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(71) Applicant: **KAWASAKI STEEL CORPORATION**
1-28, Kitahonmachi-Dori 1-Chome
Chuo-ku Kobe-Shi Hyogo 650(JP)

(72) Inventor: **Mega, Setsuo Mizushima Works**
Kawasaki Steel Corp. Mizushima-Kawasaki-Dori
1-Chome Kurashiki City Okayama Pref.(JP)

(72) Inventor: **Iida, Sachihiro Mizushima Works**
Kawasaki Steel Corp. Mizushima-Kawasaki-Dori
1-Chome Kurashiki City Okayama Pref.(JP)

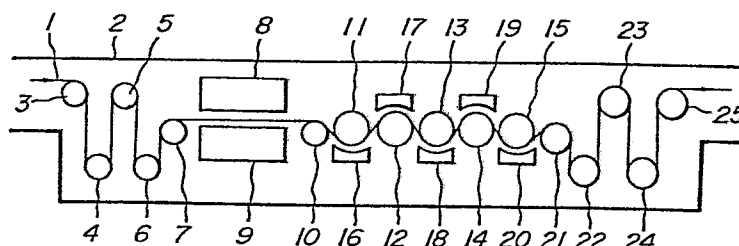
(74) Representative: **Kosmin, Gerald Emmanuel**
HASELTINE, LAKE & CO. Hazlitt House 28 Southampton
Buildings Chancery Lane
London, WC2A 1AT(GB)

(54) **Steel strip cooling method.**

(57) A method of rapidly cooling steel strips heated and soaked in a continuous heat-treatment furnace. The rapidly cooling is carried out by winding a steel strip (1) about a plurality of cooling rolls in succession (11-15) to bring the steel strips into contact therewith. The rapid cooling is started at a temperature of a range of 550-720°C and simultaneously a tensile force α (kgf/mm²) of the steel strip is adjusted within a range determined by an inequality of $(1900-T_s)/1670 < \alpha < (1980-T_s)/720$ according to the starting temperature

T_s (°C) of the rapid cooling. In another aspect, the rapid cooling is carried out by winding the steel strip about a plurality of cooling rolls in succession (11-15) to bring the steel strip into contact therewith and at the same time by jetting a gas against a back surface of the steel strip (8,9,16-20). The rapid cooling is started at a temperature of a range of 550-720°C and simultaneously a tensile force α' (kgf/mm²) of the steel strip is adjusted within a range determined by an inequality of $(1570-T_s)/1670 < \alpha' < (2410-T_s)/630$.

FIG. 1



STEEL STRIP COOLING METHOD

This invention relates to a method of cooling steel strips after continuous annealing of the steel strips, and more particularly to a method of cooling steel strips capable of enabling cooling capacity of roll cooling process to increase to a maximum possible extent without detrimentally affecting quality of steel products.

Various cooling systems have been suggested to rapidly cool steel strips after continuous annealing. A roll cooling method among them, in which a steel strip is wound about cooling rolls so as to be in contact therewith is advantageous in that its cooling speed is sufficiently high with a relatively low cost of operation without any risk of oxidation on a surface of the strip.

In a cooling process of a steel strip by roll cooling at 650-400°C after heating and keeping the steel strip in continuous annealing, a plurality of cooling rolls are usually needed for a limitation of the heat transfer coefficient between the steel strip and the rolls. In this case, if an unevenness in temperature in width directions of the steel strip occurs when the steel strip becomes in contact with the first cooling

roll about which the steel strip is wound, an excessively cooled portion of the steel strip will contract in its longitudinal direction. Such an excessively cooled condition of the steel strip is enhanced by
05 further roll cooling, so that the unevenness in temperature in the width directions is further increased.

Such a phenomenon detrimentally affects figure of a steel strip to cause serpentine movements of the steel
10 strip, which obstruct stable passing of the steel strip through the heat-treatment passage and make difficult the contact between the cooling rolls and the steel strip wound thereabout so as to lower the cooling capacity of the cooling rolls.

15 Moreover, the unevenness in temperature in the width directions of the steel strip causes compressive stresses in the width directions on a surface of the steel strip in contact with the cooling rolls with a risk of buckling of the steel strip. If the buckling
20 exceeds a certain value, the steel strip may undergo violent serpentine movements resulting in breaking down of the steel strip in a furnace.

Japanese Laid-open Patent Application
No. 59-129737 discloses a feature of providing gas
25 jetting means in opposition to cooling rolls, capable of controlling cooling intensity in width directions of

a steel strip subjected to the roll cooling, thereby reducing the unevenness in temperature in the width directions of the steel strip to prevent defects in figure of the steel strip. However, it does not solve
05 the problem of the uneven cooling sufficiently because of low contact pressure between the steel strip and the cooling rolls resulting from a slight tensile force in the steel strip of the order of less than 0.8 kgf/mm² in order to prevent the buckling of the steel strip in high
10 temperature zones in a usual continuous annealing installation.

Moreover, Japanese Laid-open Patent Application No. 59-20428 discloses a feature of cooling a steel strip under tension of 2-5 kgf/mm² with more than two
15 rolls. If even a slight fault of contact in width directions of the steel strip occurs, a large tensile force concentration locally occurs to give rise to a plastic deformation of the steel strip and an exceeding defect in figure of the steel strip causing large
20 serpentine movements of the steel strip to decrease the production capacity. Moreover, motor power for bridle rolls located upstream and downstream of the cooling rolls increases and a large number of bridle rolls are required because of a usual restriction of coefficient
25 of friction between the steel strip and bridle rolls to increase a space for the bridle rolls resulting in.

an increased initial cost.

