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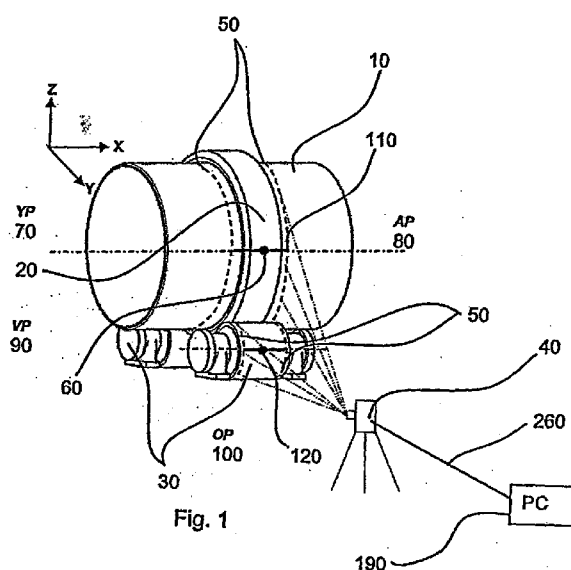
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(54) Title: METHOD FOR MEASURING AND ALIGNING A ROTARY CYLINDRICAL APPARATUS



(57) Abstract: The invention relates to a method for measuring and aligning a rotary cylindrical or other rotationally symmetrical apparatus, such as e.g. a kiln or a drum. The apparatus to be measured and aligned has a shell and at least one supporting ring. It is essential for the method that as the rotary apparatus is rotating under process conditions, measurement points are measured on the surface of the rotating object's shell in the axial direction on both sides of each supporting ring on the same circumferential line. Regression circles are calculated from the measured points, center points are determined for the calculated circles and a straight line and its center point are determined between the center points of the circles calculated on both sides of each supporting ring. A reference straight line is calculated for the center line of the shell and the object's shell is aligned to be straight by transferring the determined center points of the shell to the calculated reference line.



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METHOD FOR MEASURING AND ALIGNING A ROTARY CYLINDRICAL APPARATUS

The present invention relates to a method of and apparatus for measuring and
5 aligning a rotary cylindrical or other rotationally symmetrical apparatus, e.g. in
the form of a truncated cone. The rotationally symmetrical apparatus can be
e.g. a kiln, such as a lime kiln or a cement kiln, or a drum, used in the chemical
pulp industry.

10 Aligning a rotary cylindrical apparatus, such as a kiln or a drum, refers in this
connection to straightening of the shell thereof, e.g. in order to keep the bricks
in place in the kiln and for ensuring the desired functioning. In practice this
means transferring the center points of the shell of a rotary object to a common
straight line at the location of its supporting points. Adjustment of a rotary
15 apparatus, in its turn, commonly refers to changing the declination angles of the
support rollers of the rotary apparatus in respect of the center line of the
apparatus. The adjustment aims at decreasing the wearing of mechanical parts
and at desired functioning of the apparatus.

20 It is known from the state of art to align a rotary apparatus using e.g. the
arrangement of FI utility model 8330 comprising i.a. orientation points fixed
around the apparatus, measurement points fixed in connection with the support
rings, measurement points fixed in connection with support rollers meant for
supporting the support rings and at least two station points for setting the
25 measuring device to said station point, and further apparatuses. Thus, the
solution according to said publication utilizes, in addition to a measuring device,
also a measurement point physically fixed in the object of measurement. The
measurement point can be e.g. a target, an adhesive, a prism or a bar. In the
solution according to said publication the object is measured when it is cold.

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US-publication 5 491 553, in turn, presents an arrangement for measuring a kiln
where the measuring device is fixed on a base that is located under the kiln for

the measurement. The measuring device in the publication comprise three semiconductor lasers.

