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(54) METHOD OF CONTROLLING FLATNESS OF STRIP OF ROLLED MATERIAL, CONTROL SYSTEM AND PRODUCTION LINE

(57) A method of controlling flatness of a strip (16) of rolled material in a production line (10) comprising a hot rolling mill (12) and at least one cold rolling mill (14), downstream of the hot rolling mill (12), the method comprising determining flatness data of the strip (16) in one or more of the at least one cold rolling mill (14) and/or following passing of the strip (16) through one or more of the at least one cold rolling mill (14); determining a thickness profile target (50) of the strip (16) for the hot rolling mill (12) based on the flatness data; and passing the strip (16) through the hot rolling mill (12) and adjusting the thickness of the strip (16) based on the thickness profile target (50). A control system (38) and a production line (10) are also provided.

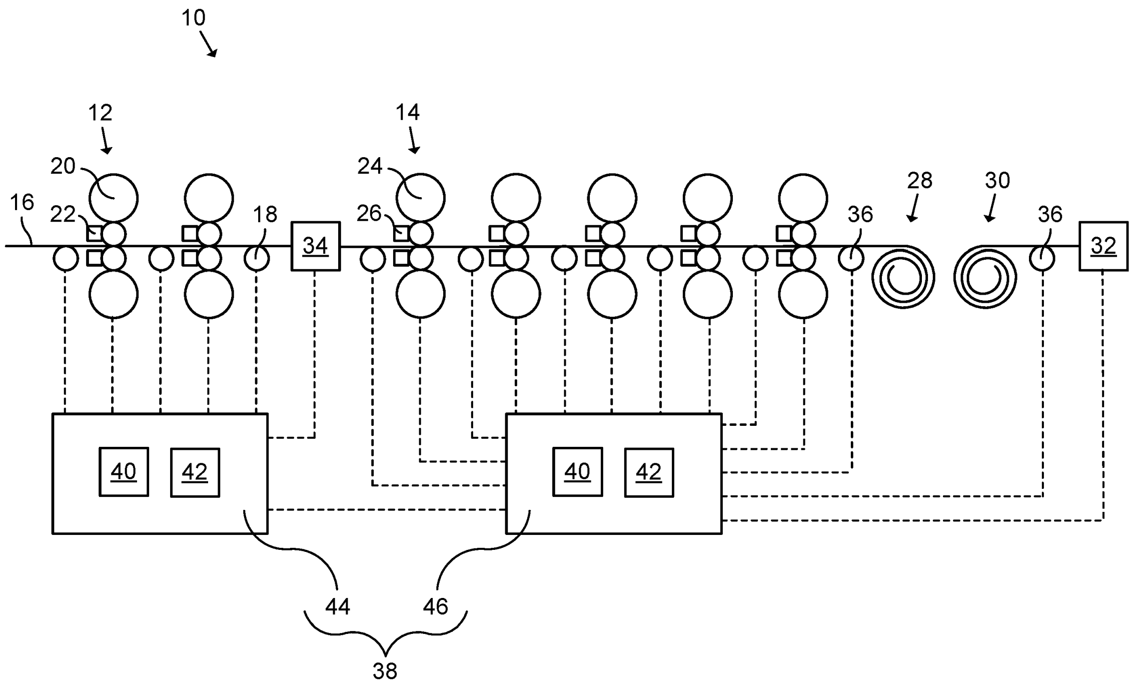

Fig. 1

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Description

Technical Field

[0001] The present disclosure generally relates to flatness control of a strip of rolled material. In particular, a method of controlling flatness of a strip of rolled material in a production line, a control system for controlling flatness of a strip of rolled material in a production line, and a production line comprising a control system, are provided.

Background

[0002] In a production line for rolled material, there are typically several different process steps, for example a smelter, hot rolling mills, cold rolling mills, a furnace, an annealer, a stretch leveler, a slitter, a coiler and an uncoiler. A key parameter of such production line is yield of the final process step and the resources required (efficiency of the overall process). Flatness of the rolled material is also a key parameter that has a direct impact on process yield at the final process step. Today in the rolling mill industry, it is common to operate the different process steps in isolation.

[0003] EP 1110635 B1 discloses a method for controlling flatness of a strip of rolled material, and a system which employs the method. Measurements of the flatness of the strip during rolling are compared to both a first flatness target and to a second flatness target. A flatness target for each of one or more subsequent processes and a measured flatness error are used to adapt a control signal for a mill stand to control and regulate the flatness of subsequent production of rolled material of the same specification.

