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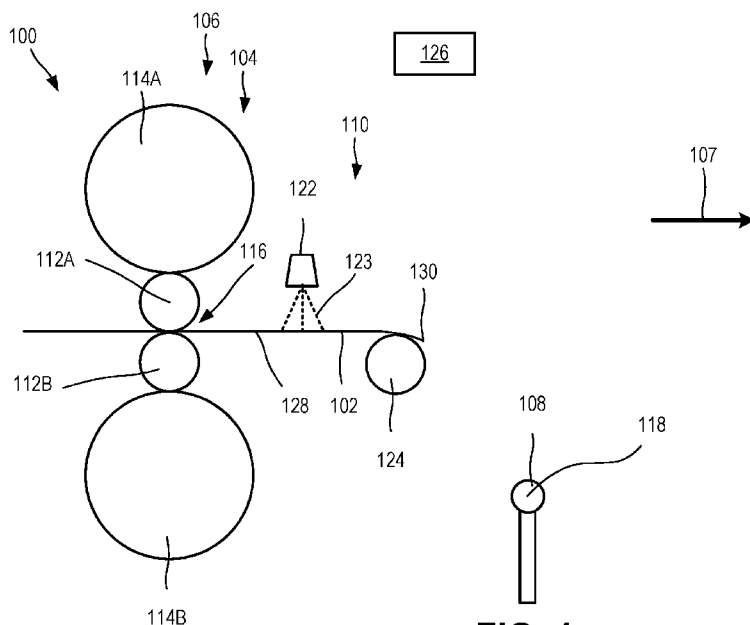


FIG. 1

(57) Abstract: A metal processing system includes an optical sensor for measuring a flatness of a material head of a metal strip being processed by the metal processing system. The optical sensor may measure the flatness of the material head before an exit tension is established in the metal strip. In some cases, the optical sensor may measure the flatness of the material head during a start of the metal processing system. A method of processing a metal strip may include receiving a metal strip from a last stand of a rolling mill and measuring a flatness of a material head of the metal strip with an optical sensor.

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MATERIAL HEAD FLATNESS CONTROL WITH OPTICAL SENSORS

REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/511,036, filed on June 29, 2023, and entitled MATERIAL HEAD FLATNESS CONTROL WITH OPTICAL SENSORS, the content of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] This application relates to the processing of metal substrates, such as but not limited to aluminum or aluminum alloy metal sheets, and more particularly to systems and methods for controlling flatness of a head or first lap of a metal substrate.

BACKGROUND

[0003] Metal rolling can be used for forming metal strips (e.g., plates, sheets, foils, slabs, etc.), (hereinafter “metal substrates”) from stock such as ingots or thicker metal strips. Depending on the desired properties of the final metal product, the metal substrate may be hot rolled, cold rolled, and/or warm rolled. Hot rolling generally refers to a rolling process where the temperature of the metal is above the recrystallization temperature of the metal. Cold rolling generally refers to a rolling process where the temperature of the metal is below the recrystallization temperature of the metal. Warm rolling generally refers to a rolling process where the temperature of the metal is below the recrystallization temperature but above the temperature during cold rolling.

[0004] An important characteristic of a metal substrate is the substrate’s flatness, or the ability of the substrate to lay flat when placed on a level surface with no externally applied loads. Off-flatness, or deviations from flatness, is caused by internal stresses in the metal substrate, and may come in various forms such as edge waves, center waves, buckling, near-edge pockets, etc. Metal substrates with poor flatness are difficult to process at high speeds, may cause steering problems during processing, may contribute to bad starts during threading, are difficult to trim and/or slit, and may be generally unsatisfactory for various customer or downstream processes. Traditionally, the flatness of the metal substrate has been measured at an exit of the rolling mill

using a shapemeter roll contacting the metal substrate. However, such traditional approaches require that the metal substrate be under exit tension (e.g., by having a first length or laps of the material head in a rewind coiler) before a measurement can be made. Such traditional approaches thereby have high material waste because the material head of the metal substrate without flatness measurement and control is scrapped. Moreover, the length of the material head without flatness measurement and control in traditional approaches increases the possibility of a bad start (e.g., due to off-centering, slippage, steering, etc.), resulting in stoppage of the processing system to correct the bad start and productivity losses.

SUMMARY

[0005] Embodiments covered by this patent are defined by the claims below, not this summary. This summary is a high-level overview of various embodiments and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings, and each claim.

[0006] According to certain embodiments, a method of processing a metal strip includes measuring a flatness of a material head of the metal strip with an optical sensor.

[0007] According to various embodiments, a method of processing a metal strip includes measuring a flatness of a material head of the metal strip before exit tension is established in the metal strip from a downstream tensioning device. The method may include generating a control signal for a flatness control actuator based on the measured flatness.

[0008] According to some embodiments, a metal processing system includes an optical sensor downstream from a last work stand of a rolling mill and upstream from a tensioning device. The optical sensor may measure a flatness of a material head of a metal strip being processed by the metal processing system.