It is a primary object of the invention to provide an improved method of cooling steel strips in roll cooling, which eliminates all the disadvantages of the prior art and is capable of preventing the uneven cooling in width directions of a steel strip to a minimum possible extent to effectively restrict defects in figure of the steel strip and inexpensively exhibiting the cooling capacity to a maximum possible extent.

In order to achieve this object, in a method of cooling steel strips heated and maintained in a continuous heat-treatment furnace, according to the invention a rapid cooling of a steel strip by winding it about a plurality of cooling rolls in succession to bring it into contact therewith is started at a temperature of a range of 550-720°C and simultaneously a tensile force α (kgf/mm²) of the steel strip is adjusted within a range determined by an inequality of $(1900-T_s)/1670 < \alpha < (1980-T_s)/720$ according to the starting temperature T_s (°C) of said rapid cooling.

In another aspect of the invention, a rapid cooling of a steel strip by winding it about a plurality of cooling rolls in succession to bring it into contact therewith and at the same time by jetting a gas against a back surface of the steel strip is started at

a temperature of a range of 550-720°C and simultaneously a tensile force α' (kgf/mm²) of the steel strip is adjusted within a range determined by an inequality of $(1570-T_s)/1670 < \alpha' < (2410-T_s)/630$ according to the starting temperature T_s (°C) of said rapid cooling.

The invention will be more fully understood by referring to the following detailed specification and claims taken in connection with the appended drawings.

Fig. 1 is a schematic view illustrating a cooling zone in a continuous heat-treatment furnace for carrying out the method according to the invention;

Fig. 2 is a graph illustrating one example of a heat cycle in a continuous annealing line;

Fig. 3 is a graph illustrating an influence of tensile force of steel strips in a cooling zone on unevenness of the steel strips;

Fig. 4 is an explanatory view illustrating variation in tensile force of a steel strip due to heat crowing of a cooling roll;

Fig. 5a is a view illustrating change in contact area between a steel strip and cooling rolls in case of average tensile force of the steel strip of 2 kgf/mm²;

Fig. 5b is a view similar to Fig. 5a but in case of average tensile force of 3 kgf/mm²;

Fig. 6 is a graph illustrating relation between steel strip temperature and yield stress;"

Fig. 7 is a graph illustrating an influence of tensile force of steel strips and starting temperature of roll cooling on the figure of cooled steel strips;

Fig. 8 is a graph illustrating relation between
05 tensile force of steel strips in a roll cooling zone and cost of bridle rolls;

Fig. 9 is a view illustrating tensile force distribution of steel strips in a heat-treatment furnace; and

10 Fig. 10 is a schematic view illustrating influence of tensile force of steel strips on rate of inferior quality steel strip in figure and rate of capacity decline due to steel strip serpentine movement.

Fig. 1 schematically illustrates a continuous
15 heat-treatment furnace for steel strips 1 suitable for carrying out the cooling process including the rapid cooling above described. The furnace comprises in a cooling zone 2 deflector rolls 3, 7, 10, 21 and 25, upstream bridle rolls 4, 5 and 6, downstream bridle
20 rolls 22, 23 and 24, gas jetting means 8 and 9, a plurality of cooling rolls 11, 12, 13, 14 and 15 for the roll cooling process and gas jetting means 16, 17, 18, 19 and 20 for assisting the roll cooling with the cooling rolls 11 -15.

25 Fig. 2 illustrates a typical heat cycle in the roll cooling process. In this heat-treatment, a steel

strip is maintained soaked at 700-800°C in a soaking zone not shown in Fig. 1 and then gradually cooled to a temperature between approximately 640°C and an A₁ transformation point (723°C) of the strip in a cooling zone upstream of the rapid cooling zone 2 shown in Fig. 1. The steel strip 1 is then cooled by jetting a gas from the gas jetting means 8 and 9 shown in Fig. 1. Thereafter, the steel strip 1 is extended around the plurality of cooling rolls 11-15 so as to be in contact therewith and is simultaneously subjected to the jetting cooling gas from the gas jetting means 16-20, so that the steel strip is rapidly cooled to about 400°C. After the steel strip 1 is then maintained at this temperature for overaging the strip, it is fed out of the heat-treatment system.

The temperature T_s at which the rapid cooling by the roll cooling is started has been slightly explained referring to Fig. 2 in connection with the gas jetting means 8 and 9 located upstream of the cooling rolls.

In rapid cooling only by the roll cooling without using gas jetting means, if the starting temperature T_s of the rapid cooling is lower than 640°C, defects in figure of strips would often occur depending upon materials and sizes of the strips. By previous applying a first cooling by means of the gas jetting means 8 and 9 in this case, a starting temperature T_s of the rapid

cooling lower than 600-550°C can be acceptable without a risk of the defects in figure of strips. However, an excessively low starting temperature such as lower than 550°C would cause a requirement of an unduly
05 widened heating zone of the gas jetting means 8 and 9 as the previous cooling resulting in increased electric power cost. Accordingly, the temperature range of 550-720°C is applicable for the starting temperature T_s of rapid cooling with the roll cooling.

10 The inventors carried out an experiment on the cooling of steel strips having thicknesses of 0.5-1.2 mm and widths of 800-1200 mm under tension 0.3-4 kgf/mm² between the bridle rolls 4-6 and 22-24 with starting cooling temperature T_s of 450-750°C by means of the roll
15 cooling system shown in Fig. 1. Fig. 3 illustrates observed results of strip figures at the termination of cooling with the starting temperature T_s of 650°C wherein results of only the roll cooling (case A) are shown in solid lines, and results of addition of gas
20 jetting onto back surfaces of the strips (case B) in broken lines.

