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(54) Continuous annealing apparatus of steel strip and tension control system for the same.

(57) In a continuous process line for manufacturing a soft steel strip for drawing, etc., the present invention relates to a continuous annealing apparatus and a tension control system for the same for preventing the occurrence of heat buckling, scratching and walking of the steel strip and improving productivity and quality.

In a continuous annealing furnace of a steel strip including a heating zone (22), a soaking zone (23), a primary cooling zone (24), an overaging zone (25) and a secondary cooling zone (26), the invention characterized in that a bridle roll (3) is interposed between the overaging zone (25) and the secondary cooling zone (26),

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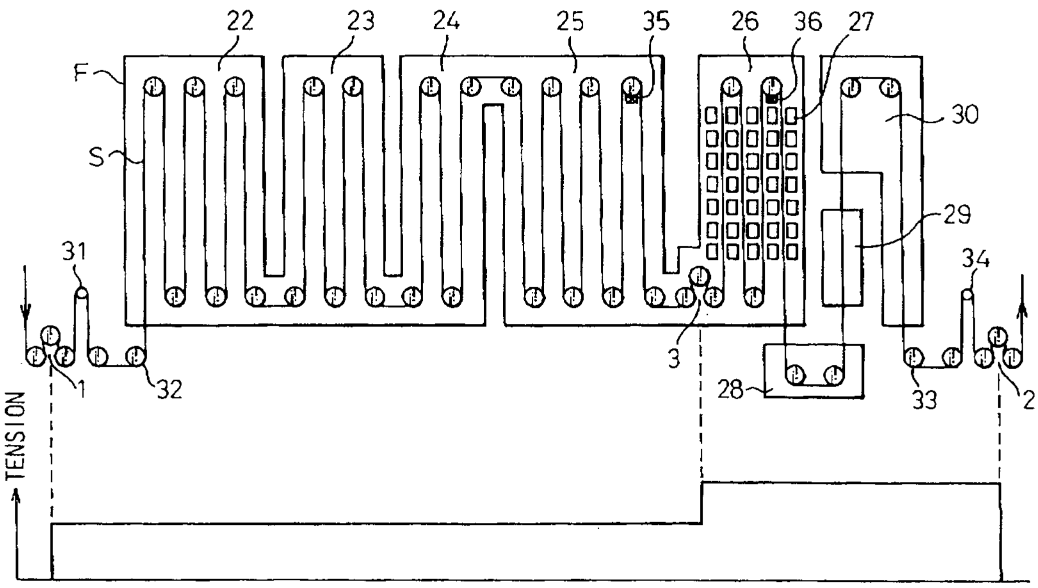
and a first bridle roll and a second bridle roll and a buffer roll coming into contact with the steel strip between both of the bridle rolls are ydisposed on an entry side and/or delivery side.

Fig. 4



1. Field of the Invention

In a continuous process line for manufacturing a soft steel strip for drawing, etc., the present invention relates to a continuous annealing apparatus and a tension control system of the same for preventing the occurrence of heat buckling, scratching and walking of the steel strip and improving productivity and quality.

Various processings are carried out for metal strips such as thin steel strips by feeding them through a continuous process line. These processings include annealing, pickling, plating, and so forth, and they are carried out in a continuous annealing line, a continuous pickling line, a continuous plating line, and so forth. When the strip is fed, the strip wound in a coil is uncoiled by a payoff reel on an uncoiling part of the line, and is welded to the trailing end of a preceding strip. On the coiling side, the strip is wound into a coil by a tension reel, and after a weld portion is cut off, a subsequent strip is wound to the tension reel.

In such a continuous process line, the steel strip must be fed at a predetermined constant speed through a process section such as an annealing furnace at the time of welding at the uncoiling part and cutting at the coiling part. Therefore, loopers are disposed between the process section and an entry section and between the process section and a delivery section so as to regulate the feed speed. When the sheet thickness or width of the strip coil to be processed changes or when a metal composition such as a kind of the steel changes, the strip feed speed inside the processing section must be changed, and the speed regulation is carried out throughout the entry and delivery sections.

Specifically, a soft steel strip for drawing or for a soft tin plate blank is manufactured by carrying out cold rolling and then annealing and overaging inside a continuous annealing furnace. This continuous annealing furnace is an elongated setup including a heating zone for heating a steel strip to a predetermined temperature, a soaking zone for annealing the steel strip, a primary cooling zone for effecting an overaging treatment, an overaging zone and a secondary cooling zone.

In process lines of the steel strip, etc., in general, bridle rolls are disposed on the entry and exit sides of the line so as to impart suitable tension to the steel strip, etc., and to allow a stable passage of the strip. When the tension is insufficient in this case, the steel strip advances in a zigzag (meander) manner and comes into contact with the setup such as a furnace wall, so that scratching occurs in the steel strip. When the tension is excessive, creases of drawing called "heat buckling" occur in the longitudinal direction of the steel strip.

Since the continuous annealing furnace of the steel strip is elongated, it is difficult to impart a suitable tension to the steel strip throughout the full length of the furnace by only the bridle rolls disposed on the upstream and downstream sides of the furnace. Therefore, Japanese Unexamined Utility Model Publication (Kokai) No. 50-139707 proposes a tension control method by disposing a bridle roll also inside the furnace. In other words, as shown in Fig. 1, the bridle rolls 3 are disposed between a heating zone 4 and a holding zone 5 and between the holding zone 5 and a cooling zone 6, besides an entry side bridle roll 1 and an exit side bridle roll 2 disposed on the entry and exit sides of the continuous annealing surface F, so as to regulate the tension of the steel strip S. (The reference describes also that an overaging zone may also be disposed.)

Japanese Examined Patent Publication (Kokoku) No. 60-7693 teaches to dispose the bridle rolls on the exist side of the heating zone and on the exit side of the soaking zone, respectively, so that the tension is increased in the heating zone, where the steel strip undergoes thermal expansion but is lowered on the exit side of the heating zone after the steel strip is softened, and in the soaking zone. The reference also teaches to dispose the bridle rolls on the entry and exit sides of a primary cooling zone so as to lower the tension in the primary cooling zone where deformation of the shape such as cooling buckle is likely to develop due to quenching.

For example, Japanese Unexamined Patent Publication (Kokai) No. 1-162727 proposes a tension control system wherein a plurality of bridle rolls are divided into two groups (7A and 7B, and 8A and 8B), a dancer roll 10 is interposed between these bridle rolls, and a tension variation, which instantaneously changes with such a high frequency that the bridle rolls alone cannot absorb, is absorbed by vertical movement of the dancer roll 10, as shown in Fig. 2. Japanese Unexamined Patent Publication (Kokai) No. 1-165726 proposes a control method for this control system. In the technologies of both of these references, the dancer roll 10 pulls up the metal strip S between a deflector roll 9C and the second bridle roll 8A and is balanced with a weight 12 by a rope 11 through a drum 13. Reference numeral 14 denotes a motor for turning and driving the drum 13 at a predetermined torque.

In an apparatus which passes a strip between a conveyor roll and a movable conveyor roll and controls the tension of the strip by the movement of the movable conveyor roll, Japanese Unexamined Patent Publication (Kokai) No. 5-43099 discloses a tension controller which includes an arm revolving round a supporting axis as the center and equipped with a movable conveyor roll on the opposite side to the supporting axis, a motor directly coupled to the supporting axis, for imparting a tension to the strip by generating a torque having the center thereof at the supporting axis in the arm, an angle detector for detecting the rotating angle of the arm, and a tension meter for detecting the tension of the strip, and which corrects the torque to be generated in the arm by the detected angle and the detected tension so as to control the tension of the strip to a target tension.

The principal portions of the apparatus of Japanese Unexamined Patent Publication (Kokai) No. 5-43099 described above are shown in Fig. 3. The roll called a "Conveyor roll" is a deflector roll 9 and the roll called a "movable conveyor roll" is a dancer roll 10. These rolls are disposed in the proximity of the bridle roll 8. The dancer roll 10 is rotatably supported by the arm 16, and when the arm 16 is turned with the supporting axis 15 being the center, the dancer roll 10 is moved up and down. Because the dancer roll 10 is moved up and down by such a mechanism, the mechanical resistance becomes smaller than the dancer roll shown in Fig. 2, and movement with low inertia becomes possible, so that tension control having high response and high accuracy can be made against a sharp tension variation from outside.

In Fig. 3, reference numeral 18 denotes a torque motor for turning the supporting axis 15, and 19 is an angle detector for detecting a rotating angle of the arm 16. Reference numeral 17 denotes a counterweight disposed on the arm 19 so as to generate a torque having the center thereof at the supporting axis 15 on the arm; 20 is a counter weight positioning motor for the counterweight 17; and 21 is a counter weight position detector. These members are disposed, whenever necessary, and are included in the invention. The torque generated on the arm can be controlled by adjusting the position of the counterweight 17, and the torque motor 18 can be compact in size.