[0009] According to various embodiments, a method of processing a metal strip includes receiving a metal strip from a last stand of a rolling mill and measuring a flatness of a material head of the metal strip with an optical sensor.

[0010] According to certain embodiments, a method of processing a metal strip includes measuring a flatness of a material head of the metal strip with an optical sensor and generating a control signal for a flatness control actuator based on the measured flatness.

[0011] Various implementations described herein can include additional systems, methods, features, and advantages, which cannot necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The specification makes reference to the following appended figures, in which use of like reference numerals in different figures is intended to illustrate like or analogous components.

[0013] FIG. 1 illustrates a metal processing system according to embodiments and before establishing exit tension in a metal substrate.

[0014] FIG. 2 illustrates the metal processing system of FIG. 1 after establishing exit tension in the metal substrate.

[0015] FIG. 3 illustrates a process for controlling flatness of a metal substrate according to embodiments.

DETAILED DESCRIPTION

[0016] Described herein are flatness control systems and methods for controlling flatness of a metal substrate during metal processing. Metal processing systems may include, but are not limited to, hot rolling mills, cold rolling mills, and warm rolling mills. As such, while the following description refers to cold rolling mills, the embodiments described herein are not limited to such metal processing systems and may be utilized in various other types of metal processing systems as desired. The flatness control systems described herein include a first flatness measuring device for measuring a flatness of the metal substrate at least before an exit tension is established in the metal substrate. The first flatness measuring device may be provided between a last work stand of the rolling mill and a downstream tensioning device, such as but not limited to a rewind coiler. In some cases, the first flatness measuring device may measure a flatness of a material head of the

metal substrate. In various embodiments, the first flatness measuring device is an optical sensor. A control signal for controlling one or more flatness control devices may be generated based on the flatness measurement from the first flatness measuring device. Optionally, the flatness control system may predict or estimate a flatness event based on the measured flatness from the optical sensor, and the control signal may be for a flatness control device based on the predicted flatness event. The flatness control systems described herein may also include a second flatness measuring device for measuring a flatness of the metal substrate after the exit tension is established in the metal substrate. The flatness control systems and methods described herein measuring the flatness of the metal substrate before exit tension is established may provide improved flatness control, reduce bad starts and losses in productivity, and/or increase overall material recovery of the process. Various other benefits and advantages may be realized with the systems and methods described herein, and the aforementioned benefits and advantages should not be considered limiting.

[0017] FIGS. 1 and 2 illustrate an example of a metal processing system 100 for a metal substrate 102 according to embodiments. In various embodiments, the metal substrate 102 may be various metals as desired, including but not limited to aluminum, aluminum alloys, steel, or other metals as desired. In some examples, metal substrate 102 may be aluminum or an aluminum alloy in the 1xxx series, 2xxx series, 3xxx series, 4xxx series, 5xxx series, 6xxx series, 7xxx series, 8xxx series and/or any other aluminum or aluminum alloy. The metal processing system 100 may include a rolling mill 104 with at least one work stand 106, a tensioning device 108, and a flatness control system 110.

[0018] In the illustrated example the rolling mill 104 is a cold rolling mill, although in other examples, the rolling mill 104 may be a warm rolling mill and/or a hot rolling mill as desired. While a single work stand 106 is illustrated, in other examples the rolling mill 104 may include a plurality of work stands 106, such as two work stands 106, three work stands 106, four work stands 106, or any other desired number of work stands 106. Each work stand 106 includes a pair of vertically aligned work rolls 112A-B. In the example of FIG. 1, the work stand 106 also includes backup rolls 114A-B that support the work rolls 112A-B. In other examples, the work stand 106 may also include intermediate rolls. A roll gap 116 is defined between the work rolls 112A-B, and the metal substrate 102 such as an aluminum or aluminum alloy sheet is passed through the roll

gap 116 along a pass line in a processing direction (represented by arrow 107). In various examples, the work stand 106 is the last or exit stand of the rolling mill 104, and the metal substrate 102 exiting the work stand 106 is passed to the tensioning device 108.

[0019] The tensioning device 108 may be various devices or equipment that establish an exit tension in the metal substrate 102. FIG. 1 illustrates the metal processing system 100 before the exit tension is established in the metal substrate 102 (e.g., an end 130 and material head 128 of the metal substrate 102 have not yet been received at the tensioning device 108), and FIG. 2 illustrates the metal processing system 100 after the exit tension is established in the metal substrate 102 (e.g., the metal substrate 102 has been received at the tensioning device 108 and tensioned by the tensioning device 108). In the example illustrated, the tensioning device 108 is a rewind coiler 118 for coiling the metal substrate 102 into a coil 120 (see FIG. 2) and forming the coil 120 establishes the exit tension in the metal substrate 102. The particular configuration of the rewind coiler 118 should not be considered limiting, and the rewind coiler 118 as the tensioning device 108 may have an over-wind configuration or an under-wind configuration as desired.

