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(54) **PLANT AND METHOD FOR THE PRODUCTION OF FLAT ROLLED PRODUCTS**

(57) Rolling plant (10) and method for producing a strip (P) starting from a slab (50) having a certain starting thickness, comprising at least one walking beam heating furnace (16) configured to heat at least the slab (50) to a starting temperature, and a rolling train (25) operatively disposed in line with at least one roughing stand (23) and configured to reduce the thickness of an intermediate rolled product (51) at exit from the roughing stand (23), until the final strip (P) is obtained; the rolling train (25) comprising at least one pre-finishing stand (26) for obtaining a pre-finished rolled product (52), and a plurality of finishing stands (31) for obtaining the final strip (P);

the plant (10) comprising load cells (40) directly associated with the pre-finishing stand (26) for detecting the rolling force applied on the pre-finished rolled product (52), a rapid heating device (28), interposed between the pre-finishing stand (26) and the finishing stands (31), for heating the pre-finished rolled product (52), and a command and control unit (44) connected both to the load cells (40) and also to the rapid heating device (28) and configured at least to selectively activate the latter (28), at least as a function of the rolling force detected by the load cells (40).

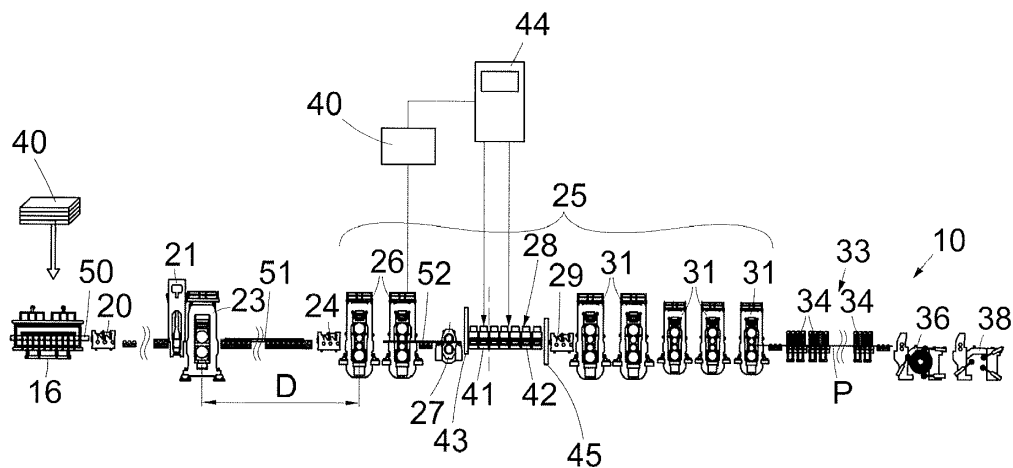


fig. 1

Description

FIELD OF THE INVENTION

[0001] The present invention concerns a plant and a method for the production of flat rolled products such as, for example, but without limitation to generality, steel strips wound in the form of coils.

BACKGROUND OF THE INVENTION

[0002] Rolling plants known as Hot Strip Mills, hereafter referred to by the acronym "HSM", are known, designed for the hot production of metal strips starting from slabs, typically with a thickness ranging from approximately 150 mm to approximately 350 mm.

[0003] Usually, HSMs comprise gas heating furnaces of the "Walking Beam" type, in which the slabs are heated to the rolling temperature in order to be subsequently subjected to a number of between three and eight roughing rolling passes, in one or more reversible stands, in order to obtain an intermediate bar having a considerably reduced thickness compared to the starting one, typically from 35 to 80 mm. The intermediate bar is then subjected to a certain number of finishing rolling steps in order to obtain the final thickness of the strip.

[0004] For all plants that use slab heating by means of "Walking Beam" type heating furnaces, it is common to present the problem of the formation of cold impressions, or "skid marks", in correspondence with the resting surfaces of the slabs on the fixed longitudinal members present inside the furnace. In fact, the longitudinal members are typically water-cooled so that they can maintain their mechanical characteristics even at temperatures above 1000 °C; in the contact zones where the (hotter) slab rests on the (colder) longitudinal members with some portions of its lower surface, the temperature is lower than the remaining lower surface that has not been in contact with the longitudinal members, and this temperature difference also endures outside the oven.

[0005] By way of example only, the "skid marks", which extend over the entire width of the slab, can have a length of approximately 200 mm, a difference in local temperature approximately 100 °C lower than the rest of the surface, and an average temperature difference, in the section concerned, comprised between approximately 15 °C and approximately 30 °C.

[0006] These cold impressions of the slab have a negative impact on the thickness control during the rolling steps, at the expense of the quality of the finished product both in terms of uniformity in the sizes of the thickness and also in terms of microstructural uniformity. This last requirement is of fundamental importance for some types of steel applications, in particular deep molding or electrical steel applications.

[0007] In the state of the art, some solutions have been proposed in which there are provided pyrometric temperature detectors downstream of the last reversible stand

in order to identify the skid marks, and one or more heating inductors located upstream of the finishing train to carry out an additional heating as a function of the temperatures identified by the pyrometric detectors, in order to compensate for the lower thermal energy of the skid marks and try to make the temperature of the bars uniform.

[0008] However, the pyrometric detectors read the surface temperature of the bar, typically the temperature of the upper surface, which is not substantially affected by significant temperature variations, since the skid marks are particularly present on the lower surface of the bars. Therefore, such a temperature measurement, carried out according to the state of the art, does not always allow to accurately identify the position of the actual temperature variations with respect to the length of the bars, resulting in partial inefficiency or inaccuracy of the action of the inductors.

[0009] Furthermore, a pyrometric measurement can in any case be influenced by the presence of both water as well as scale on the surface of the bar, further affecting the goodness of the measurement carried out and, therefore, of the subsequent thermal recovery interventions.

[0010] In any case, by its very nature, a pyrometric measurement is in any case a surface measurement, not representative of the average temperature of the section.

[0011] In order to determine the extent of the additional heating, it is therefore necessary to trace, through thermal models, the value of the average temperature in the section from the value of the surface temperature, an evaluation that is not always precise.

[0012] Therefore, since the rolling force is a function of the average temperature of the bar, it is clear that this known technique cannot provide guarantees about the magnitude of the average temperature and of the finishing rolling action and, therefore, about the goodness of the thickness control of the finished product.

[0013] It is therefore a purpose of the present invention to provide a Hot Strip Mill plant and to develop a method for the production of flat rolled products that allow to effectively make the average temperature of the bar at entry to the finishing train uniform, reducing and even eliminating the qualitative issues caused by the skid marks.

[0014] Another purpose of the present invention is to produce thin thicknesses without negatively affecting the productivity of the plant, which can reach up to 6 million tons/year.

[0015] Another purpose of the present invention is to provide a plant and to develop a method for the production of rolled products that allow to keep the mechanical and geometric properties uniform along the entire length of the coil produced.

[0016] The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

[0017] The present invention is set forth and characterized in the independent claims. The dependent claims describe aspects that represent evolutions and improvements with respect to the independent claims.

[0018] In accordance with the above purposes, a rolling plant according to the present invention is applied to produce a steel strip starting from a slab having a certain starting thickness.