In the prior art solutions, such as e.g. in publication FI 8330, a drum-like object
5 is measured stationary, i.e. cold. However, measuring of a cold kiln or drum
does not give a right result, but the geometry of the kiln or drum changes during
operation due to e.g. thermal expansion. In prior art, the thermal expansion is
not always taken into account at all, but aligning is performed in accordance
with the geometry of a cold kiln or drum. Then the alignment may differ even
10 remarkably from the correct alignment. Further, taking thermal expansion into
account during aligning is very troublesome and it is usually impossible to
perform it exactly. And, a problem that arises in measuring a cold kiln or drum is
that during the measurement and aligning the kiln or drum has to be kept out of
operation. In practice this means that the measurement and aligning are to be
15 performed during shutdown, when many repair and maintenance operations are
performed at the mill. Scheduling the measurement and aligning with the other
operations can be very difficult.

Another problem in the known solutions is caused by the aim to align the shell
20 of the apparatus in a so-called indirect way, i.g. by measuring for instance the
diameters of the support rollers, the distance between the support rollers, the
diameter of the support rings, relative differences in altitude of the bases of the
support rollers, the clearances of the casing and support ring etc. Such an
indirect cold measuring is clearly more unreliable than measuring during the
25 operation of the kiln, because the temperatures vary at different piers. For this
reason, the clearance between the shell and the ring does not remain the same,
but the center line of the kiln changes. According to prior art, the clearance is
measured through backward slip, but the measurement is not totally reliable, as
the slip changes a bit due to e.g. rotational speed.

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In the solution according to said US-publication, locating the measuring device
below the object to be measured is troublesome and time consuming.

Additionally, the equipment that is needed is weighty. For these reasons, the measurement is carried out on one side of the support ring only. Further, the measurement is carried out below the shell on one side only, whereby it is not even possible to effect the measurement in close vicinity of the support ring
5 because of the support rollers located below the support ring. An additional problem in the technique according to said US-publication is the narrowness of the sector on which the measurement points can be measured. A narrow measuring sector gives an unreliable result. Further, the shape of the shell changes the least on the lower side, which further increases the unreliability of
10 the measuring result.

The present invention provides a solution for the above problems. According to the present invention, a novel solution has been developed for measuring and aligning a rotary cylindrical apparatus.

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The invention is determined more precisely in the appended claims.

According to the present invention, the geometry of a rotary object is measured during operation. The measurement results allow aligning the object and
20 thereafter checking the alignment by re-measurement. To be more exact, an object of the invention is to determine the geometry of the object during operation by forming a three-dimensional model of the measurement points, by means of which it is possible e.g. to determine the shell's center points at the supporting points with respect to each other.

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The measurement requires an equipment, by means of which it is possible to create a model of the object in a three-dimensional coordinate system by means of the measurement points. According to the invention, the measurement uses an apparatus that is capable of measuring the
30 measurement point directly from the surface of the object being measured without any target, such as an adhesive, a prism or a bar. In practice, the measurement can be carried out with either an electronic tacheometer or a 3D-

scanner. In addition, a software is needed in the measuring and the subsequent alignment of the kiln or drum, by means of which a 3-dimensional model of the object of measurement can be created based on the measurement points.

- 5 For the measurement, an orientation point network is created around the kiln, which allows orientating the measuring device in a free or known station point in a desired coordinate system. Thus, the measuring device can be located in an easily accessible location, e.g. at a very stabile location in the surroundings of the object to be measured, and there is no need to locate it in a tight or
10 otherwise inconvenient place, e.g. below the object to be measured.

- Usually, when a rotary object is measured, a free station point is used. The orientation points are to be located in the surroundings of the object so that at least two orientation points are observable from each planned free station point.
15 All orientation points can be determined in a desired system of coordinates from one point, in order to be able to later determine the free station point with maximum accuracy.

- The aim of the measurement is to measure the center point of a rotating object at the support rings and the direction of the axes of the support rollers in relation to the calculated center line of the shell. An adequate number of measurement points are measured on the shell of the rotating object from above and from below, i.e. in the axial direction on both sides at equal distances on the same line and at the same distance from the support ring so that the measurement
25 points cover an adequate sector of the shell on both sides of each support ring. An adequate number of measurement points for reaching the required accuracy of measurement is case-dependent. According to the invention, the number of measurement points is at least three. Good results are reached with e.g. approximately ten measurement points. Naturally, the accuracy increases along
30 increasing number of measurement points. When scanning the shell of the object being measured and aligned, the measurement points occur at even intervals and their number is preferably approximately 20–60. The upper side

here refers to the side of the support roller, from where the material to be treated is fed into the kiln or drum and the lower side refers to the side from where the material is discharged from the kiln or the drum. In other words, the product moves inside the kiln or drum from above downwards. A rotating object
5 is measured from one side of the shell at minimum. According to the invention, the measurement is effected on the shell of the rotating object preferably on at least two sides.