Summary

[0004] In flatness control of a strip of rolled material, key factors determining how well flatness errors can be removed are the mechanical actuators of the cold rolling mills and the thickness profile of the incoming material. The thickness profile of the strip is created in the hot rolling mills and cannot be substantially changed in the cold rolling mills without causing flatness defects. If the mechanical actuators do not allow the roll gap of the respective cold rolling mill to be formed according to the thickness profile of the incoming material, there will likely be flatness errors in the strip. Thus, when the strip having a particular thickness profile is passed through a cold rolling mill having a particular roll gap, differences between the thickness profile and the roll gap cause flatness errors of the strip. Additionally, if there are multiple cold rolling mills having different types of roll gaps, this might also cause flatness errors.

[0005] Furthermore, if a roll gap of a cold rolling mill is controlled according to the method in EP 1110635 B1, there is a risk that a required flatness target lies outside acceptable operating conditions of the cold rolling mill. In other words, very large corrections may be required by the flatness target of the cold rolling mill to achieve the desired flatness downstream. Thus, in some cases, either the required flatness compensations cannot be achieved by the cold rolling mill or there might be a risk of causing strip break.

[0006] One object of the present disclosure is to provide a method of controlling flatness of a strip of rolled material, which method enables a reduced flatness error.

[0007] A further object of the present disclosure is to provide a method of controlling flatness of a strip of rolled material, which method enables reduced flatness errors of the strip downstream of a cold rolling mill.

[0008] A still further object of the present disclosure is to provide a method of controlling flatness of a strip of rolled material, which method enables reduced flatness errors of the strip downstream of a subsequent process with respect to a cold rolling mill.

[0009] A still further object of the present disclosure is to provide a method of controlling flatness of a strip of rolled material, which method reduces a risk of strip break.

[0010] A still further object of the present disclosure is to provide a method of controlling flatness of a strip of rolled material, which method provides an increased yield.

[0011] A still further object of the present disclosure is to provide a method of controlling flatness of a strip of rolled material, which method solves several or all of the foregoing objects in combination.

[0012] A still further object of the present disclosure is to provide a control system for controlling flatness of a strip of rolled material in a production line, which control system solves one, several or all of the foregoing objects.

[0013] A still further object of the present disclosure is to provide a production line comprising a control system, which production line solves one, several or all of the foregoing objects.

[0014] According to one aspect, there is provided a method of controlling flatness of a strip of rolled material in a production line comprising a hot rolling mill and at least one cold rolling mill, downstream of the hot rolling mill, the method comprising determining flatness data associated with the strip in one or more of the at least one cold rolling mill and/or following passing of the strip through one or more of the at least one cold rolling mill; determining a thickness profile target of the strip for the hot rolling mill based on the flatness data; and passing the strip through the hot rolling mill and adjusting the thickness of the strip based on the thickness profile target.

[0015] The production line comprises a hot rolling side with one or more hot rolling mills and a cold rolling side with one or more cold rolling mills. Hot rolling is a metalworking process that occurs above the recrystallization temperature of the material. Cold rolling occurs with the metal below its recrystallization temperature, which increases the strength via strain hardening. The rolled material may for example be aluminium, steel or copper.

[0016] Instead of using a thickness profile target in the hot rolling side that is not necessarily optimal for the downstream cold rolling side or processes downstream of the cold rolling side, the method makes use of a thickness profile target that is based on a normal or achievable flatness influencing effect downstream of the hot rolling mill. In this way, the downstream flatness influencing effect can match the incoming thickness profile of the strip and thereby reduce or eliminate flatness errors. The thickness profile target used in the hot rolling mill generates one or more flatness correction needs downstream of the hot rolling side. By selecting the thickness profile target such that these flatness correction needs can be met by the one or more cold rolling mills and/or by a subsequent process, flatness errors in the strip can be reduced.

[0017] In other words, by determining the thickness profile target of the strip for the hot rolling mill based on the flatness data, the hot rolling mill will generate a thickness profile of the strip that downstream processes, such as one or more cold rolling mills, can better compensate flatness for. The method thereby provides a feedback of flatness influencing effects from a cold rolling side, or downstream of a cold rolling side, to a hot rolling side of the production line. In the hot rolling mill, there are better possibilities of adjusting thickness profile problems, which later translate to flatness problems. The method thereby challenges the norm in the prior art regarding what is considered to be a good thickness profile from a hot rolling mill. Today, the norm is to have a thickness profile from a hot rolling mill where the shape is similar to a second order polynomial with the center of the strip being 0.5 % higher, e.g. having a crown of 0.5 %.

[0018] Each cold rolling mill may comprise at least one mechanical actuator arranged to control one or more rolls of the cold rolling mill. In this case, the flatness data may comprise a flatness model associated with one of the at least one mechanical actuator, where the flatness model defines an effect on the strip by the mechanical actuator. By adjusting a roll by means of a mechanical actuator, a roll gap of the cold rolling mill can be changed. The flatness models thus define a capacity of the mechanical actuators to change flatness of the strip.