As can be seen from the results, the low tension of the steel strips in the proximity of 0.5 kgf/mm² causes uneven cooling which detrimentally affects the
25 figure of strips because of lower contact pressure of the rolls with the strips. On the other hand, as the

tension increases, the uneven cooling is greatly prevented with the tension within 0.8-2 kgf/mm² of the case A and within 0.6-3 kgf/mm² of the case B, so that unevenness of the steel strips is less than 1% in both cases. On the other hand, if the tension further increases, it again adversely affects the figure of strips.

It is considered that the reason why such an excessive tension detrimentally affects the figure of strips is as follows. Heat transmission from the strip to the roll in contact therewith causes thermal crown of the roll in the center of the roll as shown by shaded area in Fig. 4 where the steel strip tends to be excessively cooled resulting in longitudinal contraction of the strip. The continuous roll cooling further increases such an excessive cooling. Fig. 5a illustrates the change in contact area between the steel strip and the cooling rolls in case of uneven cooling and Fig. 5b is in case that the uneven cooling does not occur. The decrease in contact area at the respective cooling rolls 11-15 causes tensile stress concentration at the excessively cooled portions of the strip, so that when average tension is more than 2 kgf/mm² in the case A and 3 kgf/mm² in the case B, it becomes in excess of yield stress of the steel strip (5-6 kgf/mm²) at a temperature of the order of 650°C shown in Fig. 6.

Accordingly, such a tensile force causes plastic deformation of the strip which will be further enhanced by the subsequent roll cooling.

Fig. 7 illustrates threshold values for causing defects in figure of steel strips (more than 1% of the unevenness) with the rapid cooling starting temperatures T_s of 400-750°C in relation to tensile forces of the strips, wherein solid lines are for the case A and broken lines are for the case B. As the starting temperature T_s is higher, the strips are prone to defects in figure. On the other hand, as the starting temperature T_s is lower, the range of the tensile force not causing defects of figure becomes wider. Such threshold values are experimentally ascertained in this manner.

According to the threshold values in Fig. 7, the tensile force not causing defects in figure with the starting temperature of 550-720°C is approximately obtained as follows.

$$\frac{T_s - 1900}{-1670} < \alpha < \frac{T_s - 1980}{-720} \text{ in case of A,}$$

$$\frac{T_s - 1570}{-1670} < \alpha' < \frac{T_s - 2410}{-630} \quad \text{in case of B}$$

In case of preventing cooling buckle particularly using the first cooling by jetting the gas from the gas jetting means 8 and 9 as shown in Fig. 1, the starting temperature for the rapid cooling is within 550-600°C. In this case, the zone causing the defects in figure is substantially the same as that shown in Fig. 7.

Fig. 8 illustrates the relation between the tensile forces of steel strips and cost of bridle rolls to be arranged upstream and downstream of cooling rolls in order to apply the tensile forces to the steels trips.

This graph shows the increase of the cost of bridle rolls with increase of the tensile forces in comparison with the cost of bridle rolls (indicated by an index 100) required to cause the tensile force of 1.0 kgf/mm² acting upon the steel strips. As shown in Fig. 8, the cost of the bridle rolls is rapidly increased in order to increase the tensile force of the steel strips to more than 3 kgf/mm², because of not only an increase of power for bridle rolls but also considerably bulky bridle rolls requiring a great space for settling such bulky bridle rolls.

According to the invention, the starting temperature of the rapid cooling of a strip winding around and in contact with a plurality of rolls is limited to 550-720°C. The lower limitation of the starting temperature is defined in order to avoid the disadvantage of increase power cost due to undue increase of the gas jetting cooling zone for unduly lowering the temperature to 550°C. The upper limitation of the starting temperature is defined in order to avoid the risk of defects of figure of steel strip at a temperature higher than 720°C.

According to the invention, moreover, the tensile force α (kgf/mm²) of the steel strip to be cooled only by roll cooling without jetting the gas against the back surface of the strip is defined within the following range.

$$(1900-T_s)/1670 < \alpha < (1980-T_s)/720$$

According to the invention, furthermore, the tensile force α' (kgf/mm²) of the steel strip to be cooled by roll cooling and by jetting the gas against the back surface of the strip is defined within the following range.

$$(1570-T_s)/1670 < \alpha' < (2410-T_s)/630$$

The reason why such ranges of the tensile forces are defined is that such ranges are absolutely necessary to restrain the unevenness of steel strip within 1%,

which is defect in figure of the steel strip as already explained by referring to Fig. 7.

Example 1

Steel strips 1 heated, soaked and gradually cooled
05 were introduced into the rapid cooling zone 2 as shown
in Fig. 1. In the rapid cooling zone 2, the cooling
rolls 11-15 were operated and the bridle rolls 4-6 and
22-24 upstream and downstream thereof were operated in
order to increase the tensile force of the steel strips
10 in contact with the cooling rolls. The gas jetting
chambers 16-20 were inoperative. The operating
conditions are shown in Table 1.

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Table 1

	I	II
Thickness of strip (mm)	0.8	1.0
Width of strip (mm)	1100	1200
Feeding speed of strip (m/min)	200	150
Tensile force of steel strip in rapid cooling zone (kgf/mm ²)	1.5	1.0
Strip temperature on entry side of rapid cooling zone (°C)	670	700
Starting temperature of rapid cooling by roll cooling (°C)	600	625
Strip temperature on rapid cooling zone side (°C)	400	400
Number of cooling rolls	5	5
Diameter of cooling rolls (mm)	1500	1500
Average winding angle (°)	90	90
Figure of cooled strip	good	good

In both the cases I and II, figures of the cooled strips were good. By defining the tensile force α kgf/mm² of steel strips in the roll cooling zone as the following inequality, a rate of steel strips of inferior quality due to defect of figure was lowered to less than 0.5%.

$$\frac{T_s - 1900}{-1670} < \alpha < \frac{T_c - 1900}{-720}$$

Moreover, the capacity decline of the operation resulting from serpentine movements of steel strips due to defects of figure was fairly prevented.

