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- **Sudarsan, Sithu Dhamodharan**
560048 Bangalore (IN)
- **Ash, Nilabja**
560040 Bangalore (IN)
- **S, Shishira**
570002 Mysuru (IN)

(71) Applicant: **ABB Schweiz AG**
5400 Baden (CH)

(74) Representative: **Zimmermann & Partner**
Patentanwälte mbB
Postfach 330 920
80069 München (DE)

(72) Inventors:
• **Rao, Vidyadhar**
560048 Bengaluru (IN)

(54) **METHOD AND CONTROL SYSTEM FOR DELIVERING ROLLING STOCK TO A COOLING BED**

(57) Embodiments of the present invention relate to delivering rolling stock 105a to 105n to a cooling bed 106 in a rolling mill 100. More specifically, the embodiments of the present invention relate to provide a feedback in a closed-loop control system to ensure the rolling stock are delivered to the cooling bed without abnormalities. A control system 110 receives a plurality of images of a rolling stock and determines one or more abnormalities

in the rolling stock. Further, one or more setpoints are determined for avoiding the one or more abnormalities in rolling stock to be delivered in future or subsequent rolling stock. The one or more setpoints are provided to one or more actuators 101, 102. The one or more actuators are operated according to the one or more setpoints and the subsequent rolling stock are delivered without the one or more abnormalities.

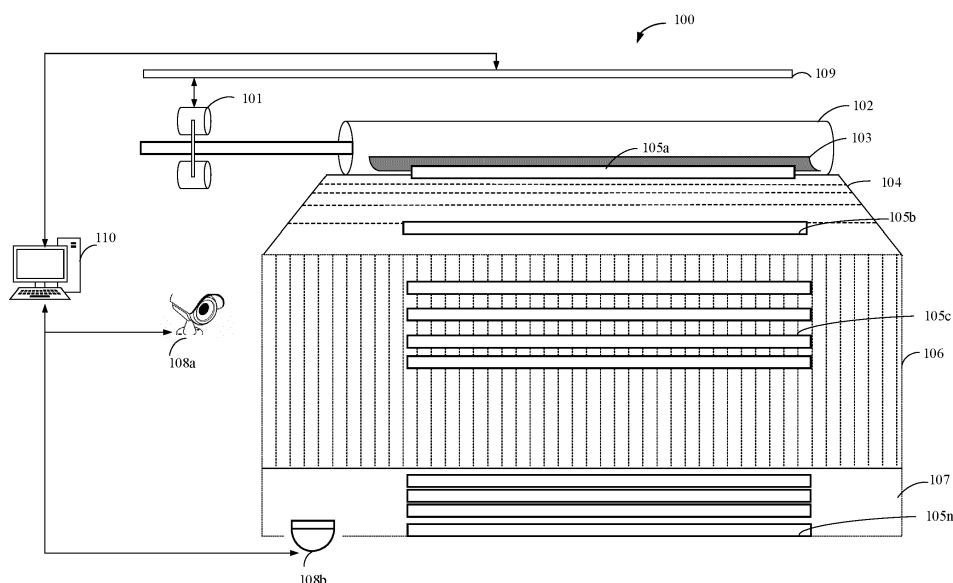


FIGURE 1

Description**TECHNICAL FIELD**

5 **[0001]** The present invention relates in general to control systems for a rolling mill. More specifically, the present invention relates to detecting abnormalities in rolling stock placed on a cooling bed and determining setpoints for control systems, for avoiding the abnormalities in subsequent rolling stocks.

BACKGROUND

10 **[0002]** A typical rolling mill involves a series of dynamic events, usually working processes involving hot material (e.g., molten steel in the form of billets or rebars). During rolling process, a plurality of process parameters (e.g., stress applied on the hot material, strain on the hot material, temperature of rolling, and the like), initial set points of actuators in the rolling mill, and parameters of the hot material are considered for various monitoring and control mechanisms. Typically, 15 the rebars are delivered to a cooling bed to undergo cooling. Once the rebars are cooled, the cooled rebars are provided to a finishing and inspection bay. The rebars are moved through different processes in the rolling mill using conveyors at high speed. Generally, the rebars are dropped on the cooling bed using rotating channels after receiving from a pinch roller which reduces the speed of movement of the rebars. Although the pinch roller reduces the speed, the rebars fall on the cooling bed unevenly. Few rolling mills employ manual operators to align the rebars on the cooling bed. Few 20 other rolling mills use aligning rollers which are controlled by motors to align the rebars on the cooling bed. The conventionally used aligning rollers push the rebars towards a hard surface to align the rebars on the cooling bed. Hence, the rebars are damaged and fail quality test. Further, the aligning rollers may not be available to align each rebar as number of aligning rollers are limited in a rolling mill. Also, the existing aligning rollers may not align rebars mis-aligned by a large extent. Also, conventional aligning of the rebars reduces productivity and misaligned rebars on the cooling bed 25 affects quality of the rebars during subsequent processes. Also, the structural properties of the rebars are established on the cooling bed. If the rebars are misaligned (e.g., rebars rolled over other rebars), it results in structural defects. Often, defective rebars have to be replaced, thus reducing plant productivity and increasing downtime.

[0003] Therefore, there is a need to address at least the above problems of determining misalignments of rebars on the cooling bed and providing feedback using closed-loop control to ensure alignments of rebars.

SUMMARY

30 **[0004]** In an embodiment, the present invention relates to a method and a control system for delivering rolling stock to a cooling bed of a rolling mill. A rolling bed comprises one or more actuators to deliver the rolling stock (e.g., rebars) 35 to a receiving end of the cooling bed. The control system is configured to perform the method steps. The control system captures a plurality of images of the rolling stock placed on the cooling bed. In an embodiment, the plurality of images may be captured from at least a lateral side (perpendicular to receiving end of cooling bed) and a transverse side (parallel to receiving end of the cooling bed) of the cooling bed. Using the plurality image, one or more abnormalities (misalignments, gaps and missing grooves) in the rolling stock are detected. Further, one or more setpoints are determined 40 required to avoid the one or more abnormalities in subsequent rolling stock. The one or more setpoints may be provided to the one or more actuators in the rolling mill. When the one or more actuators are operated according to the one or more setpoints, the one or more abnormalities are avoided in subsequent rolling stock being delivered to the cooling bed.

[0005] In an embodiment, the one or more abnormalities comprises at least one of, a mis-alignment in the rolling stock placed on the cooling bed, gaps in the rolling stock placed on the cooling bed and lack of grooves on the rolling stock 45 placed on the cooling bed.

[0006] In an embodiment, for detecting a mis-alignment in the rolling stock placed on the cooling bed an end portion of the rolling stock is detected using the plurality of images of the rolling stock. Further, a reference point is generated on the cooling bed and an amount of deviation of the end portion of the rolling stock from the reference point on the cooling bed is determined.

50 **[0007]** In an embodiment, the mis-alignments are reduced for subsequent rolling stock by operating the one or more actuators according to the one or more setpoints. One or more process parameters related to the one or more braking pinch rolls configured to pass the rolling stock and one or more channels configured to receive the rolling stock from the braking pinch rolls and deliver the rolling stock onto the cooling bed, are determined. Further, one or more parameters of the rolling stock are determined when the rolling stock is delivered from the one or more channels to the cooling bed, 55 using the plurality of images. Thereafter, one or more setpoints are determined for controlling a delivery speed of the subsequent rolling stock based on the one or more parameters of the one or more process parameters of braking pinch rolls and the one or more channels. The one or more setpoints are provided to the one or more channels to control the delivery speed of the subsequent rolling stock onto the cooling bed for placing the rolling stock substantially near to the

reference point.

[0008] In an embodiment, the one or more process parameters related to the braking pinch rolls comprises at least one of, a pressure applied by the braking pinch rolls on the rolling stock and a speed of passing the rolling stock, wherein the one or more process parameters related to the one or more channels comprises at least one of, a delivery speed of the rolling stock, a friction factor of the rolling stock into the one or more channels from the braking pinch rolls, a distance of the one or more channels from the braking pinch rolls, and a length of the one or more channels.