[0019] In this variant, the method makes use of one or more flatness models that can actually be achieved by the one or more mechanical actuators. By determining the thickness profile target based on these one or more flatness models, the roll gap can match the incoming thickness profile of the strip to reduce or eliminate flatness errors. For example, by selecting the thickness profile target such that flatness correction needs downstream can be met by the mechanical actuators of the one or more cold rolling mills, thermal actuators of the cold rolling mills become "emancipated" and can instead be used to correct local defects in the strip.

[0020] The method may thus comprise determining, for one or more mechanical actuators, the flatness model that can be achieved by the mechanical actuator. By determining the thickness profile target of the strip for the hot rolling mill based on the one or more flatness models, the hot rolling mill provides a thickness profile that the mechanical actuators can compensate. In this way, an increased flatness of the strip is achieved downstream of the cold rolling mill.

[0021] As used herein, the terms shape and flatness can be used interchangeably. One or more flatness models may be associated with each mechanical actuator. Each flatness model may depend on various parameters, such as a position of the associated mechanical actuator and/or a width of the strip.

[0022] The determination of the thickness profile target based on the flatness data may comprise machine learning. The machine learning may employ mathematical models, for example based on a measured flatness of the strip downstream of one or more of the at least one cold rolling mill, a flatness model for each of one or more mechanical actuators, and/or a thickness profile target of the hot rolling mill, as sample data.

[0023] Alternatively, the determination of the thickness profile target may be made using different statistical techniques including fuzzy logic and neuro-fuzzy logic control methods.

[0024] Each hot rolling mill may comprise one or more actuators, such as one or more mechanical actuators arranged to control one or more rolls of the hot rolling mill and/or one or more thermal actuators. Each hot rolling mill may be configured to modify the thickness profile of the strip being rolled. The hot rolling side may comprise one or more thickness profile measurement devices.

[0025] Each hot rolling mill may be controlled based on a thickness profile target. Each hot rolling mill may further comprise a thickness profile controller configured to control the hot rolling mill to minimize thickness profile errors using actuators in the hot rolling mill.

[0026] Each hot rolling mill may be a single mill stand or a tandem mill with multiple mill stands. Alternatively, or in addition, the production line may comprise a reversible hot tandem mill.

[0027] Each cold rolling mill may comprise one or more actuators, such as one or more mechanical actuators. Each mechanical actuator may be configured to control one or more of the rolls of the cold rolling mill. In this way, the roll gap of the cold rolling mill can be adjusted. The mechanical actuators may for example be controlled to provide bending of work rolls, skewing of work rolls, bending of intermediate rolls, side-shifting of intermediate rolls etc. One or more of the cold rolling mills may also comprise one or more thermal actuators.

[0028] Each cold rolling mill may be configured to modify a flatness profile of the strip being rolled. The cold rolling side may comprise one or more shape meters.

[0029] Each cold rolling mill may be controlled based on one or more flatness models. Each cold rolling mill may further comprise a flatness controller configured to control the cold rolling mill to minimize flatness errors using actuators in the cold rolling mill. Each cold rolling mill may be a single mill stand or a tandem mill with multiple mill stands. Alternatively, or in addition, the production line may comprise a reversible cold tandem mill.

[0030] The flatness data may comprise a flatness model associated with each of one or more of the at least one mechanical actuator for a plurality of cold rolling mills, and the determination of the thickness profile target may comprise determining a thickness profile target of the strip for the hot rolling mill that best matches a combination of the flatness models.

[0031] The method may thus comprise determining a plurality of flatness models associated with respective mechanical actuators of a plurality of cold rolling mills. Each flatness model may for example be expressed as a polynomial over the width of the strip and is in this case strip width dependent. Each flatness model for a mechanical actuator may be determined as a flatness influence of the mechanical actuator.

[0032] Each actuator of a cold rolling mill, either mechanical or thermal, has an influence on the flatness of the strip passing through the cold rolling mill. The flatness model is a model of this influence on the flatness by the actuator when the strip is passed through the cold rolling mill.

[0033] The influence on the flatness by each actuator may depend on a setting of the actuator and/or the actual rolling conditions. The actual rolling conditions may for example comprise the thermal crown on work rolls (depending on the strip speed and possible previous passes), the hardness of the strip, and/or the total roll force.

[0034] The method may further comprise determining a thickness profile model of the strip for the hot rolling mill, the thickness profile model defining an effect on the strip by one or more mechanical actuators of the hot rolling mill. The determination of the thickness profile target may comprise an optimization of the thickness profile model of the hot rolling mill to best match the flatness model, e.g. for mechanical actuators in the most downstream cold rolling mill. Alternatively, or in addition, the determination of the thickness profile target may comprise an optimization of the thickness profile model for a plurality of hot rolling mills to best match the flatness model of one or more mechanical actuators of the at least one cold rolling mills. In any case, the thickness profile model that solves the optimization problem may be set as the thickness profile target. Alternatively, the flatness model may be normalized in amplitude to a desired crown and then used as the thickness profile target.