Example 2

Steel strips 1 heated, soaked and gradually cooled were charged into the rapid cooling zone 2.

In the rapid cooling zone, there were provided cooling rolls 11-15, gas jetting chambers 16-20 in opposition thereto and bridle rolls 4-6 and 22-24 upstream and downstream of the gas jetting chambers in order to increase tensile forces of the steel strip in contact with the cooling rolls.

As shown in Fig. 9, the strips were fed in the heating and soaking zones under tensile force of the order of 0.7 kgf/mm². The tensile force was then increased from 0.7 kgf/mm² to 2.7 kgf/mm² according to thicknesses and widths of the strips by means of the front and rear bridle rolls 4-6 and 22-24. The steel strips were then subjected to the first cooling by the previous gas jetting means 8 and 9 and thereafter the strips were extended around the cooling rolls 11-15 to

be cooled and simultaneously cooled on their back sides
by means of the gas jetting chambers 16-20 arranged in
opposition to the cooling rolls 11-15. the tensile
force was lowered to value of the order of 0.7 kgf/mm²
05 by the rear bridle rolls 22-24.

In this manner it was possible to cool the steel
strips uniformly without detrimentally affecting figures
of the steel strips. The operating conditions are shown
in Table 2.

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Table 2

	III
Thickness of strip (mm)	0.8
Width of strip (mm)	1100
Feeding speed of strip (m/min)	200
Tensile force of steel strip in rapid cooling zone (kgf/mm ²)	2.0
Strip temperature on entry side of rapid cooling zone (°C)	670
Starting temperature of rapid cooling by roll cooling (°C)	600
Strip temperature on rapid cooling zone side (°C)	400
Number of cooling rolls	5
Delivery pressure of gas jetting against back side of strip (mmH ₂ O)	240
Average heat transfer coefficient of roll cooling and gas jetting (kcal/m ² h°C)	200
Average winding angle (°)	60
Figure of cooled strip	good

Fig. 10 illustrates the effects of the present invention in the two cases, one of which uses only the

roll cooling and the other of which uses both the roll cooling and the gas jetting. In the Example 2, particularly, by defining the tensile force α' (kgf/mm²) of the steel strips in the roll cooling zone as the following inequality, a rate of steel strips of inferior quality due to defect of figure was lowered to less than 0.5% and the capacity decline of the operation resulting from serpentine movements of steel strips due to defects of figure was significantly prevented.

$$\frac{T_s - 1570}{-1670} < \alpha' < \frac{T_s - 2410}{-630}$$

As can be seen from the above description, the cooling capacity in roll cooling of steel strips can be exhibited to the maximum possible limitation without causing any defect of figure of strips in their cooling after continuous annealing by roll cooling.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details can be made therein without departing from the spirit and scope of the invention.

Claims

1. A method of cooling steel strips heated and maintained in a continuous heat-treatment furnace, wherein a rapid cooling of a steel strip by winding it about a plurality of cooling rolls in succession to bring it into contact therewith is started at a temperature of a range of 550-720°C and simultaneously a tensile force α (kgf/mm²) of the steel strip is adjusted within a range determined by an inequality of $(1900-T_s)/1670 < \alpha < (1980-T_s)/720$ according to the starting temperature T_s (°C) of said rapid cooling.

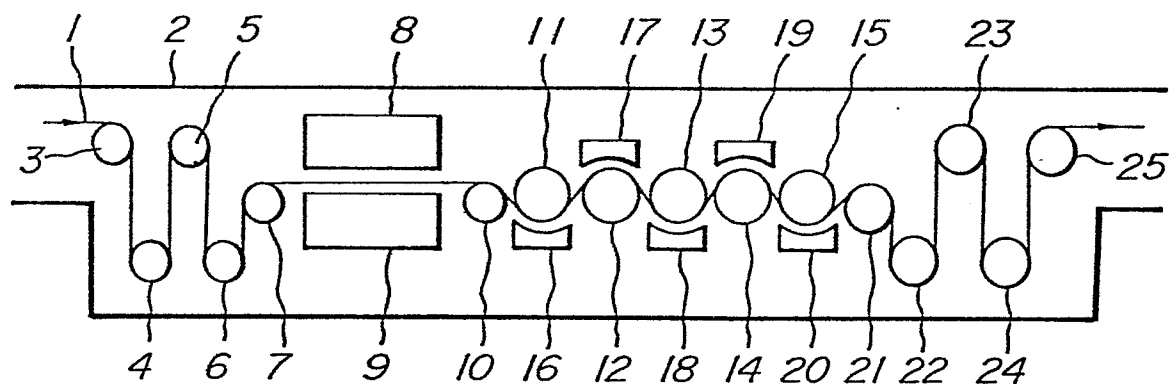
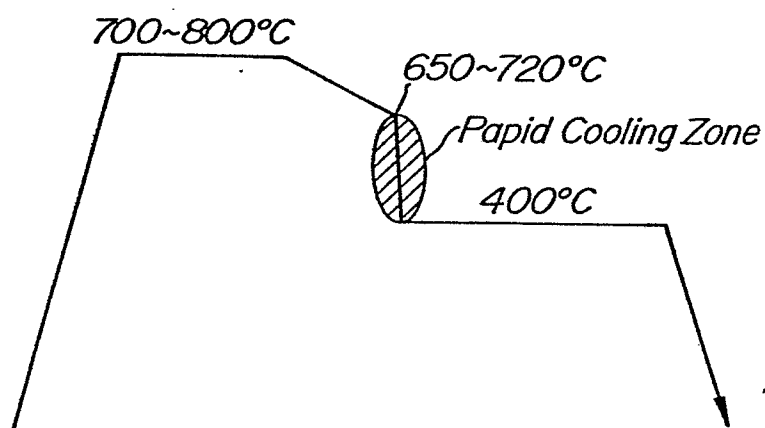
2. A method of cooling steel strips as set forth in claim 1, wherein said starting temperature of the rapid cooling is within a range of 720-640°C and the tensile force of the steel strip is within a range of 0.8-2 kgf/mm².