[0009] In an embodiment, the one or more parameters of the rolling stock comprises at least one of, a length of the rolling stock on the cooling bed, a distance of the rolling stock from the reference point on the cooling bed and a mass of the rolling stock placed on the cooling bed.

[0010] In an embodiment, the gaps between the rolling stock are detected by determining abnormal patterns of the rolling stock using the plurality of images of the rolling stock placed on the cooling bed. The abnormal patterns are indicative of gaps in between the rolling stock placed on the cooling bed. A first feedback is provided to the one or more actuators, where the one or more actuators are configured to perform one or more actions to eliminate gaps between the subsequent rolling stock delivered to the cooling bed.

[0011] In an embodiment, lack of grooves on the rolling stock is detected by detecting a surface of the rolling stock using the plurality of images of the rolling stock placed on the cooling bed. In an embodiment, non-uniform grooves (grooves not according to desired pattern) are also detected. Further, one or more geometry parameters are determined for the detected surface to identify absence of grooves or undesired groove pattern on the surface of the rolling stock, wherein a second feedback is provided to the one or more actuators, wherein the one or more actuators are configured to groove the subsequent rolling stock.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

Fig. 1 illustrates an exemplary environment of a rolling mill, for delivering a rolling stock to a cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 2 is a simplified block diagram of a control system for delivering a rolling stock to a cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 3 is an exemplary flowchart for delivering a rolling stock to a cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 4 is an exemplary flowchart for detecting mis-alignments in the rolling stock placed on a cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 5 is an exemplary illustration of detecting mis-alignments of rolling stock on a cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 6 is an exemplary flowchart for determining setpoints for aligning rolling stock on the cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 7 is an exemplary illustration of operating actuators according to setpoints for aligning rolling stock on the cooling bed, in accordance with an embodiment of the present disclosure;

Fig. 8 is an illustration of detecting gaps in rolling stock placed on a cooling bed, in accordance with an embodiment of the present disclosure; and

Figure 9 is an illustration of detecting lack of grooves on rolling stock placed on a cooling bed, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0013] Typically, in a conventional rolling mill, problems such as mis-alignments of rolling stock exist. Especially, the mis-alignments of the rolling stock exist on the cooling bed. Due to the mis-alignments, subsequent processes may not be carried out productively. Also, the mis-alignments may directly impact quality of the rolling stock. Furthermore, production downtime adds up due to correcting the mis-aligned rolling stock. The mis-alignments may be caused due to

uneven/ uncontrolled delivery of the rolling stock to the cooling bed. Typically, the rolling stock are dropped on the cooling bed using one or more actuators. The conventional actuators do not drop the rolling stock such that the rolling stock are aligned when they are dropped on the cooling bed. However, conventional rolling mill use aligning rollers to align the rolling stock after the rolling stock is dropped on the cooling bed.

[0014] In conventional rolling mill, abnormalities such as gaps between the rolling stock (due to bending of the rolling stock) on the cooling bed are manually identified and are separated from normal rolling stock. Hence, manual identification consumes substantial time, results in downtime and are prone to errors.

[0015] Another drawback in conventional rolling mill is, abnormalities such as lack of grooves on the rolling stock are either not identified or manually identified in an inspection bay (after the rolling stock is cooled in the cooling bed). Hence, the plant downtime is increased and results in wastage of materials which affects the productivity of the rolling mill.

[0016] Embodiments of the present invention relate to delivering rolling stock to a cooling bed in a rolling mill. More specifically, the embodiments of the present invention relate to provide a feedback in a closed-loop control system to ensure the rolling stock are delivered to the cooling bed without abnormalities. A control system receives a plurality of images of a rolling stock and determines one or more abnormalities in the rolling stock. Further, one or more setpoints are determined for avoiding the one or more abnormalities in rolling stock to be delivered in future or subsequent rolling stock. The one or more setpoints are provided to one or more actuators. The one or more actuators are operated according to the one or more setpoints and the subsequent rolling stock are delivered without the one or more abnormalities.

[0017] Fig. 1 illustrates an exemplary environment of a rolling mill, for delivering a rolling stock to a cooling bed. Fig. 1 shows a simplified diagram of a rolling mill (100). Although, the rolling mill (100) comprises a plurality of processes and divisions, Fig. 1 is illustrating a cooling division of the rolling mill (100). The cooling division of the rolling mill (100) comprises one or more brake pinch rollers (101), one or more rotating channels (102), an opening (103) of the channel (102), a run-in table (104), rolling stock (105a, ..., 105n), a cooling bed (106), a collection bay (107), one or more imaging units (108a, 108b), a communication line (109) and one or more processing units (110). Although Fig. 1 shows one brake pinch roll (101), one channel (102), one processing unit (110), it should be apparent to a person skilled in the art that more of such components can be used in the rolling mill (100). In an embodiment, the rolling stock (105a, ..., 105n) may be a billet, a finished product such as rebar.

[0018] The brake pinch roller (101) receive the rolling stock (105a, ..., 105n) from previous other processes (e.g., from a shearing bay or a slit roller). Typically, in all the processes in the rolling mill, the rolling stock is moved at a high speed. Hence, the brake pinch roller (101) also receives the rolling stock (105a, ..., 105n) at a high pace. The brake pinch roller (101) applies pressure on the rolling stock (105a, ..., 105n) to reduce the speed of the rolling stock (105a, ..., 105n). Also, the speed of the braking pinch roller (101) may be reduced to reduce speed of the rolling stock (105a, ..., 105n). Further, the rolling stock (105a, ..., 105n) are provided to the channel (102). In one embodiment, the channel rotates and the channel comprises the opening (103) to drop the rolling stock (105a, ..., 105n). The channel rotates such that the rolling stock (105a, ..., 105n) are received and dropped on the run-in table (104) or the cooling bed (106). In some aspects, the run-in table (104) may not be present and the rolling stock (105a, ..., 105n) are dropped on the cooling bed (106) directly. For example, in slow speed rolling mills, the brake pinch roller (101) may not be required as the rolling stock (105a, ..., 105n) are transported at slow speed and the run-in table (104) may also not be required. The presence and absence of the run-in table (104) is specific to different rolling mills (100) and should not be considered as a limitation. Typically, the rolling stock (105a, ..., 105n) has different lengths according to an end application. Hence, the opening (103) may have at least twice the length of the rolling stock (105a, ..., 105n). Due to the long length of the opening (103), the rolling stock (105a, ..., 105n) are not dropped evenly on the run-in table (104). The run-in table (104) is configured to carry the rolling stock (105a, ..., 105n) to a receiving end of the cooling bed (106) as shown in the Figure 1. The cooling bed (106) receives the rolling stock (105a, ..., 105n) at the receiving end and cools the rolling stock (105a, ..., 105n) using techniques such as water cooling or air cooling. The cooling bed (106) may be a rake type cooling bed (106) having automated movement to move the rolling stock (105a, ..., 105n) horizontally across the cooling bed (106) towards a discharge end or a delivery end of the cooling bed (106). At the discharge end of the cooling bed (106), a collection bay (107) is present. The collection bay (107) is configured to collect the rolling stock (105a, ..., 105n) together as shown in the Figure 1. The collection bay (107) may further provide the collected rolling stock (105a, ..., 105n) to subsequent process (inspection, cutting, packaging, etc) via a run-out table (not shown in Figure 1).

[0019] In an embodiment, the one or more imaging units (108a, 108b) are used capture a plurality of images of the rolling stock (105a, ..., 105n). Preferably, in one embodiment, the one or more imaging units (108a, 108b) capture the plurality of images of the rolling stock (105a, ..., 105n) placed on the cooling bed (106). The one or more imaging units (108a, 108b) may be installed at least in a lateral end (perpendicular to receiving end of cooling bed) and a transverse end (parallel to receiving end of the cooling bed) of the cooling bed (106). Hence, the plurality of images of the rolling stock (105a, ..., 105n) may be captured from one or more perspective views to detect one or more abnormalities in the rolling stock (105a, ..., 105n). The one or more imaging units (108a, 108b) may be connected to a control system (110). In an embodiment, the one or more imaging units (108a, 108b) may be part of an existing control system (110) in the

rolling mill (100). The control system (110) may be configured to monitor and control operations of the rolling mill (100). In the present disclosure the control system (110) may be part of a Distributed Control System (DCS) or a Supervisory Control And Data Acquisition (SCADA) system. The DCS or the SCADA may be configured to monitor various parameters of the rolling mill (100) and control one or more actuators in the rolling mill (100). In an embodiment, the control system (110) may communicate with the one or more actuators via the communication line (109).