[0020] The flatness control system 110 may include one or more first flatness measuring devices 122 for measuring a flatness profile of the metal substrate across its width, one or more second flatness measuring devices 124 for measuring the flatness profile of the metal substrate across its width, and a controller 126. The one or more first flatness measuring devices 122 and the one or more second flatness measuring devices 124 may be provided downstream from the rolling mill 104 and upstream from the tensioning device 108. While a single first flatness measuring device 122 and a single second flatness measuring device 124 are illustrated, any number of first flatness measuring devices 122 and/or second flatness measuring devices 124 may be utilized.

[0021] Referring to FIG. 1, the first flatness measuring device 122 may measure a flatness (represented by lines 123) in the metal substrate 102 at least before the exit tension is established in the metal substrate 102. In various embodiments, the first flatness measuring device 122 may measure the flatness of a material head 128 of the metal substrate 102, which as previously mentioned, has traditionally not been measured because the metal substrate 102 is not in tension. The material head 128 of the metal substrate 102 is generally the leading portion of the metal substrate 102 includes the end 130 and is the length of the metal substrate 102 that initially exits the last work stand 106 without exit tension. The portion of the metal substrate 102 from the last

work stand 106 to the end 130 of the metal substrate 102 at the tensioning device 108 but without being tensioned by the tensioning device 108 may be a maximum length of the metal substrate 102.

[0022] The first flatness measuring device 122 may be various devices or sensors suitable for measuring the flatness of the metal substrate 102 while the metal substrate 102 is without tension. In some non-limiting examples, the first flatness measuring device 122 is an optical sensor. Non-limiting examples of optical sensors include, but are not limited to, various types of cameras including but not limited to optical or video cameras, single or multi-stereo cameras, RGB-D cameras, laser-based sensors, thermal (e.g., infrared) cameras, visible light cameras, other wavelength cameras, machine vision cameras, combinations thereof, and/or other optical sensors as desired.

[0023] Referring to FIG. 2, the second flatness measuring device 124 may measure the flatness in the metal substrate 102 after the exit tension is established in the metal substrate 102. In some embodiments, the first flatness measuring device 122 may measure the flatness in the metal substrate 102 after the exit tension is established in addition to the second flatness measuring device 124 and/or in place of the second flatness measuring device 124. The second flatness measuring device 124 may be various devices or sensors suitable for measuring the flatness of the metal substrate 102. In some embodiments, the second flatness measuring device 124 may be a same type of flatness measuring device as the first flatness measuring device 122, although it need not be in other embodiments. In certain embodiments, the second flatness measuring device 124 may require the exit tension in the metal substrate 102 to measure the flatness profile. In the embodiment illustrated, the second flatness measuring device 124 is a roll, such as a shapemeter roll or a multi-zone flatness measuring roll. In the embodiment illustrated, the first flatness measuring device 122 measures the flatness of the metal substrate 102 before the exit tension is established in the metal substrate 102, and the second flatness measuring device 124 measures the flatness of the metal substrate 102 after the exit tension is established in the metal substrate 102.

[0024] The controller 126 may be communicatively coupled to the one or more first flatness measuring devices 122, the one or more second flatness measuring devices 124, and one or more flatness controllers. The one or more flatness controllers may be various devices or components of the metal processing system 100 for controlling the flatness of the metal substrate 102, such as

but not limited to, actuators of the rolling mill 104 (e.g., controlling tilt of the work rolls 112A-B, bending of the work rolls 112A-B, etc.) and/or the tensioning device 108. In various embodiments and as discussed below, the controller 126 may generate a control signal based on the flatness measurements from the first flatness measuring device 122 and/or the second flatness measuring device 124. The control signal may be for controlling the one or more flatness control devices and/or generating an alert to an operator (e.g., on a user interface, remote device, etc.).

[0025] Referring to FIG. 1, before the exit tension is established in the metal substrate 102, the controller 126 may receive the flatness measurement information from the first flatness measuring device 122 about the material head 128 of the metal substrate 102 and control the rolling mill 104 (or other upstream flatness control device) based on the flatness measurement information. In certain embodiments, the controller 126 may analyze the flatness measurement information from the first flatness measuring device 122 before the exit tension is established and predict or estimate a flatness event in the metal substrate 102. Non-limiting examples of flatness events predicted by the controller 126 include off-flatness, steering problems, processing speed, threading problem, quality of the metal substrate 102, combinations thereof, and/or other flatness events as desired.

[0026] Based on the predicted flatness event, the controller 126 may generate the control signal for controlling the one or more flatness control devices and/or generating an alert or other notification to the operator. As a non-limiting example, before the exit tension is established, the controller 126 may receive the flatness measurement of the material head 128 from the first flatness measuring device 122, predict a flatness event, and generate a control signal for controlling at least the last work stand 106 of the rolling mill based on the predicted flatness event. As another non-limiting example, the controller 126 may generate a control signal for providing an alert or notification (e.g., auditory alert, visual alert, etc.) based on the predicted flatness event and/or based on the flatness measurement of the material head 128. In other embodiments, the controller 126 may generate a control signal for various other controls of the one or more flatness controllers based on the flatness measurements before the exit tension is established.