3. A method of cooling steel strips heated and maintained in a continuous heat-treatment furnace, wherein a rapid cooling of a steel strip by winding it about a plurality of cooling rolls in succession to bring it into contact therewith and at the same time by jetting a gas against a back surface of the steel strip is started at a temperature of a range of 550-720°C and simultaneously a tensile force α' (kgf/mm²) of the steel strip is adjusted within a range determined by an inequality of $(1570-T_s)/1670 < \alpha' < (2410-T_s)/630$ according to the starting temperature T_s (°C) of said rapid cooling.

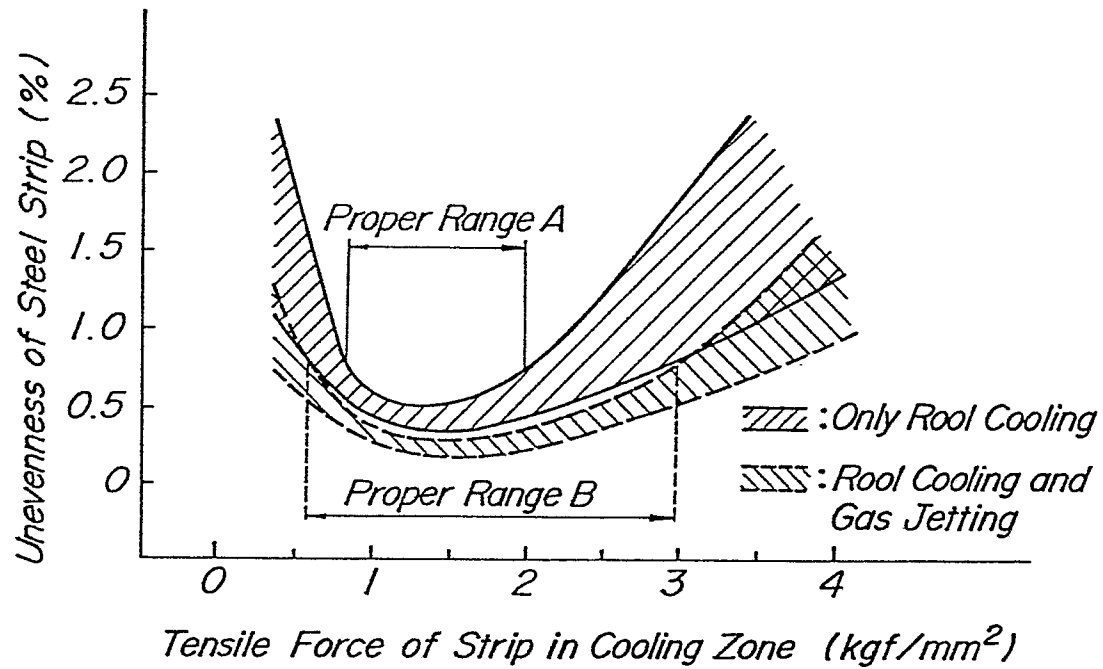
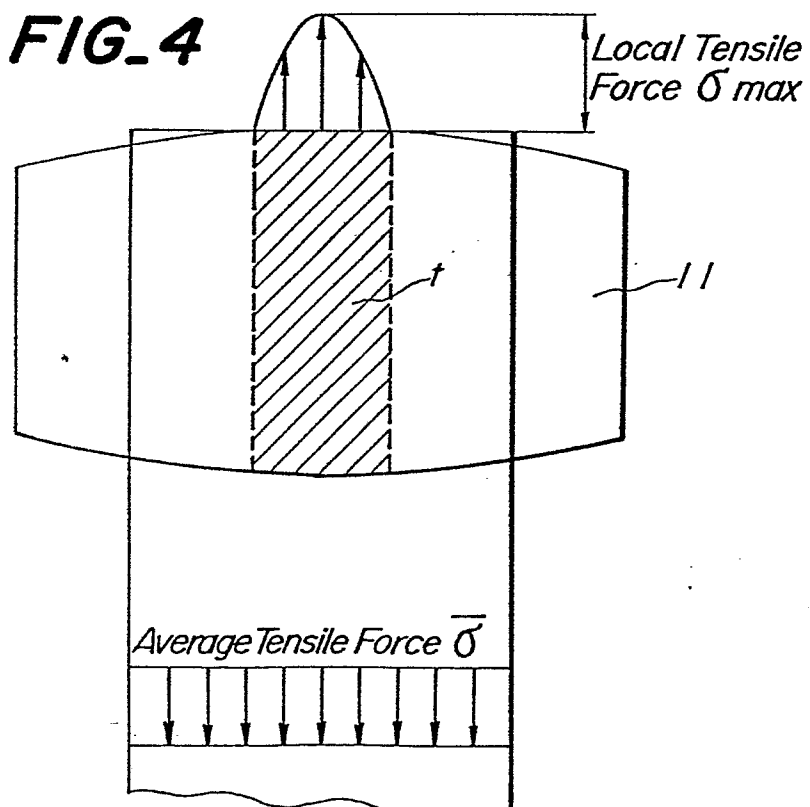
4. A method of cooling steel strips as set forth in claim 3, wherein said starting temperature of the rapid cooling is within a range of 600-550°C and the tensile force of the steel strip is within a range of 0.6-3 kgf/mm².

