A method and device for controlled straightening and cooling of a wide metal strip, especially a steel strip (1) or sheet metal, running out of a hot rolled strip rolling mill, using pinching rollers (5) arranged in the moving direction of the strip (2) behind vertical double rollers (3,4), said pinching rollers producing a tensile stress (6) acting in a longitudinal direction. According to the invention, the range of use of conventional sheet metal cooling systems can be extended to obtain a more even surface of said steel strip (1) with an increased cooling effect. This is achieved by displacing the metal strip (1) or sheet metal between a pre-straightening machine (7) and splash cooling facility (8) in defined conditions of tensile stress (6) by adjusting the tensile stress (6) and by cooling said strip or sheet metal inside said splash cooling facility (8) between successive pairs (5a) of pinching rollers and by additionally controlling the tensile stress (6).
FIG. 1

A) Action of the Pinch Rolls (i) to (i + nc)

B) Action of the Pinch Rolls (i+1) to (i+nc+1)
METHOD AND DEVICE FOR CONTROLLED STRAIGHTENING AND COOLING OF A WIDE METAL STRIP, ESPECIALLY A STEEL STRIP OR SHEET METAL, RUNNING OUT OF A HOT ROLLED STRIP ROLLING MILL

[0001] The invention concerns a method and device for controlled straightening and cooling of wide metal strip, especially steel strip or sheet, running out of a hot-rolled strip mill, with the use of pinch rolls, which are installed after (in the direction of strip flow) vertical double rolls and produce a tensile stress that acts in the longitudinal direction.

[0002] The method and device described above are basically known from DE 33 13 024 A1, which discloses a method and a device for quenching passing steel sheet, especially heavy and medium sheet, with simultaneous controlled straightening, in which the sheet, before being quenched, is straightened in a plane while hot by at least two vertical double rolls arranged one behind the other. The sheet is then drawn through a quenching installation under controlled tensile stress by at least one double roll. This method is designed to quench passing steel sheet exactly to the predetermined mechanical properties without the development of warpage or distortion and at the same to reduce roughness that is already present. Despite these measures, inadequate flatness of the sheet continues to occur due to inadequate application of tensile stress, unfavorable cooling, and other unfavorable control measures. The cooling devices used in practice, which consist essentially of nozzle units or, for the aftercooling, of laminar water curtains, cannot really be improved any further. In principle, a U-tube is used for laminar cooling units. Of course, the highest attainable cooling intensities are obtained with nozzles and suitably selected parameters. The poor automatic control and regulation behavior is a disadvantage in general and at low flow rates in particular.

[0003] The objective of the invention is to extend the range of application of conventional sheet cooling systems to obtain greater flatness of the sheet with an increased cooling effect.

[0004] In accordance with the invention, this objective is achieved by moving the metal strip or sheet between a pre-straightening machine and a splash cooling installation under defined conditions of tensile stress by adjustment of the tensile stress and by cooling the metal strip or sheet inside the splash cooling installation between successive pairs of pinch rolls and additionally controlling the tensile stress. This directly produces plastic deformation before the metal strip or sheet passes into the cooling installation. The plastic deformation improves the flatness of the entering metal strip or sheet. Another advantage is gained by the arrangement of the straightening process immediately before the cooling, which prevents renewed buildup of internal stresses and deformations due to the nonuniform cooling on the surface of the metal strip or sheet.

[0005] The cooling effect is practically limited by the induction of stresses and deformations associated with these stresses in the sheet due to the nonuniform cooling effect of the cooling medium (water) on the surface of the sheet. This (unfavorable) effect occurs especially with the use of a relatively high cooling intensity on sheets that are thin and at the same time wide. The critical product of a plant is defined by a sheet with the least thickness at the maximum width and at the same time high intensity of the cooling. The intensity of the cooling is defined by a high temperature difference between the initial and final cooling temperature using a short cooling time. In practice, pinch rolls are intended to hinder this deformation effect. However, the effect of this form of compensation is limited. The arrangement of the pre-straightening machine before the cooling installation in accordance with the invention brings about plastic deformation and reduces entry deformations and stresses directly before the cooling installation.

[0006] The deformations on entry into the cooling installation can be combated especially effectively by adjusting the tensile stress by switching the speed to the respective next or last supporting pinch roll with progressive passage of the metal strip or sheet.