[0027] As previously discussed, by measuring the flatness of the metal substrate 102 before the exit tension is established, the flatness control system 110 may control the flatness of the material head 128 of the metal substrate 102, thereby providing improved flatness control of at least the material head 128, reducing bad starts and losses in productivity, improving flatness control of

other non-head regions of the metal substrate 102, and/or increase overall material recovery of the process.

[0028] Referring to FIG. 2, after the exit tension is established in the metal substrate 102, the controller 126 may receive the flatness measurement information from the second flatness measuring device 124 (and/or the first flatness measuring device 122) and generate the control signal based on the flatness measurement information after the exit tension is established. As a non-limiting example, after the exit tension is established, the controller 126 may receive from the second flatness measuring device 124 the flatness measurement of a region of the metal substrate 102 other than the material head 128 and generate a control signal for controlling the last work stand 106 of the rolling mill 104 and/or the tensioning device 108 based on the measured flatness.

[0029] FIG. 3 illustrates an example of a process for controlling a flatness of the metal substrate 102 with the metal processing system 100. The method may be at least partially performed by the controller 126, and in some embodiments, may be fully performed by the controller 126.

[0030] In a block 302, the method includes determining or receiving an indication of whether exit tension is in the metal substrate 102. In some embodiments, block 302 may include receiving an input from the operator, receiving an input from one or more sensors, and/or other techniques or methods for determining whether exit tension is in the metal substrate 102.

[0031] Based on a determination that exit tension is not in the metal substrate 102, the method may proceed to block 304, which includes receiving the measured flatness of the metal substrate 102 using the one or more first flatness measuring devices 122. In certain embodiments, block 304 includes receiving the flatness measurement of the material head 128 of the metal substrate 102. In various embodiments, block 304 includes receiving the measured flatness from one or more optical sensors as the one or more first flatness measuring devices 122.

[0032] In a block 306, the method includes determining a control response based on the flatness measurement received in block 304. In some embodiments, block 306 includes determining a control response for a flatness control device and/or for providing an alert or notification to the operator. In certain embodiments, block 306 includes predicting a flatness event based on the flatness measurement from the one or more first flatness measuring devices 122.

[0033] In a block 308, the method includes generating the control signal for implementing the control response determined in block 306. In various embodiments, block 308 includes generating the control signal for controlling one or more flatness control devices and/or generating the control signal for generating the alert or notification. As non-limiting examples, block 308 may include generating the control signal for controlling the work stand 106 of the rolling mill 104 or other flatness control device and/or for generating the auditory and/or visual alert or notification on a user device, user interface, remote device, etc.

[0034] In a block 310, the method may include determining whether the metal substrate 102 is still being processed by the metal processing system 100. Based on the metal substrate 102 being processed, the method returns to block 302.

[0035] Based on a determination in block 302 that exit tension is in the metal substrate 102, the method may proceed to block 312. In block 312, the method includes receiving the measured flatness of the metal substrate 102 using the one or more second flatness measuring devices 124 (which as mentioned above could be the first flatness measuring device 122). In various embodiments, block 312 includes receiving the measured flatness from a shapemeter roll as the one or more second flatness measuring devices 124.

[0036] In a block 314, the method includes determining a control response based on the flatness measurement received in block 312. In some embodiments, block 314 includes determining a control response for a flatness control device and/or for providing an alert or notification to the operator.

[0037] In a block 316, the method includes generating the control signal for implementing the control response determined in block 314. In various embodiments, block 316 includes generating the control signal for controlling one or more flatness control devices and/or generating the control signal for generating the alert or notification to the operator. As non-limiting examples, block 316 may include generating the control signal for controlling the work stand 106 of the rolling mill 104, for controlling the tensioning device 108, and/or for generating the auditory and/or visual alert or notification on a user device, user interface, remote device, etc.

[0038] The above method is for illustrative purposes, and various other operations and/or combinations of operations related to controlling flatness of at least the material head region of the metal substrate may be performed as desired.

[0039] A collection of exemplary embodiments is provided below, including at least some explicitly enumerated as an “Illustration” providing additional description of a variety of example embodiments in accordance with the concepts described herein. These illustrations are not meant to be mutually exclusive, exhaustive, or restrictive; and the disclosure not limited to these example illustrations but rather encompasses all possible modifications and variations within the scope of the issued claims and their equivalents.

[0040] Illustration 1. A method of processing a metal strip, the method comprising measuring a flatness of a material head of the metal strip with an optical sensor.

[0041] Illustration 2. The method of any preceding or subsequent illustration or combination of illustrations, wherein measuring the flatness of the material head is performed before exit tension is established in the metal strip.

[0042] Illustration 3. The method of any preceding or subsequent illustration or combination of illustrations, wherein measuring the flatness of the material head is performed during a start of a rolling mill.

[0043] Illustration 4. The method of any preceding or subsequent illustration or combination of illustrations, wherein the optical sensor is a first flatness measuring device, and wherein the method further comprises: establishing exit tension in the metal strip; and measuring a flatness of the metal strip after establishing the exit tension with a second flatness measuring device.