[0035] In case the flatness data comprises one or more flatness models associated with one or more mechanical actuators for each of a plurality of cold rolling mills, the determination of the thickness profile target may comprise determining a thickness profile target of the strip for the hot rolling mill that best matches a combination of the flatness models. The flatness models of mechanical actuators of a plurality of cold rolling mills may be combined to a combined flatness model representing the total impact on the flatness of the strip by the plurality of cold rolling mills. The thickness profile target may then be determined based on the combined flatness model.

[0036] The production line may comprise a plurality of cold rolling mills, and the flatness data may comprise a flatness model associated with each of one or more of the at least one mechanical actuator of the most downstream cold rolling mill. By determining the thickness profile target of the strip for the hot rolling mill based on the flatness model of a mechanical actuator of the most downstream cold rolling mill, the best conditions for obtaining a high flatness immediately downstream of the last cold rolling mill are provided. The thickness profile target may be determined to mirror the flatness model associated with the one or more of the at least one mechanical actuator of the most downstream cold rolling mill.

[0037] The flatness model may be dependent on a width of the strip. That is, for a first width of the strip, one mechanical actuator may have a first flatness model, and for a second width of the strip, different from the first width, the mechanical actuator may have a second flatness model, different from the first flatness model. The flatness model may also be dependent on various other parameters.

[0038] The flatness data may comprise a measured flatness of the strip. The flatness data may comprise a measured flatness of the strip after passing through a subsequent process with respect to each of the at least one cold rolling mill. The subsequent process may for example be a strip coiling process, a strip uncoiling process and/or a galvanization or aluminizing process.

[0039] In this variant, the method can make use of a flatness effect on the strip from one or more subsequent processes, i.e. downstream of the most downstream cold rolling mill. By determining the thickness profile target based on the flatness effect by a subsequent process, the flatness effect can match the incoming profile thickness of the strip to reduce or eliminate flatness errors. Besides, since the flatness effect by a subsequent process is compensated in the hot rolling side, and not in the cold rolling side, the risk of strip break is reduced or eliminated.

[0040] The flatness data may be determined by means of one or more shape meters. A shape meter may for example be a Stressometer. The flatness data comprising a measured flatness of the strip may comprise a plurality of flatnesses measured along a length of the strip.

[0041] The thickness profile target may be determined based on a width of the strip. That is, the thickness profile target may be determined based on the flatness data and the width of the strip.

[0042] According to a further aspect, there is provided a control system for controlling flatness of a strip of rolled material in a production line comprising a hot rolling mill and at least one cold rolling mill, downstream of the hot rolling mill, the control system comprising at least one data processing device and at least one memory having a computer program stored thereon, the at least one computer program comprising program code which, when executed by one or more of the at least one data processing device, causes one or more of the at least one data processing device to perform the steps of determining flatness data associated with the strip in one or more of the at least one cold rolling mill and/or following passing of the strip through one or more of the at least one cold rolling mill; determining a thickness profile target of the strip for the hot rolling mill based on the flatness data; and controlling a thickness adjustment of the strip based on the thickness profile target when passing the strip through the hot rolling mill.

[0043] The control system may issue a control signal to the hot rolling mill based on the thickness profile target to control the thickness profile of the strip. The control system may for example comprise a thickness profile controller and a flatness controller. In this case, the thickness profile controller and the flatness controller may comprise the at least one data processing device and the at least one memory as defined above.

[0044] According to a further aspect, there is provided a production line comprising a hot rolling mill, at least one cold rolling mill, downstream of the hot rolling mill, and a control system according to the present disclosure. The production line according to this aspect may be of any type according to the present disclosure.

Brief Description of the Drawings

[0045] Further details, advantages and aspects of the present disclosure will become apparent from the following embodiments taken in conjunction with the drawings, wherein:

Fig. 1: schematically represents a production line; and

Fig. 2: schematically represents a typical flatness model and a typical thickness profile target.

Detailed Description

[0046] In the following, a method of controlling flatness of a strip of rolled material in a production line, a control system for controlling flatness of a strip of rolled material in a production line, and a production line comprising a control system, will be described. The same or similar reference numerals will be used to denote the same or similar structural features.