[0019] In particular, the plant according to the present invention comprises at least one heating furnace, for example of the gas type normally called Walking Beam, in which the slabs rest on fixed longitudinal members and are made to advance inside it by means of mobile longitudinal members, until the slab is heated to a certain starting temperature, for example comprised between approximately 1150 °C and 1280 °C.

[0020] Typically, the plant according to the present invention comprises at least one roughing stand of the reversible type, configured to subject the heated slab to one or more rolling passes in order to obtain an intermediate rolled product, for example with a thickness comprised between approximately 35 mm and approximately 80 mm.

[0021] According to the present invention, the plant also comprises a finishing rolling train disposed operatively in line with the roughing stand and configured to reduce the thickness of the intermediate rolled product, until a final strip is obtained having a final thickness, in some solutions, even lower than 1.2 mm, even down to 0.9 mm.

[0022] Therefore, the plant is configured as a new generation rolling plant, compared to traditional Hot Strip Mills, which operates in coil to coil mode, in which the rolled product is obtained starting from single slabs, for example with a thickness comprised between approximately 150 mm and approximately 350 mm, with all the operational, dimensional and production characteristics that this type of plant entails.

[0023] Again according to the present invention, the finishing rolling train is advantageously divided into a pre-finishing train consisting of at least one pre-finishing stand, and a finishing train consisting of a plurality of finishing stands. The pre-finishing train and the finishing train always operate in tandem and are therefore synchronized with each other.

[0024] The at least one pre-finishing stand is suitable to reduce the thickness of the intermediate rolled product in order to obtain a pre-finished rolled product, for example with a thickness comprised between approximately 10 mm and approximately 50 mm.

[0025] The finishing stands, on the other hand, are configured to reduce the thickness of the pre-finished rolled product in order to obtain the final strip, for example with a thickness comprised between approximately 0.9 mm and approximately 26 mm.

[0026] In accordance with one aspect of the present invention, the plant comprises mechanical deformation

detection means, which are directly associated with at least the last pre-finishing stand, in order to constantly detect the rolling force applied on the pre-finished rolled product.

[0027] In accordance with another aspect of the present invention, the plant advantageously provides a rapid heating device consisting of selectively activatable elements or modules, which is interposed between the last pre-finishing stand and the plurality of finishing stands so as to heat the pre-finished rolled product.

[0028] This heating can occur up to an exit temperature from the rapid heating device comprised between approximately 1000 °C and approximately 1150 °C, or in any case a temperature such that, also as a function of the operating and product parameters, the temperature of the final strip at exit from the last finishing stand is higher than at least 830 °C, and in some cases is higher than 900 °C.

[0029] Moreover, the solution according to the present invention provides that the plant is provided with a command and control unit, which is connected both to the mechanical deformation detection means of the last pre-finishing stand and also to the rapid heating device, so as to selectively activate the rapid heating device so that it can supply a localized heating surplus, or over-heating, at least as a function of the rolling force detected by the mechanical deformation detection means, in order to increase the temperature of the skid marks and therefore make the temperature of the bar uniform on its entire length.

[0030] In fact, the skid marks that are generated in the heating furnace on the resting surface of the slab on the fixed longitudinal members, resulting in more slab portions at geometrically defined intervals having a lower temperature than the rest of the slab itself, determine a greater resistance to deformation of the material, which translates into an increase in the rolling force in correspondence with the colder portions.

[0031] The value of this load increase is detected by the mechanical deformation detection means and sent to the command and control unit which, as a function of the rolling speed at exit of the pre-finished rolled product, also taking into account its thickness, commands to the rapid heating device a localized over-heating in the aforementioned zones of greater resistance to deformation, and therefore with a lower temperature, which are detected by the mechanical deformation detection means of the last pre-finishing stand.

[0032] The Applicant has verified that there is a correlation between the average temperature of the bar and the rolling force, whereby from the measurement of the latter, that is, of the variation in applied force, it is possible to derive the average temperature variation of the bar, in a specific portion thereof.

[0033] An example of this relationship is that an increase in the rolling force of approximately 4%, compared to the nominal load, corresponds to a variation in the average temperature of the bar of approximately 20 °C.

[0034] From here, knowing the thickness of the pre-finished product at exit from the last pre-finishing stand, it is possible to establish the localized over-heating value that has to be actuated by the rapid heating device in order to make the temperature of the cold impressions uniform.

[0035] Therefore, with the solution according to the present invention the plant is able to produce flat rolled products by effectively making the average temperature of the bar at entry into the finishing train uniform, to the advantage of the dimensional and microstructural quality of the finished rolled product.

[0036] Since the bar exiting from the pre-finishing train advances at a relatively low speed, of the order of 0.6 - 1.5 m/s, it is possible to carry out a precise and accurate tracking of the ski marks along the bar itself through the variations of the rolling force of the last pre-finishing stand. Thanks to the rapid response times (reactivity) of the rapid heating device, it is possible to carry out a closed loop adjustment of the inductors in order to thermally compensate for the cold bands caused by the skid marks, and therefore "level out" the temperature profile and deliver a bar with a uniform temperature on its entire length to the finishing train.

[0037] According to an advantageous embodiment, the rapid heating device comprises both first thermal induction modules, which are able to be selectively activated and regulated by the command and control unit as a function of the rolling force detected by the mechanical detection means, and also second thermal induction modules, the latter being able to be selectively activated and regulated by the command and control unit.

[0038] In particular, the rapid heating device can use the first 2-3 modules to perform the task of levelling out the temperature delta of the skid marks, while the subsequent modules can be dedicated to heating the head of the bar and, with a progressive increase in the power, also the body and tail of the bar, so that it can exit from the last finishing step at the target temperature, which is predefined as a function of the rolled product.

[0039] Each module can be activated or deactivated independently of the other modules, and each module can work at different powers.

[0040] The number of modules of the inductor can be comprised between 6 and 12, preferably between 8 and 10, of which two first modules and the remaining second modules.

[0041] Each module can have a nominal power comprised between 3 MW and 7 MW, preferably between 4 MW and 5 MW.

[0042] The overall nominal power of the inductor can be, for example, comprised between 38 MW and 45 MW.

[0043] In accordance with one example embodiment, the number of modules is equal to 10, wherein each module has a nominal power of 4.3 MW. Therefore the overall nominal power of the inductor is 43 MW.

[0044] Advantageously, to be assured that the result of the thermal restoration of the skid marks is actually

successful, a thermo-scanner is provided at least at exit from the rapid heating device, which also acts as a control of the transverse thermal profile of the product and any relative over-heating of the edges. Overall, the heating can advantageously occur up to an exit temperature from the rapid heating device comprised between approximately 1000 °C and approximately 1150 °C, or in any case at a temperature such that, also as a function of the operating and product parameters, the temperature of the final strip, at exit from the last finishing stand, can be higher than at least 830 °C and in some cases higher than 900 °C.

[0045] This advantageous aspect of the solution according to the present invention allows the steel to remain substantially in the monophasic field and, therefore, without phase transformations, before exiting from the last finishing stand.

[0046] According to another aspect of the present invention, the continuous finishing rolling train comprises between one and three pre-finishing stands and between five and six finishing stands.

[0047] The present invention also concerns a rolling method for producing a final strip starting from a slab having a certain starting thickness, in a rolling plant of the type described heretofore.

