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(71) Applicant: **TomTom-Tools GmbH**
8905 Arni (CH)

(72) Inventor: **STUTZ, Thomas**
8905 Arni (CH)

(74) Representative: **Tompkin, Christine**
Spierenburg & Partner AG
Mellingerstrasse 12
5443 Niederrohrdorf (CH)

(54) **SYSTEM TO DETECT AND ELIMINATE A CRANK IN A ROTARY KILN**

(57) A system to detect and counteract a crank in a rotary kiln having a kiln shell (1) and arranged on tyres (2, 2') supported by support rollers (3, 3') comprises a displacement sensor (5) configured and arranged to sense a displacement of the support rollers (3, 3'), a controller (11), and a plurality of nozzles (7) or fans for dispensing a cooling fluid onto the kiln shell (1). The controller (11) is configured to receive data from the displacement sensor (5), to process the received data by applying a sine fit to the data and determine amplitude and phase, to compare the amplitude of the displacement to a threshold value, and to control a valve (13) to release a cooling fluid to the nozzles (7). The system enables detection of a kiln crank and a selective cooling of the kiln shell within a determined angular range (α). A method is also claimed.

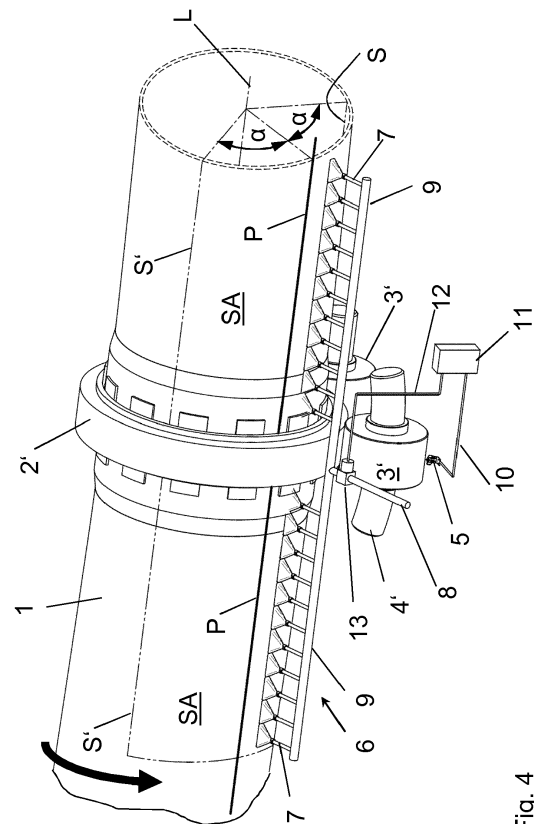


Fig. 4

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Description

Field of the invention

[0001] The invention pertains to a system and method to detect and counteract a crank in a rotary kiln, in particular to detect and counteract a deviation in the straightness of the rotary kiln during its operation.

Prior art

[0002] Rotary kilns are used to manufacture cement, lime, and other materials by processing and transporting the material through an oven having an inclined cylindrical drum that is thermally insulated on the inside by a refractory material layer. The kiln is driven by a tooth wheel or ring gear, is slowly rotated about its longitudinal axis, typically at 1-6 rotations per minute. The drum or rotary kiln shell is arranged on two or more tyres, also called riding rings which are supported by rollers. The support rollers are typically placed on support structures arranged on piers.

[0003] During operation of a rotary kiln with more than 2 piers, the kiln can develop a so-called crank, which if not counteracted, can damage the kiln, mainly the riding rings or tyres and also the rollers supporting the tyres. A crank is a deviation in the straightness of the drum where forces in the shell of the drum cause the centerline passing through the center of the three or more tyres to deviate away from its original rotary axis such that it no longer rotates on its original axis but instead develops an eccentricity following a circular path about the original rotary axis. Such crank causes cyclic load changes on the support rollers as well as on the support structures and piers of the rotary kiln. Often these load changes exceed the design limits.

[0004] A crank can be caused by errors during welding and installation of the kiln. This causes a so-called permanent crank. However, most frequently a crank in a rotary kiln is caused by an uneven temperature distribution over the entire kiln shell, in particular over the circumference. Such a crank is referred to as a thermal crank. A thermal crank is mainly caused by variations in the coating on top of the refractory layer. It can also be caused by irregularities in the insulating refractory layer. During operation of the rotary kiln, process material typically builds up on the insulating refractory material resulting in a lower heat transfer to the kiln shell. Such built-up material can break away from the refractory material in irregular amounts and time intervals. In addition, parts of the refractory layer itself can break off. The resulting variations in the thickness of the built-up coating on the refractory layer can cause uneven heat transfer to the kiln shell and hence uneven temperatures over the circumference and length of the kiln shell, possibly with several temperature extrema. The uneven temperature distribution as a whole can cause uneven thermal expansions and as a consequence a crank or deviation in the

straightness of the drum.

[0005] Known methods to control the temperature of a kiln or counteract such cranks are limited to temperature measurements and adaptation of the process parameters of the kiln operation or cooling of the outside surface of the kiln based on temperature measurements.

[0006] EP2947409 discloses a cooling system to cool areas with elevated temperature of a kiln shell based on temperature data taken by means of infrared sensors. The cooling system comprises water jets controlled by a control unit that processes the temperature data. Water is sprayed onto the outer surface of the kiln shell where the parameters for each nozzle are controlled to reach a target temperature.

[0007] It is the object of the present invention to provide a system and method to detect, control and counteract a crank in a rotating kiln shell. In particular, the system and method shall enable early detection and faster control compared to the known methods.

Summary of the invention

[0008] A system to detect and counteract a crank in a rotary kiln with three or more piers is disclosed, where the rotary kiln comprises a cylindrical kiln shell rotating about its longitudinal axis and arranged on a three or more tyres or riding rings, each supported by support rollers.

According to the invention the system comprises one or more displacement sensors configured and arranged to sense a displacement of one or more support rollers, a controller, and a cooling arrangement configured and arranged for dispensing a cooling fluid onto the kiln shell, where the controller is configured to receive data signals from the one or more displacement sensors, to process the received data, and to send a control signal to the cooling arrangement to direct the cooling fluid at the kiln.