However, when a thin steel strip is fed at a high speed, a tension variation having a particularly high frequency occurs, and the dancer roll 10 described above and shown in Fig. 2 cannot absorb such a tension variation because of a large inertia of its mechanical system. The dancer roll of the arm revolving system described above and shown in Fig. 3 can reduce the inertia of the mechanical system and can absorb the tension variation of a high frequency to a certain extent. However, to dispose the dancer roll, a considerably great space is necessary for the equipment. Particularly when an existing line is modified, the problem that the dancer roll cannot be installed at the most suitable position arises.

Specifically, in a continuous annealing furnace including a heating zone, a soaking zone, a primary cooling zone, an overaging zone and a secondary cooling zone, when cooling of the steel strip in the secondary cooling zone is carried out by a gas jet cooler, scratching is likely to occur on the surface of the steel strip, and transverse sway of the steel strip called "walking" occurs in a subsequent water cooling tank.

The problems of the scratching and walking can be solved by increasing the tension inside the furnace by using the bridle rolls on the entry and exit sides of the continuous annealing furnace, but heat buckling occurs in the overaging zone. Even when the bridle rolls are disposed inside the furnace, the effect cannot be obtained at the positions definitely described by each of the prior art references described above. Accordingly, it has been necessary in the conventional setups to carry out the operation by limiting the feed speed of the steel strip.

In a continuous process line of a steel strip, the present invention is directed to provide a compact tension control device and system which can make tension control in such a manner as not to transmit a tension variation of a high frequency to a processing section such as an annealing furnace even when such a tension variation occurs on the entry and delivery sides when a thin steel strip is fed at a high speed, etc., can stably feed the steel strip under a suitable tension, can reliably prevent buckling of the steel strip, reduction of its width and the occurrence of scratching, etc, resulting from strip meandering and fluttering, and can moreover be installed easily in an existing line.

More, the present invention aims at reliably preventing the occurrence of heat buckling, stratching and meandering (walking) of a steel strip and improving quality with high productivity in a continuous annealing furnace including a heating zone, a soaking zone, a primary cooling zone, an overaging zone and a secondary cooling zone.

A summary of the invention will be given below.

(1) In a continuous annealing furnace of a steel strip including an heating zone, a soaking zone, a primary cooling zone, an overaging zone and a secondary cooling zone, a continuous annealing apparatus of a steel strip characterized in that an in-furnace bridle roll is interposed between the averaging zone and the secondary cooling zone, a tension of the steel strip in an entry side before the in-furnace bridle roll is lowered, and the tension in a delivery side after the bridle roll is increased.

(2) In a continuous process line of a steel strip disposing a pair of out-furnace bridle rolls facing each other at an entry side and/or delivery side of the treating equipment, a tension control system of a steel strip characterized in that a first bridle roll, a second bridle roll and a buffer roll coming into contact with

the steel strip between both of the bridle rolls are disposed, the buffer roll can move in circle in a direction crossing a pass line connecting rolls before and after the buffer roll in accordance with a tension variation of the steel strip, and the tension is regulated by an angle α between an arm of said buffer roll and the pass line.

(3) The tension control system according to item (2), wherein the angle α is regulated in a control range of $0^\circ < \alpha \leqq \alpha_0$ or $\alpha_0 \leqq \alpha < 90^\circ$ as a boundary value α_0 which gives a maximal value of F defined by the formula (1) hereunder.

$$F = T_M \cos\alpha\{\sin(\tan^{-1}\frac{R'\sin\alpha}{L_1}) + \sin(\tan^{-1}\frac{R'\sin\alpha}{L_2})\} \quad (1)$$

where,

$$R' = R - \frac{b}{\sin\alpha},$$

$$L_1 = a - c - \frac{b}{\tan\alpha}, \quad L_2 = c + \frac{b}{\tan\alpha},$$

A: a fulcrum of the buffer roll,
b: a distance between the pass line and the fulcrum,
c: a distance between the fulcrum and an entry side roll of the second bridle roll,
α: an angle between the arm of the buffer roll and the pass line,
R: the arm length of the buffer roll,
a: a distance between a delivery side roll of the first bridle roll (or a deflector roll) and an entry side roll of the second bridle roll (or a deflector roll),
T_M: a tension of a steel strip,
F: a force pushing down the buffer roll by T_M.

(4) In a continuous annealing furnace of a steel strip, a continuous annealing apparatus of a steel strip characterized in that an in-furnace bridle roll is disposed in a strip pass line between an overaging zone and a secondary cooling zone, further a tension control system comprising at least one pair of out-furnace bridle rolls which are facing each other and a buffer roll coming into contact with the steel strip therebetween are disposed in an entry side and/or a delivery side of the continuous annealing furnace.

(5) The tension control system of a metal strip according to any one of items from (2) to (4), wherein an axis of said buffer roll is rotatably supported by an arm fixed to a supporting axis, and a torque motor for revolving the supporting axis is disposed.

(6) The tension control system of a metal strip according to item (5), wherein a counterweight is disposed on the supporting axis.

Fig. 1 is a longitudinal sectional view showing an example of the conventional apparatus.

Fig. 2 is an explanatory view showing an example of the conventional apparatus.

Fig. 3 is an explanatory view showing another example of the conventional apparatus.

Fig. 4 is a longitudinal sectional view showing an example of the apparatus of the present invention.

Fig. 5 is a perspective view showing an example of the apparatus of the present invention.

Fig. 6 is a perspective view showing another example of a buffer roll in the apparatus of the present invention.

Figs. 7(a) - 7(f) are explanatory views showing other examples of the apparatus of the present invention.

Fig. 8 is a longitudinal sectional view showing an example of the apparatus of the present invention.

Fig. 9(a) is a graph showing an embodiment of the apparatus of the present invention, and

Fig. 9(b) is an explanatory view of a fluttering amount W of a steel strip in the embodiment of the present invention.

Fig. 10 is a longitudinal sectional view showing an apparatus of Comparative Example.

Fig. 11 is a control system diagram in an embodiment of the present invention.

Fig. 12 is an explanatory view showing an example of a buffer roll of the present invention.

Fig. 13 is a graph showing a maximal point α_0 of the present invention.

The invention has been accomplished to solve the above mentioned problems in the prior arts.

Hereinafter, the apparatus of the present invention will be explained with reference to the drawings.

It is the first technical feature of the present invention that, in a continuous annealing furnace F of a steel strip including a heating zone 22, a soaking zone 23, a primary cooling zone 24, an overaging zone 25 and a secondary cooling zone 26 as shown in Fig. 4, an in-furnace bridle roll 3 is disposed between the overaging zone 25 and the secondary cooling zone 26.

Further, the second technical feature is that, as shown in Fig. 5, a tension control system of a steel strip characterized in that a first bridle roll, a second bridle roll and a buffer roll coming into contact with the steel strip between both of the bridle rolls are disposed, the buffer roll can move in circle in a direction crossing a pass line connecting rolls before and after the buffer roll in accordance with a tension variation of the steel strip, and the angle α is regulated in a control range of $0° < \alpha \leqq \alpha_0$ or $\alpha_0 \leqq \alpha < 90°$ as a boundary value α_0 which gives a maximal value of F defined by the formula (1) hereunder.

$$F = T_M \cos\alpha\{\sin(\tan^{-1}\frac{R'\sin\alpha}{L_1}) + \sin(\tan^{-1}\frac{R'\sin\alpha}{L_2})\} \quad (1)$$

where,

$$R' = R - \frac{b}{\sin\alpha},$$

$$L_1 = a - c - \frac{b}{\tan\alpha}, \quad L_2 = c + \frac{b}{\tan\alpha},$$

A: a fulcrum of the buffer roll,
b: A distance between the pass line and the fulcrum,
c: a distance between the fulcrum and an entry side roll of the second bridle roll,
α: an angle between the arm of the buffer roll and the pass line,
R: the arm length of the buffer roll,
a: a distance between a delivery side roll of the first bridle roll (or a deflector roll) and an entry side roll of the second bridle roll (or a deflector roll),
T_M: a tension of a steel strip,
F: a force pushing down buffer roll by T_M.

At the outset, the first technical feature will be described below.

In Fig. 4, a cold-rolled steel strip S from a payoff reel, not shown, passes through a washing apparatus and an entry side looper and enters the continuous annealing furnace F through an entry side bridle roll 1. The steel strip S is heated to a predetermined temperature in the heating zone 22, is soaked to an annealing temperature for a predetermined time inside the soaking zone 23, is then cooled in the primary, cooling zone 24, is subjected to overaging treatment in the overaging zone 25 and is thereafter cooling in the secondary cooling zone 26 and a water cooling tank 28. A steel strip having desired machinability can be thus obtained. In the secondary cooling zone, the steel strip is cooled by a gas jet cooler 27 at a suitable cooling rate. Thereafter, it is dried by a dryer 29 and is cooled in a final cooling zone 30 to a temperature at which refining rolling can be carried out. Next, the steel strip passes through the exit side bridle roll 2 and a refining rolling mill, not shown, etc., and is taken up on a tension reel. By the way, there is a line in which the refining rolling mill is not installed in the in-line arrangement, and in such a case, the final cooling zone 30 need not always be disposed.