[0048] According to one aspect of the present invention, the method comprises at least one detection step in which the rolling force applied on the intermediate rolled product is constantly detected by means of the mechanical deformation detection means; at least one heating step in which the pre-finished rolled product is heated by means of the rapid heating device; and a command step in which the rapid heating device is selectively activated by means of the command and control unit, at least as a function of the rolling force detected by the mechanical deformation detection means, in order to thermally compensate for any cold zones and make the temperature of the bar uniform on its entire length.

[0049] In accordance with another aspect of the present invention, the rolling plant provides to produce strips with a final thickness comprised between approximately 0.9 mm and approximately 26 mm, which can be wound onto reels without speed-up for productions of up to 3 million tons per year, and with a modest speed-up for productions of up to 6 million tons per year.

DESCRIPTION OF THE DRAWINGS

[0050] These and other aspects, characteristics and advantages of the present invention will become apparent from the following description of some embodiments, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 is a schematic representation of an embodiment of a new generation HSM plant for the production of flat rolled products, in accordance with the present invention;

- fig. 2 shows a graph which correlates, for a defined segment of pre-finished rolled product, the variation in rolling force used in a certain time segment;
- figs. 3 and 4 are graphic representations of the relationship between the temperature trend of the bar affected by skid marks and the consequent thickness variation, respectively, in a HSM of a known type and the corresponding trend in the case of a new generation HSM plant for the production of flat rolled products, in accordance with the present invention; and
- figs. 5 and 6 are graphical representations of the relationship between rolling speed and exit temperature for the same final rolled product with different tail speeds in a new generation HSM plant for the production of flat rolled products, in accordance with the present invention; in fig. 5 the rolling speed for head/body/tail is the same; in fig. 6 the tail is rolled with modest speed-up.

[0051] We must clarify that the phraseology and terminology used in the present description, as well as the figures in the attached drawings also in relation as to how described, have the sole function of better illustrating and explaining the present invention, their purpose being to provide a non-limiting example of the invention itself, since the scope of protection is defined by the claims.

[0052] To facilitate comprehension, the same reference numbers have been used, where possible, to identify identical common elements in the drawings. It is understood that elements and characteristics of one embodiment can be conveniently combined or incorporated into other embodiments without further clarifications.

DESCRIPTION OF SOME EMBODIMENTS OF THE PRESENT INVENTION

[0053] With reference to fig. 1, this shows a plant 10 in accordance with the present invention for the production of a flat rolled product, for example a final strip P, with a thickness comprised between approximately 0.9 mm and approximately 26 mm, wound in order to form a coil starting from slabs 50 having a starting thickness comprised between approximately 150 mm and approximately 350 mm.

[0054] The plant 10 comprises one or more gas heating furnaces 16, for example of the type known in the field with the term "walking beam", configured to receive and heat to a certain starting temperature T1 at least one slab 50, supplied even at ambient temperature. Advantageously, at exit from the gas heating furnace 16 the slab 50 has a temperature comprised between approximately 1150 °C and approximately 1280 °C.

[0055] As is known, in this type of furnace 16 the slabs 50 rest on fixed longitudinal members and are moved by means of mobile longitudinal members, not shown in the attached drawings, which are water-cooled so as not to undergo deformations and/or structural failures under the weight of the slabs at the heating temperatures.

[0056] As schematically shown in fig. 2, the lower surface of the slab 50 has, transversely, some impressions 50a known by the term "skid marks", which are formed in correspondence with the zones where the slab 50 rests on the cooled longitudinal members.

[0057] These impressions 50a have a length of approximately 200 mm and have a surface temperature approximately 100 °C lower than the surface that has not been in contact with the longitudinal members, and this temperature difference persists even outside the furnace. Considering the average temperature in the section of the slab 50, the temperature in correspondence with the impressions 50a is comprised between approximately 15°C and approximately 30°C lower than in the zones not affected by skid marks.

[0058] During rolling, this average temperature delta is attenuated, and the corresponding zone affected by the skid mark is lengthened due to the effect of the crushing as a function of the slab thickness/bar thickness ratio.

[0059] By way of example, considering an initial slab thickness of 200 mm and a thickness at exit from the last pre-finishing stand of 15 mm, the length of the bar affected by the skid mark will be $200 \times 200 / 15 = 2667$ mm and the average temperature delta is reduced to 10 - 20 °C.

[0060] By way of example only, a warehouse 40 is also part of the plant 10, disposed substantially in line and upstream of the heating gas furnace 16 and configured to store the slabs 50, for example coming from another production site or from another production area of the same establishment. This warehouse 40, only schematized in fig. 1, allows to selectively feed at least one slab 50 to the gas furnace 16, according to desired feeding sequences and timings.

[0061] A first water descaling device 20, a vertical or edging pass stand 21 and a reversible roughing stand 23, which is configured to subject the slab 50 to a certain number of passes and reduce its thickness until an intermediate rolled product 51 is obtained, are disposed, in sequence, downstream of the gas heating furnace 16. The intermediate rolled product 51 has, in an advantageous embodiment, a thickness comprised between approximately 35 mm and 80 mm. As an indication only, at the end of the desired roughing passes, the intermediate rolled product 51 has an average temperature, in the zones not affected by the impressions 50a, ranging between approximately 1000 °C and approximately 1150 °C.

[0062] It is not excluded, in other embodiments, that two roughing stands 23 can be provided, with corresponding vertical stands 21.

[0063] According to a further aspect of the present invention, the at least one reversible roughing stand 23 is in turn equipped with descaling means mounted on-board and forming an integral part of the stand itself, which are disposed both on the entry side and also on the exit side of the stand (not shown in the drawings).

[0064] A second descaling device 24 and a continuous finishing rolling train 25 are disposed, in succession,

downstream of the reversible roughing stand 23.

[0065] In particular, the continuous finishing rolling train 25 consists of two macro rolling units, one pre-finishing unit comprising two pre-finishing stands 26 and one finishing unit comprising a plurality of finishing stands 31, in this specific case five.

[0066] The continuous finishing rolling train 25 is configured to progressively reduce the thickness of the intermediate rolled product 51 in order to obtain the final strip P, with a minimum thickness of approximately 1 mm.

[0067] In some embodiments, not shown in the drawings, the plant 10 can also comprise a vertical or edging pass stand 21, both downstream of the reversible roughing stand 23, and also upstream of the continuous finishing rolling train 25.

[0068] In general, the number of pre-finishing stands 26 of the finishing rolling train 25 is comprised between one and three, while the number of finishing stands 31 is comprised between five and six and their number and disposition is chosen as a function of the steel grades, the use of the finished product and the minimum and maximum thicknesses that the final strip P assumes during rolling.

[0069] In the solution according to the present invention, two pre-finishing stands 26 are provided, distanced from the remaining finishing stands 31 of the finishing rolling train 25, so that a pre-finished rolled product 52 having a thickness comprised between approximately 10 mm and approximately 50 mm exits from the pre-finishing stands 26.

[0070] In addition, the pre-finishing stands 26 are disposed at a certain distance D from the roughing stand 23, so that the intermediate rolled product 51 is never simultaneously in operative engagement with both types of stands.

