizontal plane.

[0003] Each segment is generally formed by a plurality of rollers with which the product comes into contact, and which actually contain and guide the product. The positioning of the rollers according to the strategies selected and especially the alignment thereof determine the quality that the cast product will have. If rollers are positioned with the axis thereof not parallel to the axes of the other rollers, that is the rollers are not aligned, or rollers have eccentricities or are bent, the cast product is not contained in a homogenous manner along the whole length of the casting curve and therefore the quality thereof is compromised.

[0004] The technique normally used in the state of the art for aligning the rollers of continuous casting segments consists substantially of the sequence of steps listed below:

- the segment is removed from the casting line and placed in a specific measurement zone. Following the division between fixed part and movable part of the segment, both parts are positioned on specific support bays;
- a template is restrained to the bay so that it is above the rollers of the segment. The gap between the template and each roller is then measured using calibrated shims;
- the measurement procedure in the point above is repeated in different zones of all rollers by moving the template each time in the axial direction of the rollers. Based on the results of the measurements, shims are added to or removed from the supports of the rollers to obtain the proper alignment;
- at the end of the mechanical adjustments, a check is performed again with the template to ensure the alignment is acceptable.

[0005] In addition to being difficult and complex, the procedure described requires a very long execution time: about 4-6 hours with the employment of two operators, the time for the measurement alone being about 3.5-5 hours.

[0006] The need is therefore felt to make an innovative

system for aligning the rollers of containment and guide segments for a continuous cast product, and relative alignment method, which allows the aforesaid drawbacks to be overcome.

Summary of the invention

[0007] It is the main object of the present invention to provide a system for aligning rollers of containment and guide segments, used in the continuous casting of metallic products, such as slabs or blooms, which is significantly faster with respect to solutions of the state of the art.

[0008] It is another object of the present invention to provide a system for aligning rollers of continuous casting segments, which does not require the manual work of operators.

[0009] It is a further object of the present invention to provide a relative method for aligning the rollers of the continuous casting segments which is highly accurate and efficient.

[0010] Therefore, the present invention proposes to achieve the objects discussed above by making a measurement system for measuring the position of the longitudinal axis of rollers of a containment and guide segment for aligning rollers of continuous casting segments which, according to claim 1, comprises

- a robot having an arm provided at one end thereof with a reflector, said robot being adapted to move the reflector in order to successively put it in contact with a plurality of predetermined points of each roller of the containment and guide segment,
- a laser tracker adapted to track said reflector by means of a laser beam and to calculate the position in space of each of said points so as to determine the position of the axis of each roller,
- processing means adapted to process and impart movement commands to the robot and, therefore, to the reflector,
- at least one tag fixed on the segment and containing pre-stored information on the segment and/or on each roller therein, said information comprising said predetermined points of each roller and any previous measurements carried out at said predetermined points of each roller,
- a device for automatically recognizing the containment and guide segment, provided with a reader adapted to read said information on the segment and/or on each roller and to transmit it to the processing means, whereby said processing means impart consequent movement commands to the robot.

[0011] A second aspect of the present invention provides a method for aligning rollers of continuous casting segments which, according to claim 10, comprises the following steps:

- a) positioning the containment and guide segment in a measuring zone;
- b) determining, by means of the robot and the laser tracker, the position in space of the segment;
- c) carrying out the measurements of the position in space, by means of the robot and the laser tracker, of a plurality of predetermined points of each roller;
- d) processing the measurements carried out in step c) to generate a list of mechanical adjustments to be performed on each roller of the segment to align to each other the axes of the rollers of the segment along a predetermined surface;
- e) carrying out said mechanical adjustments,

wherein there is provided, before step b), a recognition, by means of an automatic recognition device, of the containment and guide segment which allows, by means of a reader, information on the segment and/or on each roller to be read from at least one tag fixed on the segment, and the information to be transmitted to the processing means of the measurement system, said information comprising said predetermined points of each roller on which the measurements of step c) are to be carried out, and any previous measurements carried out on the rollers of the same segment.

[0012] The solution of the invention for aligning the rollers of continuous casting segments provides using a laser tracker and a robot, which is preferably but not necessarily anthropomorphous, which has the task of moving, in an automated manner, the reflector, tracked by the laser tracker, in various predetermined points of the rollers of the segment under examination.

[0013] The laser tracking system comprises a laser emitter, usually held stationary, and a movable reflector the position of which can be calculated.

[0014] With regard to the laser tracker, it can be of any type. To obtain particularly accurate measurements, a calibrated ball can be used as a reflector, which is rested on the part under examination, and any laser tracker, which calculates the position in space of the measurement point by means of a laser beam projected onto the reflector.

[0015] In addition to the anthropomorphous robot and the laser tracker, the measurement system object of the invention advantageously comprises an automatic recognition system for recognizing the segment, of the RFID type, of the optical type or other equivalent system.

[0016] The system and the method of the invention allow the following advantages to be obtained:

- increased accuracy, higher than known systems, with tolerance of $[\pm 15 \mu\text{m} + 6 \mu\text{m}/\text{m}]$ (where m is the meters of distance between the laser tracker and the reflector; for example, if the distance is 5 meters, the accuracy is $15 + (6 \times 5) = \pm 45 \mu\text{m}$);
- quick measurement time (only about 10 minutes for the only measurement of the rollers of a whole segment, plus the manual alignment time of the rollers

which is equal to the manual alignment time of current systems);

- the measurement is completely automatic and does not require the use of any templates;
- the system is user friendly because it does not require any knowledge or experience to carry out the measurement;
- the automatic recognition of the individual segments.

