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(54) **COMPACT INTENSE COOLING DEVICE FOR STRIP IN COLD ROLLING MILL**

(57) The present invention relates to a device for cooling a flat or long metallurgical product (1) of a given width in a cold rolling mill, comprising a header (8) provided with a means for supplying a liquid coolant, a header table (28) comprising a plurality of nozzles arranged according to a well-defined two-dimensional pattern (27) for creating low pressure coolant jets towards a bottom surface of the product (1), a means for locating said header table (28) at short distance of the product (1), so as to

create a homogeneous highly turbulent liquid coolant cushion at low pressure on the surface of the product (1) in front of the header table (28), in the volume restricted by the product (1) and the header table (28), wherein the device further comprises means (15, 16, 17, 21, 30) for preventing coolant jets to be generated outside of the product (1) according to the width thereof and/or for preventing such coolant jets from splashing and from falling back onto a top surface of the product (1).

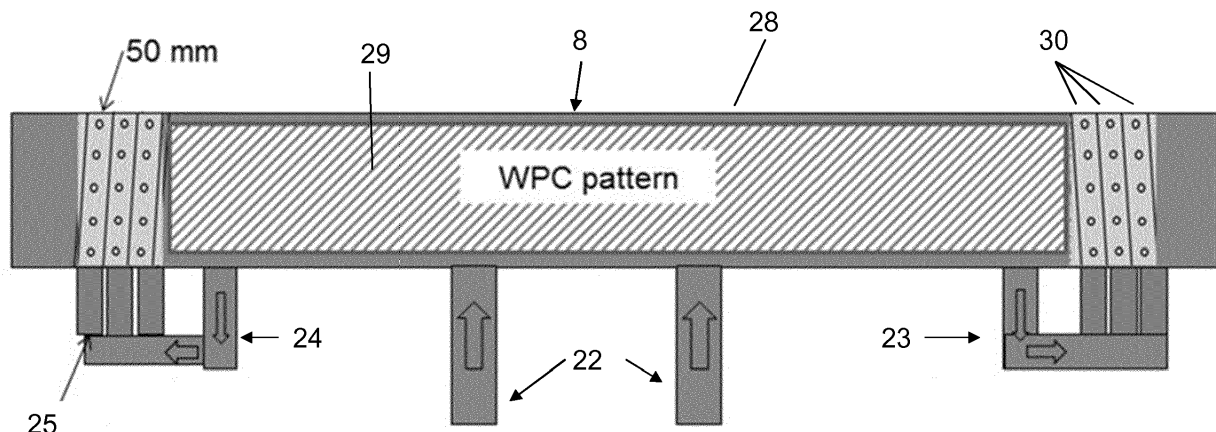


FIG. 7

Description

Field of the invention

[0001] The present invention relates to improvements in the frame of enhanced metal strip cooling methods, and particularly in the frame of the so-called water pillow cooling (WPC) technology, to be applied in the cold rolling mill. In particular, such improvements are also dedicated to avoiding the presence of coolant and dirt on the strip surface.

[0002] The invention also relates to the device for carrying out the method.

Technological background and prior art

[0003] In order to reduce the cost ratio in cold rolling mills, managers are continuously increasing the productivity thereof. Combined with the trend to roll strips with increased rolling speed, higher reduction, higher strength and with higher surface quality requirements, the mills are confronted with several operational problems.

[0004] One of the main restrictions is the increase of heat generation in the roll bite, which transfers further load onto the cold rolling mill cooling system in order to control roll and strip temperatures and leads to a decrease of lubrication properties. It is known that, due to this higher roll bite temperature, the lubricant will lose its viscosity and this will lead at some extent to a breakdown of the lubrication film.

[0005] As current mill cooling systems are not well adapted, this leads to either generation of strip defects that affect product quality (e.g. heat scratches or streaks, heat and shatter marks, flatness defects) or to a decrease in rolling speed (necessary to avoid these defects, and to avoid quickly rising rolling forces).

[0006] Therefore improved cooling is today a key requirement to increase mill performance and to assure the competitiveness of the cold rolling mill. In particular it becomes more and more important to control the roll bite temperature at higher cold rolling speeds by enhanced homogeneous cooling strategies. In order to set up enhanced homogeneous cooling, the Applicant has developed as from 1984 the so-called "Water Pillow Cooling" (WPC), which carries out a method consisting in building up high turbulence in a water cushion created on the surface of the product to be cooled thanks to the injection of straight water jets at low pressure through nozzles or holes drilled in a header.

[0007] Moreover, a related cooling technology, the so-called high turbulence roll cooling (HTRC), was already developed and patented by the Applicant under WO 2008/104037 (US 2010/0089112, etc.). It is related to a highly turbulent roll cooling device working at low pressure, under the form of a concave header provided on its internal surface with a determined pattern of nozzles or bore holes.

[0008] The industrialisation of the highly turbulent

WPC technology for metal strips as shown in FIG. 1 and FIG.2 was tested and validated in a cold strip mill, in the framework of the European pilot and demonstration RFCS project "Intense Cooling In Cold Rolling (or IN-COOL)" (see WO 2014/167138).

[0009] The above-mentioned industrial WPC strip cooling header of the Applicant was operationally integrated in the existing bottom guidance table between stand 2 and 3.