[0009] The displacement sensors measure a displacement of the support rollers away from an original ideal position and as such a deviation in the straightness of the centerline passing through the centers of the three or more tyres. Localized temperature increases and thermal expansion on the kiln shell can cause a crank such that the rotating kiln follows a path having an eccentricity about the ideal rotary axis or inclined straight line through the tyres centers. As the tyres of the kiln shell are placed on the support rollers, the eccentric path of the kiln shell causes the tyres to either move away from the support rollers or push the support rollers downward. The tyres therefore exert a varying force onto its support rollers such that the support rollers experience cyclic load changes. Increased loads cause the axis of the support rollers to bend. The displacement sensors measure a displacement of the support roller due to its bending from a given original position along the line of force exerted on the support roller by the kiln, where such displacement corresponds to load changes on the support rollers caused by a crank in the kiln.

[0010] The controller is arranged to receive measurement signals from the displacement sensors and process the received data. If the processed data yields that a given threshold value of displacement corresponding to a path variation or eccentricity is reached, the controller generates and sends a signal to a valve connected to the nozzles. A cooling fluid is then dispensed to the cooling arrangement, which directs the cooling fluid at the kiln shell during the rotation of the kiln drum to counteract the crank.

[0011] The system according to the invention enables an early detection of path variations and eccentricities and subsequently enables a quick response to such variations by starting a controlled and selective cooling process of the kiln shell as soon as a crank is detected. The system is based on the direct detection of the main parameter of a crank in a kiln shell, specifically the load changes on the support rollers due to a displacement of the center line of the tyre. The displacement of the centerline of the tyre causes a displacement of the support rollers along the line of force exerted by the tyre on the support rollers. In contrast, systems of the state of the art are based only on local measurements of the temperatures of the shell surface. The system according to the invention allows a detection of an actual crank as a result of the global temperature distribution on the entire kiln. This enables a greater flexibility in the operation of the kiln as the counteraction and elimination of a crank does not afford adaptation of the process and load parameters. A kiln equipped with a system according to the invention may be operated with a greater range of load and process parameters. Also, operating parameters may be adapted more slowly, which again allows for greater operation flexibility.

[0012] In a specific embodiment of the system the controller comprises an algorithm configured for the detection of an amplitude and phase angle of a sinusoidal function in the displacement signals received from the displacement sensor. In a particular embodiment, the algorithm is configured with a sine-fit function.

[0013] The displacement of a support roller due to a crank in the kiln shell is cyclic, i.e. recurring at each rotation of the kiln, and in particular sinusoidal with the phase length of a kiln rotation. A detection of the amplitude of the sinusoidal signal allows determination of the maximum extent of the crank along the radial direction of the kiln, and detection of the phase angle of the sinusoidal signal allows determination of the location of that maximum extent of the crank on the kiln circumference. Data drawn from such signal analysis allows a specific cooling of the kiln shell surface at particular locations and with particular cooling intensity.

[0014] The signal processing by the controller by means of a sine fit algorithm allows detection of a cyclic displacement of the support roller independent of irregularities of its surface. Signals received by the displacement sensors due to surface roughness are filtered out by the sine-fit algorithm. These possible irregularities on

the support rollers appear in a random but cyclic manner according to the rotation period of the respective support roller, which is different from and much shorter than the rotation period of the kiln.

[0015] In an embodiment the cooling arrangement comprises one or more valves and a plurality of nozzles configured to dispense and direct a liquid cooling fluid, for example water or other cooling fluid at the kiln shell. The nozzles are arranged for example in a line along the length of the kiln shell, parallel to the axis of rotation and to either side of the tyre, where the displacement sensor is positioned. The controller directs a control signal to one or more valves controlling the flow of liquid cooling medium to the nozzles.

[0016] In an alternative embodiment of the invention the cooling arrangement comprises, instead of a system to direct a liquid cooling medium to the kiln, a plurality of fans or air nozzles arranged along the kiln shell to direct an air flow at the kiln. In such system the controller directs a control signal to a motor to start driving the fans. Preferably, the fans are equipped with nozzle-shaped piping to direct the cooling air more precisely and efficiently at the kiln. Many rotary kilns are already equipped with fans for the purpose of continuous cooling of the kiln shell. The system according to the invention can use such fans for selective cooling to eliminate a crank. Alternatively, the system comprises a combination of nozzles for liquid cooling and fans or air nozzles.

[0017] A method to detect and counteract a crank in a rotary kiln comprising three or more tyres supported by support rollers comprises:

measuring a displacement of one or more support rollers along the line of force exerted by the tyres on the support rollers by means of one or more displacement sensors,
directing displacement data from the one or more displacement sensors to a controller, processing the displacement data by means of the controller and comparing the displacement data to a threshold value, and
when the threshold value is reached directing a control signal to a cooling arrangement and dispensing a cooling medium onto the kiln shell surface during its rotation in order to counteract a crank.

[0018] An embodiment of the method comprises cooling the kiln shell by means of water spray and nozzles, or by an air flow by means of fans or air nozzles, or both.

[0019] In an embodiment of the method processing the displacement data from the one or more displacement sensors comprises determining amplitude and phase of a sinusoidal function of the data. This allows detection of the extent and location of the largest extent or peak of the crank along the circumference of the kiln shell.

[0020] In a specific embodiment of the method processing the displacement data comprises applying a sine-fit algorithm to the data.

[0021] A further embodiment of the method comprises cooling the kiln shell at the location of the peak of a crank and within a given angular range about that location of said peak. This comprises in particular, determining the time or rotation position at which the peak of the crank passes a cooling arrangement, determining the time frame within which a given angular range of the kiln shell circumference about the location of the peak of the crank passes the cooling arrangement, sending a control signal to that given cooling arrangement, and directing a cooling medium at the kiln shell within the determined time frame.

[0022] A further embodiment of the method comprises cooling the kiln in an angular range about the peak of the crank to a first given degree and cooling the shell surface within a given angular range about the location of the peak of the crank to one or more lesser degrees. The location of peak of the crank corresponds to the location at which the greatest amplitude of a sinusoidal function is detected. The given angular range about the location of the peak of the crank corresponds to an angular range within which the amplitude exceeds a given value. This specific cooling is realized for example by varying the intensity of cooling within a given time frame within which the location of the crank peak passes a given cooling arrangement. The cooling intensity can be varied for example by varying the pressure of a liquid cooling medium. Specifically, the kiln shell is cooled by directing a cooling medium at a highest pressure at the time that the location of the crank peak passes the cooling arrangement and directing a cooling medium at decreased pressure within a given time before and after the crank peak passes the cooling arrangement. Alternatively, the cooling intensity can be varied by varying the number of nozzles to which cooling medium is directed or the number of fans activated, where the number of nozzles or fans is greatest at time that the location of the crank peak passes the nozzles or fans and the number is decreased within a given time before and after the crank peak has passed the nozzles or fans.