In accordance with the invention, the object rotates during the measurement at
10 least once, whereby the measurement points cover all possible positions of motion of the shell of the kiln or drum. The measuring lines are located as close to the support ring as possible and at equal distances from the ring on both sides thereof as shown in Figure 1. Measuring lines are created on the support
rollers both on the upper and the lower side on the surface of the roller and
15 from them an adequate number of points, e.g. approximately 60 points, are measured at even spacing. The axial thrust rollers can be measured using one measuring line only, because it is necessary to determine the center points of the axial thrust rollers in relation to the center line of the kiln.

20 The measured measurement points are transmitted to a computer, where the actual analysis and calculation of the results is performed. By means of the program, circular regression, i.e. best fit circle for all the measuring points is calculated from the points measured on the measuring lines. Coordinates are determined for the center points of the calculated circles in a three-dimensional
25 system of coordinates. After this, a line segment is determined between the center points of the circles calculated on both sides of the support rings of each pier and coordinates are determined for the center point of this line segment. In this way, the coordinates of the shell's center point can be determined from the center of the support ring highly accurately. The corresponding calculations are
30 carried out for the support rollers. That is, first the best fit circles are calculated from the measurement points and center point coordinates determined for them, after which a straight line is determined between the center points.

When the center point coordinates of the shell have been determined from the center of the support rings as mentioned in the above, a reference straight line can be calculated for the shell's center line. The reference straight line can be determined as a regression straight line either by taking into account the coordinates of the center points of all piers or by fixing the coordinates of the center point of one pier onto the straight line. The reference straight line can also be determined by fixing the center points of two piers as a straight line. After this it is possible to calculate the vertical and horizontal distances of the shell's center points to the determined reference straight line. Additionally, based on the reference straight line the declination angle of the object is known and can be compared to the designed declination angle. As to the support rollers, the vertical and horizontal declination angles thereof can be determined with respect to the calculated reference straight line of the object's shell, as well as the center points of the rollers' axes. By means of the calculated values the shell of the object can be aligned straight by transferring the center points of the line segments located between the center points of the calculated circular regressions to the calculated reference line. These center points for the line segments are the same as the center points of rotation of the shell. The calculation can be effected utilizing the determined center points of the support rollers' axes, or alternatively it is also possible to measure the diameters of the support rollers and the support rings, the distance between the support rollers and the clearance between the shell and the support roller, based on which the geometry required for the alignment can be solved mathematically. Additionally, the vertical declination angles of the support rollers can be adjusted to correspond to the declination angle of the shell, if needed. The the required transfers have been made, a control measurement can be effected.

Additional advantages of the invention include the following:

- the measurement is done easily and quickly during operation,
- the equipment required for the measurement is light-weighted and easily supported by one person,

- very exact measuring result, which provides good alignment and better operability of the kiln or drum,
- the measuring result can be verified by means of a re-measurement,
- the measuring and the aligning can be performed during operation,
- 5 whereby there is no need for a shut-down,
- adjustments can be anticipated and problem situations avoided, and
- the described measuring method eliminates risk factors in the measurements compared to old methods of measuring the support roller basis levels. These risk factors, especially with regard to journal
- 10 bearings, include e.g. uneven wear of journal bearing halves and dimension differences between journal boxes.

In the following, the invention is disclosed in more detail with reference to the appended drawings, of which

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Figure 1 illustrates a solution according to the invention for measuring the shell of a rotating cylindrical object,

Figure 2 illustrates the actual profile of the shell, and

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Figure 3 illustrates the apparatus according to the invention as a schematic drawing and an example of locating the orientation points and the free station point in the surroundings of the apparatus.