[0017] The dependent claims describe preferred embodiments of the invention.

Brief description of the figures

[0018] Further features and advantages of the invention will be more apparent in light of the detailed description of a preferred, but not exclusive, embodiment of a system for aligning rollers of continuous casting segments, shown by way of non-limiting example, with the aid of the accompanying drawings in which:

Figure 1 depicts a side view of a first embodiment of the system according to the invention;

Figure 2a depicts a side view of a properly aligned cylindrical roller, with the three measurement zones on the roller highlighted;

Figure 2b depicts a side view of a misaligned cylindrical roller, with the three measurement zones on the roller highlighted;

Figure 2c depicts a side view of a properly aligned cylindrical roller but bent (with subsequent eccentricity), with the three measurement zones on the roller highlighted;

Figure 2d depicts side views of a roller, with three measuring points along a circumferential perimeter of the roller highlighted;

Figure 3 depicts a diagram of a second embodiment of the system according to the invention;

figure 4 depicts a diagrammatic view from the top of the system in figure 3;

Figure 5 depicts a side view of a further embodiment of the system according to the invention.

The same reference numerals in the drawings identify the same elements or components.

Detailed description of preferred embodiments of the invention

[0019] With reference to the drawings, preferred embodiments are shown of a system for aligning rollers of a containment and guide segment, or of a continuous casting segment, suitable for containing and guiding a cast product exiting from a crystallizer in a continuous casting process.

[0020] The alignment system object of the present invention is a measurement system for measuring the position of the longitudinal axis of the rollers 9 of a containment and guide segment 8, which is used once segment

8 is removed from the casting line and is placed in a specific maintenance zone. A containment and guide segment 8 generally comprises a base structure on which the cylindrical-shaped rollers 9 are arranged. Each roller 9 is supported at the ends by supports 9', whose position with respect to the base structure can be adjusted by adding or removing at least one thickness between support 9' itself and the base structure of segment 8.

[0021] Such a measurement system, globally indicated with numeral 1, comprises, in a first embodiment thereof:

- a robot 2, which is preferably anthropomorphous, having an arm 4 provided at one end thereof with a reflector 5, and configured to move reflector 5 in order to successively put it in contact with a plurality of predetermined points of each roller 9 of the containment and guide segment 8,
- and a laser tracker 3 for tracking reflector 5 by means of a laser beam 20 and configured to calculate the position in space of each of said predetermined points so as to determine the position of the axis of each roller 9.

[0022] The accuracy in the measurements is given by the laser tracker 3 and the accuracy of the movement of robot 2 is not important. The laser tracker 3 is capable of assessing coordinates of points in space. It measures the distance between itself and reflector 5, the Azimuth angle and the Zenith angle. Due to a PSD sensor and a camera, the laser tracker 3 tracks the reflector even if the emission of the laser beam is interrupted.

[0023] Reflector 5 can be, for example, in the shape of a calibrated ball in order to always guarantee the same distance - equal to the radius of the ball - between the measurement point - that is the middle of the ball - and the surface of the roller in contact with the ball. A single reflector 5 is advantageously provided, preferably consisting of a single calibrated ball.

[0024] A position switch which operates in three or orthogonal directions can be provided between the end of arm 4 and reflector 5. This configuration ensures the contact between reflector 5 and roller 9, allows reflector 5 to be gently rested on the rollers without any significant impact, and protects against any impacts.

[0025] Advantageously, it is possible to provide an extension 21 of the arm (Fig. 5) between arm 4 and reflector 5, or between arm 4 and any position switch; the use of extension 21 allows to use robots having smaller size with respect to the ones that would be necessary in the absence thereof, thus allowing all points that may require verifying to be reached.

[0026] Advantageously, a device for automatically recognizing the containment and guide segment of the casting curve can be provided.

[0027] In a preferred embodiment, this recognition device is provided with an RFID reader 6 arranged in the maintenance zone, which automatically reads the infor-

mation concerning the containment and guide segment 8 which is placed in said maintenance zone (Fig. 1), and transmits it to processing means of the measurement system adapted to process and impart movement commands to robot 2 and, therefore, to reflector 5. Such information is stored in a tag or RFID tag 7 fixed on segment 8, for example on the base structure thereof, and comprises predetermined points of each roller 9 on which the measurements are to be performed and any data of any previous measurements carried out at said predetermined points of each roller. Said information further comprises CAD models of segment 8 from which the processing means of the measurement system derive, in known manner, the theoretical position of the longitudinal axis of each roller 9 of the segment, that is the position of the longitudinal axis of each roller at which all rollers of the segment are aligned with one another. In other words, the theoretical position of the longitudinal axis of each roller 9 of the segment is the position at which all the longitudinal axes of the rollers of the segment are lying on a curvilinear surface corresponding in shape to the shape of the casting curve.

[0028] Thereby, after the RFID reader 6 recognizes segment 8, the CAD model of the segment and all the previous measurements on the same segment are imported by the processing means of the measurement system.