Each of the bride rolls 1, 2, 3 comprises a plurality of rolls in order to increase the frictional coefficient on the surface and to increase the contact area with the steels strip S. In the apparatus of the present invention, the difference of the peripheral speed between the entry side bridle roll 1 and the in-furnace bridle roll 3 is regulated so as to regulate the tension of the steel strip S in the heating zone 22, the soaking zone 23, the primary cooling zone 24 and the overaging zone 25. Next, the difference of the peripheral speed between the in-furnace bridle roll 3 and the exit side bridle roll 2 is regulated so as to regulate the tension in the secondary cooling zone 26 and the water cooling tank 28.

To produce a thin steel sheet having excellent machinability such as drawability, the steel strip after the overaging treatment must be cooled step-wise at a suitable cooling rate. To prevent the occurrence of the shape defect such as cooling buckle, the steel strip is first cooled relatively gradually by the jet cooler 27 in the secondary cooling zone 26 and is then quenched at a high rate by the water cooling tank 28 which is economical cooling equipment. When the steel strip S is thick and wide in the conventional apparatuses, the steel strip S is greatly swayed in the secondary cooling zone 26 by strong wind of the jet cooler 27 and comes into contact with the cooler 27, so that scratches occur as already described. Further, meandering of the steel strip S is likely to occur inside the water cooling tank 29 due to hydroplaning phenomenon. When the tension inside the continuous annealing furnace F is increased so as to cope with these problems, heat buckling is likely to occur in the steel strip S inside the overaging zone 25 in which the temperature of the steel strip is relatively high.

Since the in-furnace bridle roll 3 inside the furnace is disposed between the overaging zone 25 and the secondary cooling zone 26 in the apparatus of the present invention, the tension upstream and downstream of each of these zones can be independently regulated. In other words, as shown in the tension distribution of Fig. 4, the tension in the secondary cooling zone 26 and in the water cooling tank 28 can be increased to a suitable value without excessively increasing the tension in the overaging zone 25. Accordingly, the occurrence of scratches in the secondary cooling zone and the occurrence of walk in the water cooling tank 28 can be reliably prevented without causing heat buckling in the overaging zone 25.

More, in the apparatus shown in Fig. 4, when the tension of the steel strips fluctuates in the heating zone 22, the soaking zone 23, the primary cooling zone 24 and the overaging zone 25 in the apparatus of the present invention, the tension can be adjusted by moving up and down an entry dancer roll 31. When the tension changes, a driving roll between the bridle roll 1 just before the furnace and the in-furnace bridle roll 3, such a roll 32, is used as a tension detecting roll to detect this change, and the change is fed back to a torque command of a positioning motor 19 of the entry dancer roll 31. After the entry dancer roll 13 is moved up and down, the entry dancer roll 31 is returned to the original position while adjusting the peripheral speed of the bridle roll 1 just before the furnace lest the tension inside the furnace changes.

When the tension of the steel strip S in the secondary cooling zone 26 and the water cooling tank 28 changes, the tension can be regulated by moving up and down a delivery dancer roll 34 upstream of the bridle roll 2 just after the furnace. The change of the tension can be detected by the tension detecting roll 33, etc. After the delivery dancer roll 34 is moved up and down, it is returned to the original position while adjusting the peripheral speed of the bridle roll 2 just after the furnace in case the tension changes.

It is also effective to dispose tension meter 35, 36 inside the overaging zone 25 and the secondary cooling zone 26, respectively, to measure the tension, and to feed the tension back to driving of the in-furnace bridle roll 3 and the bridle roll 2 just after the furnace.

Subsequently, a tension control system of a steel strip which is the second technical feature of the invention will be described below.

The apparatus of the present invention includes first bridle rolls 7A and 7B, second bridle rolls 8A and 8B, and a buffer roll 37 as represented by an example shown in Fig. 5. The buffer roll 37 comes into contact with a steel strip S between the first bridle rolls 7A, 7B and the second bridle rolls 8A, 8B, and can move in circle in a direction (indicated by an arrow) crossing a pass line L connecting the rolls before and after the buffer roll 37 (the second roll 7B of the first bridle rolls and the first roll 8A of the second bridle rolls in Fig. 5) in accordance with tension variation of the steel strip S. Further, a tension of a steel strip is regulated, as shown in Fig. 12, in a control range of a being $0° < \alpha \leqq \alpha_0$ or $\alpha_0 \leqq \alpha < 90°$ as a boundary value α_0 which gives a maximal value of F defined by the formula (1) hereunder.

$$F = T_M \cos\alpha\{\sin(\tan^{-1}\frac{R'\sin\alpha}{L_1}) + \sin(\tan^{-1}\frac{R'\sin\alpha}{L_2})\} \qquad (1)$$

where,

$$R' = R - \frac{b}{\sin\alpha},$$

$$L_1 = a - c - \frac{b}{\tan\alpha}, \quad L_2 = c + \frac{b}{\tan\alpha},$$

A: a fulcrum of the buffer roll,

b: a distance between the pass line and the fulcrum,

c: a distance between the fulcrum and an entry side roll of the second bridle roll,

α: an angle between the arm of the buffer roll and the pass line,
R: the arm length of the buffer roll,
a: a distance between a delivery side roll of the first bridle roll (or a deflector roll) and an entry side roll of the second bridle roll (or a deflector roll),
T_M: a tension of a steel strip,
F: a force pushing down buffer roll by T_M.

The relationship between α and F is shown in Fig. 13. T_M, a, b, c, and R are determined by an installation condition and provide α_0 which gives a maximal value F_{max}.

The formula (1) of the above becomes such an upside convex graph as α_0 is a maximal point. α is preferably used in the range of $0° < \alpha \leqq \alpha_0$ or $\alpha_0 \leqq \alpha < 90°$ because F increases and decreases before and after α_0. Further, if a mechanical installation condition is taken into consideration, preferably α is $0° < \alpha \leqq \alpha_0$. However, α can actually use in a range of $0° < \alpha \leqq 90°$ due to correction by a formula of $F = T_M \cos\alpha(\sin\theta_1 + \sin\theta_2)$ as mentioned hereafter.

The slope angle θ is different between the entry side and the delivery side, and the entry side is set to θ_1 with the delivery side being set to θ_2, as shown in the drawing.

The moving range of the buffer roll 37 in the apparatus of the present invention is designed in the manner described above and moreover, the force of inertia is extremely reduced by employing the hollow light-weight roll. Accordingly, the buffer roll 37 can exhibit more sensitive movement to the tension variation than the conventional dancer roll 10 shown in Figs. 2 and 3. In other words, even when the tension of the steel strip S exhibits a drastic high frequency variation on the entry side or delivery side, the buffer roll 37 can absorb such a variation.

The example shown in Fig. 5 represents a preferred embodiment of the present invention. The buffer roll 37 is a hollow roll and is rotatably supported by an am 16. The arm 16 is fixed to a supporting axis 15. The supporting axis 15 is supported by a bed, or the like, not shown. When the supporting axis 15 is rotated by a torque motor 18, the buffer roll 37 can move in circle in the direction crossing the pass line L.

Besides the torque motor 18 shown in Fig. 5, the buffer roll 37 can be moved in circle by hydraulic or air pressure means, in the present invention.

In Fig. 5, each bridle roll 7A, 7B, 8A, 8B has a surface having a large frictional coefficient, is so disposed as to increase the contact area with the steel strip S, and is driven for rotation by a drive motor 38A, 38B, 39A, 39B. The buffer roll 37 is a non-driven roll, and is supported by the am 16 in such a manner as to be capable of freely rotating with the passage of the steel strip S.

The steel strip S is delivered in the direction of the arrow by the revolution of each bridle roll 7A, 7B, 8A, 8B, and an entry side tension T_1 and a delivery side tension T_2 are cut off by the frictional resistance with each roll. In the apparatus of the present invention, the buffer roll 37 is brought into contact with the steel strip S between the first bridle rolls 7A, 7B and the second bridle rolls 8A, 8B in such a manner as to push up the steel strip S above the pass line L in the example shown in the drawings, and to impart an intermediate tension T_M.