25 Figure 1 illustrates a solution according to a preferred embodiment of the invention, showing a part of a shell 10 of a drum or kiln being aligned, a support ring 20, support rollers 30, a measuring device 40, upper side 70 and lower side 80 of the support ring and the left side 90 and the right side 100 of the shell. On both sides of the support ring measuring lines 50 are determined, from

30 which the measurement points are measured. The measured measurement points are transmitted from the measuring device via a data transfer line to a computer 190, e.g. a PC-based apparatus, which produces a three-dimensional

model of the apparatus and performs the actual analyzing and calculation of the results that is required for the alignment. By means of the program, circular regressions are calculated from the measured points. Coordinates are determined for the center points of the calculated circles in a 3-dimensional system of coordinates. After this, a line segment 110 is determined between the center points of the circles calculated on both sides of the support rings 20 of each pier and coordinates are determined for the center point 60 of this line segment. In this way, the coordinates of the shell's 10 center point of rotation 60 can be determined from the center of the support ring 20 highly accurately. The corresponding calculations are carried out for the support rollers 30. That is, first the best fit circles are calculated from the measurement points and center point coordinates determined for them, after which a line segment is determined between the center points and a center point 120 for said line segment.

Figure 2 illustrates the actual profile of the shell in the measuring line and the center point 170 of rotation. Continuous lines 130 illustrate the shape of the shell during rotation. The center point 170 of the circle 180 calculated in accordance with the invention, as described in the above, illustrates the center point of rotation of the shell, not the geometric center point 140. The rotation center point 170 is determined by forming a circular regression 180 from an adequate number of measurement points 160 measured from the measuring line 50 along a sector 150 of adequate size, the center point of which circular regression illustrates the average center point of rotation of the shell. As a shell of a kiln or drum, especially when hot, has a known tendency to dent at the support rollers as well as from above during rotation, the actual shape of the shell is not circular, but predominantly oval. Further, the shell can move slightly radially during rotation, so that by measuring the shell during rotation, the average rotation center point 170 of the shell is obtained in accordance with Figure 2.

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Figure 3 illustrates an example of the location of the measurement points and a free station point in the surroundings of the object. The Figure 3 shows a

rotating cylindrical apparatus, e.g. a kiln or a drum 300. It is carried by support rings 20 supported upon support rollers 30, the middlemost of which support rings is surrounded by shown axial thrust rollers 220. The axial thrust rollers can also be measured and aligned. According to the invention, at least one axial thrust roller 220 is measured by creating a measurement line on the surface of each roller and measuring measurement points on at least one side. Circular regressions are calculated from these measurement points and center points are defined for the circular regressions that illustrate the center point of the axial thrust rollers. The axial thrust rollers are aligned to the same straight line with the shell of the kiln by transferring the center point of the circular regression calculated from the axial thrust roller as seen from above to the regression straight line illustrating the shell.

Additionally Figure 3 illustrates a straight line 210 that in a simplified way illustrates the actual measured center line of the kiln, and a reference straight line 200. The reference straight line 200 can be determined as a regression straight line either by taking into account the coordinates of the center points of all piers or by fixing the coordinates of the center point of one pier onto the straight line. The figure also illustrates a number of orientation points 240, which have allowed determining the free station points 230 and the measured center lines 250 of the support rollers' axes.

Although the above description relates to an embodiment of the invention that is in the light of present knowledge considered the most preferable, it is obvious to a person skilled in the art that the invention can be modified in many different ways within the broadest possible scope defined by the appended claims alone.