[0010] The one-sided intensive cooling results in an efficient cooling of the entire thin strip product. This could be verified in reduced surface defect occurrence on the bottom as well as on the top surface. Moreover, because only the bottom of the strip product surface is cooled, a limited interference with the direct oil or emulsion application is realised. Furthermore, thanks to the efficient low pressure cooling technology developed by the Applicant, the reduction of electric pump energy by using WPC contributes to a lower environmental impact.

[0011] A direct result of the efficient strip cooling is an increased rolling speed and a decreased occurrence of temperature-related heat defects. This is especially the case for cold rolling mills which are usually producing at the limits of their capabilities. A second result is a lower temperature in the roll bite to obtain enhanced lubrication properties (higher viscosity) to lower the rolling forces.

[0012] One of the problems which have been addressed to date in the INCOOL-project is the absence of width-control in the WPC cooling headers. This means that for a narrower strip, water can be sprayed next to and out of the strip, on each side thereof. FIG. 3 schematically shows the effect of water being sprayed at the sides of the strip consisting in possible fallbacks draining off oil, dirt, etc. onto the strip.

[0013] This can give problems like the following :

- the coolant may hit dirty (e.g. oily) parts of the mill and some dirt may fall back onto the strip, resulting in product rejection by the quality control;
- the coolant may splash over the damming rolls and end up in the lubrication zone, thereby disturbing the lubrication process.

Aims of the invention

[0014] The present invention aims at providing an efficient strip cooling at the cold rolling mill which additionally provides width-control in the cooling header.

[0015] In particular the invention also aims at providing a solution to avoid the presence of (excessive) coolant and dirt on the strip surface, resulting in a cooling which is out-of-control regarding the width-aspect cooling, by reducing or preventing the above-mentioned side-sprays.

Summary of the invention

[0016] A first aspect of the present invention is related

to a device for cooling a flat or long metallurgical product of a given width in a cold rolling mill, comprising a header provided with a means for supplying a liquid coolant, a header table comprising a plurality of nozzles arranged according to a well-defined two-dimensional pattern for creating low pressure coolant jets towards a bottom surface of the product, a means for locating said header table at short distance of the product, so as to create a homogeneous highly turbulent liquid coolant cushion at low pressure on the surface of the product in front of the header table, in the volume restricted by the product and the header table, wherein the device further comprises means for preventing coolant jets to be generated outside of the product according to the width thereof and/or for preventing such coolant jets from splashing and from falling back onto a top surface of the product.

[0017] According to preferred embodiments, the device is further limited by one or a suitable combination of the following characteristics:

- said means comprise side plates located at the lateral sides of the product, interposed before and parallel to the latter, said plates preventing side coolant jets beyond the width of the product from impinging on the product top surface ;
- said means comprise side plates located at the lateral sides of the product and behind the latter, said plates being not parallel to the product, and inclined so as to deflect outwards side coolant jets, the latter being not impinging on the product top surface ;
- said means comprise sideways-oriented nozzles which are positioned either close to each side of the header or as from the middle of the header to the sides thereof;
- a number of evacuation orifices of the coolant are machined in the header table ;
- upstanding edges are provided at the lateral sides of the header table to further restrict the volume for the highly turbulent liquid coolant cushion at low pressure ;
- the device is provided with means for generating ultrasonic waves inside the highly turbulent liquid coolant cushion ;
- the header is made of at least three compartments in the direction transverse to the product displacement, which can be each fed or not with coolant, in all or nothing mode, so as to adapt the cooling width to the width of the product;
- the header comprises a central compartment and at least three side compartments at each side thereof in the direction transverse to the product displacement, which can be each fed or not with coolant, in all or nothing mode, so as to adapt the cooling width to the width of the product;
- the central compartment of the header is fed by a primary coolant supply and the side compartments are fed from the central compartment by a secondary coolant supply equipped with valves ;

- the side compartments are inclined of an angle ranging from 0° to 30° about the moving direction of the strip ;
- the header table is further provided with a high pressure flat jet nozzle row for cooling purpose and for wiping coolant outwards ;
- the device comprises a compact integrated work roll cooling device.

[0018] A second aspect of the present invention relates to a method for cooling a flat or long metallurgical product in a cold rolling mill, by using the cooling device as described above, comprising the following steps:

- positioning said cooling device on the entry or exit side of work rolls of a rolling stand or between two rolling stands, and on the bottom side of the product, so as to create a gap between the internal surface provided with nozzles and the product being comprised between 5 and 200 mm ;
- supplying one or more compartments of the header of the cooling device, in the direction transverse to the product moving direction, with a liquid coolant and spraying the latter into said gap on the product, so as to restrict the width of the spraying to the product width ;
- adjusting the pressure of the liquid coolant to a value of between 0.1 and 4 bar and the specific flow rate between 10 and 500 m³/hour/m², in order to create in said gap a liquid coolant cushion in a highly turbulent state.

[0019] Advantageously, the liquid coolant is an emulsion consisting essentially of water comprising an amount of oil between 0.05% and 4%, and preferably less than 1%.

Brief description of the drawings

[0020]

FIG. 1 schematically represents the principle of WPC strip cooling applied to the cold rolling mill, according to prior art.

FIG. 2 is an example of schematic layout for the experimental setup intended for WPC strip cooling, according to prior art.

FIG. 3 schematically shows vertically upwards oriented nozzles leading to spraying outside of the strip and splashing, according to prior art.