[0020] The control system (110) is configured to capture the plurality of images of the rolling stock (e.g., 105c) and determine one or more abnormalities in the rolling stock (105c) placed on the cooling bed (106). The control system (110) may use image processing techniques to detect the one or more abnormalities. Further, the control system (110) determines one or more setpoints required to avoid the one or more abnormalities in subsequent rolling stock (e.g., 105a). The determined one or more setpoints are provided to the one or more actuators (e.g., brake pinch rollers (101) and the channel (102)). The one or more actuators are operated according to the one or more setpoints to avoid the one or more abnormalities in the subsequent rolling stock (e.g., 105c).

[0021] Fig. 2 is a simplified block diagram of the control system (110) for delivering a rolling stock (105a, ..., 105n) to a cooling bed (106). The control system (110) comprises one or more processors (201a, ..., 201n), a memory (202) and a communication module (203). The one or more processors (201a, ..., 201n) are configured to perform the various steps of Fig. 3, Fig. 4 and Fig. 6. The memory (202) is configured to store processor executable instructions. The communication module (203) is configured to establish a communication between the one or more processors (201a, ..., 201n) and the memory (202). Also, the communication module (203) is configured to establish communication with external devices such as the one or more imaging units (108a, 108b) and the one or more actuators (brake pinch rollers (101) and the channel (102)).

[0022] Fig. 3 is an exemplary flowchart for delivering a rolling stock (105a, ..., 105n) to a cooling bed (106).

[0023] At step (301), the control system (110) captures the plurality of images of the rolling stock (105a, ..., 105n). In an embodiment, the rolling stock (105a, ..., 105n) may be placed on the cooling bed (106) in the rolling mill (100) as shown in the Fig. 1. The plurality of images may be captured by the one or more imaging units (108a, 108b). In an embodiment, the control system (110) receives the plurality of images and pre-processes the plurality of images. Pre-processing the plurality of images comprises, but not limited to, denoising, scaling, contrast enhancement, image restoration, color image processing, wavelet and multi-resolution processing, image compression, morphological processing, resizing, segmentation, and the like.

[0024] At step (302), the control system (110) detects one or more abnormalities in the rolling stock (105a, ..., 105n). In an embodiment, the one or more abnormalities may include, but not limited to, mis-alignment of the rolling stock (105a, ..., 105n) on the cooling bed (106), gaps between the rolling stock (105a, ..., 105n) (due to bending of the rolling stock (105a, ..., 105n)), and lack of grooves on the rolling stock (105a, ..., 105n).

[0025] At step (303), the control system (110) determines one or more setpoints to be provided to the one or more actuators. The one or more setpoints are a feedback to the one or more actuators to form a closed-loop control operation. The one or more setpoints are determined to ensure that the subsequent rolling stock (e.g., 105a) are void of the one or more abnormalities. The present invention discloses a monitoring and feedback mechanism where a first set of rolling stock (e.g., 105c) is monitored and the one or more abnormalities are determined. Further, the one or more setpoints are determined based on the monitoring, and the one or more setpoints are provided to ensure the one or more abnormalities are not present in the next set of the rolling stock (e.g., 105a).

[0026] Fig. 4 is an exemplary flowchart for detecting mis-alignments in the rolling stock placed on a cooling bed (106). The method (400) is described by making reference to Fig. 5. Fig. 5 is an exemplary illustration of detecting mis-alignments of the rolling stock (105a, ..., 105n) on a cooling bed (106).

[0027] At step (401), the control system (110) detects an end portion of the rolling stock (105a, ..., 105n). Referring to the Fig. 5, the rolling stock (105a, 105b, 105c and 105d) are placed on the cooling bed (106). The one or more imaging units (108a, 108b) capture the plurality of images of the rolling stock (105a, 105b, 105c and 105d). The control system (110) uses the plurality of images of the rolling stock (105a, 105b, 105c and 105d) and detects an end portion of the rolling stock (105a, 105b, 105c and 105d). In an embodiment, conventional image processing techniques may be used to detect the end portion of the rolling stock (105a, 105b, 105c and 105d). In an embodiment, the end portion of the rolling stock (105a, 105b, 105c and 105d) may be either end of the rolling stock (105a, 105b, 105c and 105d). In an embodiment, the plurality of images are used to determine the end portion of the rolling stock (105a, 105b, 105c and 105d). In one embodiment, one image may be sufficient to determine the end portion of the rolling stock (105a, ..., 105n). The end portion of the rolling stock (105a, 105b, 105c and 105d) is useful to determine a location where the rolling stock (105a, 105b, 105c and 105d) are dropped on the cooling bed (106). The rolling stock (105a, 105b, 105c and 105d) may be dropped very close to an end of the cooling bed (106), which is not desirable, as the rolling stock (105a, 105b, 105c and 105d) may be damaged as they hit the end of the cooling bed (106).

[0028] Referring back to Fig. 4, at step (402), the control system (110) generate a reference point on the cooling bed (106). The control system (110) generates the reference point on the cooling bed (106), away from the end of the cooling bed (106). The reference point is generated to detect the mis-alignment of the rolling stock (105a, 105b, 105c and 105d)

on the cooling bed (106). The reference point may be a single point, or a series of points to form a reference line (reference point and reference line are interchangeably used in the present invention). Reference is again made to Fig. 5, showing the reference point or line (501). As shown, the reference line (501) can have a certain distance from the end of the cooling bed (106). The reference line (501) is an imaginary point or position on the cooling bed (106) used to align the rolling stock (105a, 105b, 105c and 105d) with respect to that position on the cooling bed (106). For example, the reference line (501) may be at least 5 metres from the end of the cooling bed (106). In an embodiment, the distance of the reference line (501) may be determined such that, when the rolling stock (105a, 105b, 105c and 105d) are dropped on the cooling bed (106) substantially close to the reference line (501), the rolling stock (105a, 105b, 105c and 105d) are not close to the end of the cooling bed (106). The rolling stock (105a, 105b, 105c and 105d) may be aligned such that the end portion of the rolling stock (105a, 105b, 105c and 105d) match with the reference line (501) or the end portion are at a specific distance from the reference line (501).

[0029] Referring back to Fig. 4, at step (403), the control system (110) determines an amount of deviation of the end portion of the rolling stock (105a, 105b, 105c and 105d) from the reference line (501). As seen in Fig. 5, the deviation is determined by calculating a distance of the end portion of the rolling stock (105a, 105b, 105c and 105d) from the reference line (501). As shown, d1 represents the deviation of the rolling stock (105a) from the reference line (501), d2 represents the deviation of the rolling stock (105b) from the reference line (501), d3 represents the deviation of the rolling stock (105c) from the reference line (501), and d4 represents the deviation of the rolling stock (105d) from the reference line (501). Considering the rolling stock (105a, 105b, 105c and 105d) are rebars in an example, each rebar (105a, 105b, 105c and 105d) may be dropped at different position on the cooling bed (106). Hence, the distance of the end portion of each rebar (105a, 105b, 105c and 105d) from the reference line (501) is calculated to determine the mis-alignment among the rebars (105a, 105b, 105c and 105d). As seen in Fig. 5, the rebars (105a, 105b, 105c and 105d) are at different distances from the reference line (501). In an embodiment, Hough transformation may be used to determine the mis-alignment of the rebars (105a, 105b, 105c and 105d). The cooling bed (106) may be divided into a plurality of segments (not shown). Once the mis-alignment is determined, a segment among the plurality of segments corresponding to each rebar (105a, 105b, 105c and 105d) may be identified. The identified segment for each rebar (105a, 105b, 105c and 105d) is used to determine the dropping position of the rebars (105a, 105b, 105c and 105d) on the cooling bed (106). Once the mis-alignment are determined and segments are identified, an indication or a notification may be provided to an operator in the rolling mill (100). In an embodiment, aligning rollers (not shown) may be used to align the rebars (105a, 105b, 105c and 105d) with respect to the reference line (501).