When the entry side tension T_1, for example, changes to $T_1 + \Delta T$ containing a high frequency tension variation ΔT under this state, the intermediate tension T_M, too, is to change to $T_M + \Delta T$. However, the buffer roll 37 pushes up the steel strip S by a predetermined torque by the torque motor 18 and this torque is in equilibrium with the intermediate tension T_M. In consequence, the buffer roll 37 to have a low inertia moves mechanically up and down by the rotating movement in accordance with the tension variation component ΔT and is kept at the intermediate tension T_M. In other words, the buffer rolls moves down when ΔT is positive and moves up when ΔT is negative, and even though the entry side tension T_1 changes, the buffer roll 37 absorbs the change component and does not affect the delivery side tension T_2. When the entry side tension returns to T_1, the buffer roll 37, too, returns to its original position. Similarly, even when the delivery side tension T_2 changes, it does not affect the entry side tension T_1.

More, when the entry side tension T_1 changed to $T_1 + \Delta T$, the intermediate tension, too, changed to $T_M + \Delta T$, and this tension was detected. In this way, the driving force of the torque motor 18 was controlled, and the tension variation can be absorbed by electrically moving the buffer roll up and down. Even when the tension variation of high frequency, which this control could not follow, existed, the variation could be absorbed because the buffer roll 37 pushing up the steel strip with the torque balancing with T_M moved mechanically up and down.

In the apparatus of the invention, an upward torque was imparted by a predetermined driving force of the torque motor 18 to the buffer roll 37 so as to push up the steel strip S, and the pushed up force is regulated by the inclined angle α. The inclined angle α can be regulated in the range of $0 \leqq \alpha \leqq 90°$. In a reference position control of α, a tension set value was input, the driving force was imparted to the torque motor 18, and the tension was detected and was fed back so as to attain a target tension value. The tension correction was made in accordance with the formula (2) because the force applied to the buffer roll 37 changes with the inclined angle α and the slope angles θ_1 and θ_2, even if the intermediate tension T_M is predetermined. The F is input and a torque of the torque motor 18 is set.

$$F = T_M \cos\alpha (\sin\theta_1 + \sin\theta_2) \quad (2)$$

where

F : a force pushing up the buffer roll 37,

T_M: a tension of the buffer roll portion (Intermediate tension)

More, in the apparatus of the invention, when the tension variation of the steel strip S is slow and mild, the torque of the torque motor 18 is regulated, or the peripheral speed of rotation of the first bridle rolls 7A, 7B or of the second bridle rolls 8A, 8B is regulated by regulating the drive motors 38A, 38B or 39A, 39B, and in this manner, control can be effected. When the buffer roll 37 is returned to the original position after the tension variation ΔT is absorbed by the buffer roll 37, the peripheral speed of the first bridle rolls or the torque of the torque motor 18 is regulated.

When the apparatus of the present invention is disposed on the entry side and/or the delivery side of processing equipment such as annealing equipment in the continuous process line of the steel strip, the tension variation occurring due to drastic acceleration and deceleration in the operation of the loopers on the entry and delivery sides of the line is prevented from being transmitted to the processing equipment, and the steel strip inside the processing equipment can always be fed at a suitable predetermined tension. Accordingly, the occurrence of buckling and scratching can be reliably prevented. Further, the tension variation when the steel strip feed speed is changed in the processing equipment can be absorbed, and buckling and scratching can also be prevented reliably in the same way.

Next, it is preferred in the present invention to fit a counterweight 17 to the supporting shaft 15 of the buffer roll 37 as in the example shown in Fig. 6. In the example shown in Fig. 6, the counterweight 17 generates an upward torque in the buffer roll 37, and when it is employed for the example shown in Fig. 5, the driving force of the torque motor 18 can be reduced. Besides the example shown in Fig. 6, the position and weight of the counterweight 17 can be regulated in accordance with the direction of the contact of the buffer roll 37 with the steel strip S and with the magnitude of the torque.

When the apparatus of the present invention is applied to the continuous process line, it can be easily installed at the most suitable position whether the line may be a new line or an existing line. An application example is shown in Figs. 7(a) - 7(f). In Fig. 7(a), deflector rolls 9 are disposed between the buffer roll 37 and the first bridle roll 7B and between the buffer roll 37 and the second bridle roll 8A, and the winding angle of the steel strip S at each bridle roll is constant irrespective of the rotating movement position of the buffer roll 37. Accordingly, the buffer roll is not affected.

However, in the case of Fig. 5 where the deflector rolls 9 do not exist or in the cases of Figs. 7(b) et seq where the winding angle of the bridle rolls 7B and 8A changes with rotating movement position of the buffer roll 37, there occurs no problem so long as the necessary winding angle of the bridle rolls is retained.

The buffer roll 37 may push down the steel strip S as shown in Figs. 7(b) and 7(c) or may pull up the steel strip S as shown in Fig. 7(d) or may push the steel strip S in the transverse direction as shown in Figs. 7(e) and 7(f). By the way, besides the bridle roll comprising a pair of rolls, the bridle roll may comprise a set of three rolls 7A, 7B, 7C as shown in Fig. 7(e) or may comprise only one roll.

Subsequently, the third technical feature of the invention will be described below. An example of the preferred embodiment is shown in Fig. 8. The example is combined with the first and second technical features. Namely, the in-furnace bridle roll 3 is interposed between the overaging zone 25 and the second cooling zone 26 of the continuous annealing portion, further the bridle rolls 7A, 7B, 8A, 8B are disposed at entry and/or delivery side in proximity to the outside of the furnace, at least one pair of them facing each other, and the buffer roll 37 mentioned previously is disposed in at least one position between the facing bridle rolls. In such a manner, tension values before and after the in-furnace bridle roll can be regulated independently of each other because the in-furnace bridle roll is interposed between the overaging zone and the second cooling zone.

Further, due to the bridle rolls 7A, 7B, 8A, 8B of entry and/or delivery side and the buffer roll 37, the tension variation occurring due to drastic acceleration and deceleration in the operation of the loopers on the entry and delivery sides of the line is prevented from being transmitted to the steel strip inside the continuous annealing furnace can always be fed at a suitable predetermined tension.

EXAMPLE

Example 1

Continuous annealing was carried out by feeding soft steel strips having sheet thickness of 0.24 mm and 0.26 mm and a width of 1,024 mm to the apparatus of the present invention shown in Fig. 4. In the secondary cooling zone 26, the gap between the gas jet cooler 27 and the steel strip S was 150 mm, and the flow velocity of wind from the gas jet cooler 27 was set to 30 m/sec. The strip speed was 500 m/min for the strip having the thickness of 0.24 mm and was 430 m/min for the strip having the thickness of 0.26 mm. The fluttering amount of the steel strip S when the tension Tb of the strip S was changed in the secondary cooling zone 26 by the in-furnace bridle roll 3 and the bridle roll 2 just after the furnace was measured. As a result, the fluttering amount W of the steel strip S could be kept stably within the range of 100 mm and scratching did not occur at all when the tension Tb was made greater than the tension Ta in the heating zone 22 to the overaging zone 25 and keeping the difference ΔT (= Tb - Ta) at not smaller than 4 N/mm^2. By the way, the tension Ta in the heating zone 22 to the overaging zone 25 was set to 6 N/mm^2. The fluttering amount W represents the fluttering amount on one side from a pass line of the steel strip S indicated by dash line as shown in Fig. 9(b).

The problem of meandering of the steel strip S could also be eliminated by setting ΔT to at least 4 N/mm^2. This walking occurred when water entered the gaps between the steel strip S and the rolls inside the water cooling tank 28 and the steel strip swayed in the axial direction of the rolls due to hydroplaning. This problem could be solved by the apparatus of the present invention because invasion of water was suppressed by the increase of the tension.

Incidently, even when the tension of the steel strip S was regulated in the manner described above in the secondary cooling zone 26, the tension in and before the ovaraging zone 25 could be kept constant, and the occurrence of heat buckling could not be observed.

Comparative example

In the continuous annealing furnace F shown in Fig. 4, the in-furnace bridle roll 3 was not disposed, but support rolls 40 coming into contact with the steel strip S between the gas jet coolers 27 were disposed at two positions between the upper and lower rolls for each pass of the secondary cooling zone 26 as shown in Fig. 4, so as to suppress fluttering of the steel strip S. When the strip was fed under the same condition as that of Example of the present invention except that ΔT = 0, the occurrence of scratching due to the contact with the gas jet coolers 27 could be restricted but in this case, the support rolls 40 had to be driven. Because the gas jet coolers 27 could not be disposed at the positions of the support rolls 40, the effective cooling length decreased as a whole and the number of passes of the secondary cooling zone 26 had to also be increased. For these reasons, the cost of production became approximately three times that of the present invention in mechanical and electrical setups.

Example 2

In a continuous annealing line of a cold-rolled thin steel strip, the apparatus of the present invention was disposed on each of the entry and delivery sides of an annealing equipment so as to carry out the tension control. The tension control on the entry side of the annealing equipment will be explained with reference to Fig. 11. The steel strip S was introduced into the annealing equipment, not shown in the drawing, through the first bridle rolls 7A and 7B, the deflector roll 9, the buffer roll 37, the deflector roll 9, the second bridle rolls 8A and 8B, and the deflector roll 9.