FIG. 4A schematically represents sideways oriented nozzle jets according to one embodiment of the present invention. FIG. 4B schematically represents headers having several transverse compartments inside which can be switched on/off for width adaptable cooling, according to another embodiment of the invention. FIG. 4C schematically represents a header with movable side plates for width-adaptable

cooling according to still another embodiment of the invention. FIG. 4D schematically represents a header with water edge masking plates according to still another embodiment of the invention.

FIG. 5 represents a WPC header having holes machined on the header table for faster water evacuation.

FIG. 6A schematically represents a WPC header with upstanding walls at the edges outside of the strip while FIG. 6B schematically represents such a WPC header with integrated ultrasonic actuators.

FIG. 7 schematically is a plane view representing the concept of a width-adaptable cooling device according to a preferred embodiment of the present invention with different side sections controlled by valves.

FIG. 8 shows a perspective view of an embodiment for a realistic compact WPC design according to the present invention, integrated with a work roll cooling device.

Description of detailed embodiments of the invention

[0021] Figure 1 schematically shows the implementation of a WPC strip cooling system at the cold rolling mill according to the present invention. Two stands (n, n+1) have been represented on FIG. 1. Each stand has two work rolls 2, and on its strip entry side, a strip lubrication system 5 provided with neat oil and a roll cooling and lubrication system by emulsion 6. At the exit side of stand n is a roll cooling emulsion system 7, a wiping roll 3 and a tension roll 4. The WPC strip cooling device 8 is also located at the exit side of the first stand n.

[0022] The cooling system should enable higher rolling speeds without running into temperature-related strip defects. Inevitably the necessary pump energy decreases in comparison with more conventional cooling techniques because the turbulent cooling techniques operate here at low pressure.

[0023] In strip cooling, the water cushion is determined by the coolant flow and the evacuation speed of the coolant liquid. This clearly indicates that each application requires a detailed study of coolant flow and coolant performance strongly influenced by the size and geometry of the cooling headers. Also, the scope of the present invention is not restricted by the detailed engineering characteristics presented below.

Experimental procedures

[0024] Cold rolling pilot line tests were performed at an industrial cold strip mill with a WPC strip cooling unit prototype. The strip cooling unit, pyrometers and a lubrication system were integrated in a cold rolling pilot facility. The full layout is schematically given in FIG. 2.

[0025] The mill was used in the two-high configuration with a work roll 2 having a diameter of 397 mm and a Ra-

roughness of 1 micron. The material grade (temper 61 C) had an initial strip thickness of 1.82 mm. The material width was 100 mm. It is a single stand reversible mill (uncoiler 9, coiler 10) that can run in two-high (work roll 2 diameter = 400 mm) or four-high configuration (work roll 2 diameter = 140 mm). An entry roll cooling 13 is provided to the work rolls 2. Temperature at the entry side and the exit side of the work rolls 2 are measured by pyrometers 12. All relevant process parameters are automatically logged. The specifications of the mill enable the simulation of rolling process in production mills. Coolant emulsion is applied by a recirculation system (capacity of 4000 l). Extra lubricant was applied with Direct-Application unit (DA) 11.

Various embodiments of the invention and related functions

[0026] In one embodiment represented on FIG. 4A, the header 8 is provided with sideways-oriented nozzles 15 so as to partially or fully prevent that the upwards water jets next to the strip finally fall down back on the top surface (as represented on FIG. 3 in the absence of sideways-oriented nozzles). This very simple solution prevents water accumulation on the strip top surface. Sideways-oriented nozzles 15 are positioned either only at the side of the header 8 or can start from the middle of the header 8 to provide even better water evacuation.

[0027] In one embodiment, the WPC header 8 is composed of a number of compartments or sections 21 (A, B, C, etc.), which can be each and independently "switched on or off", i.e. fed with water or not, using individual external or internal valves. This allows to easily adapt cooling to the width of the strip 1 (FIG. 4B).

[0028] In another embodiment, a parallel moving side-plate 16 is provided on each side of the strip product 1 so that to reject back the upwards sprayed water. Advantageously the moving plates are following the strip width and are positioned between the WPC header 8 and the strip product 1 (FIG. 4C). As a result, the water jets will not hit the other parts of the mill and will not fall back on the top surface of the strip product.

[0029] In an alternative embodiment, water edge-masking plates 17 are located behind the strip product 1 and oriented/inclined so that the upwards water jets next to the sides of the strip product 1 are rejected backwards or outwards, the water being not hitting other parts of the mill and not falling back on the top surface of the strip product (FIG. 4D).

[0030] In one embodiment, a number of orifices 18 are machined in the WPC header 8 for faster evacuation of coolant and thus for more efficient cooling (FIG. 5).

[0031] In one embodiment, upstanding edges 14 are provided on the sides of the table in order to create the homogeneous water pillow cushion 19 so that the water evacuation through the front and back of the WPC header 8 is delayed (FIG. 6A). So, a homogeneous turbulent cushion is ensured along the width of the strip. Addition-

ally, thanks to the presence of a water pillow cushion 19, an ultrasonic cleaning mechanism 20 may be advantageously implemented inside the WPC header 8 (FIG. 6B).
[0032] In one embodiment (not shown), a row of high pressure flat jet nozzles may be integrated in the WPC header for strip cleaning, while the low pressure WPC nozzles are used for strip cooling. The high pressure nozzles are also used as a wiper so that the water can be directly and quickly evacuated.