[0071] In the solution according to the present invention, at least one load cell 40, only schematized in the attached drawings, is associated with the last pre-finishing stand 26, by means of which the increases in the rolling force are detected, which are caused by the greater resistance to crushing of the "colder" impressions 50a compared to the rest of the pre-finished rolled product 52.

[0072] It is not excluded that, in place of the load cell 40, another mechanical deformation detection device can be used, suitable for the purpose of continuously detecting the rolling load applied in order to obtain the pre-finished rolled product 52.

[0073] As graphically shown in fig. 2, each impression 50a corresponds to a corresponding peak "A" of the rolling force which, for a temperature of approximately 20 °C lower, corresponds to an increase of approximately 4% of the force required for rolling compared to the bar parts comprised between two consecutive skid marks.

[0074] In the example solution shown in the drawings, downstream of the pre-finishing stands 26 there is disposed a flying shear 27, of the "crop shear" type, to trim the heads and tails of the pre-finished rolled product 52 in order to facilitate its entry into the finishing stands 31

and to reduce the chances of obstruction, especially for the production of final strips having a thickness of less than 3.0 mm.

[0075] The plant 10 according to the present invention further comprises a rapid heating device 28 interposed between the pre-finishing stands 26 and the finishing stands 31 of the continuous rolling train 25.

[0076] The rapid heating device 28 is configured to heat, in a selective and adjustable manner, the pre-finished rolled product 52 before it enters the finishing stands 31.

[0077] Preferably, the rapid heating device 28 comprises, for example, an induction furnace consisting of thermal induction modules which are able to be selectively activated, even independently of each other.

[0078] In particular, the rapid heating device 28 comprises two first thermal induction modules 41 disposed immediately downstream of the flying shear 27 and, in this specific case, five second thermal induction modules 42. Both the first and also the second thermal induction modules 41 and 42 are preferably of the transverse flow type, so as to affect the entire cross-section of the pre-finished rolled product 52.

[0079] Moreover, the plant 10 according to the present invention comprises a command and control unit 44 which is connected both to the load cell 40 associated with the last stand 26 of the pre-finishing unit, and also to the rapid heating device 28, so as to selectively and individually command both the drive as well as the over-heating intensity to be given to the cold impressions 50a.

[0080] Since the bar exiting from the pre-finishing train advances at a relatively low speed, of the order of 0.6 - 1.5 m/s, it is possible to carry out an accurate and precise tracking of the skid marks along the bar itself, through the variations of the rolling force of the last pre-finishing stand. Thanks to the rapid response times (reactivity) of the rapid heating device 28, it is possible to carry out a closed loop adjustment of the inductors in order to thermally compensate for the cold bands caused by the skid marks, and then level out the temperature profile and deliver a pre-finished rolled product 52 with a uniform temperature on its entire length to the finishing stands 31.

[0081] In particular, the first thermal induction modules 41 are selectively commanded to perform a localized over-heating in correspondence with the impressions 50a, so as to substantially "level out" the surface temperature thereof. The second thermal induction modules 42 are instead selectively driven to raise the overall temperature of the pre-finished rolled product 52, in a head/body/tail differentiated manner, in order to obtain a certain constant target temperature for the entire length of the product 52 at exit from the rapid heating device 28.

[0082] Advantageously, to be assured that the result of the thermal restoration of the skid marks is actually successful, a thermo-scanner 45 is provided at exit from the rapid heating device 28, which also acts as a control of the transverse thermal profile of the product 52, and any relative over-heating of the edges.

[0083] By way of example only, the temperature to which the pre-finished rolled product 52 is heated, that is, the temperature that it assumes at exit from the rapid heating device 28, reaches a value advantageously comprised between approximately 1000 °C and approximately 1150 °C.

[0084] This allows to reduce the value of the rolling mass flow MF_L required to obtain the aforementioned optimum temperature of at least 830 °C, for example comprised between 830 °C and 920 °C, at the exit of the last finishing stand 31.

[0085] Advantageously, downstream of the rapid heating device 28 and upstream of the finishing stands 31 there is also disposed a third water descaling device 29, having the function of further cleaning the surface of the pre-finished rolled product of scale, before it enters the finishing stands 31.

[0086] Therefore, the scale that has been created on the surface of the pre-finished rolled product 52 is effectively removed, thereby preventing qualitative defects on the rolled strip P such as, for example, rolled-in scale.

[0087] By way of example only, in the embodiment of a plant 10 shown, downstream of the finishing stands 31 there is disposed a cooling device 33 comprising a plurality of showers 34 which are able to be selectively activated even independently of one another to cool the strip P.

[0088] In addition, two winding reels 36, 38 are disposed at exit from the showers 34 in order to wind the strip P into coils and for its subsequent storage and shipment.

[0089] The solution according to the present invention, thanks to the standardization of the average temperature of the pre-finished rolled product 52, by means of the closed loop adjustment of the modules 41 and 42 of the rapid heating device 28 that selectively over-heat the cold bands of the intermediate bar which are detected through the variations of the rolling force on the last pre-finishing stand and that raise the overall temperature of the pre-finished rolled product 52, allows an optimal control of the thickness during the finishing rolling, guaranteeing the exit temperature from the last finishing stand of at least 830 °C.

[0090] The present invention also concerns a method for the production of a strip P, wound to form a coil, starting from slabs 50 having a starting thickness comprised between approximately 150 mm and approximately 350 mm.

[0091] The method provides to heat at least one slab 50 in the gas heating furnace 16 to a temperature of 1150 - 1280 °C, and then feed the latter toward the first descaling device 20.

[0092] Subsequently, the slab 50 is moved toward the edging pass stand 21 and then toward the reversible roughing stand 23, in correspondence with which it is subjected to some rolling passes that reduce its thickness until the intermediate rolled product 51 is obtained, having a thickness comprised in a range of approximately

35 mm to approximately 80 mm. Preferably, the number of rolling passes carried out by the reversible roughing stand 23 is no higher than five.

[0093] The intermediate rolled product 51 is then transported to the second descaling device 24, in which it is subjected to surface descaling and subsequently moved toward the continuous rolling train 25.

[0094] The intermediate rolled product 51 then enters the pre-finishing stands 26 where its thickness is reduced further, until the pre-finished rolled product 52 with a thickness comprised between approximately 10 mm and approximately 50 mm is defined.

[0095] In this step, the load cell 40 associated with the last pre-finishing stand 26 detects the variations of the rolling force which are applied by the pre-finishing stand 26 on the pre-finished rolled product 52, because of the cold impressions 50a generated upstream, as mentioned, by the contact of the slab 50 with the longitudinal members of the gas furnace 16.

[0096] The measurement carried out by the load cells 40 on the last pre-finishing stand 26 accurately detects the trend of the rolling forces and therefore the position of the skid marks along the pre-finished rolled product 52, this measurement is transmitted to the command and control unit 44 which provides to command a certain over-heating to the first modules 41 in correspondence with the impressions 50a detected, in order to level out the thermal differences and make the average temperature of the pre-finished rolled product 52 that is fed to the finishing stands 31 uniform.

[0097] Upstream of the rapid heating device 28, the pre-finished rolled product 52 is subjected to a thermal scan by means of a thermal scanner 43, suitable to perform a complete thermal scan of the section of the pre-finished rolled product 52 entering the device 28.