Each bridle roll 7A, 7B, 8A, 8B was driven by each drive motor 38A, 38B, 39A, 39B and the buffer roll 37 was driven by the drive motor 18 and imparted a suitable tension to the steel strip. A tension meter 41 for detecting an intermediate tension T_M of the strip was equipped in the proximity of the roll 7B. More, a tension meter 42 for detecting a tension T_2 of a strip inside the annealing equipment was equipped behind the second bridle roll 8B. A detecting tension of the tension meter 42 was fed back to a target tension 56-(T_2) to make the strip S impart, the tension difference was input to a tension regulator 52 and was converted to a speed command adjustment. The converted speed command was summed up to a strip speed reference inside furnace 57 and input to a speed regulator 50 as a speed command. A speed regulation was made to the driving motor 39A, 39B for the second bridle roll 8A, 8B by the speed command and a tension inside furnace was regulated to a target tension T_2. A detecting tension of the tension meter 41 was fed back to a target tension 55(T_M) to make the strip S impart, the tension difference was input to a tension regulator 51 and was converted to a torque command for adjustment. The converted torque command was input to a current regulator 47 as a torque command (current command). A current regulation was made to driving motor 18 for the buffer roll 37 by the torque command and an intermediate tension of the strip was regulated to a target tension T_M.

An upward torque was imparted by a predetermined driving force of the torque motor 18 to the buffer roll 37 so as to push up the strip S. Both slope angles θ_1 and θ_2 with respect to the pass line were set to about 11° an angle between the pass line and an arm of the buffer roll is set to about 30° and were used as a reference position of the buffer roll 37. The tension correction was made in accordance with the formula (2) because the force applied to the buffer roll 37 changed with the inclined angle α and the slope angles θ_1 and θ_2, even if the intermediate tension T_M was predetermined. The F was input and a torque of the torque motor 18 was set.

$$F = T_M \cos\alpha(\sin\theta_1 + \sin\theta_2) \quad (2)$$

where

F: a force pushing up the buffer roll 37,

T_M: a tension of the buffer roll portion (Intermediate tension)

When the entry side tension T_1 changed to $T_1 + \Delta T$, the intermediate tension also changed to $T_M + \Delta T$, and this tension was detected by the tension meter 41. In this way, the driving force of the torque motor 18 was controlled, and the tension variation was absorbed by moving up and down the buffer roll. Even when the tension variation of high frequency, which this control could not follow, existed, the variation could be absorbed because the buffer roll 37 pushing up the steel strip with the torque balancing with T_M moved up and down.

The torque motor 18 was equipped with an angle detector 19, and this detector 19 detected the rotating angle of the torque motor 18 when the buffer roll 37 moved up and down due to the variation of the entry side tension T_1, so that the rotating peripheral speeds of the first bridle rolls 7A and 7B could be regulated and the buffer roll 37 was returned to the original position. Namely, an angle α of an arm detected by using an angle detector 19 was fed back to a target position reference (target angle) 54 and seeked a difference to be adjusted, that was converted to a speed command value by a position regulator 53. The speed command value was summed up to desire a strip speed reference inside furnace 57 and input to a speed regulator 49 as a speed command. A speed regulation was made to a driving motor 38A for the first bridle roll 7A, 7B by the speed command and the angle α of the arm was regulated to a target angle.

Reference numeral 57 denotes the strip speed reference inside the furnace, and a predetermined speed inside the furnace is input to the speed regulator 49 of the first bridle rolls 7A, 7B and to the speed regulator 50 of the second bridle rolls 8A, 8B.

In such a control system of the invention, a two step tension control system was installed for a tension variation or the like from entry side of the first bridle roll by the buffer roll 37 and the second bridle roll 8A, 8B using a tension meter 41, 42, further, for up and down movement of the buffer roll, a position control system was installed by using an angle detector 19, and thus a tension control of a strip S with high response and high precision compared to the conventional control system could be made.

Incidentally, the buffer roll having a low inertia can absorb a tension variation, which the above tension control system cannot absorb, by mechanically moving up and down.

Conclusively, the following result was obtained by comparing with simulation of the effect of a tension control according to the invention and the conventional method.

Here, as a prerequisite of the simulation, when a tension variation of 90 kg was imparted from the entry side of upstream bridle roll, an actual tension record (that is a value of a tension meter 42) in delivery side of downstream bridle roll was obtained.

Table 1

A tension variation according to various control systems		
Present invention system	Conventional	
	A system	B system
200 N	300 N	400 N

It is apparent from Table 1 that the control system of the invention is most excellent in comparison with the conventional systems.

As mentioned above, the tension control system according to the present invention employs the buffer roll having an extremely low inertia, and when this system is used in a continuous process line of a steel strip such as a continuous annealing line of a thin steel strip, a thin strip can be fed stably at a suitable tension even when any tension of a high frequency occurs in the entry side equipment, the delivery side equipment, and so forth, without transmitting such a tension variation to the processing equipment such as the annealing apparatus. Accordingly, the present system can reliably prevent the occurrence of buckling and scratching of the strip. Further, the present system can be easily installed at an optimum position of an existing line because its installation space is small.

Moreover, in the continuous annealing furnace of a steel strip including the heating zone, the soaking zone, the primary cooling zone, the overaging zone and the secondary cooling zone, the present invention disposes the in-furnace bridle roll between the overaging zone and the secondary cooling zone, and thus can independently regulate the tensions before the overaging zone and after the secondary cooling zone. Accordingly, the present invention can prevent heat buckling resulting from an excessive tension in the overaging zone, and can reliably prevent the occurrence of scratching of the steel strip due to contact with the gas jet cooler and the occurrence of walking resulting from invasion of water in the water cooling tank.

Accordingly, it is no longer necessary in the present invention to lower the feed speed of the steel strip to cope with the occurrence of heat buckle, scratch and walk, as has been necessary in the prior art, and quality of the steel strip can be improved while maintaining high productivity. Further,the structure of the in-furnace roll added is simple, and its costs of production and maintenance are also low.

Claims

1. In a continuous annealing furnace of a steel strip including a heating zone, a soaking zone, a primary cooling zone, an overaging zone and a secondary cooling zone, a continuous annealing apparatus of a steel strip characterized in that an in-furnace bridle roll is interposed between said overaging zone and said secondary cooling zone, a tension of said steel strip in an entry side before said in-furnace bridle roll is lowered, and said tension in a delivery side after said bridle roll is increased.

2. In a continuous process line of a steel strip disposing a pair of out-furnace bridle rolls facing each other at an entry side and/or delivery side of a treating equipment, a tension control system of a steel strip characterized in that a first bridle roll, a second bridle roll and a buffer roll coming into contact with said steel strip between both of said bridle rolls are disposed, said buffer roll can move in circle in a direction crossing a pass line connecting rolls before and after said buffer roll in accordance with a tension variation of said steel strip, and said tension is regulated by an angle α between an arm of said buffer roll and said pass line.

3. The tension control system according to claim 2, wherein the angle α is regulated in a control range of $0^\circ < \alpha \leqq \alpha_0$ or $\alpha_0 \leqq \alpha < 90^\circ$ as a boundary value α_0 which gives a maximal value of F defined by the formula (1) hereunder.

$$F = T_M \cos\alpha\{\sin(\tan^{-1}\frac{R'\sin\alpha}{L_1}) + \sin(\tan^{-1}\frac{R'\sin\alpha}{L_2})\} \quad (1)$$

where,

$$R' = R - \frac{b}{\sin\alpha},$$

$$L_1 = a - c - \frac{b}{\tan\alpha}, \quad L_2 = c + \frac{b}{\tan\alpha},$$

A: a fulcrum of the buffer roll,
b: a distance between the pass line and the fulcrum,

c: a distance between the fulcrum and an entry side roll of the second bridle roll,
α: an angle between an arm of the buffer roll and the pass line,
R: the arm length of the buffer roll,
a: a distance between a delivery side roll of the first bridle roll (or a deflector roll) and an entry side roll of the second bridle roll (or a deflector roll),
T_M: a tension of a steel strip,
F: a force pushing down the buffer roll by T_M.

4. In a continuous annealing furnace of a steel strip, a continuous annealing apparatus of a steel strip characterized in that an in-furnace bridle roll is disposed in a strip pass line between an overaging zone and a secondary cooling zone, further a tension control system comprising at least one pair of out-furnace bridle rolls which are facing each other and a buffer roll coming into contact with said steel strip therebetween are disposed in an entry side and/or a delivery side of said continuous annealing furnace.

5. The tension control system of a metal strip according to any one of claims from 2 to 4, wherein an axis of said buffer roll is rotatably supported by an arm fixed to a supporting axis, and a torque motor for revolving said supporting axis is disposed.

6. The tension control system of a metal strip according to claim 5, wherein a counterweight is disposed on said supporting axis.