[0023] A further embodiment of the method comprises adapting the intensity of cooling the kiln at the location of the peak of the crank according to the height of the determined peak amplitude of the sinusoidal displacement signal which corresponds to the potentially damaging force of the detected peak of the crank. This allows fast cooling in case of a large crank in order to counteract the crank as fast as possible. In case of a slighter crank it allows less intense cooling.

[0024] The results from processing the data by means of detecting and analyzing a sinusoidal function to the received data allows determination of the force of the crank in a kiln. This data is used to activate nozzles in varying pressure, varying time frame and in varying number of nozzles or fans. The disclosed variants of the activation of the cooling nozzles allows a cooling of the kiln shell. Two or all variants of the cooling method may also be combined in order to maximize the cooling effect. The method therefore allows a cooling that is specific to

the detected crank and enables a fast elimination of a crank. This minimizes damage to the support rollers, kiln tyres as well as the entire support structures and piers, and allows a significant increase in operation lifetime of the kiln of as much as decades.

[0025] A further embodiment of the method comprises cooling the kiln shell over its entire circumference except at and about a location radially opposite from the crank peak. Such cooling method can be applied when the temperature of the kiln as a whole reaches critically high levels. In such case the kiln must be cooled as a whole in that all nozzles or fans are activated for the time of entire revolutions of the kiln. In order to counteract a crank and simultaneously lower the temperature of the kiln as a whole, the nozzles or fans are activated to cool the kiln shell in those sections where the temperature is critically elevated and over its entire circumference except within an area radially opposite the crank peak.

[0026] The invention will be described in greater detail, by way of example, with reference to figures as follows.

Brief description of the figures

[0027]

Fig. 1a and b show a typical kiln supported by three piers and with a crank, whereby

Fig. 1a shows a displacement of a center tyre away from its support rollers and

Fig. 1b shows a displacement of the center tyre toward its support rollers.

Fig. 2a shows the arrangement of a displacement sensor arranged below a support roller corresponding to the detail indicated in Fig. 1b.

Fig. 2b shows a view of the rotary kiln shell of Fig. 2a in cross-section and the position of a displacement sensor in relation to the support roller and kiln shell.

Fig. 3 shows a schematic of the monitoring and control system according to the invention arranged on a kiln having three tyres and cooling system with water spray.

Fig. 4 shows the kiln about its center tyre and the system of Fig. 3 in an enlargement.

Fig. 5 shows a variant of the system according to the invention with a cooling system having air fans.

Fig. 6 shows an example of signal data received and analyzed by the controller of the system.

Embodiments of the invention

[0028] Figure 1a and b show a kiln shell 1 having a crank due to localized temperature variation of its surface and to which a system and method according to the invention may be applied in order to eliminate the crank. The kiln shell 1 placed on three tyres 2, 2', which are supported by two support rollers 3, 3' arranged on shafts 4, 4' respectively. The two figures 1a and b show two

positions of the rotary movement where in Fig. 1 a the kiln swings upward away from the support rollers 3' of the center tyre 2' and bending downwards towards the support rollers 3 at the tyres 2 at either end of the kiln bending the shafts 4 of those support rollers 3. (In all figures the crank is shown in exaggeration in order to better illustrate the geometry.) In reality the forces caused by a crank are high, however the displacements of the tyres are only on the order of less than one mm). In Fig. 1b the kiln crank points downward toward the support rollers 3' of the center tyre 2' bending the shafts 4' of those support rollers 3'. The broken line L indicates the longitudinal axis of the rotary kiln 1. During normal rotary movement with no crank present, the kiln rotates about this axis L with the centerline passing through the centers of the three tyres 2, 2' remaining on the axis L. During a rotatory movement with a crank as shown in Fig. 1 a and b the kiln shell 1 rotates about its longitudinal axis L where however the cylindrical kiln shell 1 follows a path having an eccentricity with respect to its longitudinal axis L and the center line through the tyre centers deviates from the axis L. At the location of the center tyre 2' the kiln center is positioned above the axis L, and at the location of the two other tyres 2 the kiln center is positioned below the axis L. The bending due to such crank can cyclically overload and damage the support rollers, tyres and support structures limiting the operating life time of the kiln or requiring repairs with associated downtime.

[0029] Fig. 2a shows in detail the arrangement of a displacement sensor 5 below the support roller 3' of the center tyre 2'. The sensor 5 is placed in the line of force exerted on the support roller 3' by the tyre 2'. It is configured to sense a displacement of the support roller in a sub-millimeter range, for example in the order of magnitude of 0.1 mm to 0.4 mm.

[0030] Fig. 2b shows the kiln in a cross-section at the location of the center tyre 2'. The cross-section shows the tyre 2' arranged about the kiln shell 1 and the refractory layer 1' on the inside surface of the kiln shell. During operation of the kiln a layer 1" can build up on the refractory layer 1', where the built-up layer 1" has an uneven thickness over the circumference causing uneven heat transfer and uneven thermal expansion over the circumference of the kiln. The figure furthermore illustrates the bending of the support roller shafts 4', 4" due to a downward displacement of the center line C of the tyre 2'. This displacement causes load changes along the line of force LF exerted by the tyre 2' on the rollers 3'. While the roller shaft 4' remains in place at a location 4' away from the support roller itself, the load changes cause a displacement of the center line C' of the support roller 3' and a downward bending of the shaft 4" at the location of the center of the roller 3' and along the line of force LF. The displacement sensor 5 is positioned beneath the support roller 3' and oriented for displacement measurement in the direction of the line of force LF.

[0031] Fig. 3 shows the kiln as a whole with a system according to the invention arranged to detect and coun-

teract a crank in the kiln. The system comprises the displacement sensor 5 placed at one of the two support rollers 3' and of the center tyre 2' and a cooling nozzle system 6 having a plurality of nozzles 7 each directed to the kiln surface, a feed line 8 for a cooling fluid, and a distribution line 9 for directing the fluid to each of the nozzles 7.