[0029] In a possible variant of the solution, tags or RFID tags can be provided on all rollers 9; it is therefore possible in this variant to know the previous inspections carried out on each roller and to apply preventive maintenance concepts. Indeed, the processing means load the information concerning each roller and in certain cases indicate the activities to be carried out without the need to take the measurement (for example, if the roller has already exceeded the maximum operating hours).

[0030] Alternatively, the automatic recognition device can be of the optical type or other equivalent type. In the variant with optical recognition device, an optical reader reads the information concerning the containment and guide segment 8 that is placed in the maintenance zone, said information being stored in a tag in the form of a barcode or other equivalent code, fixed on the segment.

[0031] More generally, tag 7, in the form of an RFID tag or barcode, is fixed on the base structure of the segment and/or on each roller of the segment.

[0032] Furthermore, reader 6, of RFID type or of optical type, arranged in the maintenance zone, can be provided directly on robot 2.

[0033] Since they are provided with a database comprising initial geometric information of the rollers to be measured, for example of shape and of theoretical position, and possibly also comprising the geometric and position information detected previously, said processing means are advantageously configured to perform a geometric and position comparison between the geometric and position information of the individual roller just measured and geometric and position information in the data-

base.

[0034] An important aspect comes from the fact that by knowing exactly the shape and the size of the segment and of the individual rollers - even if irregular in shape - the processing means can compare such data with those detected by means of reader 6, thus succeeding in imparting precise movement commands to robot 2, optimizing the movement of reflector 5, while also avoiding any obstacles.

[0035] A further advantage lies in the fact that it is possible to provide driving means for transmitting a rotational motion to roller 9 during the measurement with reflector 5 in contact therewith, said driving means being preferably connected to robot 2. Reflector 5 is therefore held in contact with roller 9, which is put into rotation; thereby, it is possible to appreciate any eccentricities of the roller.

[0036] In a second embodiment of the invention, which comprises all the features described above for the first embodiment, robot 2 is installed on a jib crane 10 (Fig. 3), adapted to move robot 2 in order to reach any point of any roller 9 of segment 8 (Fig. 4).

[0037] In Fig. 4 for example, the jib crane 10 can be moved from a middle position, depicted by a solid line, to the side positions 10', 10'', indicated with dotted lines. A respective area of action 11, 11', 11'' of robot 2 corresponds to each of the three positions of the jib crane. It can be seen that these three areas of action 11, 11', 11'' covers all the rollers 9 of segment 8.

[0038] The additional advantage of this second embodiment is that it allows the use of a smaller robot 2, thus reducing weight and costs of the robot. Among other things, the accuracy of the movement of the jib crane 10 is not important because the accuracy in the measurements is given by the laser tracker.

[0039] A further advantage lies in the possibility of providing an extension of the arm between arm 4 of the robot and reflector 5, or between arm 4 and any position switch; the use of the extension also allows smaller cranes to be used with respect to the ones that would be necessary in the absence thereof, thus allowing all points which may require verifying, to be reached.

[0040] By using the embodiments of the measurement system described above, it is possible to carry out a method for aligning the longitudinal axes of the rollers 9 of a containment and guide segment 8, which comprises the following steps:

- a) positioning the containment and guide segment 8 in a maintenance zone;
- b) determining, by means of robot 2 and the laser tracker 3, the position in space of segment 8;
- c) carrying out the measurements of the position in space, by means of robot 2 and the laser tracker 3, of predetermined points for determining the information to be obtained: for example, a plurality of points of at least two zones of each roller can be measured so as to calculate the position of the axis of each roller;

d) processing the measurements carried out in step c), by comparing the data collected in the various measuring points, to generate a list of mechanical adjustments to be performed on each roller 9 of segment 8 to align the axes of the rollers 9 along a predetermined surface;

e) carrying out said mechanical adjustments,

[0041] Advantageously, before step b), there is provided a recognition, by means of the automatic recognition device, of the containment and guide segment 8 of the casting curve which allows the predetermined points of each roller on which to carry out the measurements of step c), to be loaded into the measurement system, thus automatically defining said predetermined points, and any previous measurements or inspections carried out on the same segment. Once the type of segment is recognized, the system practically automatically knows the points of the rollers where the measurements are to be taken. Such automatic recognition allows, by means of reader 6, information on the segment and/or on each roller to be read from at least one tag 7 fixed on the segment, and the information to be transmitted to the processing means of the measurement system, said information comprising said predetermined points of each roller 9 on which to carry out the measurements of step c), and said any previous measurements carried out on the rollers of the same segment.

[0042] Initial zero measurements are in practice carried out in step b), adapted to determine the exact position in space of the segment with respect to a reference system (x, y, z).

[0043] In step c) for example, at least two zones of each roller, which preferably comprise the two ends, can be the subject of measurement. Furthermore, it is preferable to carry out the measurements on at least three points along the circumferential perimeter of each of said at least two zones. Even more preferably, at least three zones of each roller, which comprise the two ends and the middle zone of the roller, can be the subject of measurement. Therefore in this step c), measurements required to understand the position and the conditions of each roller are carried out.

[0044] In step d), the processing comprises the steps of:

- calculating the actual position in space of the axis of each roller by using the coordinates of at least six measuring points per roller: for example, three measuring points along the circumferential perimeter at both ends of the roller;
- comparing the actual position of the axis of each roller with a respective theoretical position of each roller, at which the rollers of the segment are aligned with one another;
- calculating the shift to impose to the supports of each roller so as to bring the axis thereof to the proper position, that is to said theoretical position.