[0047] Fig. 1 schematically represents a production line 10. The production line 10 comprises a plurality of hot rolling mills 12 and a plurality of cold rolling mills 14. The cold rolling mills 14 are arranged downstream of the hot rolling mills 12. In the example in Fig. 1, the production line 10 comprises two hot rolling mills 12 and five cold rolling mills 14. The production line 10 thus comprises a hot rolling side comprising the hot rolling mills 12 and a cold rolling side comprising the cold rolling mills 14.

[0048] Fig. 1 further shows a strip 16 of rolled material, for example aluminium. In Fig. 1, the strip 16 is conveyed to the right through each hot rolling mill 12 and through each cold rolling mill 14. In this example, the hot rolling mills 12 and the cold rolling mills 14 are each composed in a multi stand tandem mill. In the first hot rolling mill 12, the strip 16 is a slab that is squeezed between rolls such that the thickness is reduced.

[0049] The production line 10 of this example further comprises a plurality of thickness profile measurement devices 18. However, the production line 10 may alternatively comprise only one thickness profile measurement device 18 downstream of the last hot rolling mill 12. Each thickness profile measurement device 18 is configured to measure a thickness profile of the strip 16. In the example in Fig. 1, one thickness profile measurement device 18 is arranged upstream of the most upstream hot rolling mill 12, one thickness profile measurement device 18 is arranged downstream of the most downstream hot rolling mill 12, and one thickness profile measurement device 18 is arranged between each pair of adjacent hot rolling mills 12.

[0050] Each hot rolling mill 12 comprises a plurality of rolls 20 and one or more mechanical actuators 22 for controlling the rolls 20. Similarly, each cold rolling mill 14 comprises a plurality of rolls 24 and one or more mechanical actuators 26 for controlling the rolls 24. Each hot rolling mill 12 and each cold rolling mill 14 also comprises thermal actuators (not illustrated).

[0051] Each hot rolling mill 12 is configured to modify a thickness profile of the strip 16 by means of its mechanical actuators 22. To this end, each hot rolling mill 12 is controlled based on a thickness profile target. The thickness profile target indicates a change in thickness over the width of the strip 16 through the hot rolling mill 12.

[0052] Each cold rolling mill 14 is configured to modify a flatness of the strip 16 by means of its mechanical actuators 26. To this end, each cold rolling mill 14 is controlled by means of one or more flatness models. Each flatness model defines a flatness effect on the strip 16 caused by one of the mechanical actuators 26.

[0053] The production line 10 of this specific example further comprises a coiler 28, an uncoiler 30 and a galvanization or aluminizing station 32. Each of the coiler 28, the uncoiler 30 and the galvanization or aluminizing station 32 constitutes an example of a subsequent process with respect to each of the cold rolling mills 14. The production line 10 of this specific example further comprises a cleaning and pickling station 34 between the hot rolling side and the cold rolling side.

[0054] The production line 10 further comprises a plurality of shape meters 36. Each shape meter 36 is configured to measure a flatness of the strip 16. In the example in Fig. 1, one shape meter 36 is arranged upstream of the most upstream cold rolling mill 14, one shape meter 36 is arranged downstream of the last cold rolling mill 14, and one shape meter 36 is arranged between each pair of adjacent cold rolling mills 14. One shape meter 36 is also arranged downstream of the uncoiler 30, i.e. between the uncoiler 30 and the galvanization or aluminizing station 32.

[0055] The production line 10 further comprises a control system 38. The control system 38 comprises at least one data processing device 40 and at least one memory 42. In Fig. 1, the control system 38 is illustrated as comprising two data processing devices 40 and two memories 42. The at least one memory 42 comprises program code which, when executed by one or more of the at least one data processing device 40, causes one or more of the at least one data processing devices 40 to perform, or command performance of, various steps as described herein.

[0056] In this specific example, the control system 38 comprises a thickness profile controller 44 and a flatness controller 46. Each of the thickness profile controller 44 and the flatness controller 46 comprises a data processing device 40 and a memory 42. The control system 38 for controlling the production line 10 may however be implemented in different ways.

[0057] The flatness controller 46 controls the cold rolling mills 14 to minimize flatness errors based on signals received from the cold rolling mills 14 and/or from the shape meters 36. The thickness profile controller 44 controls the hot rolling mills 12 to minimize thickness profile errors based on signals received from the hot rolling mills 12 and/or the thickness profile measurement devices 18, and from the flatness controller 46.

[0058] The deformation of the thickness profile of the strip 16 induced by rolling depends on several factors, such as temperature of the strip 16, aspect ratio of the strip 16, i.e. width divided by thickness, and the ratio coefficient of friction to strip entry thickness. The predominant factor is the aspect ratio of the strip 16. If the aspect ratio is greater than 30, deformation of the strip 16 is essentially plane strain, i.e. the strip 16 is reduced in thickness and increased in length with little or no change in width. In cold rolling, especially when rolling thin strips 16, the aspect ratio is typically much higher than 30. In hot rolling on the other hand, the aspect ratio is typically less than 30, particularly for the most upstream hot rolling mill(s) 12, and thus a profile deformation of the strip 16 occurs with a significant increase in width of the strip 16.