[0032] Fig. 4 shows the same detection and counter-action system as shown in Fig. 3 and additionally showing all elements of the monitoring and control system, namely all connecting lines, the controller, and a valve for a cooling medium. The displacement sensor 5 is connected by means of a line 10 to a controller 11 allowing the displacement measurement signals to be transmitted to the controller. The controller 11 is connected by means of a control line 12 to a valve 13, for example a solenoid valve. The valve 13 is arranged in the feed line 8 for the cooling fluid and is connected to a cooling medium reservoir (not shown). The cooling fluid is in this case water or another liquid cooling medium. After the valve 13 the line 8 leads to the distribution line 9 directing the cooling fluid to the array of nozzles 7 arranged along the length of the kiln shell 1. During operation of the kiln and rotation of the shell, the displacement sensor 5 measures the position of the support roller 3' at given, regular time intervals and sends the data signals via line 10 to the controller 11. The controller 11, configured with a sine-fit algorithm, analyses the displacement data signals for signal amplitude and phase angle of a sinusoidal function. If a displacement is detected having a sinusoidal function it compares the amplitude of the sinusoidal function with a given threshold value, for example +/- 0.2 mm, corresponding to a displacement of the support roller caused by a crank of the kiln which needs to be counteracted. If the amplitude of a detected sinusoidal signal exceeds that threshold value it generates a control signal and sends it via line 12 to the solenoid valve 13. The valve 13 is then opened allowing a cooling fluid from line 8 to flow into the distribution lines 9 which direct the fluid to the individual nozzles 7.

[0033] The controller 11 determines, based on its analysis of the sinusoidal signal, the amplitude of the signal as well as the phase. The amplitude is proportional to the radial extent of the crank of the kiln and displacement of the support roller away from its original position. The phase indicates the location P of the highest degree of the crank on the circumference of the kiln. This location P of the peak of the crank can be a result of the sum of a temperature distribution over the entire kiln length and circumference, possibly with several temperature extrema. At this location P of the peak the kiln surface needs to be cooled the most, while within a range SA about that location P of the crank peak may be cooled to a lesser degree or lesser degrees. Depending on the amplitude of the sinusoidal curve, the range SA of cooling is automatically adjusted by the controller 11. In the figure, an exemplary range SA for cooling is indicated to either side of the peak line P ranging in either direction from the line

P over an angle α to the lines S and S', respectively. The determined size of the angular range of necessary cooling determines the time frame within which the valve 13 is to remain open. For example, the range for cooling could be determined to be $\pm 20^\circ$, however can be increased as large as $\pm 90^\circ$ or half of the kiln circumference. In case that the kiln surface temperature is excessively elevated the system can be used to cool the surface of the kiln over a number of revolutions of the kiln depending on the type and intensity of the cooling fluid dispensed by the nozzles.

[0034] Alternatively, several lines for cooling fluid with valves may each be connected with the controller 11. Each of the lines is connected to direct cooling fluid to some of the nozzles 7. Also, multiple cooling arrangements each with a feed line, distribution line and nozzles or even individual valves 13 for each nozzle are possible.

[0035] Once the crank has been completely counteracted and the cyclic displacement of the support roller has diminished to zero, the cooling process is terminated by keeping the valve 13 closed. Measurement of the displacement however continues as long as the kiln is in operation.

[0036] Alternatively, the valves 13 are kept permanently open in order to cool the entire kiln and control its global temperature.

[0037] Fig. 5 shows a variant of the system having, instead of the nozzles for liquid cooling fluid, a set of fans 15 for directing cooling air at the kiln surface. A further variant comprises a set of air nozzles connected to an air feed line and a cooling air source. Another further variant may comprise a combination of liquid cooling fluid nozzles and air fans or air nozzles.

[0038] The longitudinal range covered by the cooling system encompasses about 2 to 3 times the kiln diameter to both sides of the center tyre 2'. However, it can also cover up to the entire length of the kiln.

[0039] Fig. 6 shows sample data received by the controller 11 from the displacement sensor 5. By means of a sine fit algorithm a sinusoidal function has been determined for the signal data. According to the sine-function displacements vary in the range of 0.4 mm peak to peak, or ± 0.2 mm about the peak P yielding a maximum crank at kiln rotation location 0° . A range of SA with angle $\alpha = \pm 60^\circ$ about, i.e. before and after the peak of the crank has been chosen in this case for a cooling of the kiln surface. Depending on the severity of the crank reflected by the amplitude of the sine-function, the angular range SA can be adjusted. Alternatively, the intensity of the cooling, that is pressure and number of nozzles, can be varied.

Terms used in figures

[0040]

- 1 kiln shell
- 1' refractory layer

- 1" built-up layer on refractory layer
- 2,2' riding ring or tyre
- 3,3' support roller
- 4,4' shaft of support roller
- 5 4" shaft of support roller at center of the support roller
- 5 displacement sensor
- 6 cooling system
- 7 nozzle
- 10 8 feed line
- 9 distribution line
- 10 signal line
- 11 controller
- 12 control line
- 15 13 valve
- 15 air fans
- S, S' line of beginning and end of cooling range
- P line of crank peak
- α angular range of cooling
- 20 SA range of cooling
- L longitudinal axis of kiln rotation without crank
- LF line of force
- C center line of the center tyre
- C' center of the support roller shaft
- 25

Claims

1. System to detect and counteract a crank in a rotary kiln, the rotary kiln comprising a kiln shell (1) rotating about its longitudinal axis (L) and arranged on three or more tyres (2, 2') each supported by support rollers (3, 3') **characterized in that**

the system comprises one or more displacement sensors (5) configured and arranged to sense a displacement of one or more support rollers (3, 3'), a controller (11), and a cooling arrangement (6) for dispensing a cooling fluid onto the kiln shell (1), where the controller (11) is configured to receive data signals from the one or more displacement sensors (5), to process the received data, and to send a control signal to the cooling arrangement (6) directing the cooling fluid at the kiln (1).

2. System according to claim 1 **characterized in that**

the controller (11) comprises an algorithm configured for the detection of amplitude and phase of a sinusoidal function in the displacement signals received from the displacement sensor (5).

3. System according to claim 2 **characterized in that**

the controller (11) comprises an algorithm configured with a sine-fit function.

4. System according to one of the claims 1 to 3 **characterized in that**

the cooling arrangement (6) comprises one or more valves (13) and a plurality of nozzles (7) to direct a liquid cooling medium at the kiln.

5. System according to one of the claims 1 to 3 characterized in that
the cooling arrangement (6) comprises a plurality of fans (15) to direct an air flow at the kiln.