[0030] Fig. 6 is an exemplary flowchart for determining setpoints for aligning rolling stock (105a, ..., 105n) on the cooling bed (106). The method (600) is described by making reference to Fig. 7. Fig. 7 is an exemplary illustration of operating the one or more actuators according to setpoints for aligning rolling stock on the cooling bed (106). The mis-alignments of the rolling stock (105a, ..., 105n) may be due to uneven falling or dropping of the rolling stock (105a, ..., 105n) on the cooling bed (106). The rolling stock (105a, ..., 105n) are dropped on the cooling bed (106) using the channel (102). The channel (102) receives the rolling stock (105a, ..., 105n) from the braking pinch rollers (101). Hence, the braking pinch rollers (101) and the channel (102) are operated such that the rolling stock (105a, ..., 105n) are dropped on the cooling bed (106) such that they are substantially close to the reference line (501), thereby aligning the rolling stock (105a, ..., 105n).

[0031] At step (601), the control system (110) determines a plurality of process parameters of the braking pinch roller (101) and the channel (102). The one or more process parameters related to the braking pinch rollers (101) comprises at least one of, a pressure applied by the braking pinch rollers (101) on the rolling stock (105a, ..., 105n) and a speed of passing the rolling stock, (105a, ..., 105n). The one or more process parameters related to the channel (102) comprises at least one of, a delivery speed of the rolling stock (105a, ..., 105n), a friction factor of the rolling stock (105a, ..., 105n) into the channel (102) from the braking pinch rollers (101), a distance of the channel (102) from the braking pinch rollers (101), and a length of the channel (102). The plurality of parameters of the braking pinch roller (101) and the channel (102) can be obtained from the DCS or the SCADA. The plurality of parameters of the braking pinch roller (101) and the channel (102) are obtained when the rolling stock (105a, ..., 105n) are dropped on the cooling bed (106), to determine which parameters among the plurality of parameters of the braking pinch roller (101) and the channel (102) affect the dropping of the rolling stock (105a, ... 105n) on the cooling bed (106).

[0032] At step (602), the control system (110) determines one or more parameters of the rolling stock (105a, ..., 105n) when the rolling stock (105a, ..., 105n) are delivered to the cooling bed (106). The one or more parameters of the rolling stock (105a, ..., 105n) comprises at least one of, a length of the rolling stock (105a, ..., 105n) on the cooling bed (106), a distance of the rolling stock (105a, ..., 105n) from the reference point (501) on the cooling bed (106) and a mass of the rolling stock (105a, ..., 105n).

[0033] At step (603), the control system (110) determines the one or more setpoints for controlling a delivery speed of subsequent rolling stock (105a, ..., 105n) to the cooling bed (106). Referring to Fig. 7, the subsequent rolling stock (105e, 105f, 105g, 105h) are delivered to the cooling bed (106) after delivering the rolling stock (105a, 105b, 105c, 105d). As shown in the Fig. 7, the mis-alignment is determined on the rolling stock (105a, 105b, 105c, 105d) and the one or

more setpoints are determined to control the delivery speed of the subsequent rolling stock (105e, 105f, 105g, 105h). The one or more setpoints are determined to compute an amount of braking to be applied by the braking pinch rollers (101), to release or drop the rolling stock (105a, ..., 105n) on the cooling bed (106) uniformly. The speed at which the rolling stock (105a, ..., 105n) are released from the braking pinch rollers (101) is determined using the below equation:

$$L_{\text{sliding}} = L_c + D_{\text{bpr-c}} - (L_{\text{rs}} + D_{\text{align}}) \quad (1)$$

$$\text{FreeDecFact} = \text{func}(L_{\text{rs}}) \quad (2)$$

$$S_{\text{brk}} = \sqrt{2 * L_{\text{sliding}} * \text{FreeDecFact}} \quad (3)$$

where,

L_{sliding} - free sliding length of the rolling stock (105a, ..., 105n) in the channel (102) after receiving from the braking pinch rollers (101);

L_c - length of the channel (102);

$D_{\text{bpr-c}}$ - distance between the braking pinch rollers (101) and the channel (102);

L_{rs} - length of the rolling stock (105a, ..., 105n);

D_{align} - distance of the rolling stock (105a, ..., 105n) from the reference line (501);

FreeDecFact - friction factor for free sliding of the rolling stock (105a, ..., 105n) into the channel (102); and

S_{brk} - speed at which the rolling stock (105a, ..., 105n) is released from the braking pinch rollers (101).

[0034] From equation (1), the L_{sliding} is determined to understand how much the rolling stock (105a, ..., 105n) will slide into the channel (102) when released by the braking pinch rollers (101). A value of L_{sliding} is dependent on the length of the rolling stock (105a, ..., 105n), the distance between the braking pinch rollers (101) and the channel (102), the length of the channel (102) and the distance between the rolling stock (105a, ..., 105n). Still referring to Fig. 7, when the rolling stock (105a, 105b, 105c, 105d) are dropped on the cooling bed (106), the above parameters are obtained.

[0035] From the equation (2), the FreeDecFact is determined. The FreeDecFact is a function of the L_{rs} . As the L_{rs} increases, the FreeDecFact may also increase as the frictional surface increases. As the FreeDecFact increases, the L_{sliding} may decrease.

[0036] From the equation (3) the S_{brk} is determined. The S_{brk} is a function of the L_{sliding} and the FreeDecFact . Using the equation (3), the speed at which the rolling stock (105a, ..., 105n) is released from the braking pinch rollers (101) is determined. Therefore, the subsequent rolling stock (105e, 105f, 105g, 105h) are dropped uniformly on the cooling bed (106). In Fig. 7, the S_{brk} is provided to the braking pinch roller (101) after monitoring the rolling stock (105a, 105b, 105c, 105d). When the braking pinch roller (101) is operated to release the subsequent rolling stock (105e, 105f, 105g, 105h), the subsequent rolling stock (105e, 105f, 105g, 105h) are dropped uniformly on the cooling bed (106). In Fig. 7, the S_{brk} is determined such that the subsequent rolling stock (105e, 105f, 105g, 105h) are dropped on the cooling bed (106) at a distance (d) from the reference line (501). In an embodiment, the distance (d) may be less than a threshold value (d_{th}). As seen, the subsequent rolling stock (105e, 105f, 105g, 105h) are arranged uniformly and the end portion of the subsequent rolling stock (105e, 105f, 105g, 105h) are aligned with respect to the reference line (501). Hence, the subsequent rolling stock (105e, 105f, 105g, 105h) are not damaged while being aligned, unlike conventional methods. Also, the S_{brk} can be determined based on different profiles of the rolling stock (105a, ..., 105n). For example, the S_{brk} varies based on different mass of the rolling stock (105a, ..., 105n). The mass of the rolling stock (105a, ..., 105n) can be estimated from the length of the rolling stock (105a, ..., 105n). Hence, S_{brk} can be varied for rolling stock (105a, ..., 105n) having different mass.