[0059] The ability to change the thickness profile of the strip 16 decreases as the aspect ratio increases. Conversely, the ability to correct shape defects of the strip 16 increases and is greatest at the final or most downstream cold rolling mill 14.

[0060] In cold rolling, the thickness profile of the strip 16 and the flatness of the strip 16 are associated. This means that there will be less or no flatness defects in cold rolling if one can provide a roll gap to mirror the incoming thickness profile of the strip 16, i.e. equal elongation transverse the strip 16. The thickness profile of the strip 16 is mainly established in the hot rolling side. Downstream of the hot rolling side, the strip 16 is too cold and too thin compared to its width to be able to change its thickness profile without causing shape issues. It is therefore difficult or impossible to change the thickness profile of the strip 16 in the cold rolling side without causing flatness problems.

[0061] Fig. 2 schematically represents an example of a typical flatness model 48 and a typical thickness profile target 50. The flatness model 48 is a combination of a second order polynomial and a fourth order polynomial. A flatness model 48 of a mechanical actuator 26 is one example of flatness data associated with the strip 16 in a cold rolling mill 14. A plurality of flatness models 48 may be determined for one mechanical actuator 26. In particular, one or more flatness models 48 may be determined for mechanical actuators 26 of the most downstream cold rolling mill 14.

[0062] The thickness profile target 50 in Fig. 2 is a second order polynomial. The thickness profile target 50 is 1 % thicker at the center of the strip 16. The thickness profile target 50 in Fig. 2 thus has a 1 % crown.

[0063] As shown in Fig. 2, there is a discrepancy between the thickness profile target 50 and the flatness model 48. This discrepancy cause difficulties for the cold rolling mill 14 to maintain the incoming thickness profile in the roll bite and thus achieve good flatness.

[0064] By making the thickness profile target 50 more closely conform to the flatness model 48, the mechanical actuator 26 of the cold rolling mill 14 can better address flatness errors by means of its roll gap. To this end, the flatness controller 46 is further configured to determine one or more flatness models 48 for one or more mechanical actuators 26. The thickness profile controller 44 may receive one or more flatness models 48 from the flatness controller 46 and determine a thickness profile target 50 for the one or more hot rolling mills 12 based on a combination of the flatness models 48. The thickness profile target determined in this way is not limited to a polynomial or a combination of polynomials, but can be expressed in alternative ways. The thickness profile target 50 can for example be determined by means of machine learning using one or more flatness models 48, one or more measured flatnesses (e.g. a flatness measured immediately downstream of the last cold rolling mill 14) and the thickness profile target 50 as training data.

[0065] The thickness profile target 50 is based on one or more flatness models 48 that can actually be achieved by the respective mechanical actuator 26. Therefore, the mechanical actuators 26 of the cold rolling mills 14 can match the thickness profile from the hot rolling mills 12 to reduce flatness errors.

[0066] Even if a good flatness is obtained in the most downstream cold rolling mill 14, this flatness may change in subsequent processes, for example when the strip 16 is subjected to coiling and uncoiling. This change may for example depend on cooling effects and where in the coil a particular section of the strip 16 is positioned. The thickness profile target 50 may therefore be determined based on a measured flatness of the strip 16 after passing through any of the subsequent processes 28, 30, 32. Also a measured flatness of the strip 16 constitutes an example of flatness data. As shown in Fig. 1, a flatness of the strip 16 is measured immediately upstream of the coiler 28 and immediately downstream of the uncoiler 30. A flatness effect by the coiling and uncoiling can then be determined based on difference between these measured flatnesses. By determining the thickness profile target 50 based on the flatness effect from the coiling and uncoiling, the strip 16 can be made more flat after uncoiling. Moreover, since the flatness effect from coiling and uncoiling is addressed in the hot rolling side and not in the cold rolling side, the risk for strip break is reduced.

[0067] While the present disclosure has been described with reference to exemplary embodiments, it will be appreciated that the present invention is not limited to what has been described above. For example, it will be appreciated that the dimensions of the parts may be varied as needed. Accordingly, it is intended that the present invention may be limited only by the scope of the claims appended hereto.

Claims

1. A method of controlling flatness of a strip (16) of rolled material in a production line (10) comprising a hot rolling mill (12) and at least one cold rolling mill (14), downstream of the hot rolling mill (12), the method comprising:

- determining flatness data associated with the strip (16) in one or more of the at least one cold rolling mill (14) and/or following passing of the strip (16) through one or more of the at least one cold rolling mill (14);
- determining a thickness profile target (50) of the strip (16) for the hot rolling mill (12) based on the flatness data; and
- passing the strip (16) through the hot rolling mill (12) and adjusting the thickness of the strip (16) based on the thickness profile target (50).