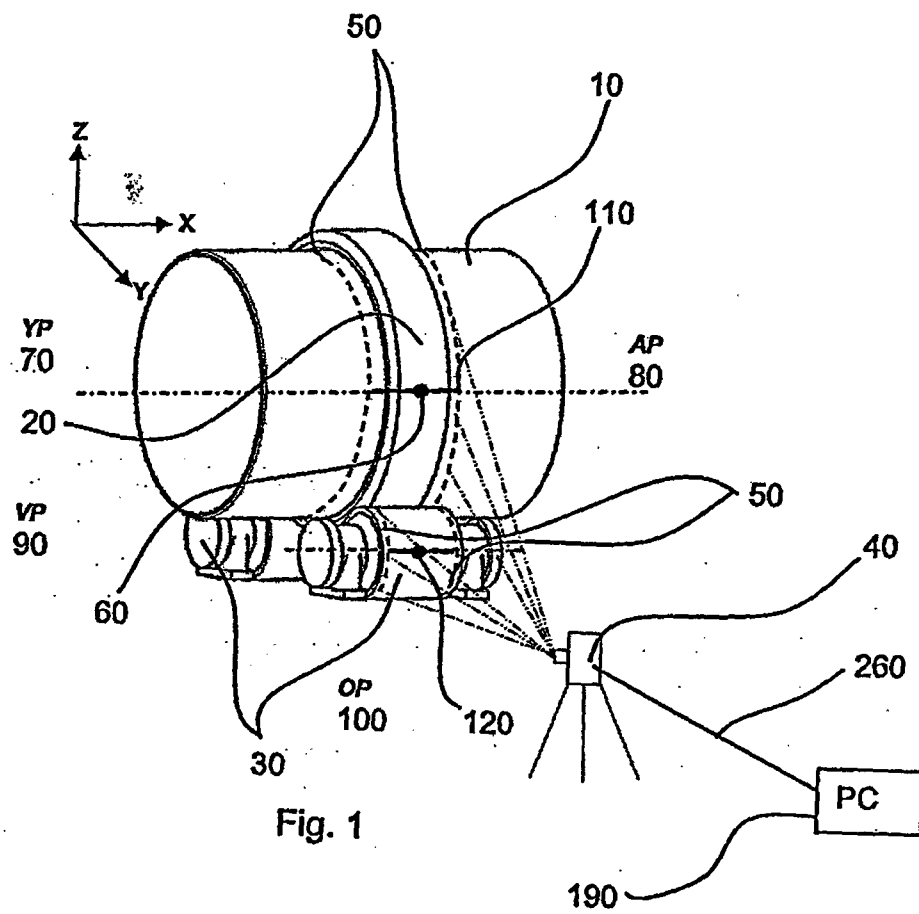
CLAIMS

1. A method of measuring and aligning a rotary cylindrical or other rotationally symmetrical apparatus (300), such as e.g. a kiln or a drum, said apparatus having a shell (10) and at least one support ring (20), each of which has a set of support rollers (30), by means of a measuring device (40), **characterized** in that when the rotary apparatus (300) rotates under process conditions:
- measurement points (160) are measured on the shell (10) of the rotating object (300), directly from the surface thereof, in the axial direction on both sides of each support ring (20) along the same circular measuring line (50) essentially at equal distances from the support ring (20),
 - circular regressions (180) are calculated from the measured measurement points (160),
 - center points (170) are determined for the calculated circles (180),
 - a line segment (110) is determined between the center points (170) of the circles (180) calculated on both sides of the support ring (20) of each pier and coordinates are determined for the center point (60) of this line segment, which center point (60) simultaneously is the center point of rotation of the shell (10),
 - a reference straight line (200) is calculated for the center line of the shell (10) as a regression straight line,
 - the distances of the center points of the line segments between the center points of the circular regressions (180) to the defined reference straight line (200) are calculated, and
 - the shell (10) of the object (300) is aligned straight by transferring the determined center points (60) of the line segments between the circular regressions (180) to the calculated reference line (200).
2. A method according to claim 1, **characterized** in that the support rollers (30) are measured by creating measuring lines (50) on the surface of each roller both on the upper and the lower side and measuring measurement points, circular regressions are calculated from the measurement points, center point coordinates are determined to the circular regressions, and

center point coordinates are determined to the circular regressions, and a line segment is defined between the center points and a center point (120) is defined for the line segment.