Fig.1

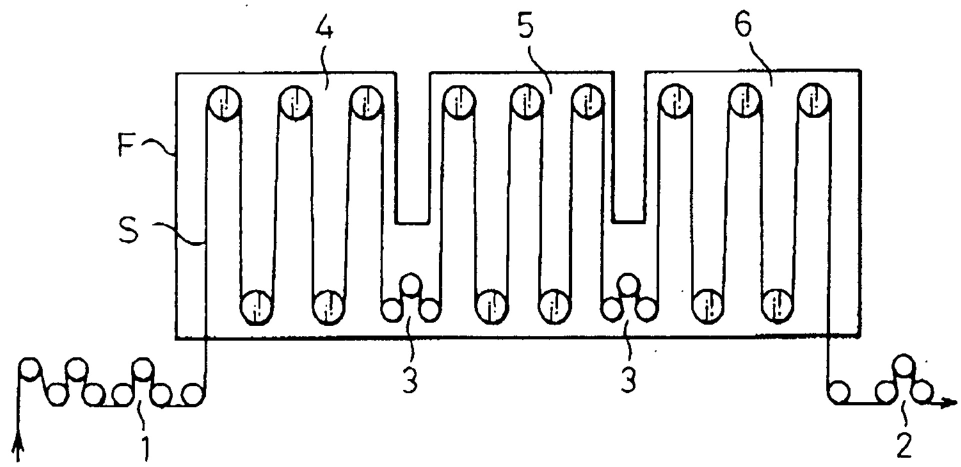


Fig.2

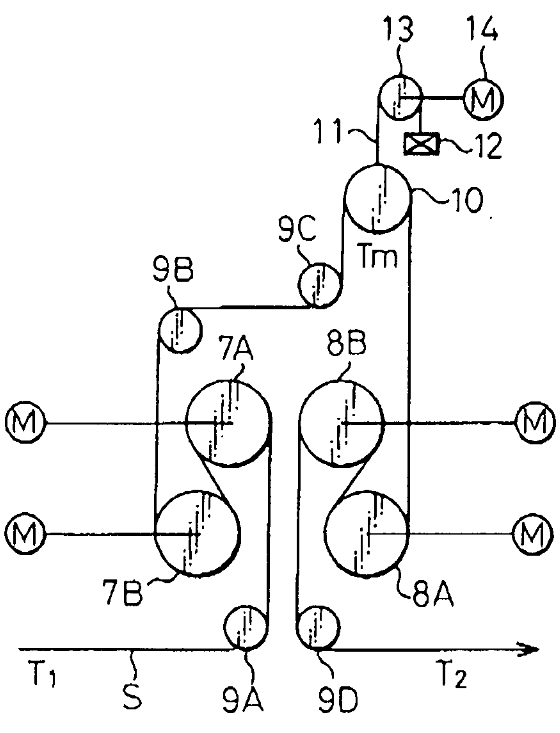


Fig.3

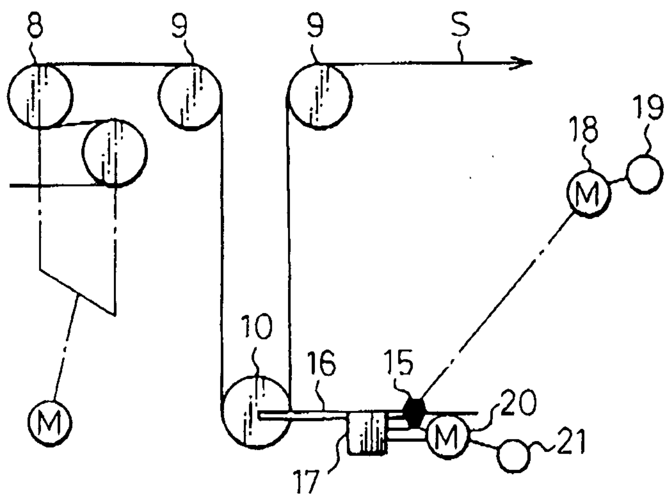


Fig. 4

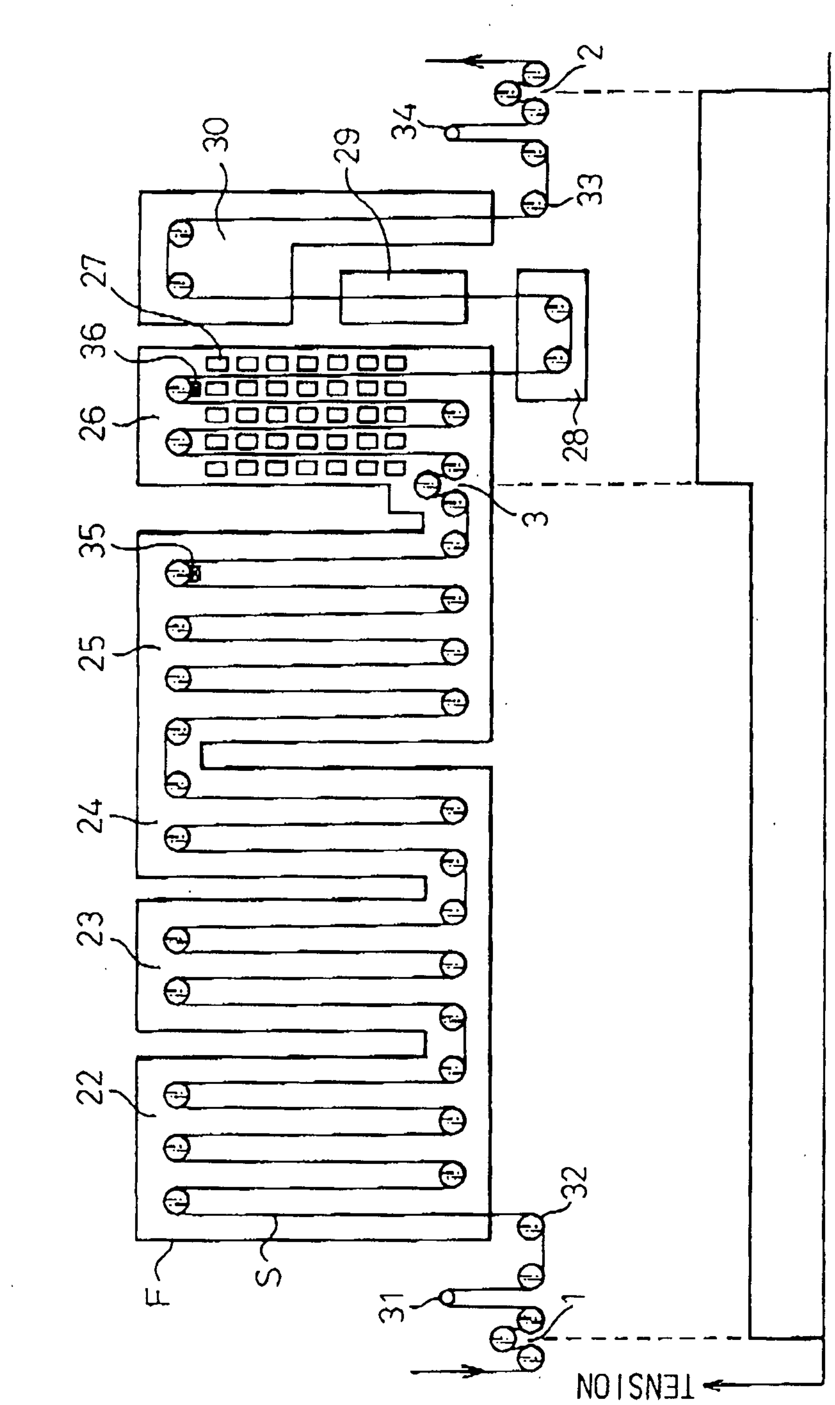
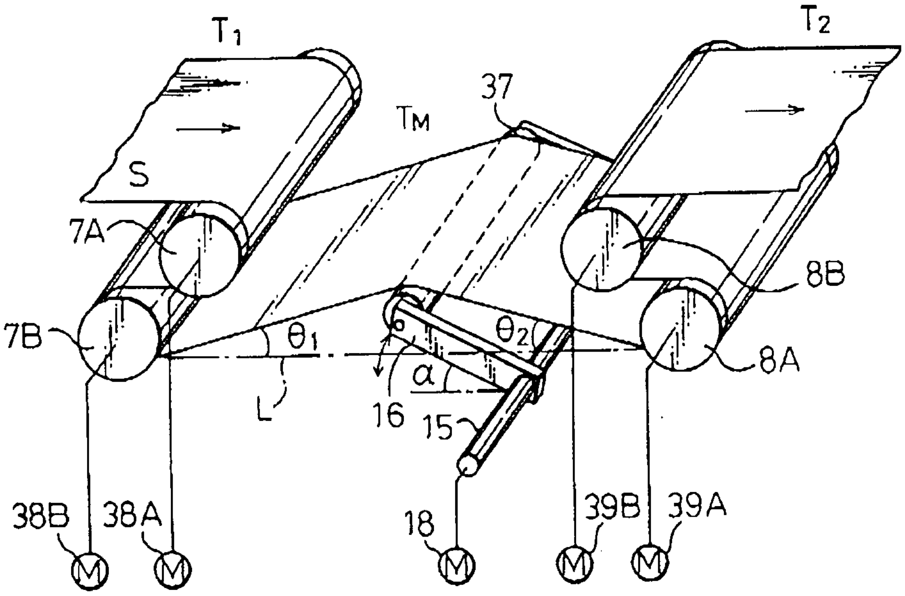