2. The method according to claim 1, wherein each cold rolling mill (14) comprises at least one mechanical actuator (26) arranged to control one or more rolls (24) of the cold rolling mill (14), and wherein the flatness data comprises a flatness model (48) associated with one of the at least one mechanical actuator (26), the flatness model (48) defining an effect on the strip (16) by the mechanical actuator (26).

3. The method according to claim 2, wherein the production line (10) comprises a plurality of cold rolling mills (14), wherein the flatness data comprises a flatness model (48) associated with each of one or more of the at least one mechanical actuator (26) for a plurality of cold rolling mills (14), and wherein the determination of the thickness profile target (50) comprises determining a thickness profile target (50) of the strip (16) for the hot rolling mill (12) that best matches a combination of the flatness models (48).

4. The method according to claim 2 or 3, wherein the production line (10) comprises a plurality of cold rolling mills (14), and wherein the flatness data comprises a flatness model (48) associated with one or more of the at least one mechanical actuator (26) of the most downstream cold rolling mill (14).

5. The method according to claim 4, wherein the thickness profile target (50) is determined to mirror the flatness model (48) associated with each of one or more of the at least one mechanical actuator (26) of the most downstream cold rolling mill (14).

6. The method according to any of claims 2 to 5, wherein the flatness model (48) is dependent on a width of the strip (16).

7. The method according to any of the preceding claims, wherein the flatness data comprises a measured flatness of the strip (16).

8. The method according to claim 7, wherein the flatness data comprises a measured flatness of the strip (16) after passing through a subsequent process (28, 30, 32) with respect to each of the at least one cold rolling mill (14).

9. The method according to any of the preceding claims, wherein the flatness data is determined by means of one or more shape meters (36).

10. The method according to any of the preceding claims, wherein the thickness profile target is determined based on a width of the strip (16).

11. A control system (38) for controlling flatness of a strip (16) of rolled material in a production line (10) comprising a hot rolling mill (12) and at least one cold rolling mill (14), downstream of the hot rolling mill (12), the control system (38) comprising at least one data processing device (40) and at least one memory (42) having at least one computer program stored thereon, the at least one computer program comprising program code which, when executed by one or more of the at least one data processing device (40), causes one or more of the at least one data processing device (40) to perform the steps of:

- determining flatness data associated with the strip (16) in one or more of the at least one cold rolling mill (14) and/or following passing of the strip (16) through one or more of the at least one cold rolling mill (14);

- determining a thickness profile target (50) of the strip (16) for the hot rolling mill (12) based on the flatness data; and
- controlling a thickness adjustment of the strip (16) based on the thickness profile target (50) when passing the strip (16) through the hot rolling mill (12).

12. A production line (10) comprising a hot rolling mill (12), at least one cold rolling mill (14), downstream of the hot rolling mill (12), and a control system (38) according to claim 11.

