COIL WINDER COOLING DEVICE

Inventors: Karl-Heinz Spiecker, Duisburg; Wolfgang Mudersbach, Dinslaken; Rolf Michel, Duisburg, all of Germany

Assignee: Demag Aktiengesellschaft, Germany

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ABSTRACT

The invention relates to a process for cooling and forming coils of wire or steel as it emerges hot-rolled from the output stand of a rolling train. The wire or steel is cooled down from the terminal rolling temperature by controlled procedures to enhance the quality of the finished wire and, in turn, to improve the output of the process from an economical standpoint.

12 Claims, 9 Drawing Figures
Fig. 1
COIL WINDER COOLING DEVICE

This application is a continuation-in-part of application Ser. No. 394,983, filed Sept. 7, 1973, now abandoned.

BACKGROUND OF THE INVENTION

Conventionally, wire passes through water nozzles equipped with cooling pipes and heat transfer arrangements between the output roll stand and the reel. However, because of the short length of the cooling section between the output roll stand and the reel, coupled with the high terminal rolling speed, the cooling time is necessarily too short to achieve cooling of the entire cross-section of the wire or strip prior to entering the reel.

Conventionally, wire or highly refined steel is cooled in static air from the time of entering the reel until a time after leaving the reel in coil form. However, this method results in long delays as well as undesirable, non-uniform cooling over the coil cross-section. Because of the long cooling period, too much undesirable surface scale forms, and the final product contains perlite and ferrite with an unacceptably high ferrite content.

Proposals to overcome these problems include inserting the formed coil into a liquid bath, preferably a salt bath. This type of cooling is effective, but the advantages thereof are outweighed by the cost which prohibits its use for mass production application.

A continuous water cooling treatment has also been proposed but is unsatisfactory because it sometimes leads to a formation of martensite, which is undesirable for further processing. Furthermore, with this type of treatment, the cooling over the cross-section of the wire is non-uniform. Of course, both cooling in static air, as well as cooling in a liquid bath are types of continuous cooling.

SUMMARY OF THE PRESENT INVENTION

The object of the present invention is to avoid the drawbacks of the earlier cooling methods. To that end, the new and improved method generally comprises an intermittent type of cooling with brief cooling alternating with compensation periods of ambient air contact, so that rapid cooling is achieved with substantially reduced scale formation. Thus, a final structure is produced of perlitic and ferritic with the desired much higher perlite content compared to ferritic than was previously achieved. Uniform cooling is effected over the entire cross-section and the length of the wire. Furthermore, because of the accelerated cooling achieved, much less expensive installations are required.

The above is achieved by cooling the wire in progressive stages during winding on the winder drum which revolves around an axis, or alternatively after completing a full winding layer. In this way, the wire or double-refined steel is intermittently cooled, i.e., intensive liquid cooling zones are alternated with zones wherein the wire or double-refined steel is exposed to ambient air. This causes intermittent reheating of the previously cooled outer area from the inside out, resulting in a uniform temperature distribution over the entire cross-section of the material being treated. This uniform cooling results in a shorter cooling period, together with a final product with lower scale formation and more desirable material content.

In the invention herein, a horizontal winder drum is used. Because of this, cooling application takes place over the entire circumference of the winding drum. Winding on the drum takes place by winding from one end to the other and then back, with movement back and forth, so that one or more layers of wire or strip may be wound, as desired.

In the practice of this invention, it will be understood that the diameter or thickness of the wire being treated will determine the time intervals (width of cooling application) to be used with the alternating air compensation periods. Generally, wire having a thickness or diameter within the range of between about 10 and 50 mm may be used. Larger diameters require longer alternating cooling application, so that the underlying layers will be partially cooled as well. The invention contemplates the use of a water nozzle system as well as a liquid bath for cooling during winding.

The cooling device comprises cooling manifolds on which nozzles are arranged with the manifolds disposed parallel to the axis of the winding drum at a radial distance from the surface of the wire or steel. In order to guarantee, with an increased number of winding layers, the same radial clearance of the nozzles from the surface of the wire or steel, the cooling manifolds are movable radially, so that the clearance of the nozzles from the circumference of the coil is regulated as a function of the coil diameter. During the entire winding time, cooling takes place uniformly over the width of the reel. The spraying design of the nozzles is configured so that the wound coil is cooled over a specific portion of the coil circumference, while the remaining portion of the circumference is in a compensation period with no cooling. The length of cooling and compensating portions over the circumference of the coil is adjusted to the size and characteristics of the wire and/or steel being treated.