Fig. 5


T1
T2
37
TM
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7A
8B
7B
θ1
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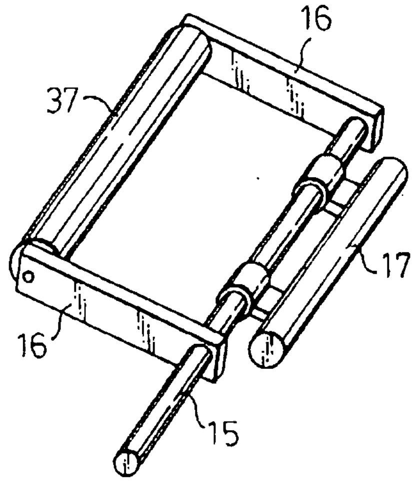
Fig. 6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37
17
16
15

Fig.7(a)

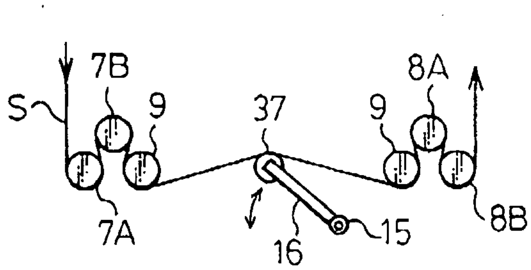


Fig.7(b)

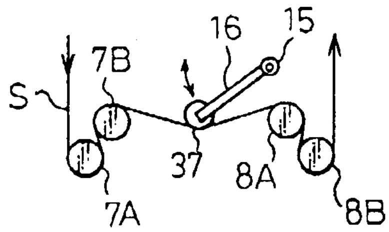


Fig.7(c)

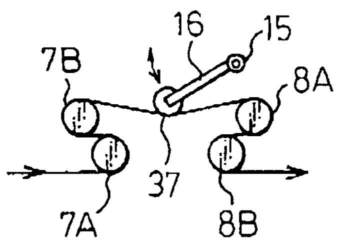


Fig.7(d)

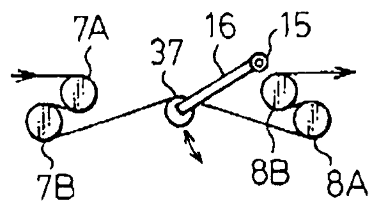


Fig.7(e)

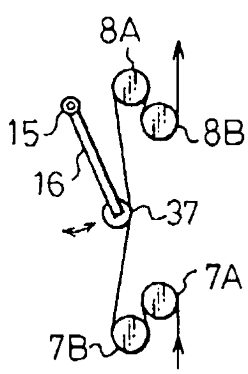


Fig.7(f)

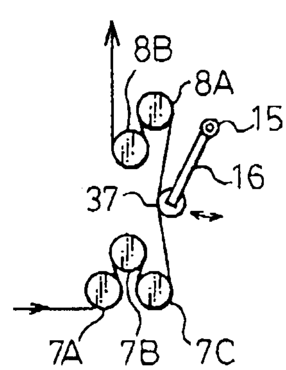


Fig.8

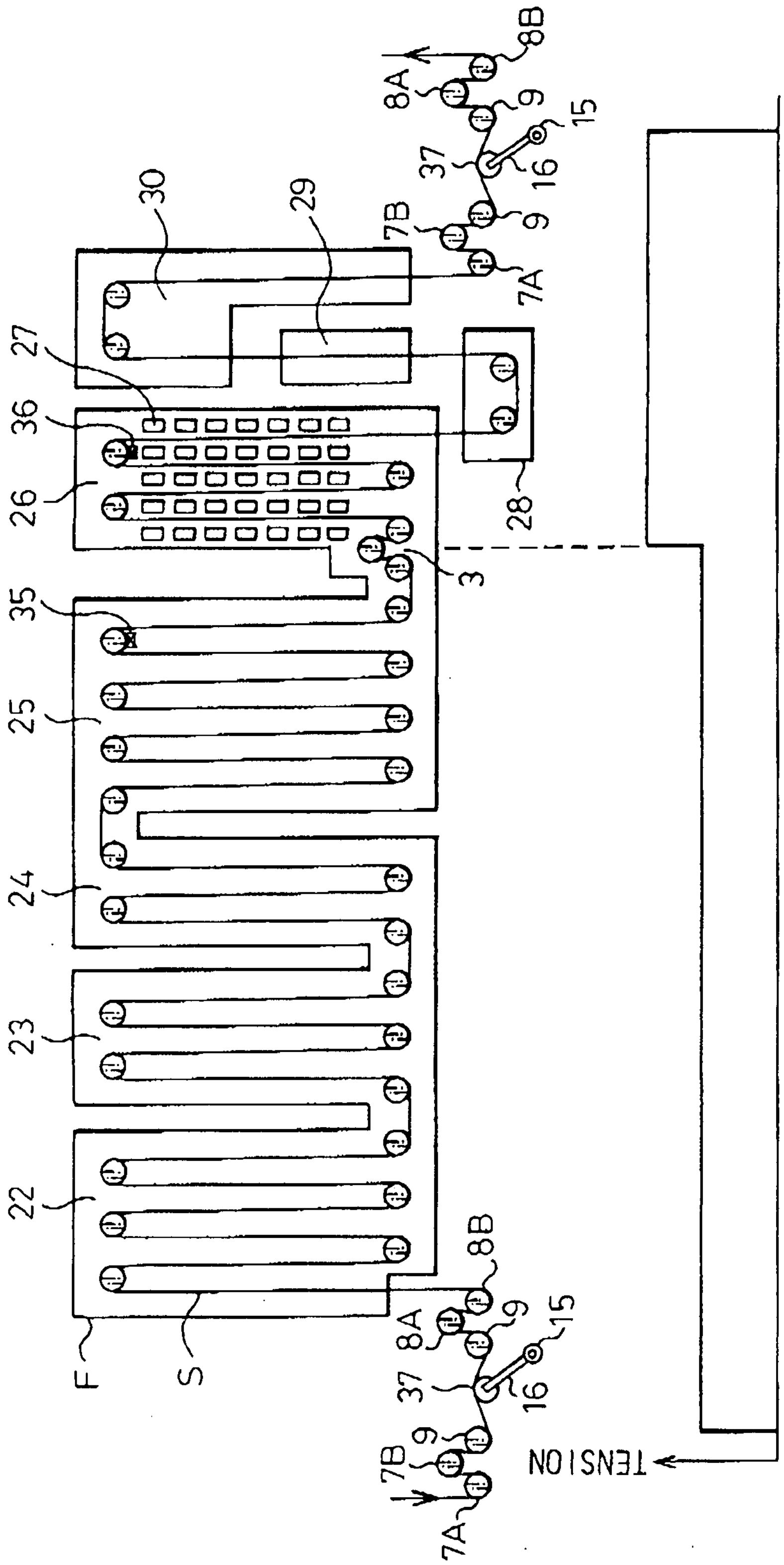


Fig.9(a)

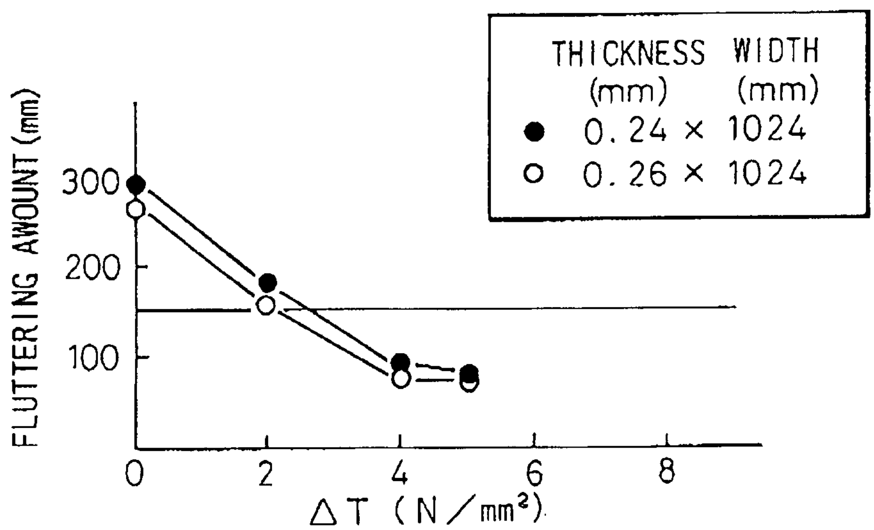

THICKNESS WIDTH
(mm) (mm)
● 0.24 × 1024
○ 0.26 × 1024
FLUTTERING AWOUNT (mm)
300
200
100
0
2
4
6
8
ΔT (N/mm²)