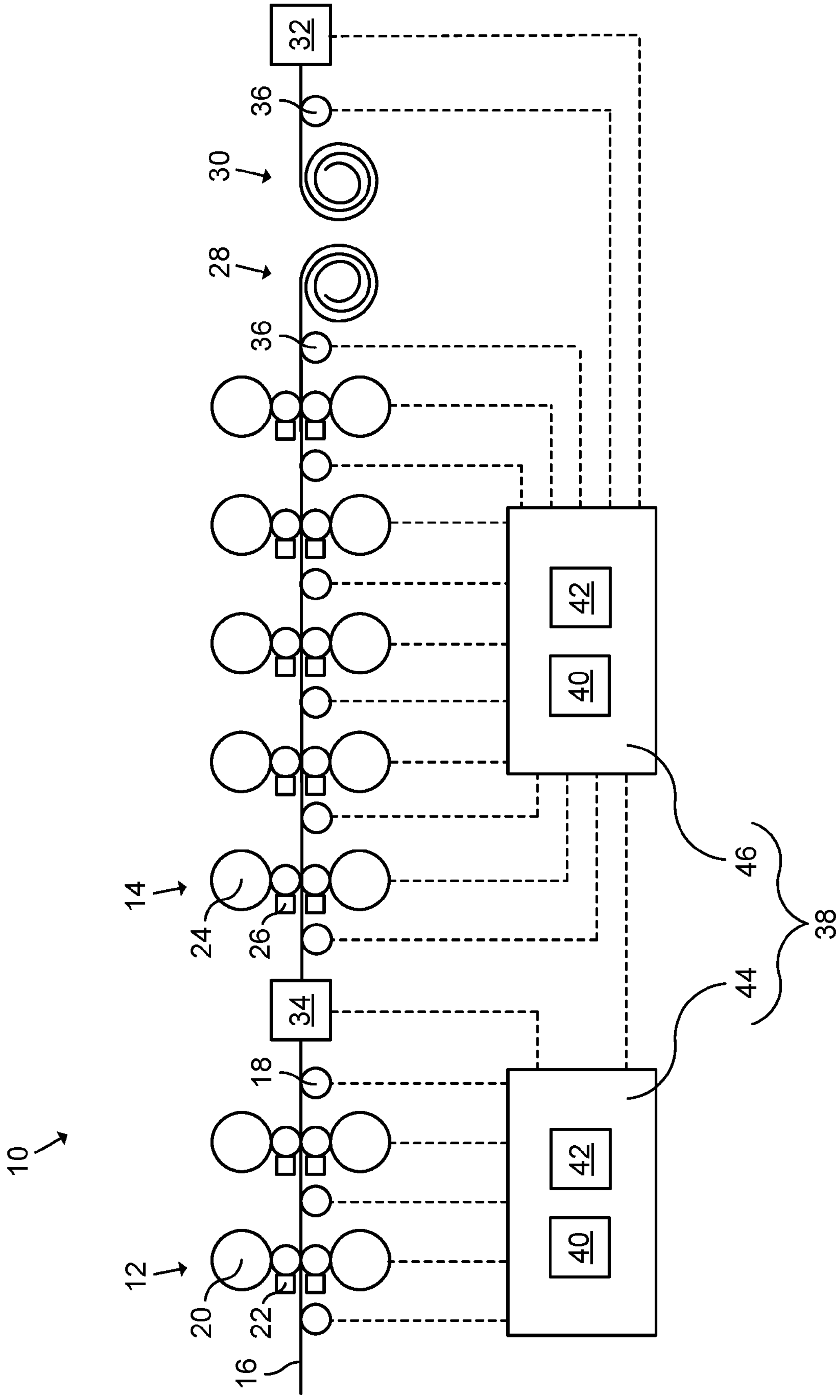

Fig. 1

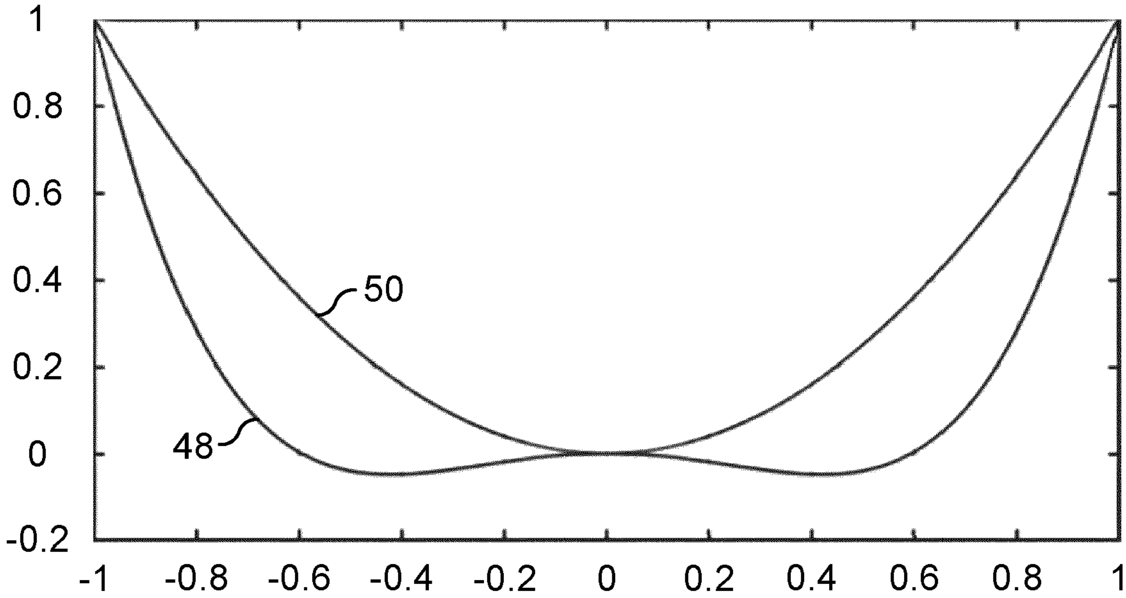

Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 7970

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP S60 20088 B2 (TOKYO SHIBAURA ELECTRIC CO) 20 May 1985 (1985-05-20) * abstract; claim 1; figures 1-2 * -----	1-12	INV. B21B37/28
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B21B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	20 August 2020	Forciniti, Marco

CATEGORY OF CITED DOCUMENTS

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20-08-2020

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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