EXAMPLE

[0033] According to a preferred embodiment tested on pilot installation, and shown on FIG. 7, the WPC nozzle pattern header 8 will be fed in a central compartment 29 by a primary coolant supply 22, while, on each side, up to three cooling zones 30 can be activated using suitable valves 25 interposed in a secondary coolant supply, a right secondary supply 23 and a left secondary supply 24. The valves 25 will be chosen in order to satisfy the requirements of pressure, flow rate, controllability, durability and accessibility. Also the valves 25 need to be very compact so they can fit within the header enclosure.

[0034] Advantageously, on each side, the cooling zones 30 are inclined of an angle ranging from 0° to 30° about the moving direction of the strip.

[0035] Finally FIG. 8 depicts an embodiment for a work roll cooling device 26 that is integrated in a very compact manner with the above strip cooling device 8.

Symbols of reference

[0036]

1. Metal strip
2. Work roll
3. Wiping roll
4. Tension roll
5. Strip lubrication (neat oil)
6. Roll cooling & lubrication by emulsion
7. Roll cooling by emulsion
8. Strip cooling header (WPC)
9. Uncoiler
10. Coiler
11. Direct oil application (DA)
12. Pyrometer
13. Entry roll cooling
14. Upstanding edge
15. Sideways-oriented nozzle
16. Parallel moving plate
17. Oblique moving plate
18. Coolant evacuation orifice
19. Coolant cushion
20. Ultrasonic actuator
21. Compartment of the header
22. Primary coolant supply
23. Secondary right coolant supply
24. Secondary left coolant supply

25. Selection valve
26. Integrated work roll cooling
27. Cooling nozzle pattern
28. Header table
29. Central compartment
30. Side compartment

Claims

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1. A device for cooling a flat or long metallurgical product (1) of a given width in a cold rolling mill, comprising a header (8) provided with a means for supplying a liquid coolant, a header table (28) comprising a plurality of nozzles arranged according to a well-defined two-dimensional pattern (27) for creating low pressure coolant jets towards a bottom surface of the product (1), a means for locating said header table (28) at short distance of the product (1), so as to create a homogeneous highly turbulent liquid coolant cushion at low pressure on the surface of the product (1) in front of the header table (28), in the volume restricted by the product (1) and the header table (28), wherein the device further comprises means (15, 16, 17, 21, 30) for preventing coolant jets to be generated outside of the product (1) according to the width thereof and/or for preventing such coolant jets from splashing and from falling back onto a top surface of the product (1).

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2. The device according to Claim 1, wherein said means comprise side plates (16) located at the lateral sides of the product (1), interposed before and parallel to the latter, said plates (16) preventing side coolant jets beyond the width of the product from impinging on the product top surface.

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3. The device according to Claim 1, wherein said means comprise side plates (17) located at the lateral sides of the product (1) and behind the latter, said plates (17) being not parallel to the product (1), and inclined so as to deflect outwards side coolant jets, the latter being not impinging on the product top surface.

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4. The device according to Claim 1, wherein said means comprise sideways-oriented nozzles (15) which are positioned either close to each side of the header (8) or as from the middle of the header (8) to the sides thereof.

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5. The device according to Claim 1, wherein a number of evacuation orifices (18) of the coolant are machined in the header table (28).

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6. The device according to Claim 1, wherein upstanding edges (14) are provided at the lateral sides of the header table (28) to further restrict the volume for

the highly turbulent liquid coolant cushion at low pressure.

7. The device according to Claim 6, wherein it is provided with means for generating ultrasonic waves (20) inside the highly turbulent liquid coolant cushion. 5
8. The device according to Claim 1, wherein the header (8) is made of at least three compartments (21) in the direction transverse to the product displacement, which can be each fed or not with coolant, in all or nothing mode, so as to adapt the cooling width to the width of the product (1). 10
9. The device according to Claim 1, wherein the header (8) comprises a central compartment (29) and at least three side compartments (30) at each side thereof in the direction transverse to the product displacement, which can be each fed or not with coolant, in all or nothing mode, so as to adapt the cooling width to the width of the product (1). 15 20
10. The device according to Claim 9, wherein the central compartment (29) of the header (8) is fed by a primary coolant supply (22) and the side compartments (30) are fed from the central compartment by a secondary coolant supply (23, 24) equipped with valves (25). 25
11. The device according to Claim 9, wherein the side compartments (30) are inclined of an angle ranging from 0° to 30° about the moving direction of the strip. 30
12. The device according to Claim 1, wherein the header table (28) is further provided with a high pressure flat jet nozzle row for cooling purpose and for wiping coolant outwards. 35
13. The device according to Claim 1, comprising a compact integrated work roll cooling device (26). 40
14. A method for cooling a flat or long metallurgical product (1) in a cold rolling mill, by using the cooling device of Claim 1, comprising the following steps: 45
 - positioning said cooling device on the entry or exit side of work rolls (2) of a rolling stand or between two rolling stands, and on the bottom side of the product (1), so as to create a gap between the internal surface provided with nozzles and the product (1) being comprised between 5 and 200 mm ; 50
 - supplying one or more compartments of the header of the cooling device, in the direction transverse to the product moving direction, with a liquid coolant and spraying the latter into said gap on the product (1), so as to restrict the width of spraying coolant to the width of the product 55

(1) ;

- adjusting the pressure of the liquid coolant to a value of between 0.1 and 4 bar and the specific flow rate between 10 and 500 m³/hour/m², in order to create in said gap a liquid coolant cushion in a highly turbulent state.