[0045] The theoretical position of each roller 9 of segment 8 can be preferably derived from the CAD models of the segment, which are pre-stored in tag 7.

[0046] By measuring at least nine points per roller, that is by providing three additional measuring points along the circumference or circumferential perimeter of the middle zone of the roller, it is also possible to calculate any bending of the roller. By carrying out the measurements in at least three points along the circumferential perimeter of each of said three zones (the two ends and the middle zone), it is therefore possible to calculate the eccentricity of each roller. It is also possible to obtain the radius of the roller in the three different zones by assessing the degree of wear thereof.

[0047] The mechanical adjustments can be mainly of three types:

- adding shims between support 9' of roller 9 and the base structure of the segment if the axis of the roller is to be raised;
- removing shims between support 9' of roller 9 and the base structure of the segment if the axis of the roller requires to be lowered;
- replacing the roller in the case of excessive wear or reaching the maximum operating time.

[0048] The mechanical adjustments carried out in step e) are therefore generally carried out with shims which are added to or removed from the supports 9' of the rollers 9 to vary the alignment thereof depending on the instructions obtained in step d).

[0049] It is also possible to provide the use of a pair of Google-glasses by means of which, when the operator looks at a segment/a roller, all the information concerning the segment/roller is displayed and the adjustments to be carried out to perform the alignment of the rollers are indicated. It is possible to reduce the time required for the adjustment activities by means of this further functionality, and the work of the operator becomes more practical and safer.

[0050] After step e), that is the actual alignment of the rollers of the containment and guide segment, which is carried out manually, a further inspection is carried out on the segment to verify the correctness of the operations carried out and to possibly further correct the position of the rollers.

Claims

1. A measurement system (1) for measuring the position of the longitudinal axis of the rollers of a containment and guide segment, adapted to contain and guide a cast product exiting from a crystallizer in a continuous casting process, the system comprising
 - a robot (2) having an arm (4) provided at one end thereof with a reflector (5), said robot being

adapted to move the reflector (5) in order to successively put it in contact with a plurality of predetermined points of each roller of the containment and guide segment,

- a laser tracker (3) adapted to track said reflector (5) by means of a laser beam and to calculate the position in space of each of said points so as to determine the position of the axis of each roller,

- processing means adapted to process and impart movement commands to the robot (2) and, therefore, to the reflector (5),

- at least one tag (7) fixed on the segment (8) and containing pre-stored information on the segment and/or on each roller therein, said information comprising said predetermined points of each roller (9) and any previous measurements carried out at said predetermined points of each roller,

- a device for automatically recognizing the containment and guide segment, provided with a reader (6) adapted to read said information on the segment and/or on each roller and to transmit it to the processing means, whereby said processing means impart consequent movement commands to the robot (2).

2. A system according to claim 1, wherein said reader (6) is an RFID reader and said at least one tag (7) is an RFID tag, or wherein said reader (6) is an optical reader and said at least one tag (7) is a barcode.
3. A system according to claim 1 or 2, wherein said tag (7) is fixed on a base structure of the segment and/or on each roller of the segment.
4. A system according to any one of the preceding claims, wherein said information further comprises CAD models of the segment (8) whereby the processing means of the measurement system can derive the theoretical position of the longitudinal axis of each roller (9) of the segment (8).
5. A system according to any one of the preceding claims, wherein the robot (2) is an anthropomorphic robot.
6. A system according to any one of the preceding claims, wherein the reflector (5) consists of a single calibrated ball.
7. A system according to any one of the preceding claims, wherein driving means are provided for transmitting a rotational motion to a roller during the measurement with the reflector thereon, said driving means being connected to the robot (2).
8. A system according to any one of the preceding

claims, wherein the robot (2) is installed on a jib crane (10), adapted to move the robot in order to reach with the reflector (5) any point of any roller of the segment.

9. A system according to any one of the preceding claims, wherein a position switch is provided between the end of the arm (4) and the reflector (5).

10. A method for aligning the longitudinal axes of the rollers of a containment and guide segment, adapted to contain and guide a cast product exiting from a crystallizer in a continuous casting process, the method being carried out by a measurement system according to claim 1 and comprising the following steps:

- a) positioning the containment and guide segment (8) in a measuring zone;
- b) determining, by means of the robot (2) and the laser tracker (3), the position in space of the segment (8);
- c) carrying out the measurements of the position in space, by means of the robot (2) and the laser tracker (3), of a plurality of predetermined points of each roller;
- d) processing the measurements carried out in step c) for generating a list of mechanical adjustments to be performed on each roller of the segment for aligning the axes of the rollers of the segment along a predetermined surface;
- e) carrying out said mechanical adjustments,

wherein there is provided, before step b), a recognition, by means of an automatic recognition device, of the containment and guide segment (8) which allows, by means of a reader (6), information on the segment and/or on each roller to be read from at least one tag (7) fixed on the segment, and the information to be transmitted to the processing means of the measurement system, said information comprising said predetermined points of each roller (9) on which to carry out the measurements of step c) and any previous measurements carried out on the rollers of the same segment.