[0007] In one embodiment, the pinch rolls are set with a spacing such that a cooling unit is formed between two rolls, depending on the spacing.

[0008] In a refinement of the invention, this spacing can be adjusted to a half-length of the resulting characteristic form for a strip or sheet with the least thickness, at maximum width and high cooling intensity.

[0009] The device for the controlled straightening and cooling of a wide metal strip, especially a steel strip or sheet, running out of a hot-rolled strip mill is equipped with vertical pairs of double rolls and pairs of pinch rolls which follow them (in the direction of strip flow), between each of which a cooling unit is installed.

[0010] In accordance with the invention, the stated objective is achieved with a device of this type by installing a pre-straightening machine before the pairs of pinch rolls with the cooling units, between which a controlled tensile stress can be produced. This makes it possible to transmit a tensile force even before the cooling, so that the magnitude of the deformations that are present is already reduced here. An even more exact determination of the tensile stresses inside the cooling units then occurs.

[0011] In accordance with other features, the cooling units are each designed for a high and an intermediate cooling intensity.

[0012] The effect of the cooling can be increased still further by providing the cooling unit with finely adjustable cooling elements at the outlet of the metal strip.

[0013] The cooling can be further developed in such a way that the cooling unit is designed for a high and/or an intermediate cooling intensity in accordance with a predetermined product spectrum.

[0014] The invention can be further improved by also making it possible to produce tensile stresses between the last, supporting pinch rolls or the straightening rolls at the trailing end of the metal strip or sheet and the pinch rolls or the straightening rolls at the leading end of the metal strip or sheet.

[0015] The embodiments of the invention illustrated in the drawings are explained in greater detail below.

[0016] FIG. 1 shows a system diagram of the cooling with pinch rolls and of the drive control with the tensile stresses produced.
FIG. 2A shows a perspective view of the steel strip or sheet with distortions in the form of center waviness.

FIG. 2B shows a side view of two pairs of pinch rolls arranged with a certain spacing distance.

FIG. 3 shows the arrangement of the cooling devices for the given cooling intensity.

FIG. 4 shows a view of a total installation for straightening and cooling.

The metal strip, especially the steel strip 1 or sheet, is conveyed by a tensile stress 6 acting in the longitudinal direction (strip flow direction 2) for controlled cooling and straightening with the use of pinch rolls 5 arranged after in the direction of strip flow 2 vertical, double rolls 3 and 4. In the process, the metal strip 1 is moved between a pre-straightening machine 7 and a splashing cooling installation 8 under defined conditions of tensile stress 6 by adjustment of the tensile stress (by the straightening roll rotational drive motors). The metal strip 1 is then cooled inside the splash cooling installation between successive pairs of pinch rolls 5a. The tensile stress is additionally controlled. The splash cooling installation 8 comprises cooling units 9 installed between each two pairs of pinch rolls 5a. (FIG. 1).

While the metal strip 1 is entering at roller table speed 1, the tensile stress 6 is controlled via a suitable torque 11 by a feedback control system 12, which is designated (A) action of the pinch rolls 5 (i) to (i+nc). As soon as the trailing end 1a of the strip passes through, which is designated (B) action of the pinch rolls 5 (i) to (i+nc), suitable tensile stress is transmitted to the trailing end 1a of the strip, and only the comparison speed is measured beyond the end 1a of the strip without using the feedback control system 12. Both for the trailing end 1a of the strip and the leading end 1b of the strip, the tensile stress 6 is adjusted by switching the speed to the respective next or last supporting pinch roll 5 with progressive passage of the metal strip (see FIG. 1).

The pinch rolls 5 are installed with a certain spacing 13, such that the cooling unit 9 is formed between two pinch rolls 5, depending on the spacing 13. For example, the spacing 13 can be based on a half-length 14 of the resulting wavelength 15 for a metal strip with the least thickness, at maximum width and high cooling intensity. The typical wavelength 15 develops in the steel strip 11 (FIG. 2A).

The cooling units are each designed for a high or an intermediate cooling intensity (FIG. 2B), such that the spacing 13 corresponds to the half wavelength 15 (cf. FIG. 2B). The behavior of the wave 16 is clearly shown by the dotted lines 17 in FIGS. 2A and 2B.