[0098] This scan allows to identify the temperature of the pre-finished rolled product 52, substantially on its entire length considering its complete cross-section, in order to communicate the real temperature conditions of the product 52 itself to the command and control unit 44 and, consequently, to command the second modules 42, so as to define the extent of the heating to be given to the entire pre-finished rolled product 52 and to make its temperature uniform.

[0099] Downstream of the rapid heating device 28 the pre-finished rolled product 52 is subjected to another thermal scan by means of a thermal scanner 45 in order to check its temperature at exit, both in its length and also in the transverse thermal profile. The transverse thermal profile can be modified by acting on the shifting position of the individual rapid heating modules 28.

[0100] Thanks to the thermal uniformity given by the rapid heating device 28, it is possible to feed the finishing stands 31 with a thermally uniform product 52 at a value advantageously comprised between approximately 1000 °C and approximately 1150 °C and, at the same time, reduce the value of the rolling mass flow MF_L required, in order to obtain the aforementioned optimal tempera-

ture of at least 830 °C, for example comprised between 830 °C and 920 °C, at the exit of the last finishing stand.

[0101] To better clarify the product characteristics and the advantages deriving from the solution according to the present invention, please note a comparison between what is shown graphically in figs. 3 and 4.

[0102] Fig. 3 shows a traditional HSM plant, in which we have a roughing stand 92, a finishing rolling train 94 provided with finishing stands in substantial continuity with each other, downstream of which there is provided a cooling device 96, to produce a final strip P.

[0103] As disclosed in the state of the art, in traditional HSM plants the temperature control of the bar at exit from the roughing stand 92 is carried out by means of pyrometric detectors 93, with all the disadvantages already explained.

[0104] By performing a control scan of the final strip P at exit from the finishing rolling train 94, the following are outlined: curve B1, relating to the temperatures, and curve C1, relating to the thicknesses, both in relation to a segment of strip P.

[0105] As can be seen, although some thermal measurement has been made with the pyrometric detectors 93, both the trend of the temperatures as well as the trend of the thicknesses, in the unit of length of the finished strip P, have peaks and troughs with considerable differential, in particular in correspondence with the impressions 50a caused by the skid marks, to the detriment of the quality of the final strip P produced.

[0106] Instead, with the plant 10 solution according to the present invention, carrying out the same control scan of the final strip P, at exit from the finishing rolling train 25, the following are outlined: curve B, relating to the temperatures, and curve C, relating to the thicknesses, both in relation to a same segment of strip P.

[0107] For better understanding, we have overlapped the curves B and C delineated by the scan of the strip P produced with the plant 10 according to the present invention with the respective curves B1 and C1 obtained with the traditional plant described above.

[0108] One can see that, both in relation to the temperatures and also in relation to the thicknesses, there is a much more constant trend of the curves, to the benefit of a greater thermal and dimensional uniformity of the final strip P. This uniformity results in a higher quality of the final strip P obtained with the plant 10 according to the present invention.

[0109] The reduction of the rolling mass flow MF_L allows to carry out the rolling with a reduced rolling speed V_L , preferably lower than 12 m/s, and at the same time to reach the optimum temperature of at least 830 °C at the exit of the continuous rolling train 25 also for the tail of the final strip P, eliminating the need for the "speed-up" as a tool for reaching the target temperature. An example of such an embodiment is schematized graphically in fig. 5.

[0110] According to some embodiments, it may be necessary to resort to speed-up in order to be able to increase

line productivity when making very thin thicknesses, or to reach very high productivity with other thicknesses. An example of such an embodiment is schematized graphically in fig. 6.

[0111] It is clear that modifications and/or additions of parts or steps may be made to the plant 10 and to the method for the production of flat rolled products as described heretofore, without departing from the field and scope of the present invention, as defined by the claims.

[0112] It is also clear that, although the present invention has been described with reference to some specific examples, a person of skill in the art will be able to achieve other equivalent forms of method and plant 10 for the production of flat rolled products, having the characteristics as set forth in the claims and hence all coming within the field of protection defined thereby.

[0113] In the following claims, the sole purpose of the references in brackets is to facilitate their reading and they must not be considered as restrictive factors with regard to the field of protection defined by the claims.

Claims

1. Rolling plant (10), for producing a final strip (P) starting from a slab (50) having a certain starting thickness, comprising at least one walking beam heating furnace (16) configured to heat at least said slab (50) to a certain temperature, and a finishing rolling train (25) operatively disposed in line with at least one roughing stand (23) and configured to reduce the thickness of an intermediate rolled product (51), at exit from said roughing stand (23), until said final strip (P) is obtained; said finishing rolling train (25) comprising at least one pre-finishing stand (26) able to reduce the thickness of said intermediate rolled product (51) in order to obtain a pre-finished rolled product (52), and a plurality of finishing stands (31) able to reduce the thickness of said pre-finished rolled product (52), in order to obtain said final strip (P), **characterized in that** it comprises mechanical deformation detection means (40) directly associated at least with the last of said at least one pre-finishing stand (26) and able to detect the rolling force applied on said pre-finished rolled product (52), a rapid heating device (28), interposed between said at least one pre-finishing stand (26) and said plurality of finishing stands (31), for heating said pre-finished rolled product (52), and a command and control unit (44) connected both to said mechanical deformation detection means (40) and also to said rapid heating device (28) and configured at least to selectively activate said rapid heating device (28), at least as a function of the rolling force detected by said mechanical deformation detection means (40), in order to thermally compensate for any cold zones and make the temperature of the bar uniform on its entire length.

2. Plant (10) as in claim 1, **characterized in that** said rapid heating device (28) comprises first thermal induction modules (41) able to be selectively activated and regulated by said command and control unit (44), as a function of the rolling force detected by said mechanical deformation detection means (40). 5
3. Plant (10) as in any claim hereinbefore, **characterized in that** said rapid heating device (28) comprises second thermal induction modules (42) able to be selectively activated and regulated by said command and control unit (44), as a function of a certain target temperature of said intermediate rolled product (52) to be obtained at exit from said heating device (28). 10
4. Plant (10) as in the previous claims, **characterized in that** said first thermal induction modules (41) and said second thermal induction modules (42) are of the transverse flow type. 20
5. Plant (10) as in any claim hereinbefore, **characterized in that** it comprises thermal scanning means (45) disposed at exit from said rapid heating device (28) and configured for the transverse thermal detection of said pre-finished rolled product (52). 25
6. Plant (10) as in any claim hereinbefore, **characterized in that** it comprises first thermal scanning means (43) disposed upstream of said rapid heating device (28) and configured to thermally scan said prefinished rolled product (52). 30
7. Rolling method, for producing a final strip (P) starting from a slab (50) having a certain starting thickness, in a rolling plant (10) comprising at least one walking beam heating furnace (16) configured to heat at least said slab (50) to a certain starting temperature, and a finishing rolling train (25) disposed operatively in line with at least one roughing stand (23) and configured to reduce the thickness of an intermediate rolled product (51), at exit from said roughing stand (23), until said final strip (P) is obtained; said finishing rolling train (25) comprising at least one pre-finishing stand (26) able to reduce the thickness of said intermediate rolled product (51) in order to obtain a pre-finished rolled product (52), and a plurality of finishing stands (31) able to reduce the thickness of said pre-finished rolled product (52) in order to obtain said final strip (P), **characterized in that** it comprises at least one detection step in which, by means of mechanical deformation detection means (40) directly associated at least with the last of said at least one pre-finishing stand (26), the rolling force applied on said pre-finished rolled product (52) is detected, at least one heating step in which, by means of a rapid heating device (28) interposed between said at least one pre-finishing stand (26) and said plurality of finishing stands (31), said pre-finished rolled product (52) is heated, and a command step in which, by means of a command and control unit (44) connected both to said mechanical deformation detection means (40) and also to said rapid heating device (28), said rapid heating device (28) is selectively activated at least as a function of said rolling force detected by said mechanical detection means (40), in order to thermally compensate for any cold zones and make the temperature of the bar uniform on its entire length. 35 40 45 50 55
8. Method as in claim 7, **characterized in that** in said detection step, said mechanical deformation detection means (40) detect one or more impressions (50a) of said pre-finished rolled product (52) to which there corresponds a greater resistance to deformation of the material which involves an increase in the rolling force exerted by said pre-finishing stand (26).
9. Method as in claim 8, **characterized in that** in said rapid heating step, first thermal induction modules (41) of said rapid heating device (28) are selectively activated by said command and control unit (44) to carry out a localized over-heating in correspondence with said impressions (50a) of said pre-finished rolled product (52), at least as a function of the greater resistance to deformation of the material which involves an increase in the rolling force, in order to increase the temperature of said impressions (50a) and make the temperature of said pre-finished rolled product (52) uniform on its entire length.