11. A method according to claim 10, wherein said information comprises the theoretical position of each roller (9) of the segment (8) at which the rollers of the segment are aligned with one another; and wherein step d) comprises the steps of:

- calculating the actual position of the longitudinal axis of each roller in space using the coordinates measured in step c), of at least three points along the circumferential perimeter of each of at least two zones of each roller;
- comparing the actual position of the longitudinal

axis of each roller with a respective theoretical position of the longitudinal axis;

- calculating the shift to impose to the supports (9') of each roller (9) so as to bring the longitudinal axis thereof to the respective theoretical position.

12. A method according to claim 11, wherein the theoretical position of each roller (9) of the segment (8) is derived from the reading of CAD models of the segment (8) pre-stored to said tag (7), fixed on the segment and/or on each roller of the segment.

13. A method according to claim 11, wherein in step c), measurements are carried out in at least three points along the circumferential perimeter of each of only two zones of each roller.

14. A method according to claim 11, wherein in step c), measurements are carried out in at least three points along the circumferential perimeter of each of three zones of each roller: a first zone being at a first end of the roller, a second zone being at a second end of the roller; and a third zone being at a middle zone of the roller.

15. A method according to any one of claims 10 to 14, wherein said mechanical adjustments comprise at least one of the following operations:

- adding shims between at least one support (9') of at least one roller (9) and the base structure of the segment;
- removing shims between at least one support (9') of at least one roller (9) and the base structure of the segment;
- replacing at least one roller.