FIG. 3 shows the cooling effect of the different individual types of cooling devices 9. In the graph of temperature as a function of time, the solid curve represents the behavior of the temperature 20 in the center of the strip or sheet, and the broken curve represents the surface temperature 21. Splash cooling units 8u are used in the sections (1). Cooling units 9, which consist of U-tube units 22, are provided at the outlet 18 of the steel strip 1.

On the basis of the temperature ΔT-center (1), the temperature in the center of the steel strip 1 or the temperature ΔT-center (2) is reached.

The temperature ΔT-surface is reached while still in the zone of the splash cooling units 8u. When the U-tube units 22 are used, the necessary cooling stop temperature is attained in small increments by the U-tube units 22. Martensite formation by surface subcooling is prevented above the temperature T-martensite.

Tensile stresses 6 can be produced in the same procedure between the last supporting pinch rolls 5 or straightening rolls 23 at the trailing end 1a of the metal strip 1 or sheet and the pinch rolls 5 or the straightening rolls 24 at the leading end 1b of the metal strip 1.

FIG. 4 shows a complete installation, in which, in the direction of strip flow 2, the pre-straightening machine 7 is followed by the splash cooling installation 8 with the pairs of pinch rolls 5a and the cooling units 9 and then by a laminar cooling installation 25.

List of Reference Numbers

0029 1 metal strip, steel strip or sheet
0030 1a trailing end of the strip
0031 1b leading end of the strip
0032 2 direction of strip flow
0033 3 double roll
0034 4 double roll
0035 5 pinch roll
0036 5a pair of pinch rolls
0037 6 tensile stress.
0038 7 pre-straightening machine
0039 8 splash cooling
0040 8u splash cooling units
0041 9 cooling unit
0042 10 roller table speed
0043 11 torque
0044 12 feedback control system
0045 13 spacing
0046 14 half-length
0047 15 resulting wavelength
0048 16 wave behavior
0049 17 dotted line
0050 18 outlet
0051 19 cooling element
0052 20 strip or sheet center
0053 21 surface temperature
0054 22 U-tube units
0055 23 straightening roll
0056 24 straightening roll
0057 25 laminar cooling installation
1. Method for controlled straightening and cooling of wide metal strip, especially steel strip or sheet, running out of a hot-rolled strip mill, with the use of pinch rolls, which are installed after (in the direction of strip flow) vertical double rolls and produce a tensile stress that acts in the longitudinal direction, wherein the metal strip or sheet is moved between a pre-straightening machine and a splash cooling installation under defined conditions of tensile stress by adjustment of the tensile stress, and that the metal strip or sheet is cooled inside the splash cooling installation between successive pairs of pinch rolls, and the tensile stress is additionally controlled.

2. Method in accordance with claim 1, wherein the tensile stress is adjusted by switching the speed to the respective next or last supporting pinch roll with progressive passage of the metal strip or sheet.

3. Method in accordance with claim 1, wherein the pinch rolls are set with a spacing, such that a cooling unit is formed between two rolls, depending on the spacing.

4. Method in accordance with claim 3, wherein this spacing can be adjusted to a half-length of the resulting characteristic form for a strip or sheet with the least thickness, at maximum width and high cooling intensity.

5. Device for controlled straightening and cooling of a wide metal strip, especially steel strip or sheet, running out of a hot-rolled strip mill, with vertical pairs of double rolls followed (in the direction of strip flow) by pairs of pinch rolls, between each of which a cooling unit is installed, wherein a pre-straightening machine (7) is installed before the pairs of pinch rolls (5a) with the cooling units (9), between which a controllable tensile stress can be produced.

6. Device in accordance with claim 5, wherein the cooling units (9) are each designed for a high and an intermediate cooling intensity.

7. Device in accordance with claim 5, wherein the cooling unit (9) is provided with finely adjustable cooling elements (19) at the outlet (18) of the metal strip (1).

8. Device in accordance with claim 5, wherein the cooling unit (9) is designed for a high and/or an intermediate cooling intensity in accordance with a predetermined product spectrum.

9. Device in accordance with claim 5, wherein tensile stresses (6) can also be produced between the last, supporting pinch rolls (5) or the straightening rolls (23) at the trailing end (1a) of the metal strip (1) or sheet and the pinch rolls (5) or the straightening rolls (24) at the leading end of the metal strip (1) or sheet.

* * * * *