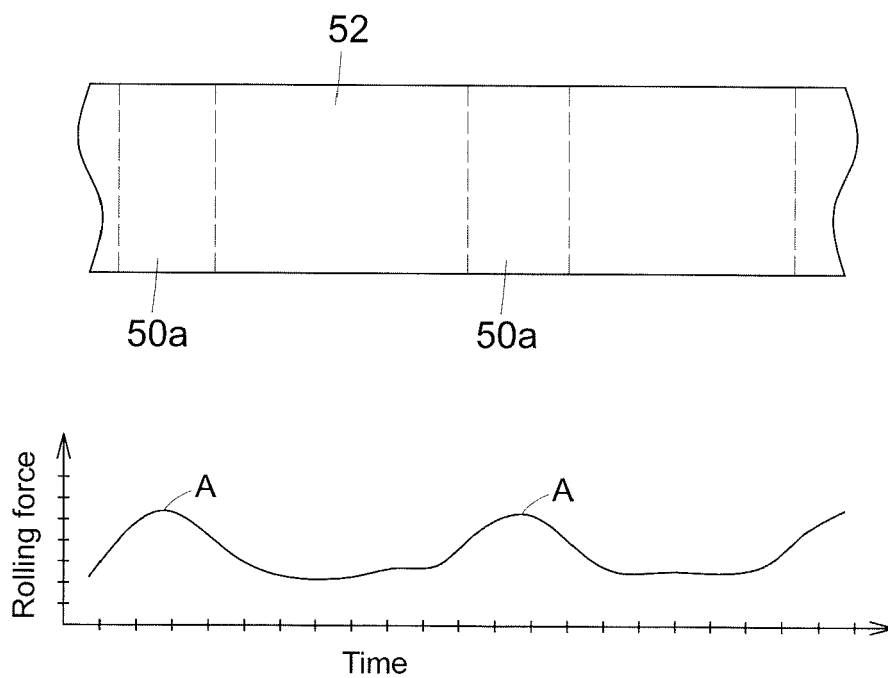
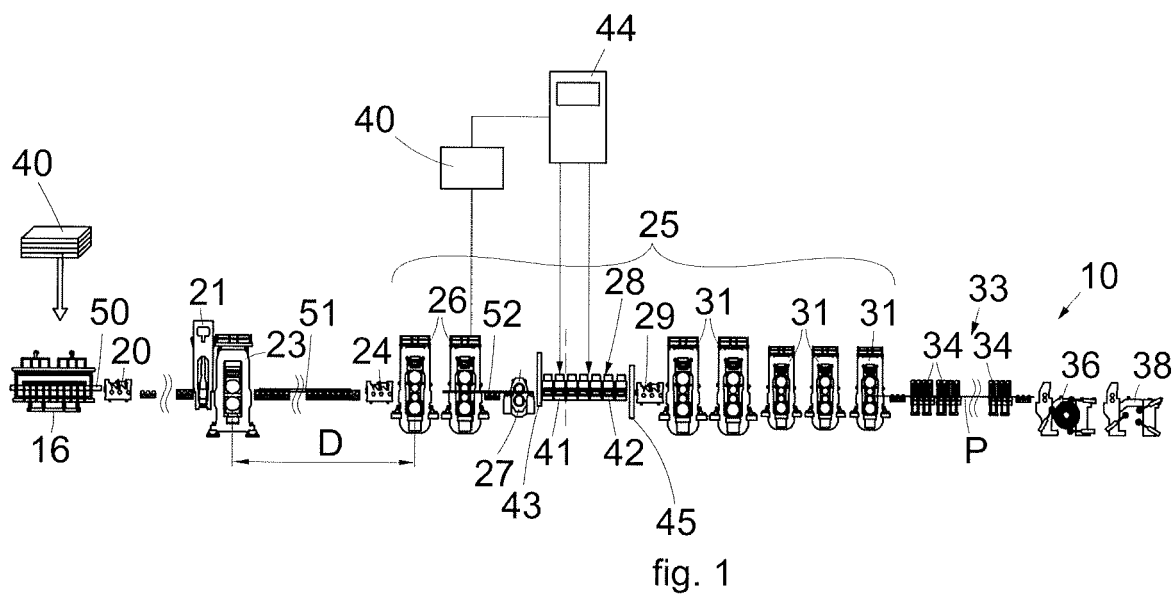