[0044] Illustration 5. The method of any preceding or subsequent illustration or combination of illustrations, wherein the second flatness measuring device is a roll.

[0045] Illustration 6. The method of any preceding or subsequent illustration or combination of illustrations, further comprising controlling a flatness control actuator based on the measured flatness from the optical sensor.

[0046] Illustration 7. The method of any preceding or subsequent illustration or combination of illustrations, further comprising predicting a flatness event based on the measured flatness from the optical sensor and generating a control signal for a flatness control device based on the predicted flatness event.

[0047] Illustration 8. A method of processing a metal strip, the method comprising: measuring a flatness of a material head of the metal strip before exit tension is established in the metal strip

from a downstream tensioning device; and generating a control signal for a flatness control actuator based on the measured flatness.

[0048] Illustration 9. The method of any preceding or subsequent illustration or combination of illustrations, wherein measuring the flatness of the material head of the metal strip comprises measuring the flatness with an optical sensor.

[0049] Illustration 10. The method of any preceding or subsequent illustration or combination of illustrations, wherein measuring the flatness is performed between a last stand of a rolling mill and a tensioning device.

[0050] Illustration 11. The method of any preceding or subsequent illustration or combination of illustrations, wherein generating the control signal further comprises controlling rolling mill as the flatness control actuator.

[0051] Illustration 12. The method of any preceding or subsequent illustration or combination of illustrations, further comprising measuring a flatness of the metal strip after exit tension is established in the metal strip from the downstream tensioning device with a flatness measuring device contacting the metal strip.

[0052] Illustration 13. The method of any preceding or subsequent illustration or combination of illustrations, wherein the flatness measuring device contacting the metal strip comprises a shapemeter roll.

[0053] Illustration 14. A metal processing system comprising an optical sensor downstream from a last work stand of a rolling mill and upstream from a tensioning device, the optical sensor configured to measure a flatness of a material head of a metal strip being processed by the metal processing system.

[0054] Illustration 15. The metal processing system of any preceding or subsequent illustration or combination of illustrations, further comprising a controller communicatively coupled with the optical sensor, wherein the controller is configured to: predict a flatness event based on the measured flatness from the optical sensor; and generate a control signal for a flatness control device based on the predicted flatness event.

[0055] Illustration 16. The metal processing system of any preceding or subsequent illustration or combination of illustrations, further comprising a controller communicatively coupled with the

optical sensor, wherein the controller is configured to generate a control signal for a flatness control actuator based on the measured flatness.

[0056] Illustration 17. The metal processing system of any preceding or subsequent illustration or combination of illustrations, further comprising the flatness control actuator, wherein the flatness control actuator comprises at least one work stand of the rolling mill.

[0057] Illustration 18. The metal processing system of any preceding or subsequent illustration or combination of illustrations, further comprising: the last work stand of the rolling mill; and the tensioning device.

[0058] Illustration 19. The metal processing system of any preceding or subsequent illustration or combination of illustrations, wherein the rolling mill is a cold rolling mill, and wherein the tensioning device comprises a rewind coiler.

[0059] Illustration 20. The metal processing system of any preceding or subsequent illustration or combination of illustrations, wherein the optical sensor is configured to measure the flatness of the material head before exit tension is established in the metal strip.

[0060] Illustration 21. A method of processing a metal strip, the method comprising receiving a metal strip from a last stand of a rolling mill and measuring a flatness of a material head of the metal strip with an optical sensor.

[0061] Illustration 22. A method of processing a metal strip, the method comprising: measuring a flatness of a material head of the metal strip with an optical sensor; and generating a control signal for a flatness control actuator based on the measured flatness.

[0062] The subject matter of embodiments of the present disclosure is described here with specificity to meet statutory requirements, but this description is not necessarily intended to limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described. Directional references such as “up,” “down,” “top,” “bottom,” “left,” “right,” “vertical,” “horizontal,” “lateral,” “longitudinal,” “front,” and

“back,” among others, are intended to refer to the orientation as illustrated and described in the figure (or figures) to which the components and directions are referencing.

[0063] The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, or gradients thereof, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate embodiments of the invention, and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0064] The above-described aspects are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Many variations and modifications can be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure. Moreover, although specific terms are employed herein, as well as in the claims that follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the described embodiments, nor the claims that follow.

CLAIMS

That which is claimed:

1. A method of processing a metal strip, the method comprising measuring a flatness of a material head of the metal strip with an optical sensor.
2. The method of claim 1, wherein measuring the flatness of the material head is performed before exit tension is established in the metal strip.
3. The method of claim 1, wherein measuring the flatness of the material head is performed during a start of a rolling mill.
4. The method of claim 1, wherein the optical sensor is a first flatness measuring device, and wherein the method further comprises:
 - establishing exit tension in the metal strip; and measuring a flatness of the metal strip after establishing the exit tension with a second flatness measuring device.
5. The method of claim 4, wherein the second flatness measuring device is a roll.
6. The method of claim 1, further comprising controlling a flatness control actuator based on the measured flatness from the optical sensor.
7. The method of claim 1, further comprising predicting a flatness event based on the measured flatness from the optical sensor and generating a control signal for a flatness control device based on the predicted flatness event.
8. A method of processing a metal strip, the method comprising:
 - measuring a flatness of a material head of the metal strip before exit tension is established in the metal strip from a downstream tensioning device; and
 - generating a control signal for a flatness control actuator based on the measured flatness.