5. A method of cooling steel strips as set forth in claim 1 or 3, wherein before the steel strip is cooled by the cooling rolls, the steel strip is cooled by jetting a gas against the steel strip.

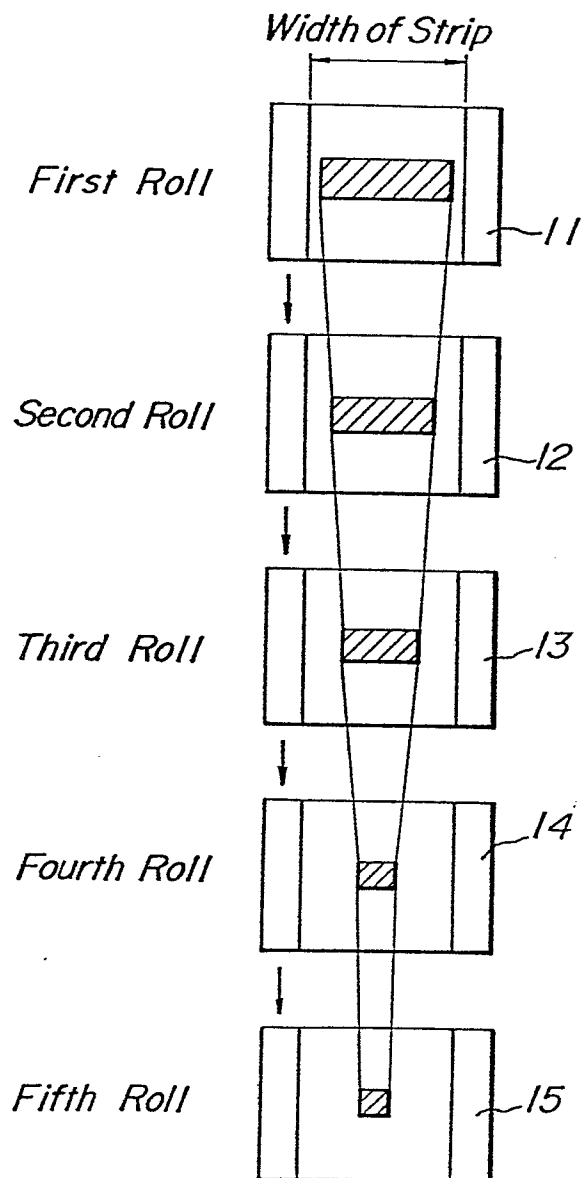
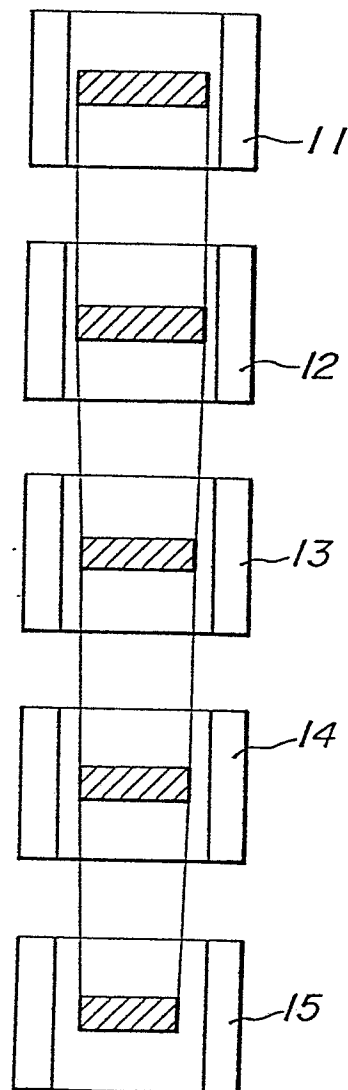
6. A method of cooling steel strips as set forth in claim 1 or 3, wherein the tensile force of the steel strips is adjusted by bridle rolls arranged upstream and downstream of the cooling rolls.