[0037] Fig. 8 is an illustration of detecting gaps between the rolling stock (105a, ..., 105n) placed on a cooling bed (106). In an embodiment, the gaps between the rolling stock (105a, ..., 105n) may be caused due to bending of the rolling stock (105a, ..., 105n). In case of rebars (105a, ..., 105n), the bending occurs when the rebars (105a, ..., 105n) are not properly placed on the cooling bed (106). For example, when the rebars (105a, ..., 105n) (which are at high temperature) are placed close to each other on the cooling bed (106), due to the contact between the rebars (105a, ..., 105n), the bends may occur in the rebars (105a, ..., 105n). Typically, the bends in the rebars (105a, ..., 105n) are detected by an operator who isolates the bent rebars (e.g., 105e) from the other rebars (105a, 105b, 105c, 105d, 105f, 105g). However, many times, the operator may not be able to identify the bent rebars (105e) and such bent rebars (105e) may be delivered to customers. The present invention uses the image processing techniques to identify the bent rebars (105e) by identifying gaps in the rebars (105a, ..., 105g) placed on the cooling bed (106). The control system (110)

determines abnormal patterns (801) of the rebars (105a, ..., 105g) using the plurality of images. In an embodiment, normal or expected patterns may be fed to the control system (110) indicating correct shape of the rebars (105a, ..., 105g). For example, rectangular patterns in the plurality of images may indicate that the rebars (105a, ..., 105g) are having a correct shape. The abnormal patterns (801) are indicative of gaps in the rebars (105a, ..., 105g). The abnormal patterns (801) are determined by comparing a pattern identified in the plurality of images with the normal patterns. When the pattern is different from the normal patterns by a threshold value, the pattern is determined to be abnormal pattern (801). In an embodiment, a contour segmentation may be used to determine the abnormal pattern (801). For example, the shape of the rebar (105e) may be determined by tracing a surface or edge of the rebar (105e). The surface or edge is traced by joining pixels in the plurality of images. When the traced curve does not match a reference curve (normal pattern), such a curve indicates an abnormal rebar (105e). Further, a segment of the cooling bed (106) corresponding to the rebar (105e) having the abnormal pattern (801) is identified. Further, a notification is provided to indicate the bent rebar (105e) on the cooling bed. An operator may adjust the process variables of the one or more actuators based on an amount of bending of the rebar (105e). In an embodiment, the control system (110) may generate the one or more setpoints according to the amount of bent in the rebar (105e). The one or more setpoints are provided to the one or more actuators such that subsequent rebars are devoid of the bents. For example, temperature of the rebar (105e) plays a major role forming bends on the rebar (105e). A non-uniform temperature across the length of the rebar (105e) may cause bends across length of the rebar (105e). When the rebars (105e) falls on the cooling bed (106), the gaps are not same between the rebar (105e) and an adjacent rebar (105d). A reason for non-uniform temperature can originate from a faulty control system which may be responsible for forced cooling of the rebar (105e), or due to degradation in material composition, or improper temperature profile when a billet is discharged from a preheating furnace to the rolling mill (100). An operator in the rolling mill (100) may determine a cause of the bends in the rebar (105e) and take appropriate measures to generate the one or more setpoints. For example, the furnace temperature may be adjusted such that the billet is received at the rolling mill (100) at a correct temperature.

[0038] Figure 9 is an illustration of detecting lack of grooves on rolling stock (105a, 105b, 105c, 105d) placed on a cooling bed (106). The grooves or ribs on the rebars (105a, 105b, 105c, 105d) are essential to enhance anchorage in concrete structures to hold structures in place and avoid slippage of the concrete material from the rebars (105a, 105b, 105c, 105d). The design of ribs or grooves ensure the constructions owing to the strength of the bond with the concrete. However, often, the ribs or grooves are not present in few rebars (105b, 105c). Such rebars (105c) are identified manually and rolling machines (901a, ..., 901n) are inspected to determine the fault. This decreases productivity and increases downtime. The present invention detects the lack of grooves and/ or non-uniformity of the grooves on the rebars (105a, 105b, 105c, 105d). Further, the present invention determines one or more setpoints for the grooving machine to groove the rebars (105a, 105b, 105c, 105d).

[0039] The control system (110) detects a surface of the rebars (105a, 105b, 105c, 105d) using the plurality of images. Further, the control system (110) determines one or more geometry parameters for the detected surface to identify absence of grooves and /or non-uniform grooves on the surface of rebars (105a, 105b, 105c, 105d). For example, pixel intensity in the plurality of images may be used to determine the geometry parameters. As seen in Fig. 9, the rebars (105b, 105c) may have different pixel intensity compared to other rebars (e.g., 105d). The change in pixel intensity may indicate a change in geometric parameter (lack of grooves). Hence, such rebars (105b, 105c) having lack of grooves or non-uniform grooves may be notified to the operator. In an embodiment, the lack of grooves or the non-uniform grooves are notified to the operator and timely inspection can be performed. Thus, subsequent rolling stock may be devoid of the abnormalities such as lack of grooves and/ or non-uniform grooves.

[0040] In an embodiment, the present invention provides a closed-loop feedback to ensure one or more abnormalities are avoided in the rolling stock (105a, ..., 105n). Therefore, substantial amount of downtime is reduced and the productivity is increased. Also, high quality of the rolling stock (105a, ..., 105n) is ensured.

Claims

1. A method of delivering rolling stock to a cooling bed in a rolling mill, wherein the rolling stock is delivered to the cooling bed using one or more actuators in the rolling mill, wherein the rolling stock is dropped on a receiver end of the cooling bed, wherein the method is performed by a control system, the method comprising:

capturing a plurality of images of the rolling stock placed on the cooling bed;
 detecting one or more abnormalities in the rolling stock using the plurality of images of the rolling stock; and
 determining one or more setpoints required to avoid one or more abnormalities in subsequent rolling stock based on one or more parameters of the rolling stock;
 wherein the one or more setpoints are provided to the one or more actuators, wherein the one or more actuators are configured to deliver the subsequent rolling stock to the cooling bed avoiding the one or more abnormalities.

2. The method of claim 1, wherein the one or more abnormalities comprises at least one of, a mis-alignment in the rolling stock placed on the cooling bed, gaps between the rolling stock placed on the cooling bed and lack of grooves on the rolling stock placed on the cooling bed.

3. The method of claims 1 or 2, wherein detecting the mis-alignment in the rolling stock placed on the cooling bed comprises:

detecting an end portion of the rolling stock from the plurality of images of the rolling stock;
generating a reference point on the cooling bed; and
determining an amount of deviation of the end portion of the rolling stock from the reference point on the cooling bed;

4. The method of claim 3, further comprises:

determining one or more process parameters related to the one or more braking pinch rollers configured to pass the rolling stock and one or more channels configured to receive the rolling stock from the braking pinch rollers and deliver the rolling stock onto the cooling bed;
determining one or more parameters of the rolling stock when the rolling stock is delivered from the one or more channels to the cooling bed, using the one or more images;
determining the one or more setpoints for controlling a delivery speed of the subsequent rolling stock on the cooling bed based on the one or more parameters of the rolling stock, the one or more process parameters of braking pinch rollers and the one or more channels, wherein the first setpoints are provided to the one or more channels to control the delivery speed of the subsequent rolling stock onto the cooling bed for placing the rolling stock substantially near to the reference point.

5. The method of claim 4, wherein the one or more process parameters related to the braking pinch rollers comprises at least one of, a pressure applied by the braking pinch rollers on the rolling stock and a speed of passing the rolling stock, wherein the one or more process parameters related to the one or more channels comprises at least one of, a delivery speed of the rolling stock, a friction factor of the rolling stock into the one or more channels from the braking pinch rollers, a distance of the one or more channels from the braking pinch rollers, and a length of the one or more channels.

6. The method of claim 4, wherein the one or more parameters of the rolling stock comprises at least one of, a length of the rolling stock on the cooling bed, a distance of the rolling stock from the reference point on the cooling bed and a mass of the rolling stock placed on the cooling bed.

7. The method of claims 1 or 2, wherein detecting gaps comprises:
determining abnormal patterns of the rolling stock using the plurality of images of the rolling stock placed on the cooling bed, wherein the abnormal patterns are indicative of gaps between the rolling stock placed on the cooling bed, wherein a first feedback is provided to the one or more actuators, wherein the one or more actuators are configured to perform one or more actions to eliminate gaps in the subsequent rolling stock delivered to the cooling bed.

8. The method of claims 1 or 2, wherein detecting lack of grooves on the rolling stock comprises:

detecting a surface of the rolling stock using the plurality of images of the rolling stock placed on the cooling bed; and determining one or more geometry parameters for the detected surface to identify absence of grooves on the surface of the rolling stock, wherein a second feedback is provided to the one or more actuators, wherein the one or more actuators are configured to groove the subsequent rolling stock.