- 5 3. A method according to claim 1 or 2, **characterized** in that also the vertical declination angles of the support rollers' axes (30) are measured and compared to the declination angle of the shell (10).
- 10 4. A method according to any one of the preceding claims, **characterized** in that after the required transfers a control measurement is performed.
- 15 5. A method according to any one of the preceding claims, **characterized** in that the declination angle of the center line of the object (300) obtained from the reference line (200) is compared to the design declination angle.
- 20 6. A method according to any one of the preceding claims, **characterized** in that the measuring is carried out using a device (40) that is capable of measuring the measurement point (160) directly from the surface of the object (300) of measurement without any target sign, such as an adhesive target, a prism or a bar.
7. A method according to any one of the preceding claims, **characterized** in that the shell (10) is measured in the axial direction on at least one side.
- 25 8. A method according to any one of claims 1–7, **characterized** in that the shell (10) of the rotating object (300) is measured in the radial direction preferably on at least two sides.
- 30 9. A method according to any one of the preceding claims, **characterized** in that further at least one axial thrust roller (220) is measured by creating a measurement line on the surface of each roller and measuring measurement points on at least one side, circular regressions are calculated from the

measurement points, center points are defined for the circular regressions, which center points illustrate the center point of the axial thrust rollers, and the axial thrust rollers are aligned to the same straight line with the shell of the kiln by transferring the center point of the regression circle calculated from the roller as seen from above to the regression straight line illustrating the shell.