fig. 2

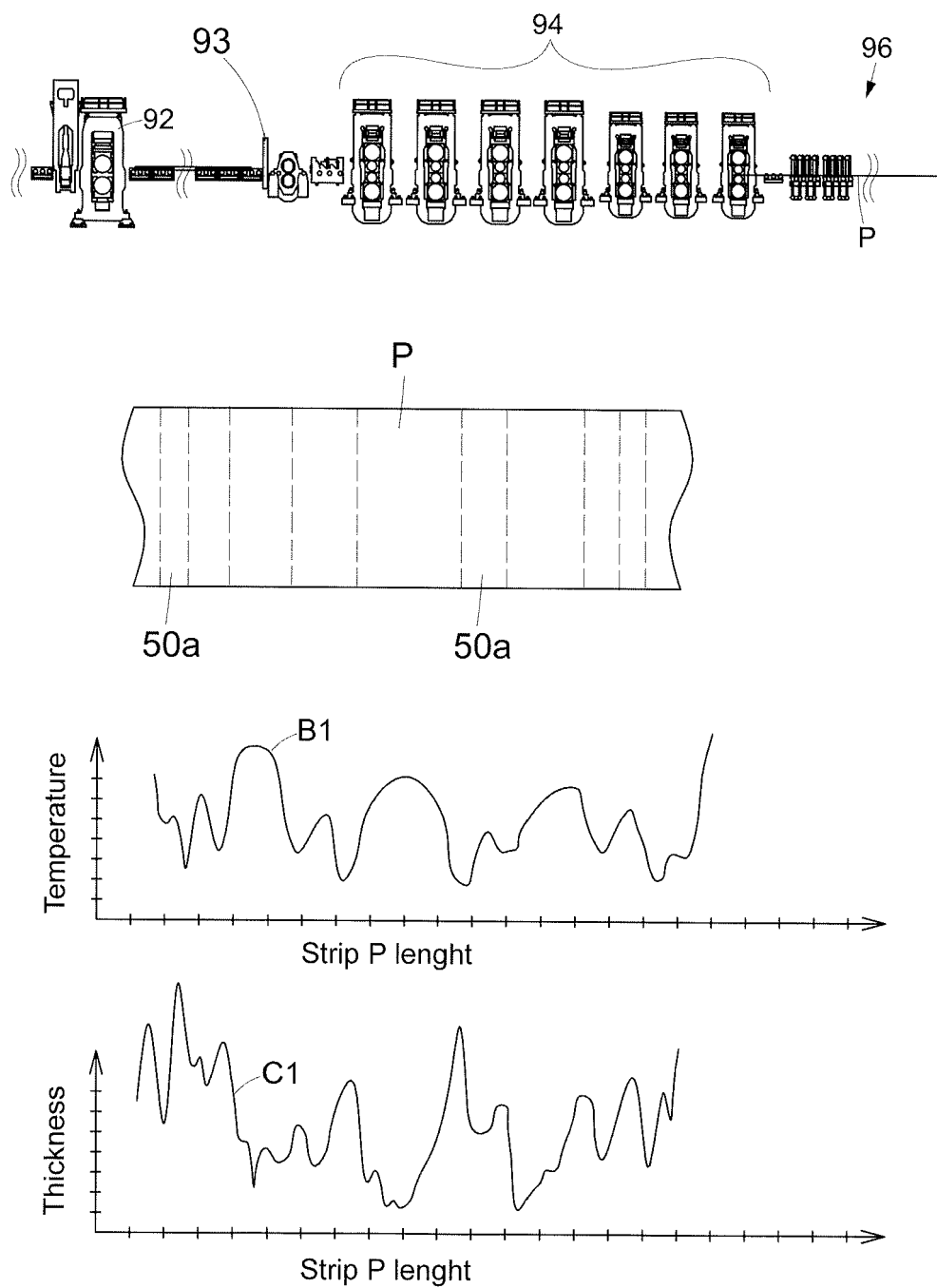


fig. 3
(STATE OF THE ART)

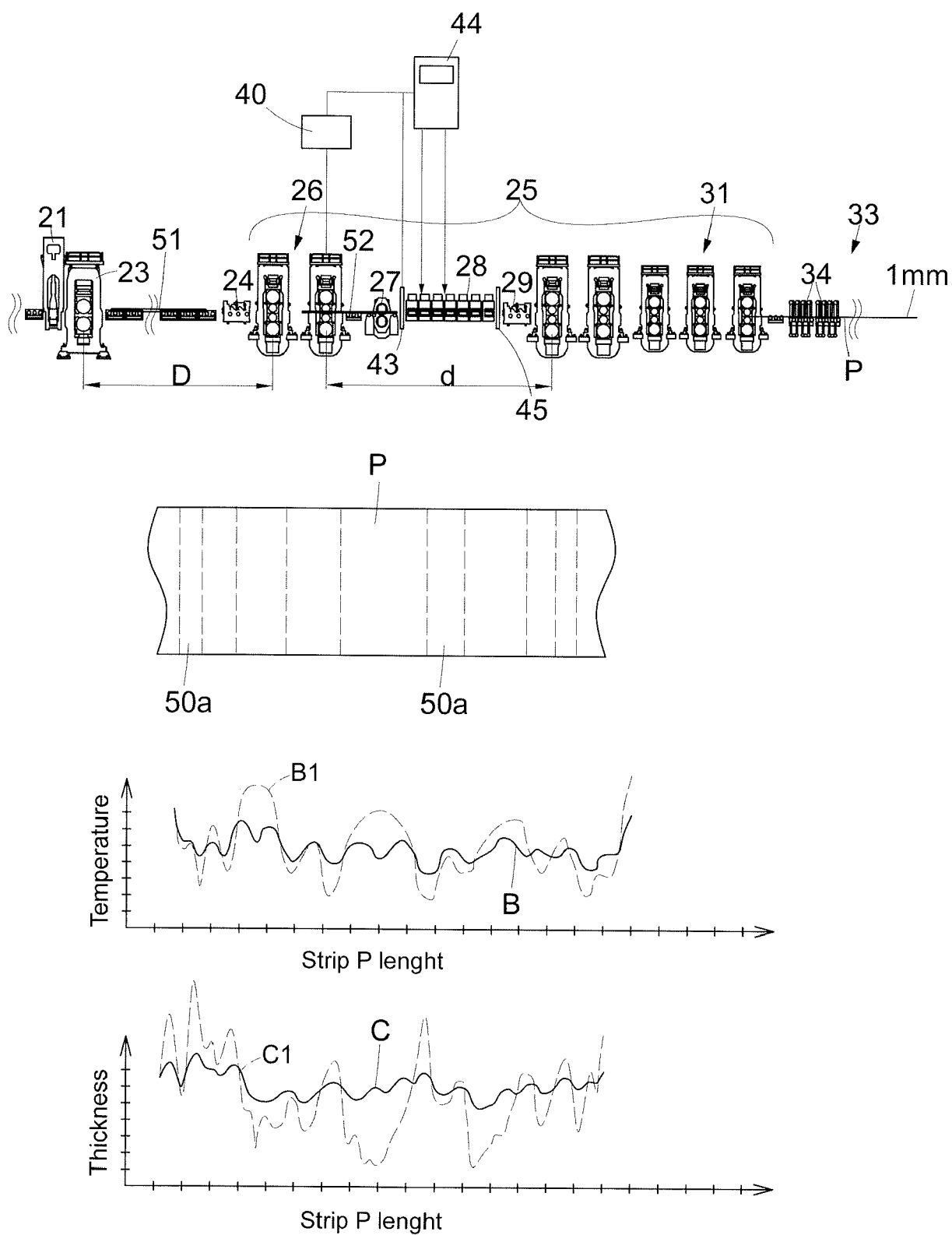
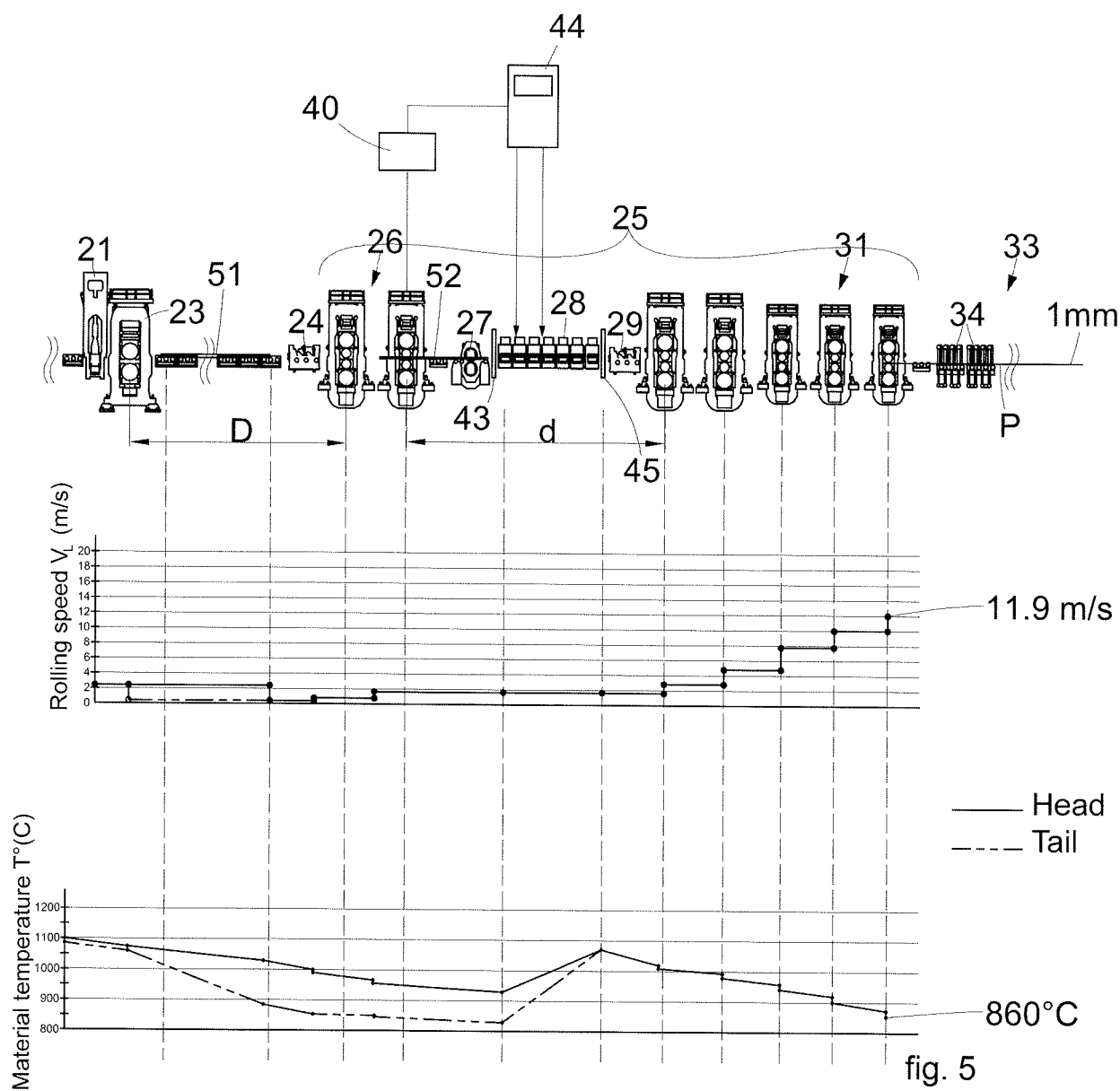