9. A control system for delivering rolling stock to a cooling bed in a rolling mill, wherein the rolling mill comprises one or more actuators for delivering the rolling stock to the cooling bed, one or more imaging units for capturing images of the rolling stock, a receiver end of the cooling bed for receives the rolling stock delivered by the one or more actuators, wherein the control system comprises:

one or more processors configured to:

receive a plurality of images of the rolling stock placed on the cooling bed;
detect one or more abnormalities in the rolling stock using the plurality of images of the rolling stock; and

determine one or more setpoints required to avoid one or more abnormalities in subsequent rolling stock based on the one or more parameters;
wherein the processor provides the one or more setpoints to the one or more actuators, wherein the one or more actuators are configured to deliver the subsequent rolling stock to the cooling bed avoiding the one or more abnormalities.

10. The control system of claim 9, wherein the one or more processors are configured to detect abnormalities comprising at least one of, a mis-alignment in the rolling stock placed on the cooling bed, gaps between the rolling stock placed on the cooling bed and lack of grooves on the rolling stock placed on the cooling bed.

11. The control system of claims 9 or 10, wherein the one or more processors detect the mis-alignment in the rolling stock placed on the cooling bed, wherein the one or more processors are configured to:

detect an end portion of the rolling stock from the plurality of images of the rolling stock;
generate a reference point on the cooling bed; and
determine an amount of deviation of the end portion of the rolling stock from the reference point on the cooling bed;

12. The control system of claim 11, wherein the one or more processors are further configured to:

determine one or more process parameters related to the one or more braking pinch rollers configured to pass the rolling stock and one or more channels configured to receive the rolling stock from the braking pinch rollers and deliver the rolling stock onto the cooling bed;
determine one or more parameters of the rolling stock when the rolling stock is delivered from the one or more channels to the cooling bed, using the one or more images;
determine the one or more setpoints for controlling a delivery speed of the subsequent rolling stock on the cooling bed based on the one or more parameters of the rolling stock, the one or more process parameters of braking pinch rollers and the one or more channels, wherein the first setpoints are provided to the one or more channels to control the delivery speed of the subsequent rolling stock onto the cooling bed for placing the rolling stock substantially near to the reference point.

13. The control system of claims 9 or 10, wherein the one or more processors are configured to detect gaps, wherein the one or more processors are configured to:
determine abnormal patterns of the rolling stock using the plurality of images of the rolling stock placed on the cooling bed, wherein the abnormal patterns are indicative of gaps between the rolling stock placed on the cooling bed, wherein a first feedback is provided to the one or more actuators, wherein the one or more actuators are configured to perform one or more actions to eliminate gaps in the subsequent rolling stock delivered to the cooling bed.

14. The control system of claims 9 or 10, wherein the one or more processors are configured to detect lack of grooves on the rolling stock, wherein the one or more processors are configured to:

detect a surface of the rolling stock using the plurality of images of the rolling stock placed on the cooling bed;
and
determine one or more geometry parameters for the detected surface to identify absence of grooves on the surface of the rolling stock, wherein a second feedback is provided to the one or more actuators, wherein the one or more actuators are configured to groove the subsequent rolling stock.