15. The method according to Claim 14, **characterized in that** the liquid coolant is an emulsion consisting essentially of water comprising an amount of oil between 0.05% and 4%, and preferably less than 1%.

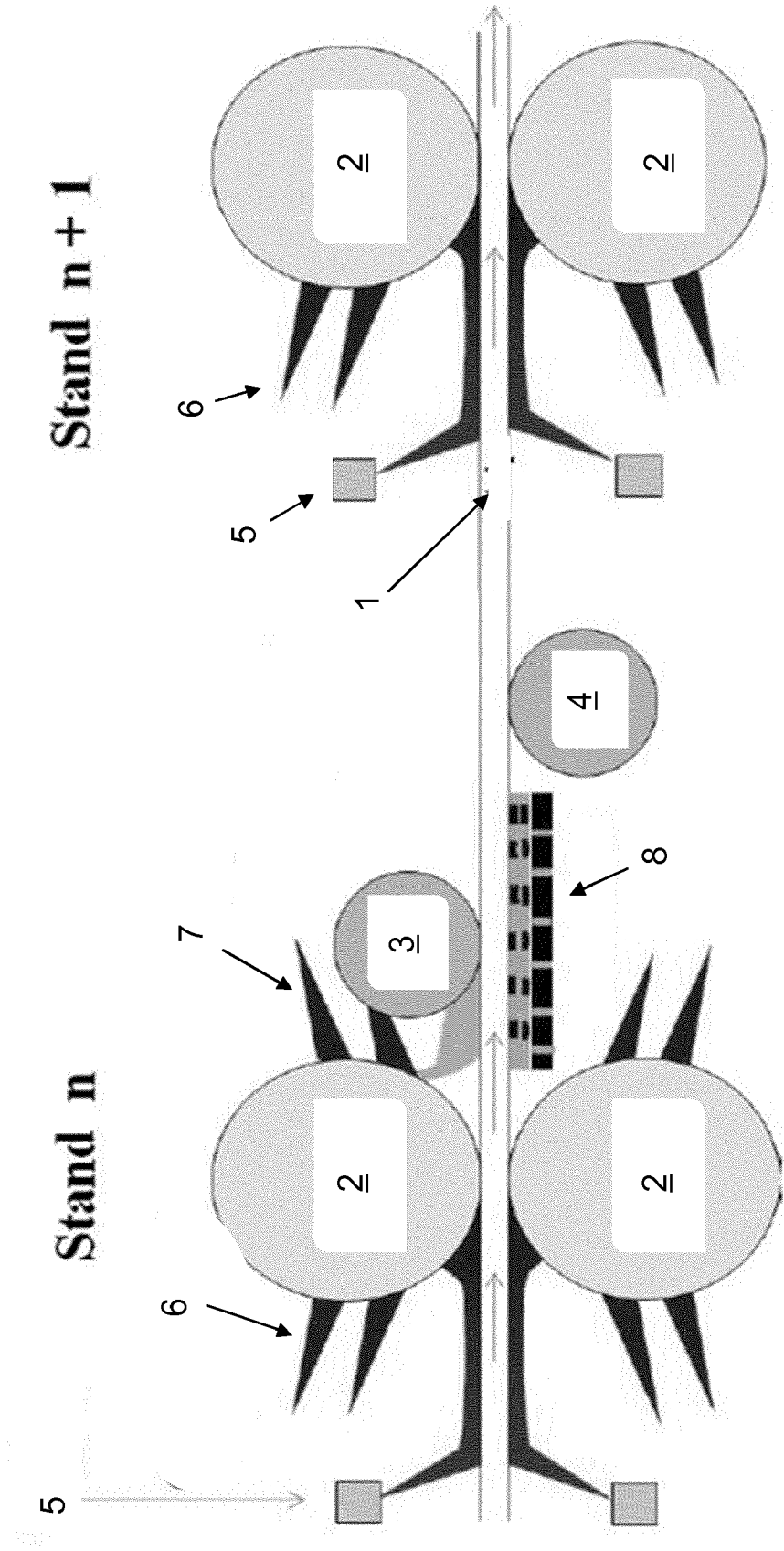


FIG. 1

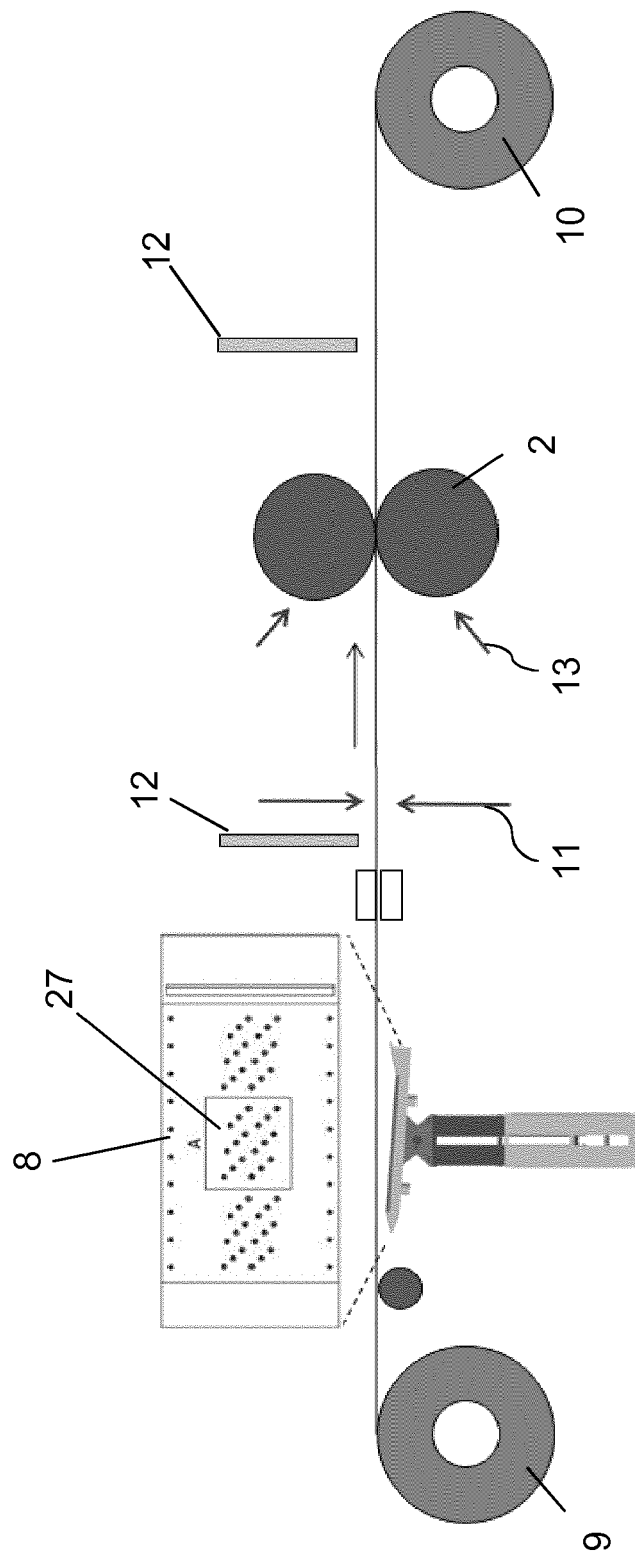