6. Method to detect and counteract a crank in a rotary kiln the rotary kiln comprising a kiln shell (1) rotating about its longitudinal axis (L) and arranged on three or more tyres (2, 2') each supported by support rollers (3, 3') characterized by
measuring a displacement of the one or more support rollers (3, 3') along the line of force exerted by the tyres (2, 2') on the support rollers (3, 3') by means of one or more displacement sensors (5),
directing displacement data from the one or more displacement sensors (5) to a controller (11),
processing the displacement data by means of the controller (11) and comparing the displacement data to a threshold value, and
upon reaching the threshold value directing a control signal to a cooling arrangement (6) and dispensing a cooling medium onto the kiln shell surface (1) during its rotation.

7. Method according to claim 6 characterized by
cooling the kiln shell (1) by means of water spray and nozzles (7), or air flow and fans (15) or air nozzles, or both.

8. Method according to claim 6 or 7 characterized by
processing the data from the one or more displacement sensors (5) and detecting an amplitude and phase of a sinusoidal function of the data.

9. Method according to claim 8 characterized by
applying a sine-fit algorithm to the displacement data.

10. Method according to one of the claims 6-9 characterized by
cooling the kiln shell (1) at a location (P) of the largest extent of displacement of the kiln shell (1) and within a given angular range (α , SA) about that location (P) of largest extent of displacement of the kiln shell (1).

11. Method according to claim 10 characterized by
cooling the kiln (1) at a location (P) of largest extent of displacement of the kiln shell (1) at a given first degree of cooling intensity, and cooling the kiln shell (1) within a given angular range (α) about the location

(P) of largest extent of displacement to lesser degrees by means of varying the intensity of cooling within said given angular range (α).

12. Method according to one of the claim 8 to 11 characterized by
adapting the cooling intensity at a location (P) of largest extent of crank according to the size of peak amplitude of the sinusoidal function.

13. Method according to one of the claims 6-12 characterized by
directing cooling fluid to a specific number of nozzles (7) or activating a specific number of fans (15) along the length of the kiln shell (1).

12. Method according to claim 6 or 7 characterized by
cooling the kiln shell (1) over its entire circumference except at an area about a location radially opposite from a location (P) of largest extent of displacement of the kiln shell (1).