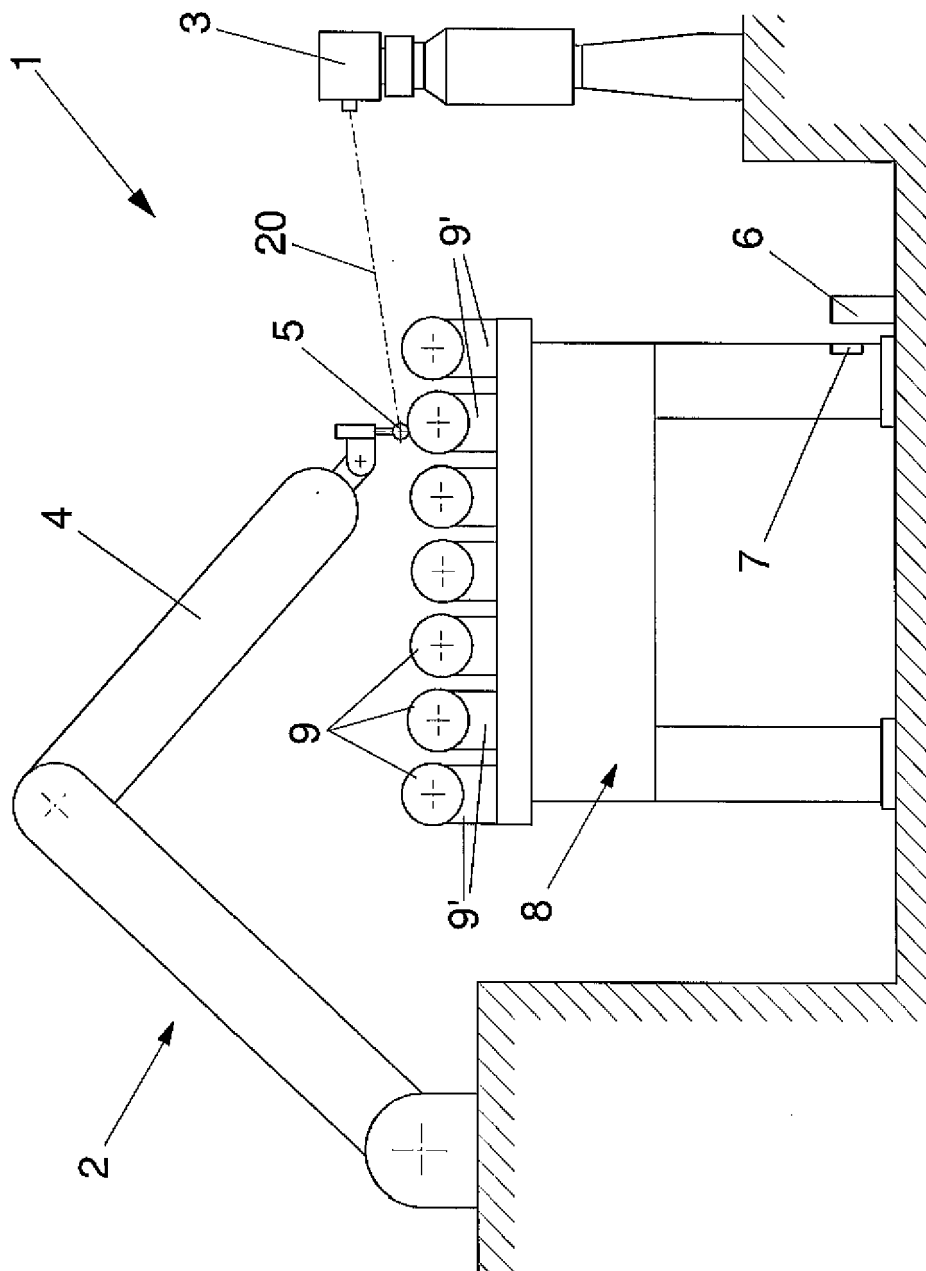


Fig. 1

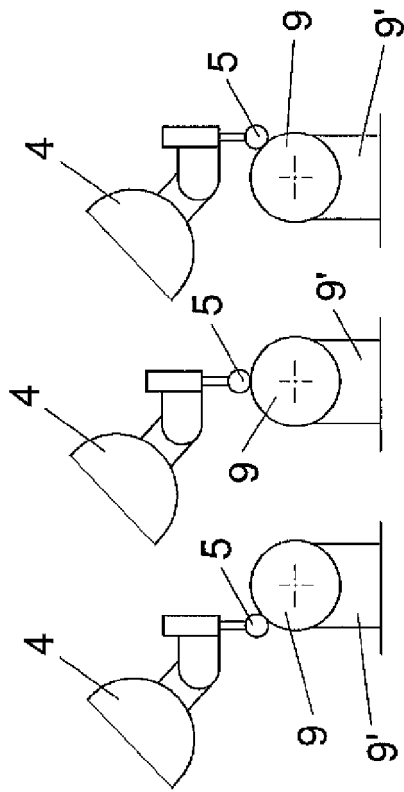


Fig. 2d

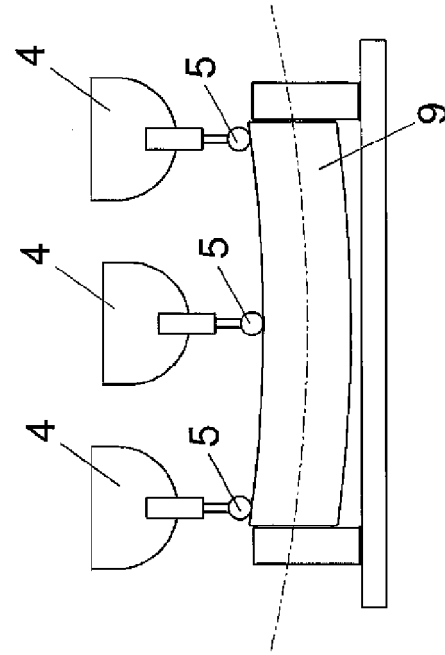


Fig. 2c

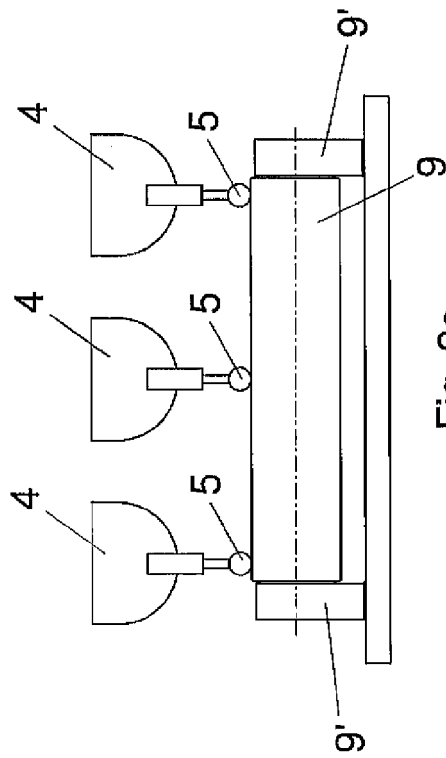