FIG.2

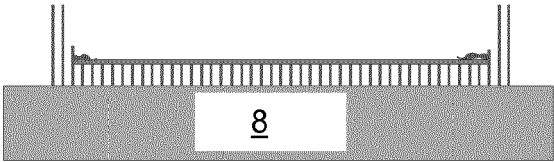


FIG. 3

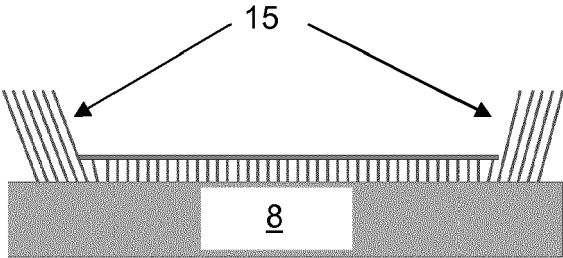


FIG. 4A

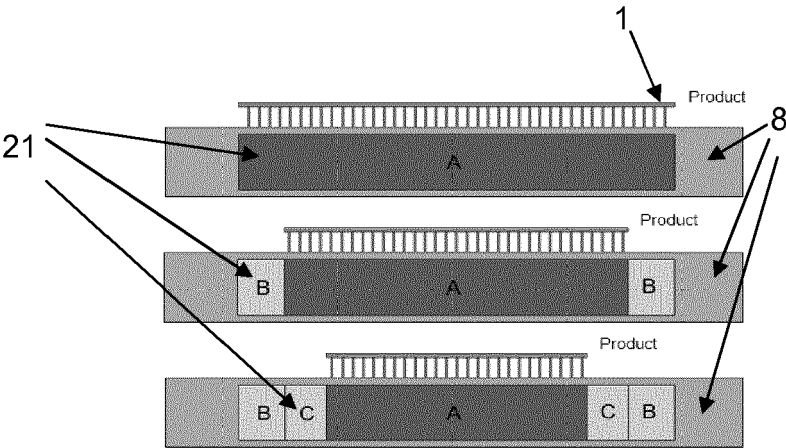


FIG. 4B

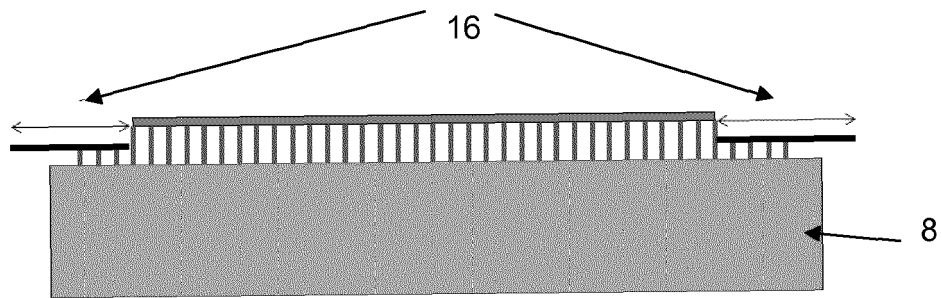


FIG. 4C

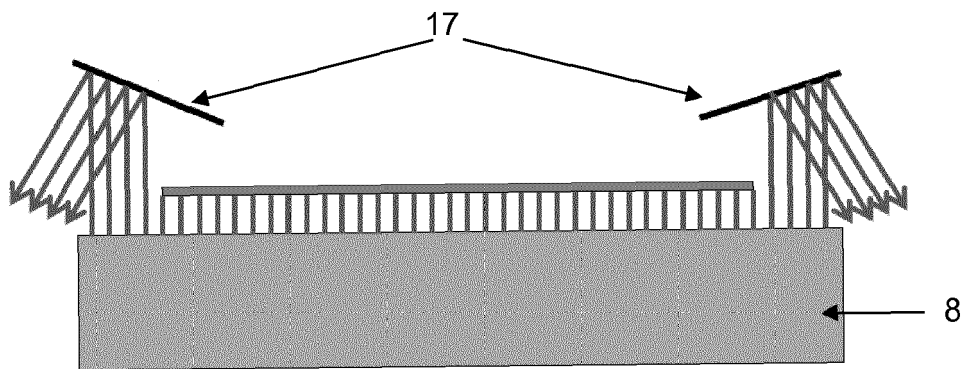


FIG. 4D