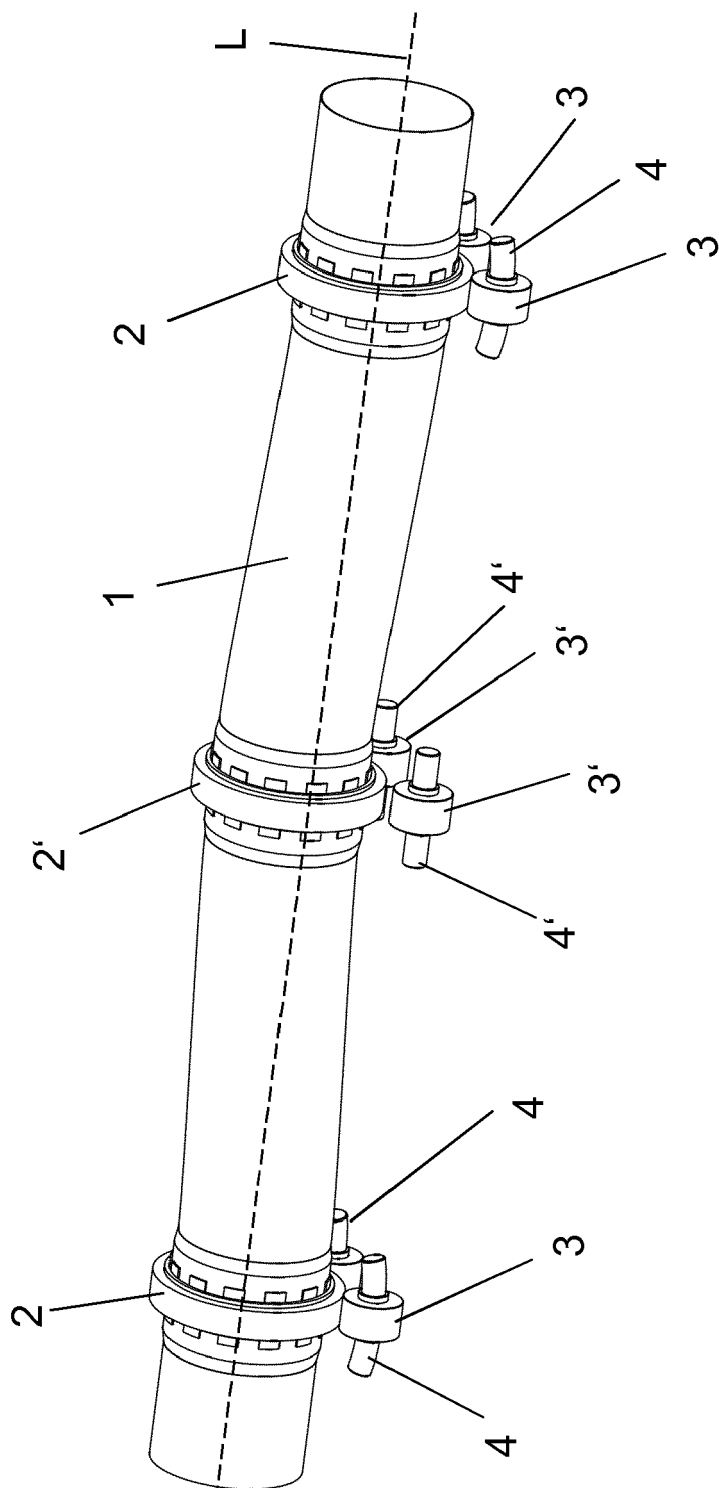


Fig. 1a

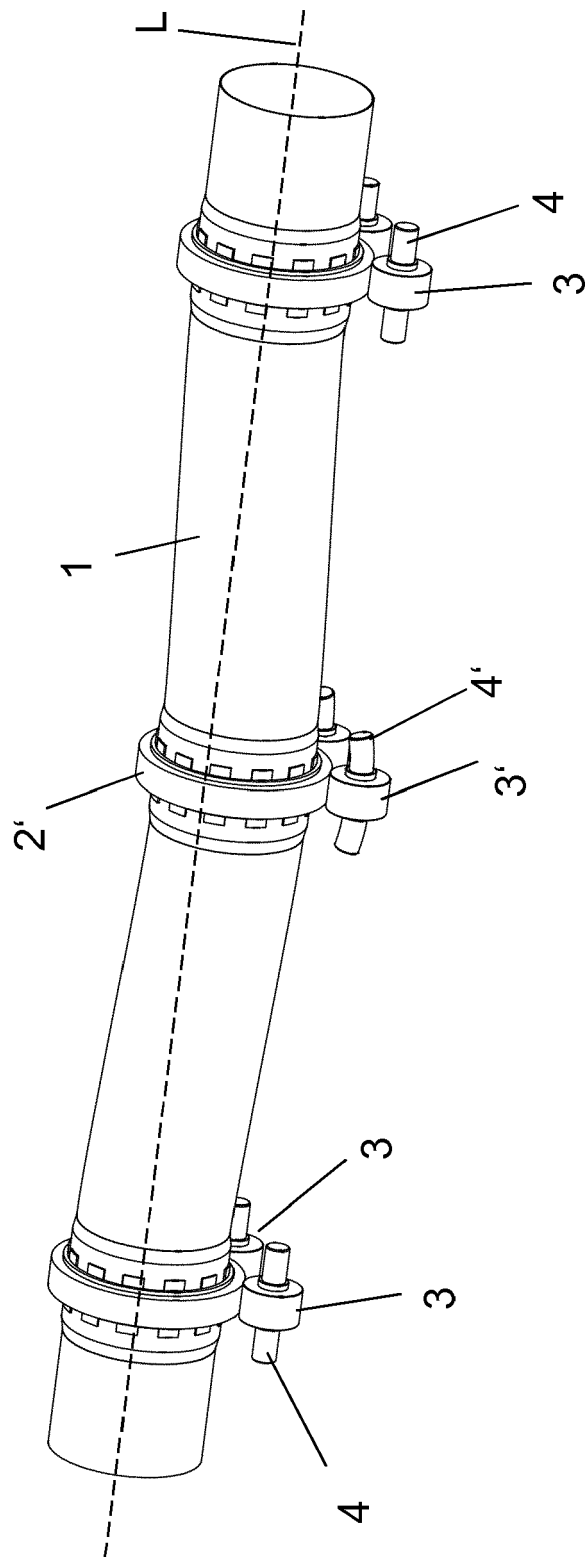
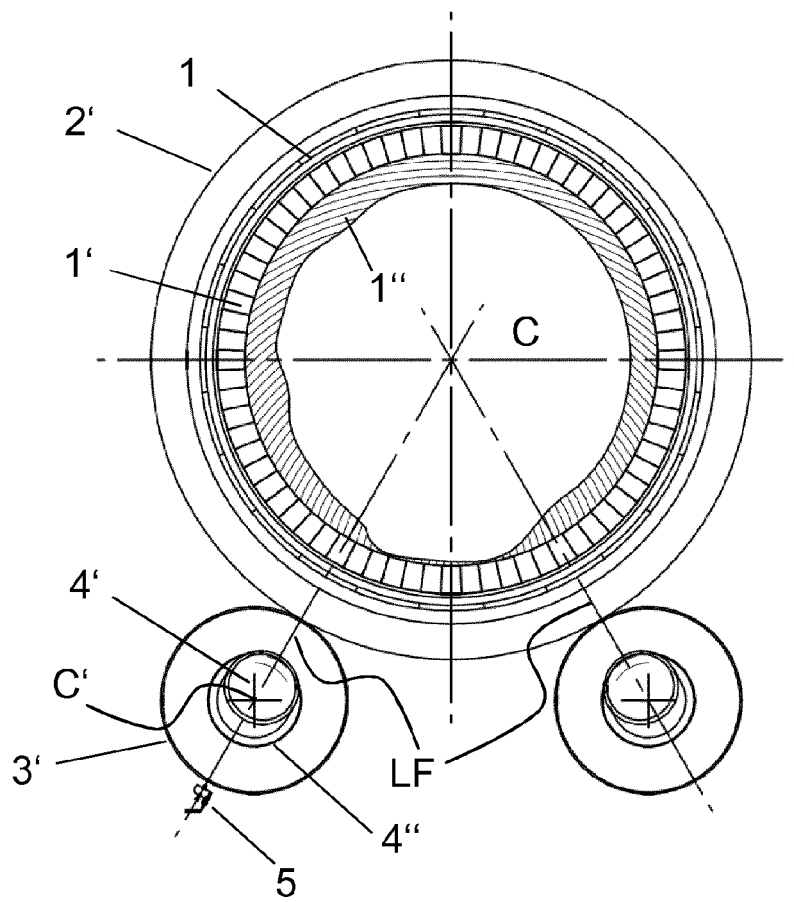
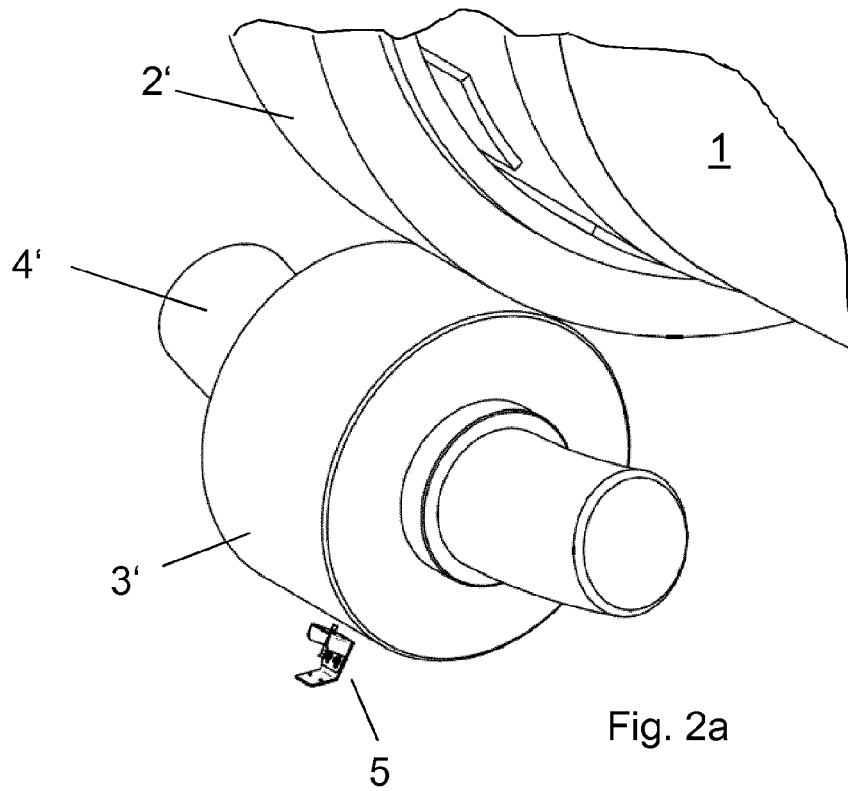