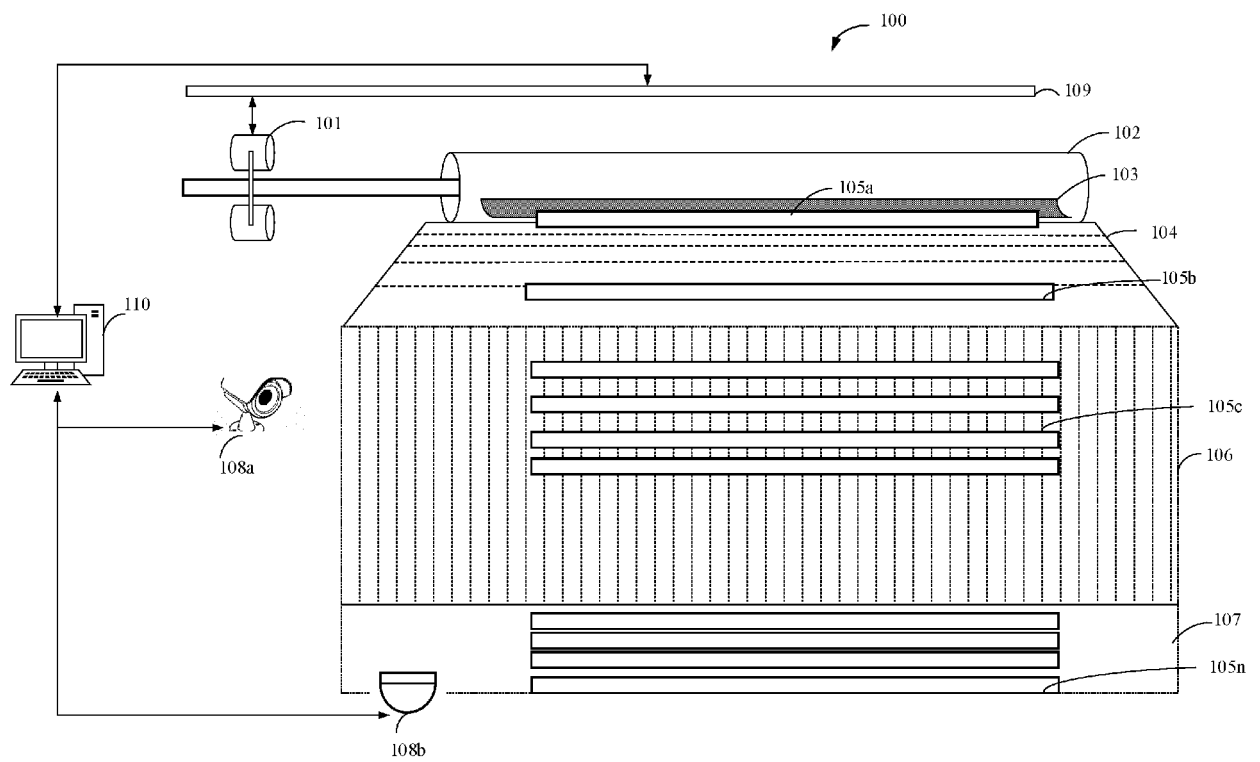


FIGURE 1

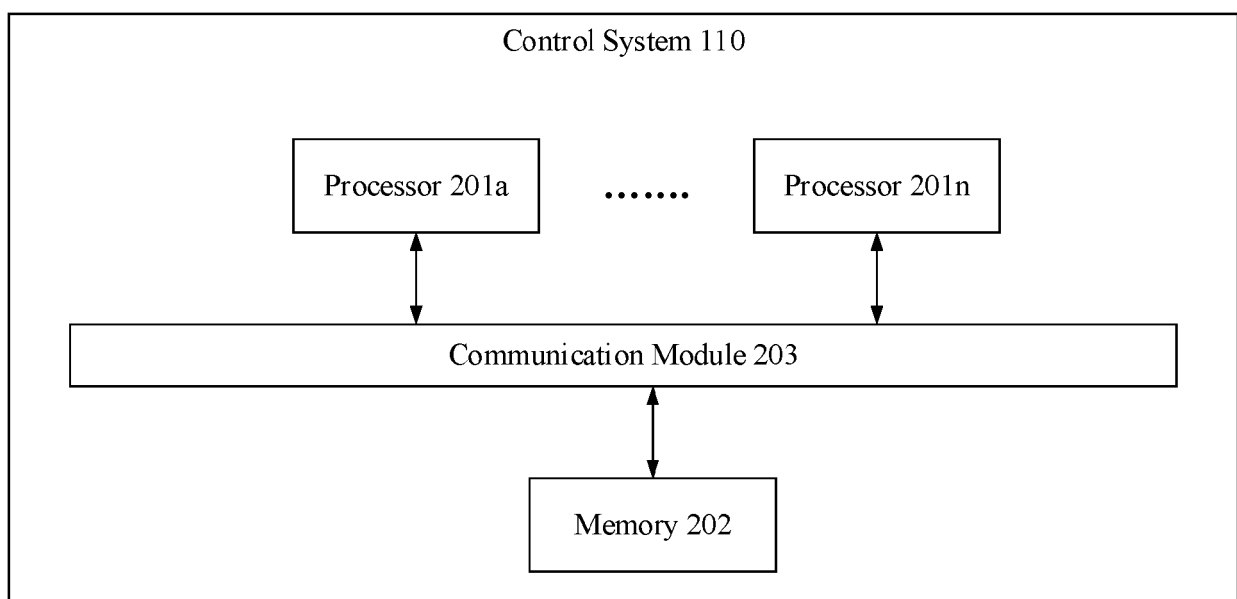


FIGURE 2

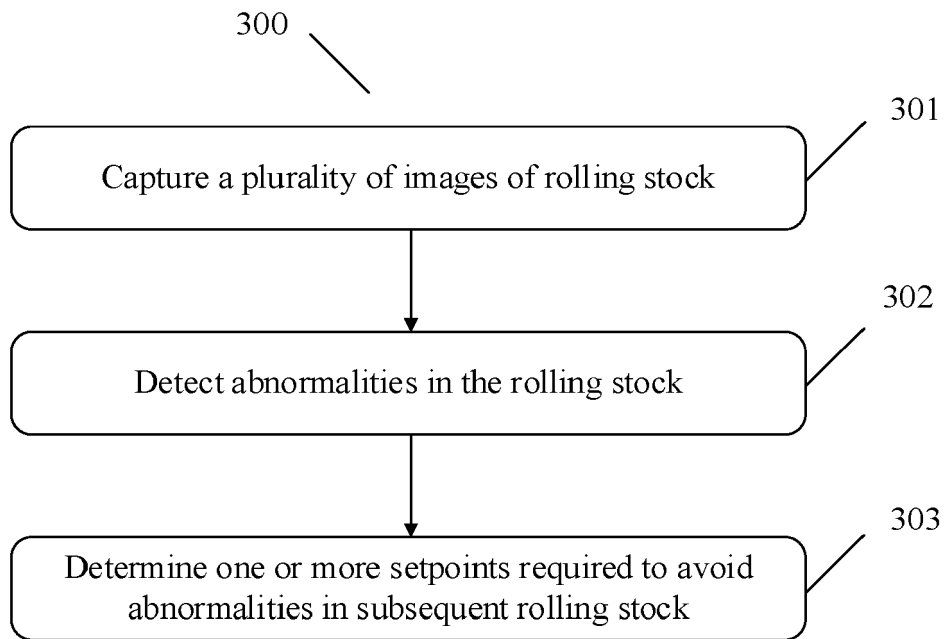


FIGURE 3

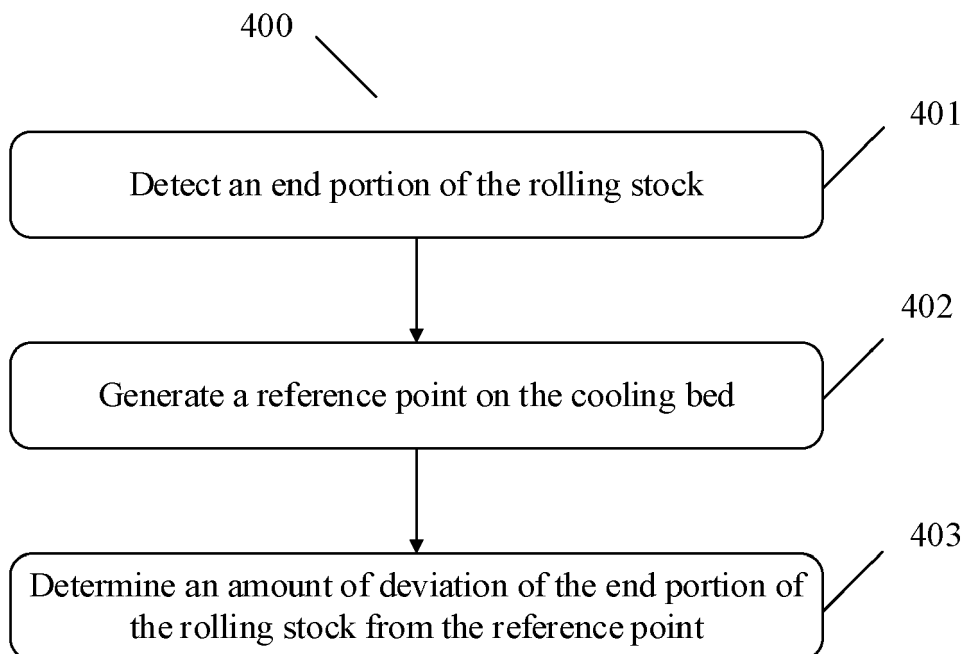


FIGURE 4

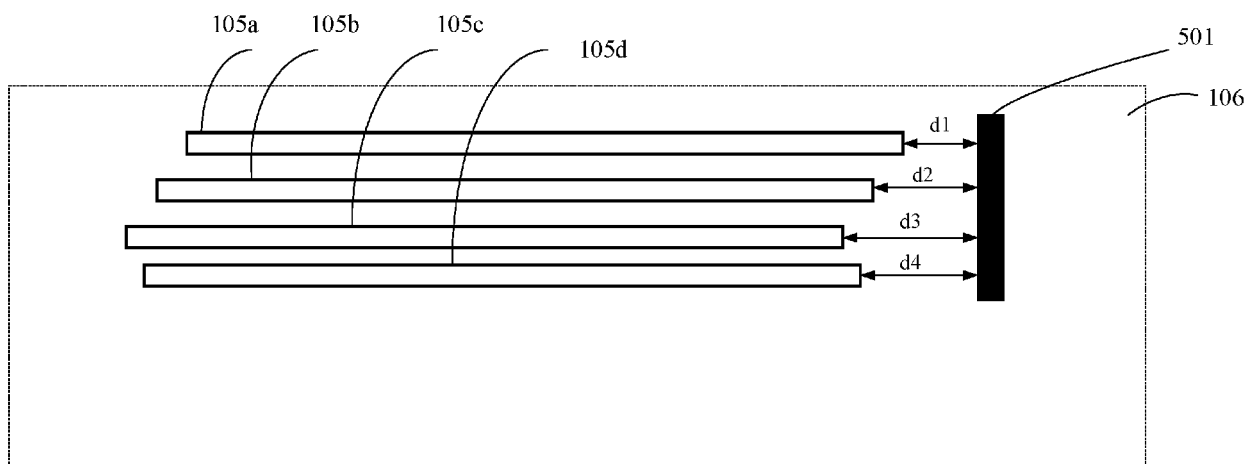


FIGURE 5

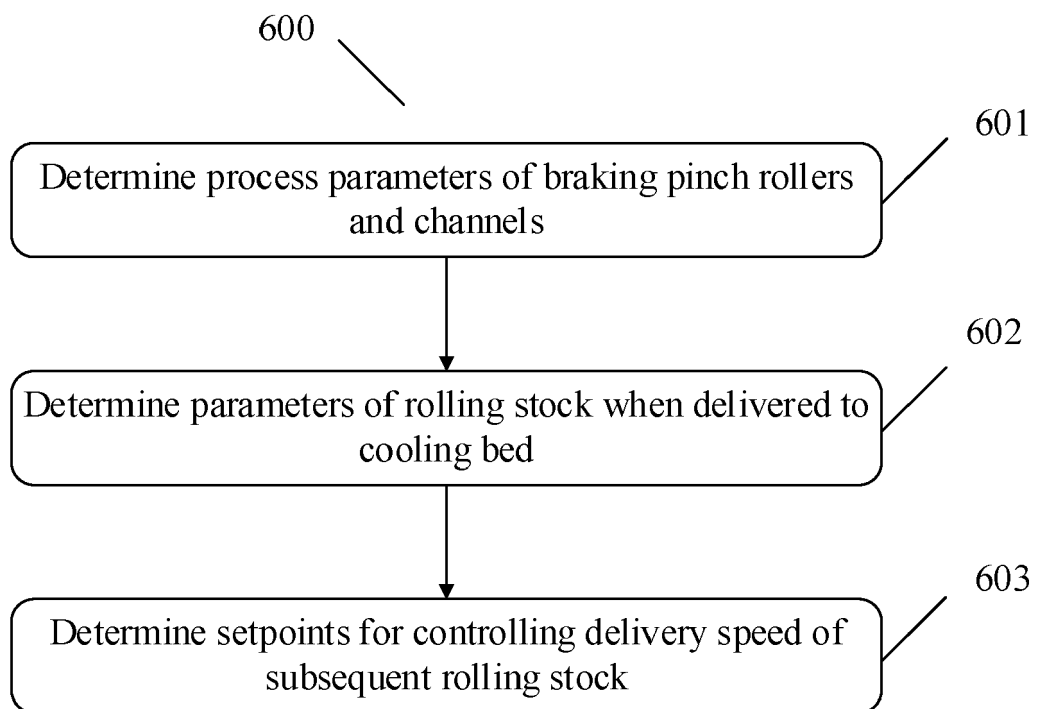


FIGURE 6

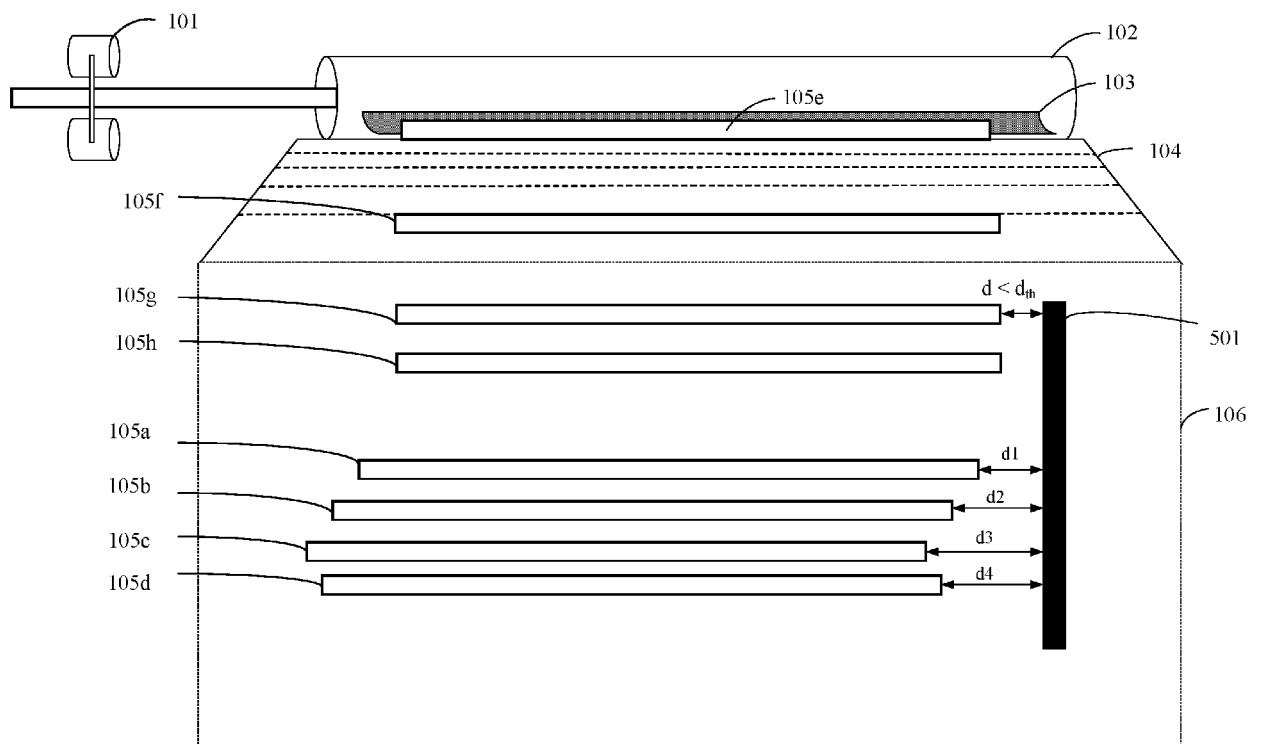


Figure 7

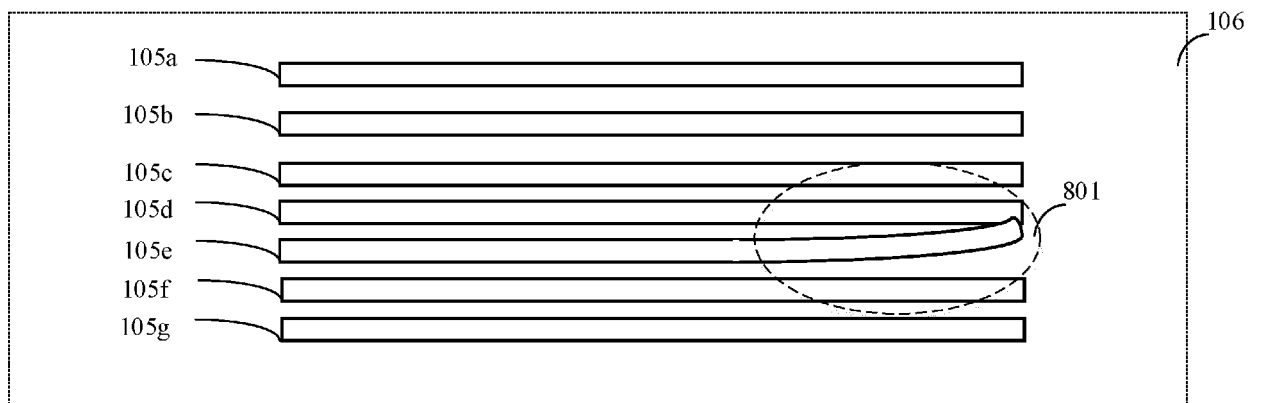