fig. 4



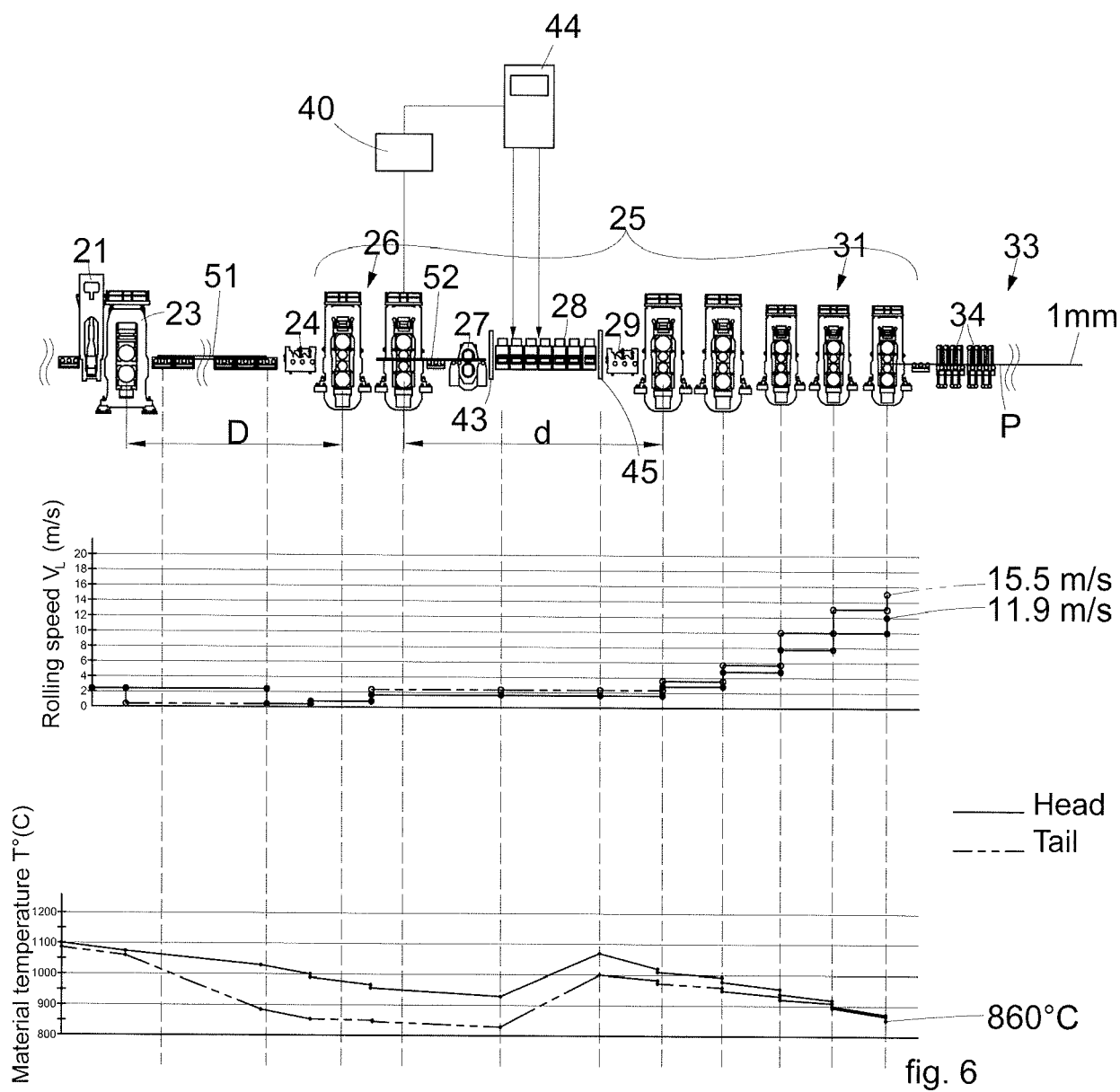


fig. 6



EUROPEAN SEARCH REPORT

Application Number

EP 24 15 4031

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Place of search Munich		Date of completion of the search 17 April 2024	Examiner Frisch, Ulrich
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	

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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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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