FIG. 1**FIG. 2**

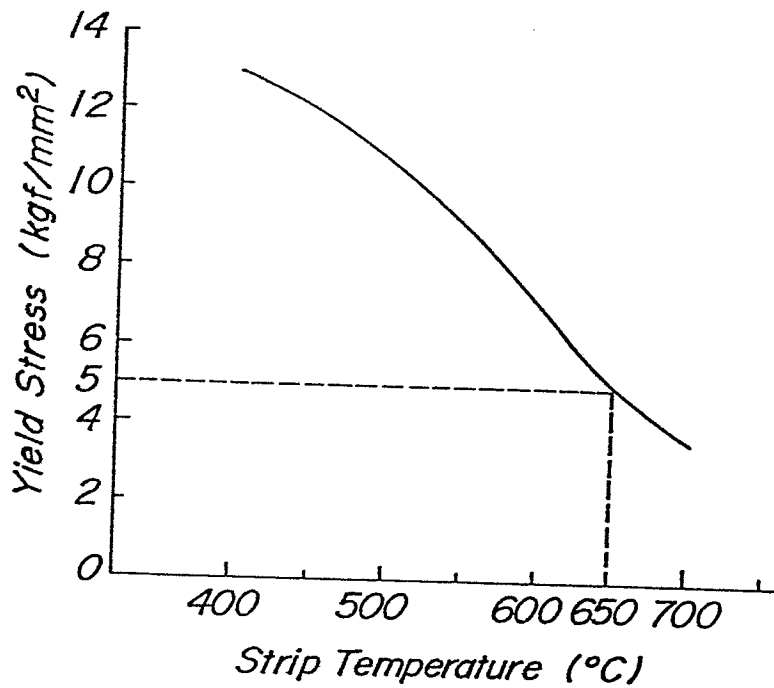
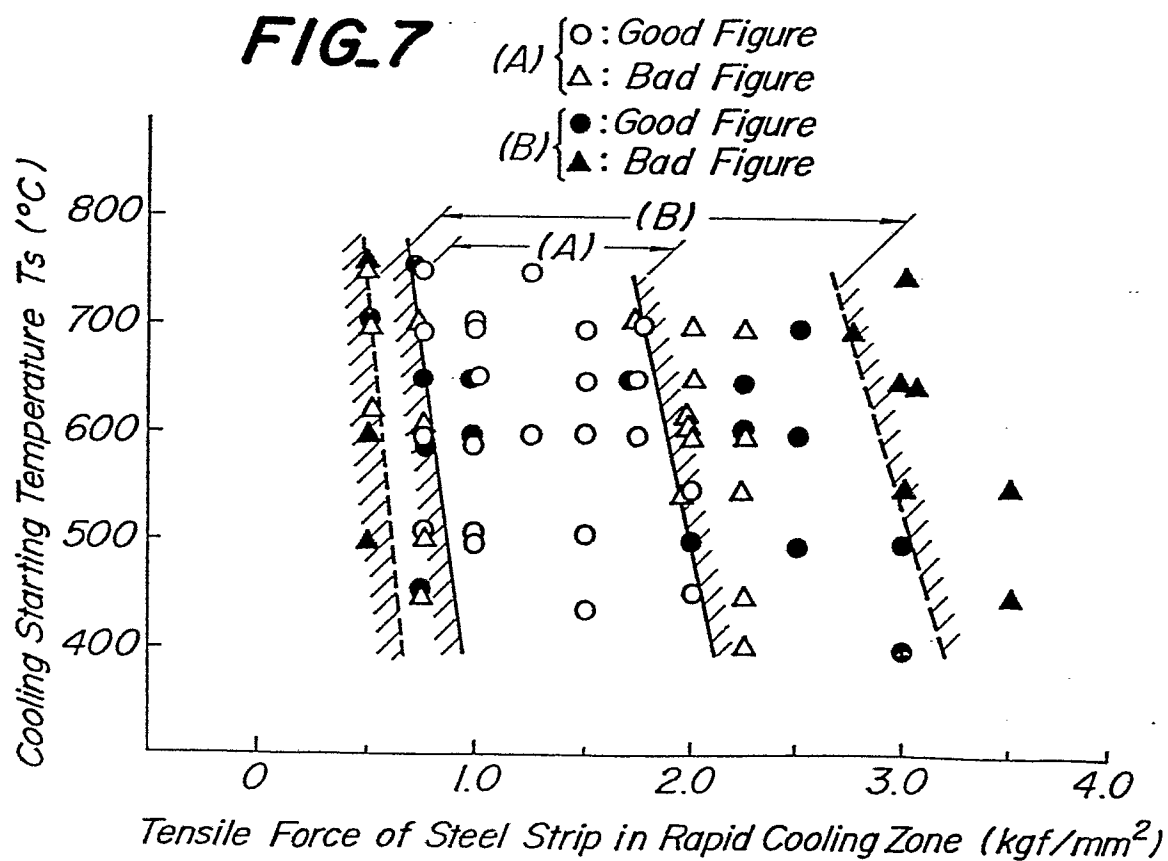
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FIG. 3**FIG. 4**