Fig. 1b



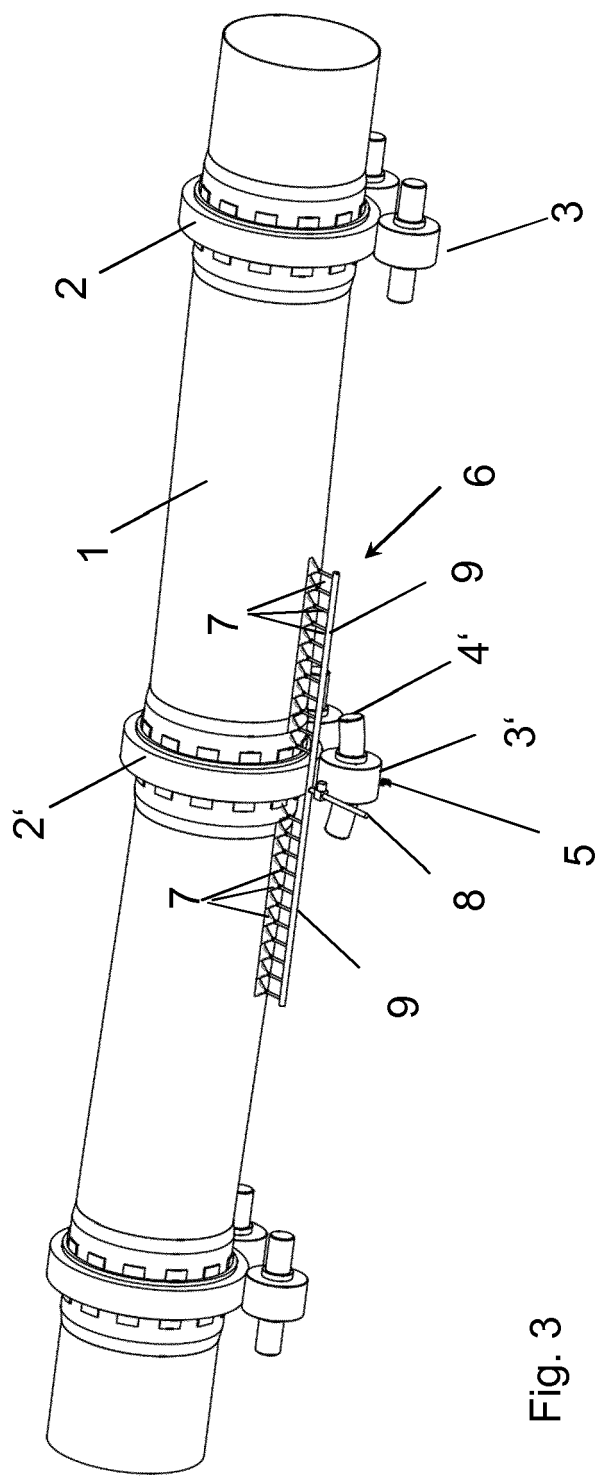


Fig. 3

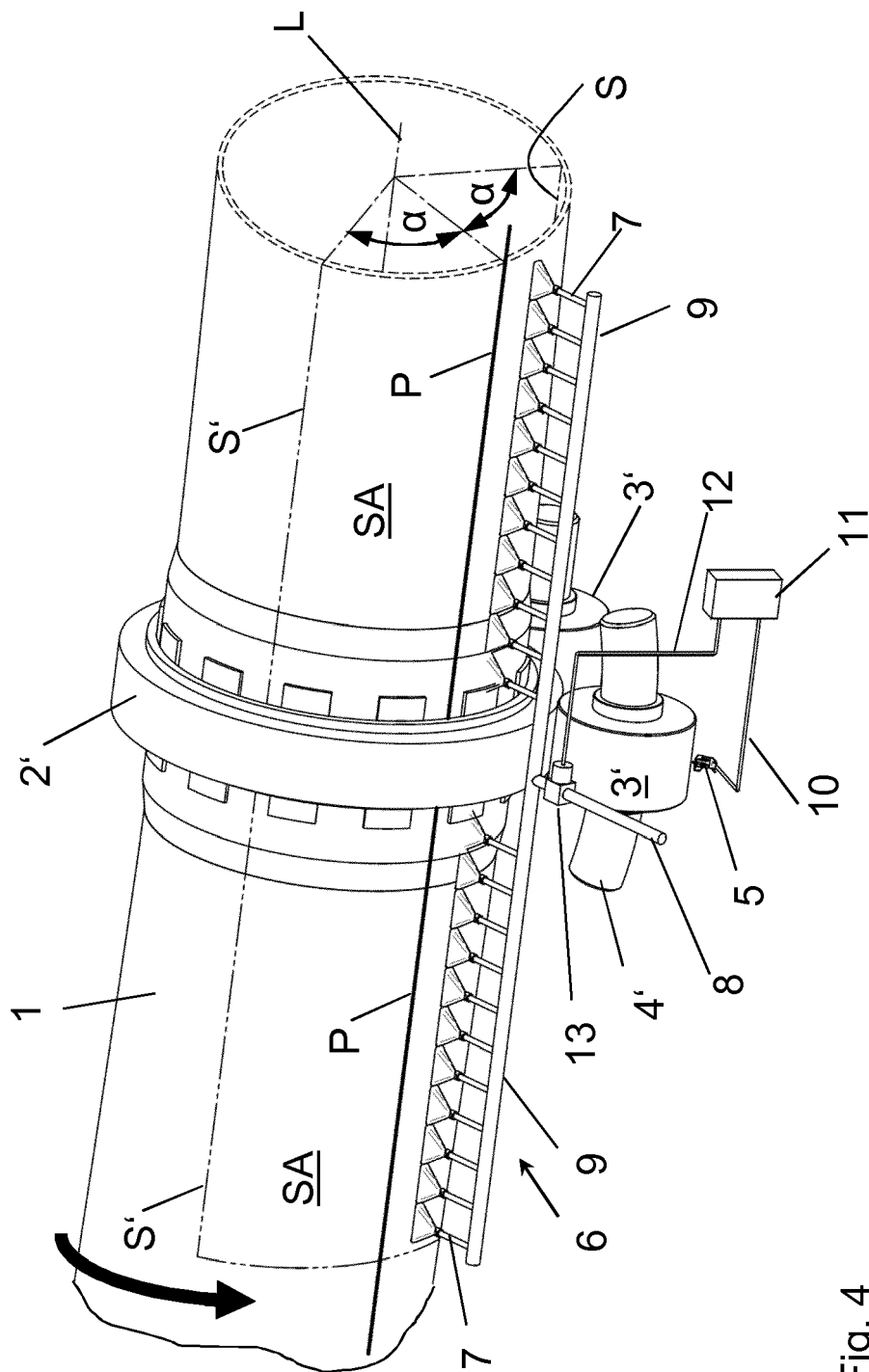


Fig. 4

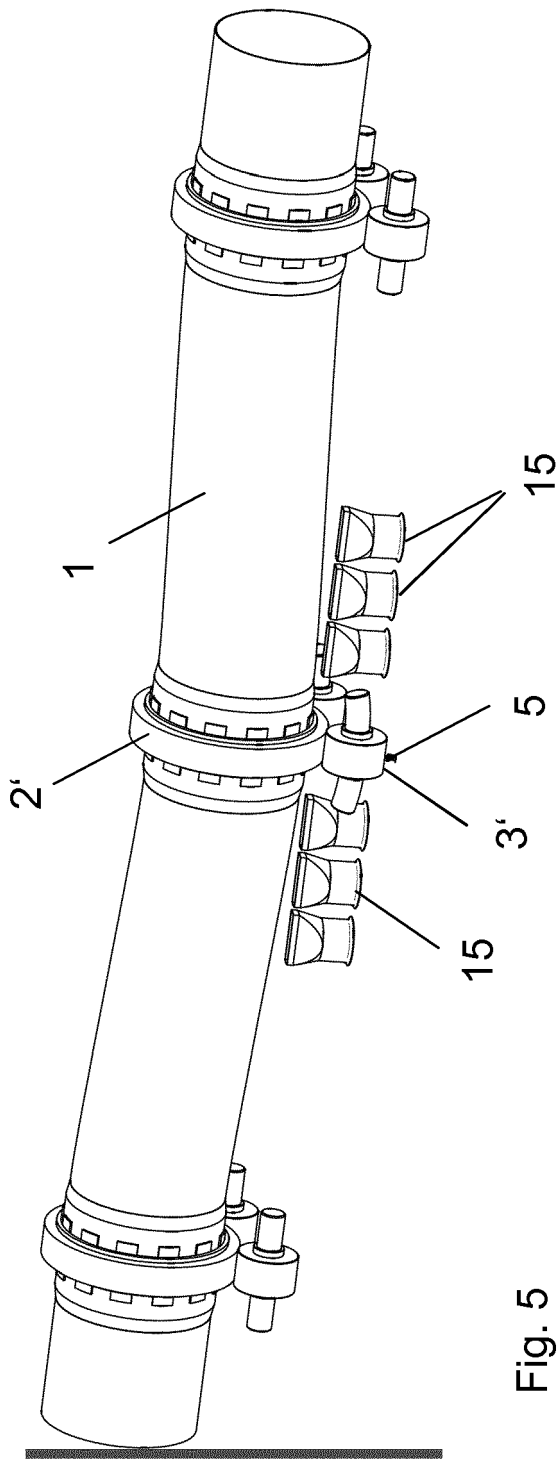


Fig. 5

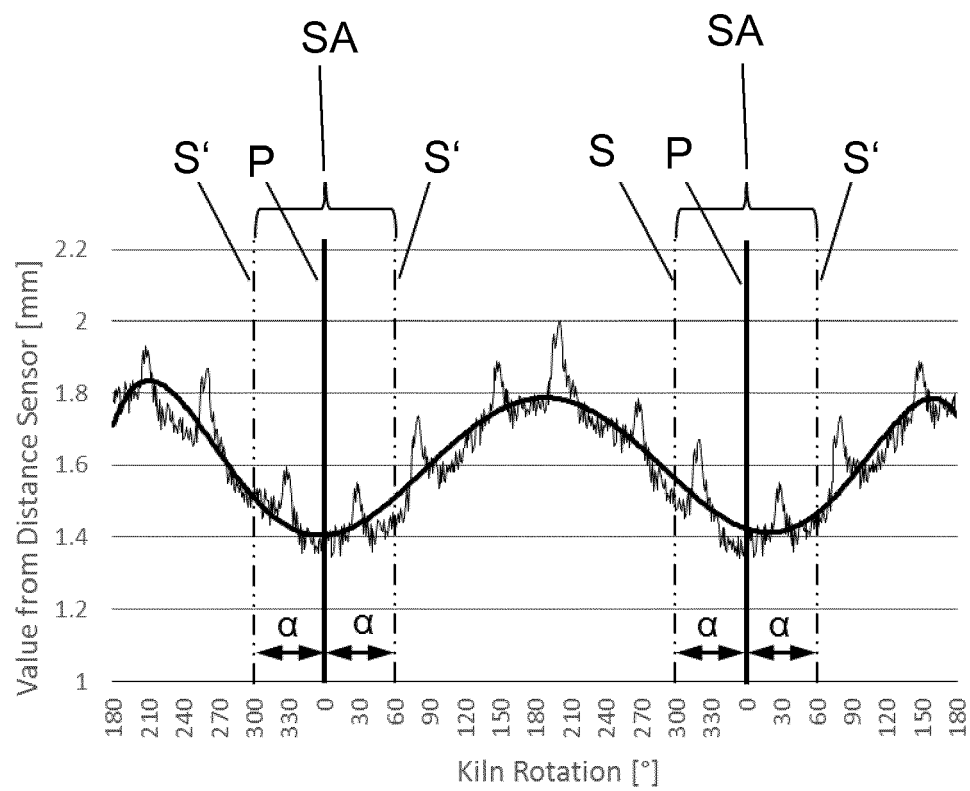


Fig. 6



EUROPEAN SEARCH REPORT

Application Number
EP 16 16 7660

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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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