9. The method of claim 8, wherein measuring the flatness of the material head of the metal strip comprises measuring the flatness with an optical sensor.
10. The method of claim 8, wherein measuring the flatness is performed between a last stand of a rolling mill and a tensioning device.
11. The method of claim 10, wherein generating the control signal further comprises controlling rolling mill as the flatness control actuator.
12. The method of claim 8, further comprising measuring a flatness of the metal strip after exit tension is established in the metal strip from the downstream tensioning device with a flatness measuring device contacting the metal strip.
13. The method of claim 12, wherein the flatness measuring device contacting the metal strip comprises a shapemeter roll.
14. A metal processing system comprising an optical sensor downstream from a last work stand of a rolling mill and upstream from a tensioning device, the optical sensor configured to measure a flatness of a material head of a metal strip being processed by the metal processing system.
15. The metal processing system of claim 14, further comprising a controller communicatively coupled with the optical sensor, wherein the controller is configured to:
 - predict a flatness event based on the measured flatness from the optical sensor; and
 - generate a control signal for a flatness control device based on the predicted flatness event.
16. The metal processing system of claim 14, further comprising a controller communicatively coupled with the optical sensor, wherein the controller is configured to generate a control signal for a flatness control actuator based on the measured flatness.
17. The metal processing system of claim 16, further comprising the flatness control actuator, wherein the flatness control actuator comprises at least one work stand of the rolling mill.

18. The metal processing system of claim 14, further comprising:
the last work stand of the rolling mill; and
the tensioning device.
19. The metal processing system of claim 18, wherein the rolling mill is a cold rolling mill,
and wherein the tensioning device comprises a rewind coiler.
20. The metal processing system of claim 14, wherein the optical sensor is configured to
measure the flatness of the material head before exit tension is established in the metal strip.
21. A method of processing a metal strip, the method comprising receiving a metal strip from
a last stand of a rolling mill and measuring a flatness of a material head of the metal strip with an
optical sensor.
22. A method of processing a metal strip, the method comprising:
measuring a flatness of a material head of the metal strip with an optical sensor; and
generating a control signal for a flatness control actuator based on the measured flatness.