Fig. 2a

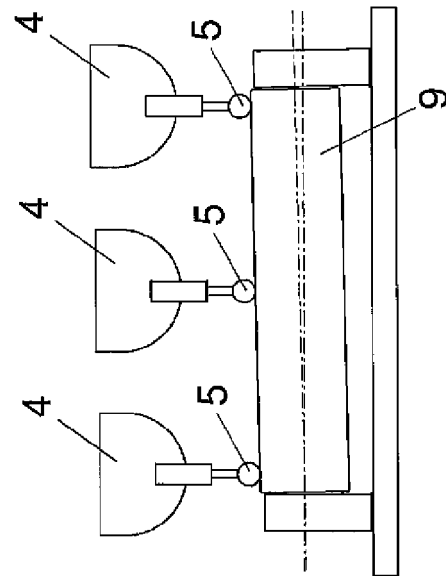


Fig. 2b

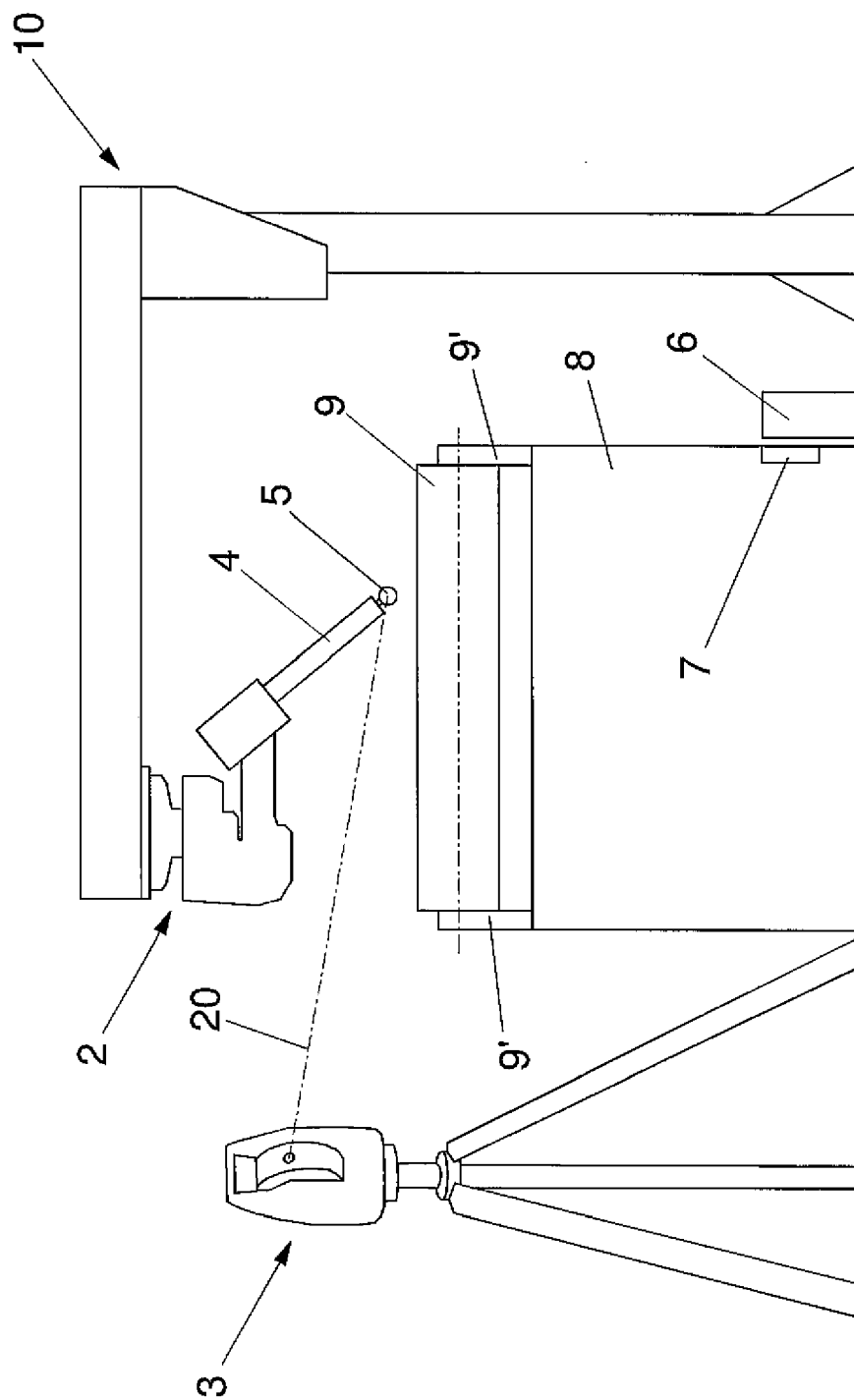


Fig. 3

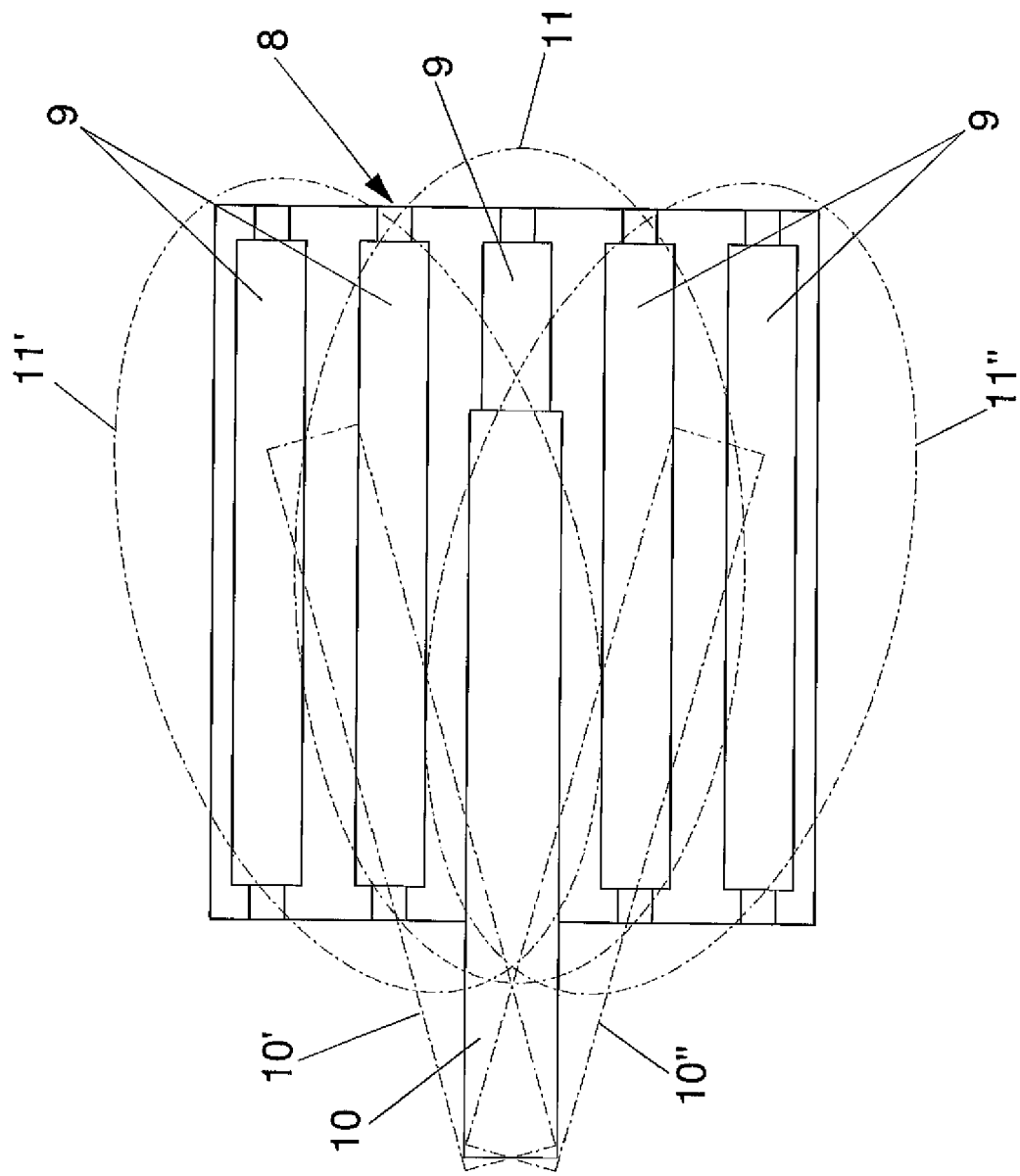


Fig. 4

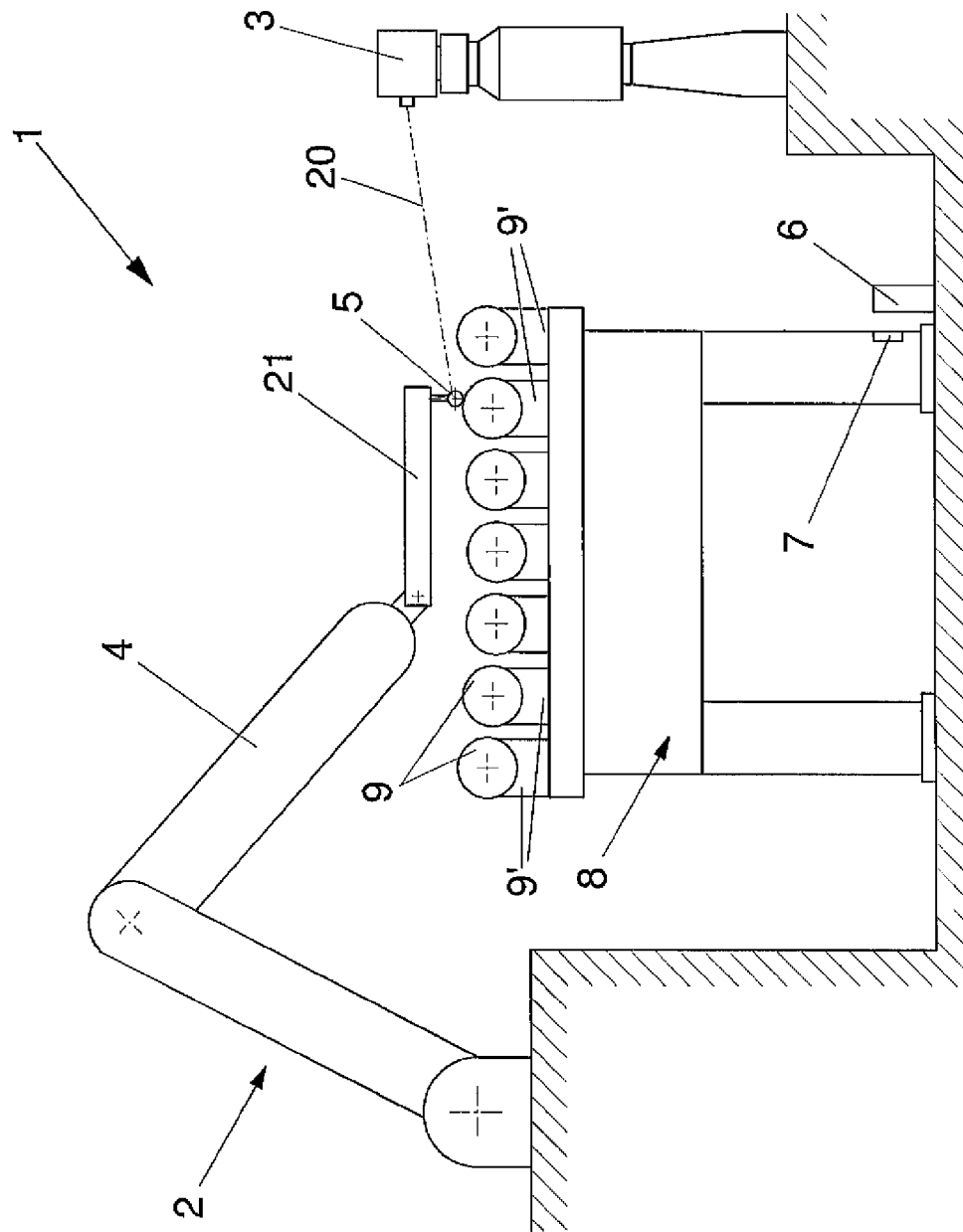


Fig. 5



EUROPEAN SEARCH REPORT

 Application Number
EP 15 16 4201

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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