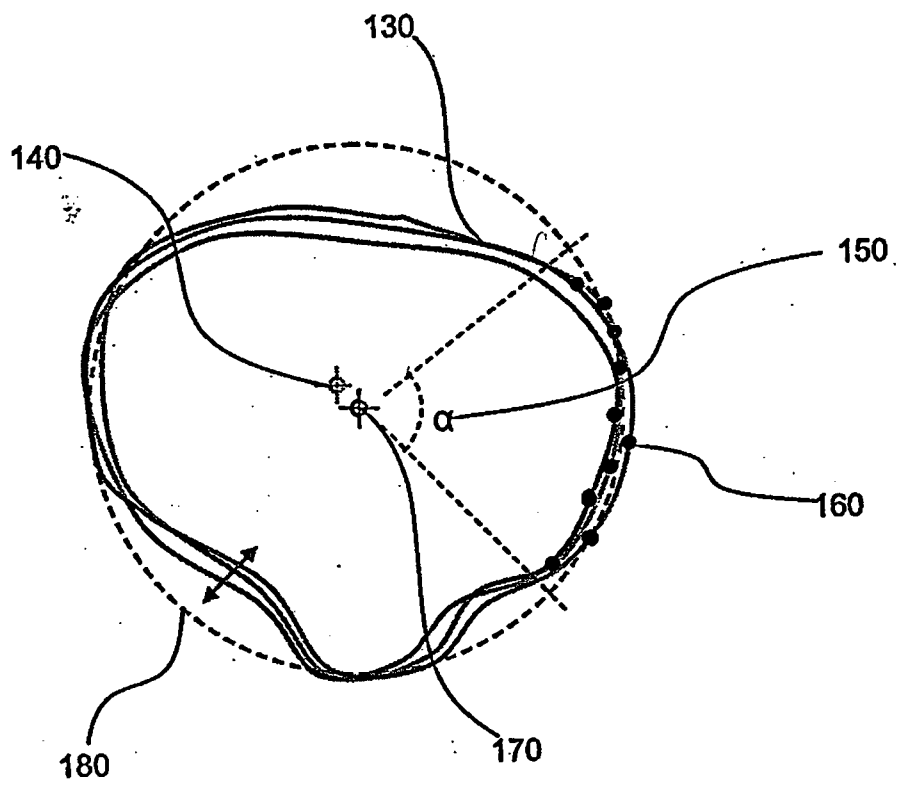
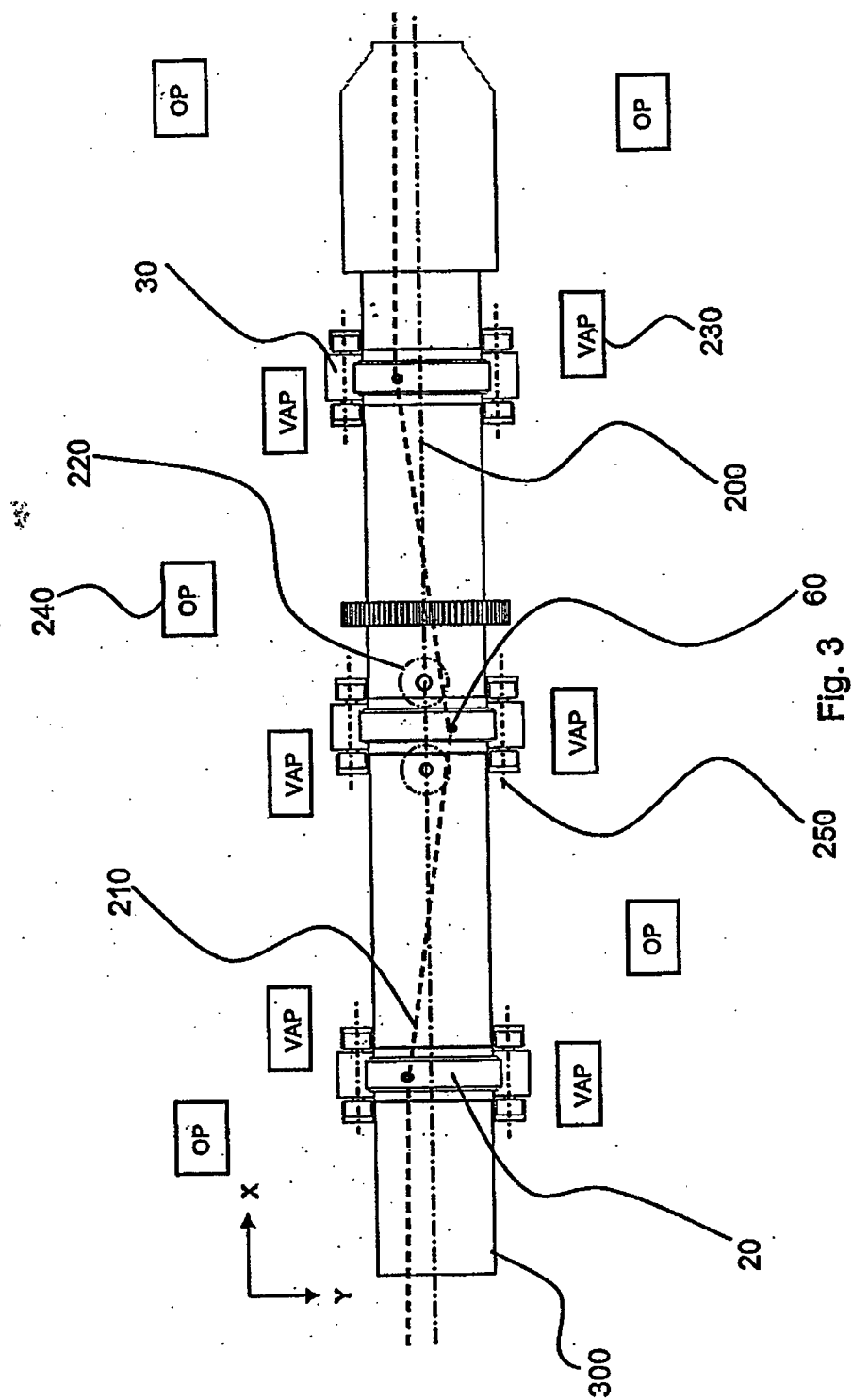


Fig. 2

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INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2010/050891

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B21/24 G01B21/20 F27B7/42 G01B7/28
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01B F27B B27B B21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 420 663 A2 (HARTCO ENG INC [CA]) 3 April 1991 (1991-04-03) * abstract column 4, line 3 - column 11, line 7 figures 1-4	1-9
A	----- JP 6 159942 A (UBE INDUSTRIES) 7 June 1994 (1994-06-07) the whole document	1-9
A	----- US 7 110 910 B1 (DEFFENBAUGH MARK [US] ET AL) 19 September 2006 (2006-09-19) * abstract column 3, line 54 - column 6, line 34 figures 1-7 ----- -/--	1-9

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

4 March 2011

Date of mailing of the international search report

16/03/2011

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INTERNATIONAL SEARCH REPORT

International application No

PCT/FI2010/050891

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2010/050891

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