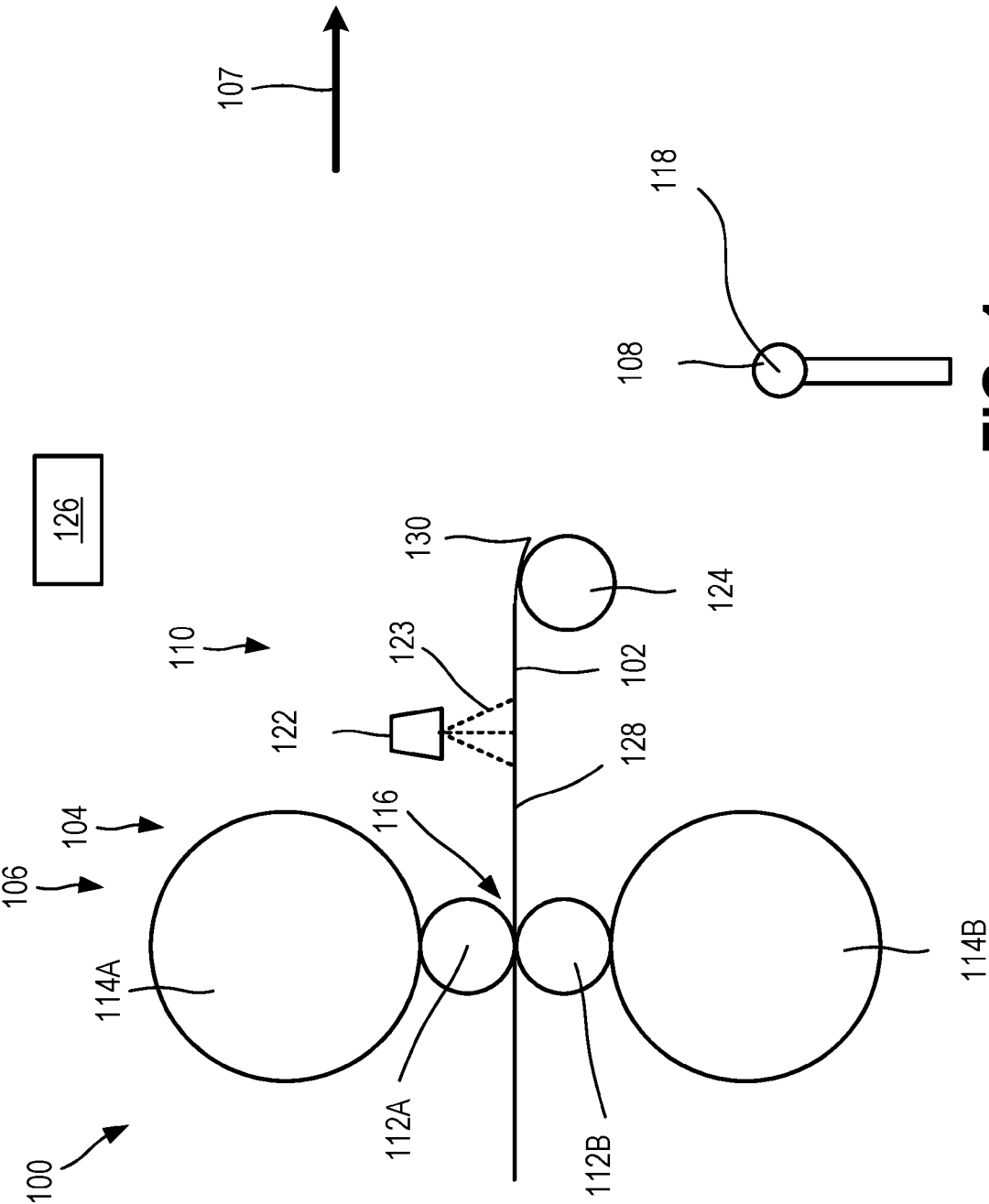


FIG. 1

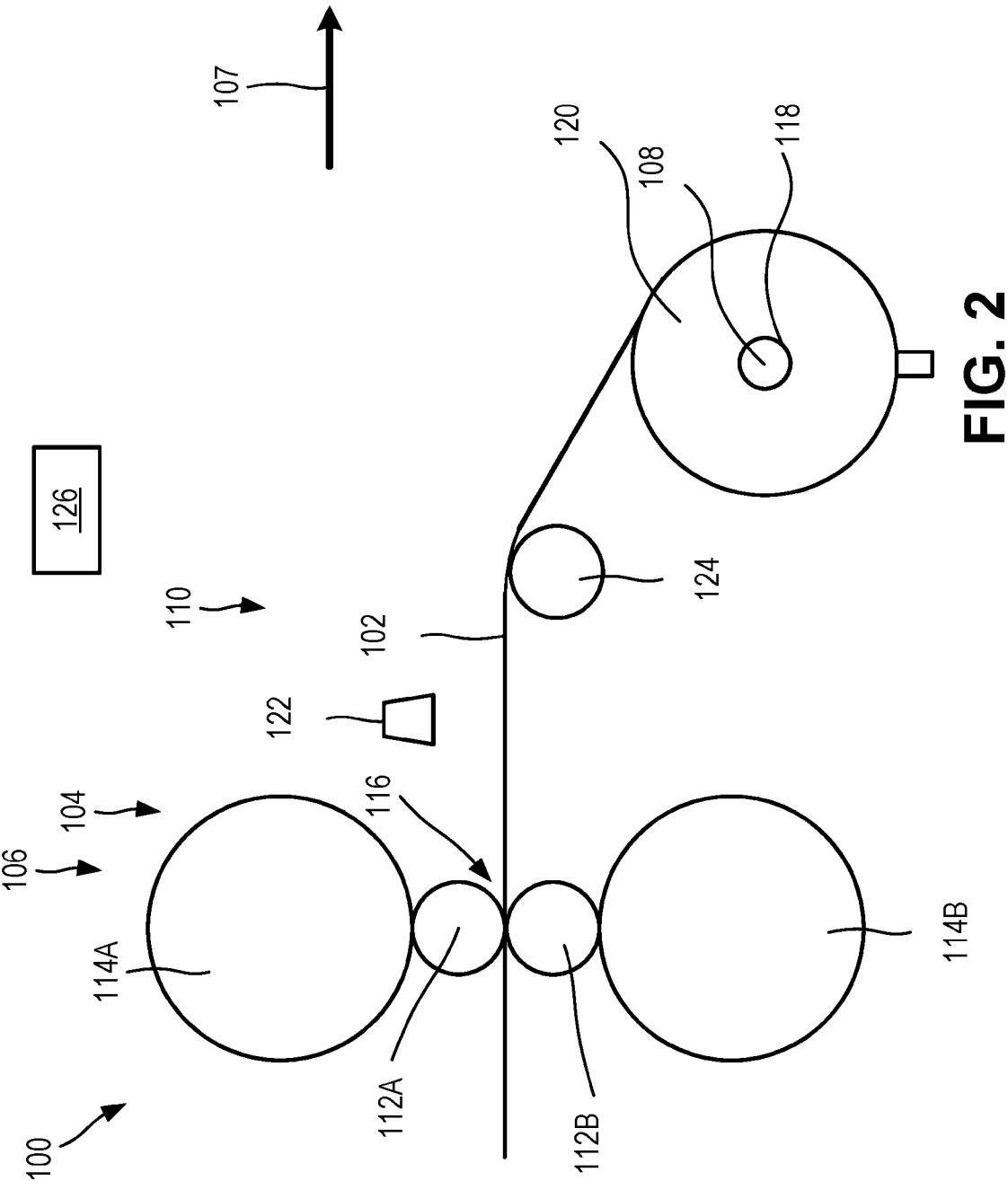


FIG. 2

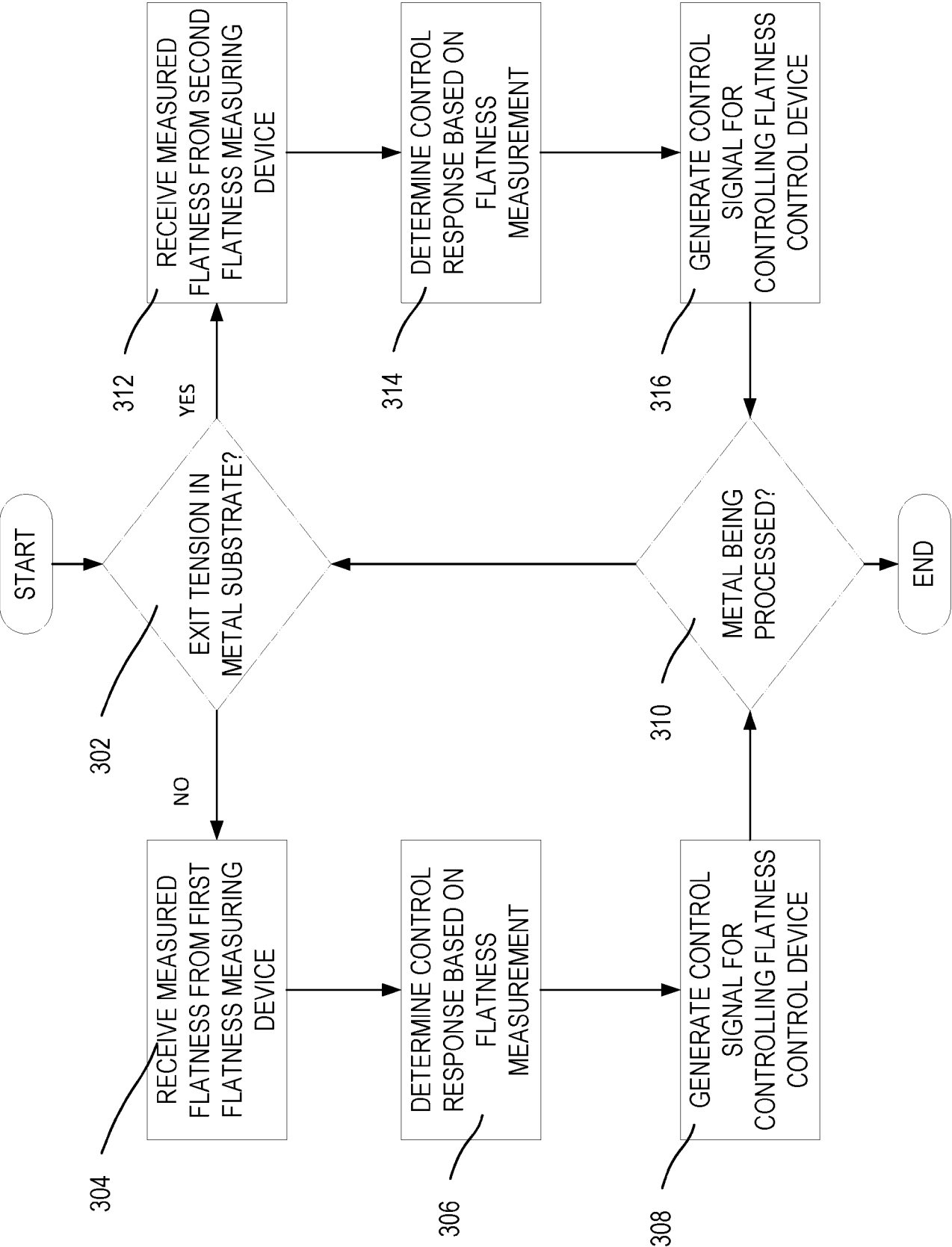


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2024/035576

A. CLASSIFICATION OF SUBJECT MATTER INV. B21B38/02 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) B21B		
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 practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 258 492 A1 (SIEMENS AG [DE]) 8 December 2010 (2010-12-08) paragraph [0026] - paragraph [0043]; figures 1,2 -----	1 - 22
X	US 5 018 377 A (LAWSON KENNETH T [GB]) 28 May 1991 (1991-05-28) column 2, line 26 - column 3, line 24; figures 1,2 -----	1 - 22
☐ 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 "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 24 September 2024		Date of mailing of the international search report 08/10/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Frisch, Ulrich

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2258492	A1	08-12-2010	NONE

US 5018377	A	28-05-1991	DE 68903738 T2 08-04-1993
			EP 0367500 A2 09-05-1990
			JP H02175008 A 06-07-1990
			US 5018377 A 28-05-1991