Fig.9(b)

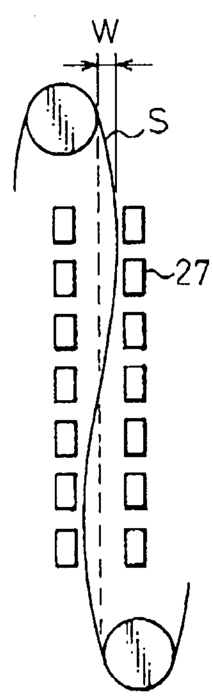

W
S
27

Fig.10

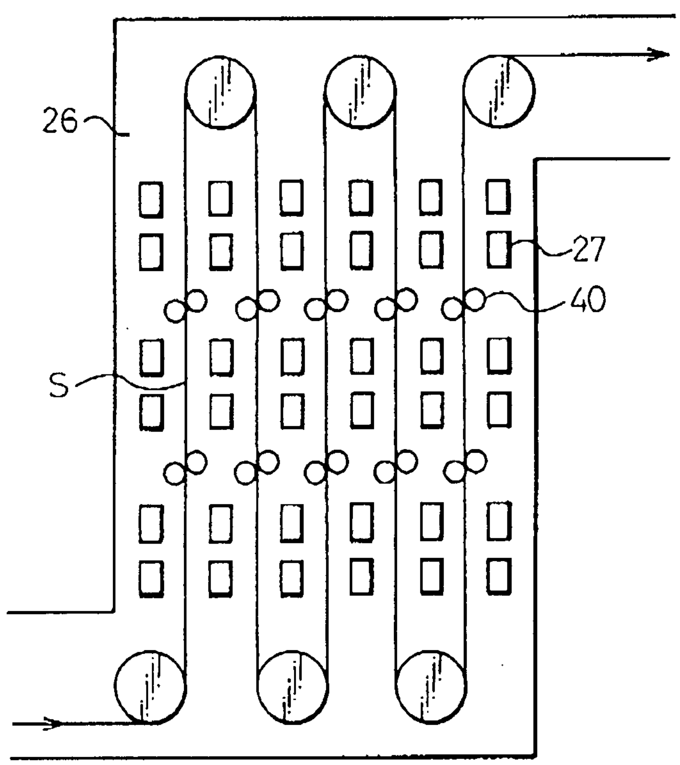
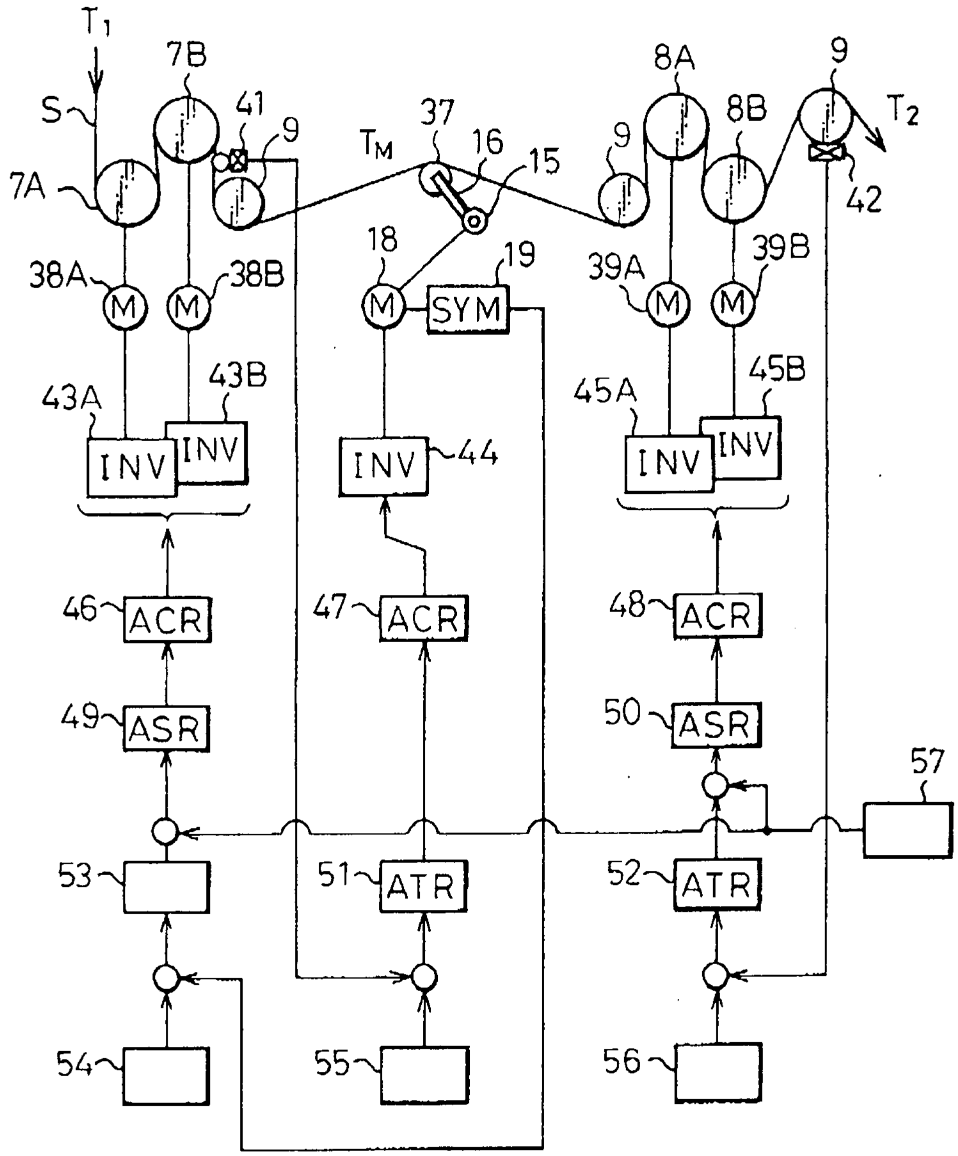


Fig. 11



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8B
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38B
M
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SYM
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39B
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M
43A
43B
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45B
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INV
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Fig.12

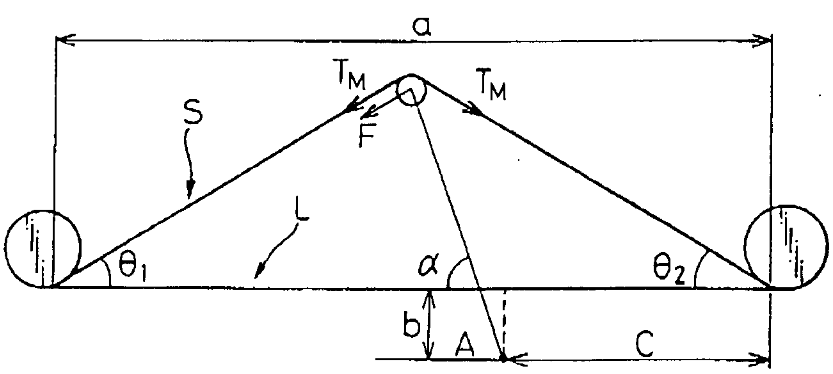
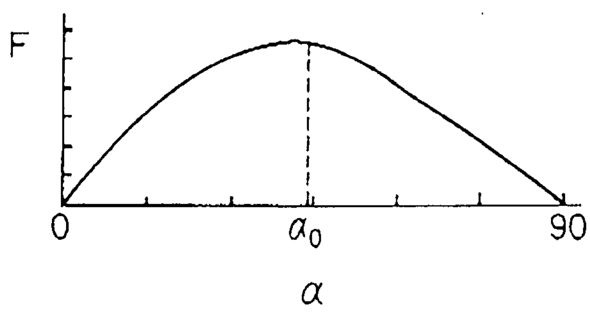


Fig.13



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 6061

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.6)
X	EP-A-0 036 035 (KAWASAKI STEEL CORPORATION) * claims; figures * ---	1	C21D9/56
X	BE-A-669 761 (ARMCO STEEL CORPORATION) * claims; figures 1,5 * ---	2	
A	EP-A-0 030 614 (KAWASAKI STEEL CORPORATION) ---		
A,D	EP-A-0 031 013 (KAWASAKI STEEL CORPORATION) ---		
A	EP-A-0 487 274 (SELAS CORPORATION) ---		
A	DE-A-21 41 906 (SCHWEIZERISCHE ALUMINIUM AG) -----		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
C21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 June 1995	Mollet, G

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
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