FIGURE 8

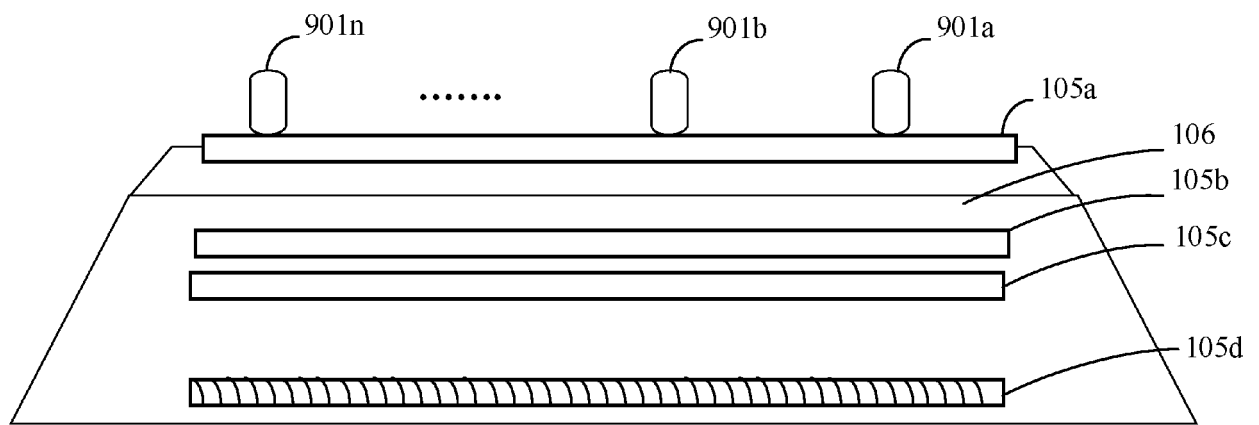


FIGURE 9



EUROPEAN SEARCH REPORT

 Application Number
 EP 20 16 8802

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Place of search Munich		Date of completion of the search 24 August 2020	Examiner Forciniti, Marco
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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