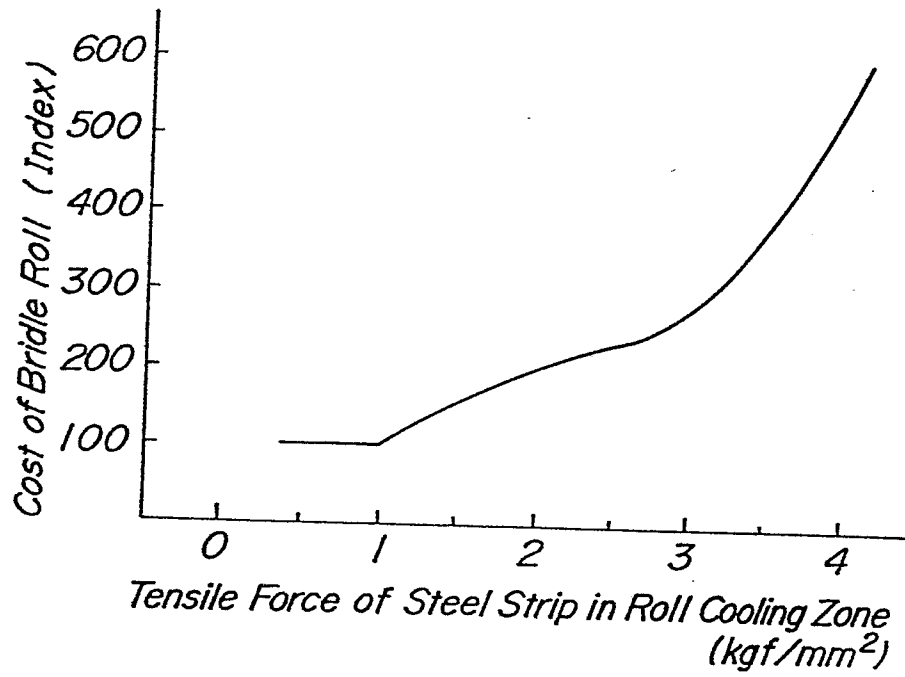
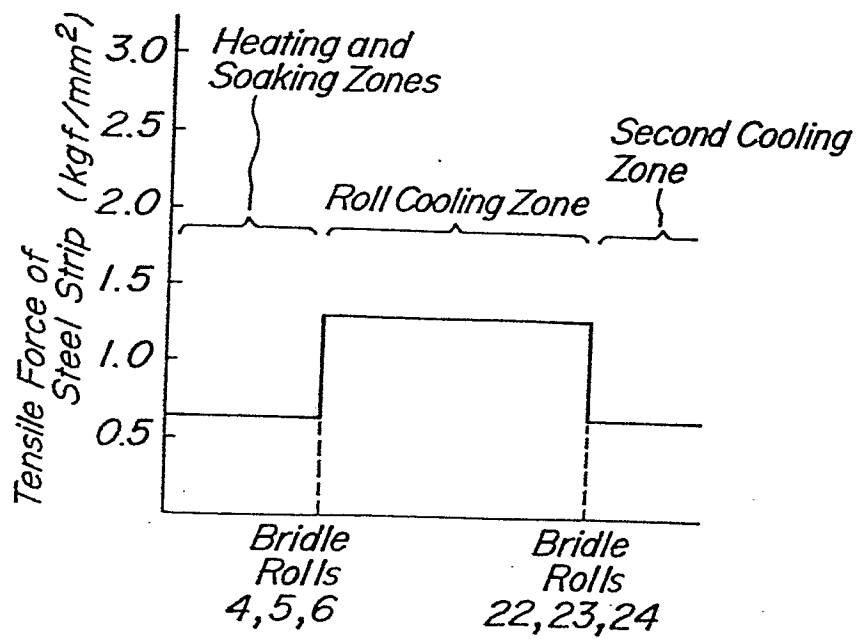
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FIG. 5a**FIG. 5b**

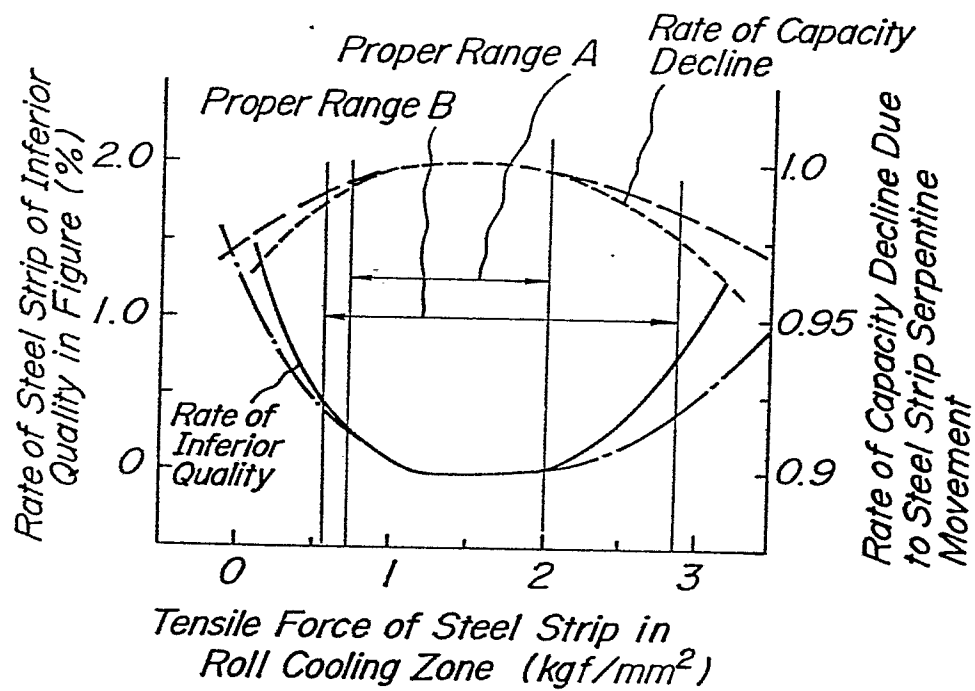
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FIG. 6**FIG. 7**

5/6

FIG. 8**FIG. 9**

6/6

FIG. 10



European Patent
Office

EUROPEAN SEARCH REPORT

0230780

Application number

EP 86 31 0098

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	EP-A-0 155 753 (MITSUBISHI JUKOGYO KAWASAKI STEEL) * Claim 1; page 8, lines 17-21 *	1-5	C 21 D 9/573
Y	EP-A-0 117 083 (NIPPON STEEL) * Claims 1-3; page 6 *	1,2	
Y	DE-A-3 324 548 (KAWASAKI STEEL) * Claim; page 12, lines 9-17 *	1,2	
D,A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 106 (C-223)[1543], 18th May 1984; & JP-A-59 20 428 (NIPPON KOKAN K.K.) 02-02-1984		
A	EP-A-0 145 485 (MITSUBISHI JUKOGYO KAWASAKI STEEL) * Claims 1-4 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	EP-A-0 058 607 (STEIN HEURTEY) * Claim 1 *		C 21 D
D,A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 251 (C-252)[1688], 16th November 1984; & JP-A-59 129 737 (KAWASAKI SEITETSU K.K.) 26-07-1984		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 17-04-1987	Examiner GREGG N.R.
CATEGORY OF CITED DOCUMENTS		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	
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			