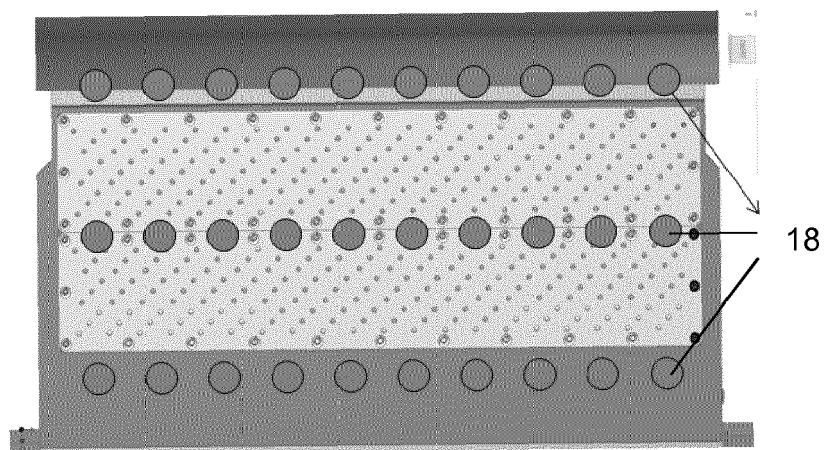


FIG. 5

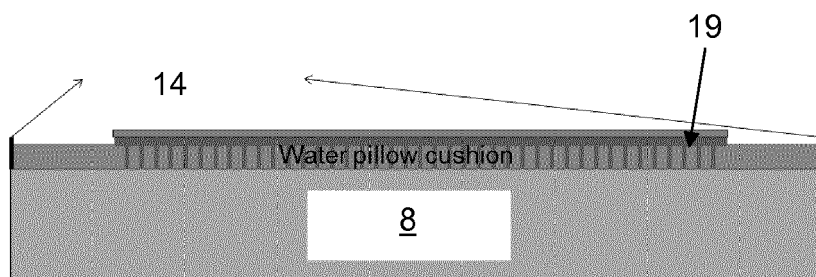


FIG. 6A

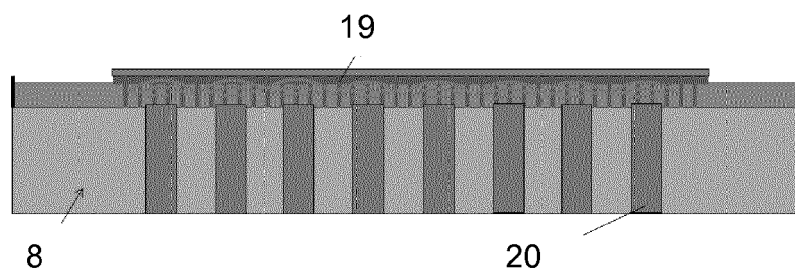


FIG. 6B

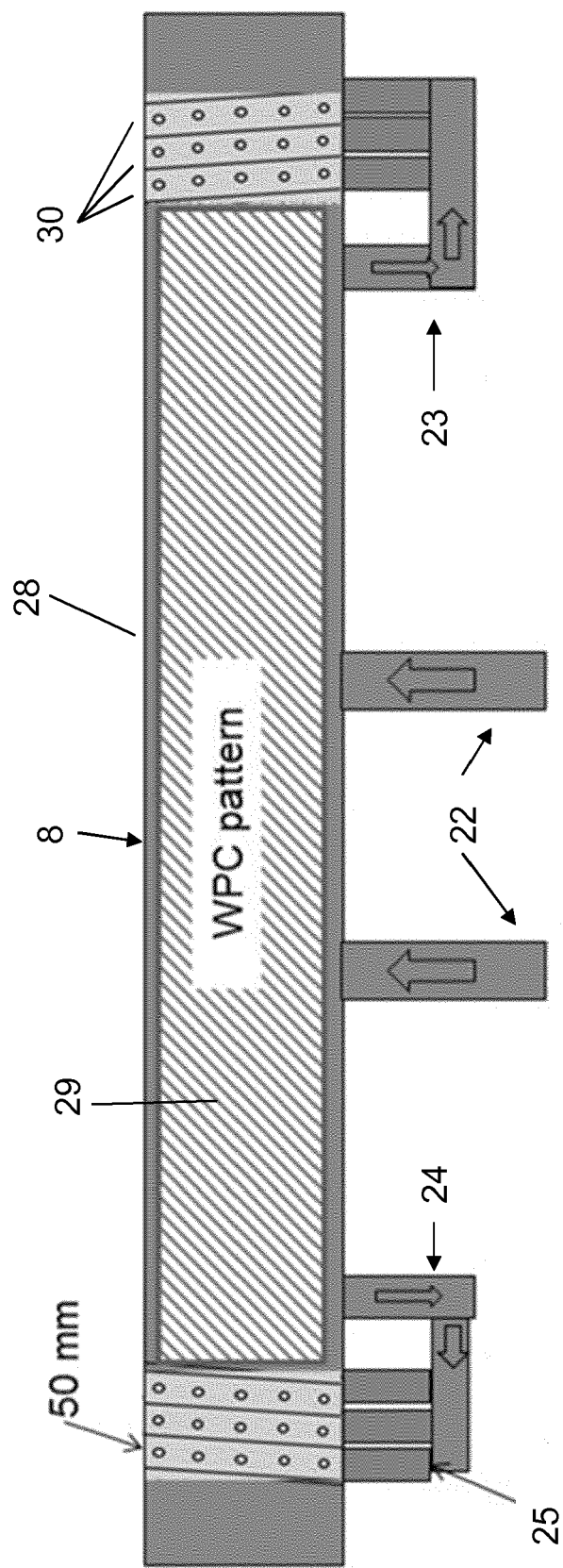


FIG. 7

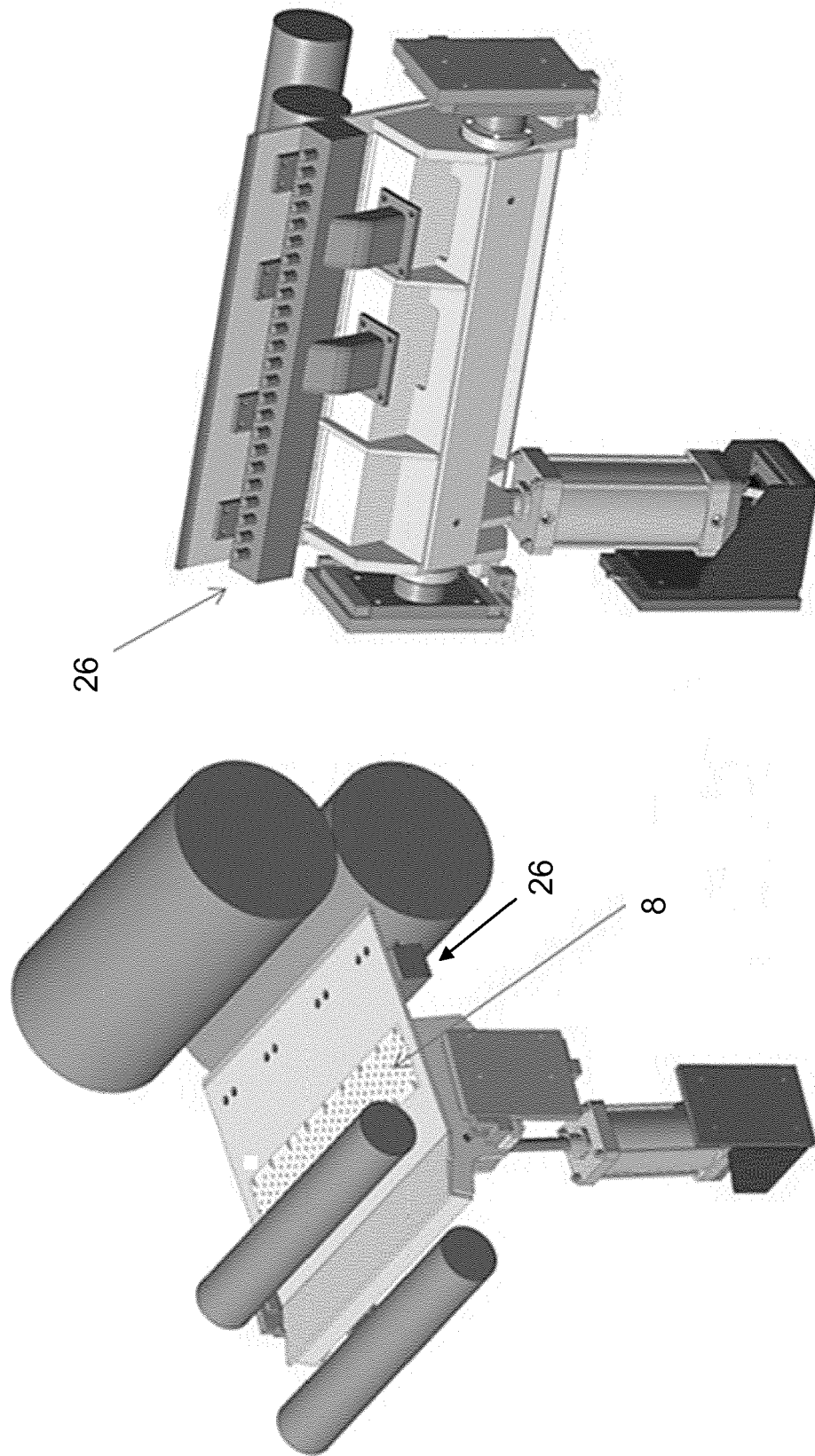


FIG. 8



EUROPEAN SEARCH REPORT

Application Number
EP 17 18 9898

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Place of search Munich		Date of completion of the search 15 February 2018	Examiner Frisch, Ulrich
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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