In the operation described above, it is important to maintain proper control, or a non-uniform cooling can take place because of the continuous winding and the different cooling times of individual windings involved. In addition, the cooling time can be too long, i.e., absolutely and relative to the compensating time, so that the surface temperature of the coil would fall below an admissible temperature too quickly. For this reason, a cooling manifold is provided, in accordance herewith, which is divided over the reel width into cooling sections, so that cooling is obtained only in the area "associated" with coil windings. Thus, each manifold can be put into operation in a sectionalized manner as required. In winding the coil, cooling is effected in the narrowest zone of the newly formed windings, i.e., an "associated" cooling is obtained.

Thus, the cooling time of a cooling section is adjusted in such a way that, in reversing the winding action for a new layer, the double cooling time of the preceding layer without the corresponding compensating time (only by rotation of the circumference) does not fall below the martensite-forming temperature, for example, to a lower critical temperature. In case the dimensions and the characteristics of the coil permit a faster change from cooling to compensating time than is possible by applying the cooling described above, this can be obtained by cooling simultaneously at several points along the longitudinal extent of the winder drum. Furthermore, several cooling manifolds can be affixed around the circumference, so that the cooling over the
circumference of the winder drum is effected in a spaced manner. Thus, the cooling sections of the various cooling bars can overlap or overcross.

With the invention herein, cooling may be effected in several ways. For example, cooling application may take place only after the completion of the winding of a layer during one or several revolutions of the winder drum. In this manner, cooling starts only on reversing the winding direction, and temperature compensation is effective during the winding of a new layer. In another practical embodiment of the invention, part of the coil circumference is cooled by inserting it into a cooling bath during or after the winding. In this embodiment, the coil is also wound on the winding drum. Below the winding drum, a basin with the applicable coolant is located in such a way that a small portion of the circumference of the coil is inserted in the bath. The rotation of the winder drum produces alternating cooling periods and non-cooling or compensation time periods over the circumference. The cooling times in the bath can be further regulated by the depth of the insertion of the drum into the bath.

Finally, the intensity of the cooling can be adjusted by regulating the quantity of the coolant related to the unit of time and to the unit of surface from a minimum to a maximum, or in reverse. Contrasting with above intermittent cooling between the output roll stand and the reel, the coil is repeatedly and thoroughly cooled by liquid jets, followed by a compensating time in static air, during which the fringe zone can be reheated from the inside out. This periodic cooling and reheating during the compensating time can be regulated as described above. In this way, a uniform cooling over the cross-section is obtained, until the desired temperature has been reached.

In case the cooling during the reeling is insufficient, i.e., if the temperature is too high, an accelerated cooling of the coil can be effected in one or several consecutive cooling stages. After a complete structural change has taken place, a continuous cooling by water can be applied for certain steels possessing characteristics which are immune to crack formation, in order to reach the desired final temperature as quickly as possible.

Before describing this invention in more detail, it may be well to note that this invention has been found particularly appropriate for cooling refined carbon or non-alloyed steels having a carbon content of no more than 1.0%. However, by choosing the right proportion between cooling and compensating times, and the quantity of cooling liquid utilized in the cooling zone, even alloyed steels may be cooled using the methods herein. That is, by applying a specified quantity of cooling liquid in liters per minute to a specified area of cooling zone in square centimeters, for example, enhanced cooling may be achieved herein in substantially reduced times without undesirably high quantities of ferrite in relation to perlite, or the formation of martensite.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cooling transformation diagram with superimposed cooling curves illustrating how cooling governs the final content of the coiled materials.

FIG. 2 is a somewhat diagrammatic front elevational representation of the cooling device utilizing nozzles with the side wall of the cooling bed removed for clarity;

FIG. 3 is a somewhat diagrammatic top plan view of the cooling device showing the spooling arrangement;

FIG. 4 is a diagrammatic end elevational view of the device of FIG. 3;

FIG. 5 is a diagrammatic end elevational view of a further embodiment of the invention, showing the use of a cooling bath;

FIG. 6 is a micro-photograph of carbon steel cooled with the invention herein having a carbon content of 0.15%;

FIG. 7 is a micro-photograph of carbon steel as in FIG. 6, but with a carbon content of 0.33%;

FIG. 8 is a micro-photograph similar to FIG. 6 with carbon steel having a carbon content of 0.43%; and

FIG. 9 is a micro-photograph similar to FIG. 6 with carbon steel having a carbon content of 0.73%.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

In FIG. 1, graphic illustrations of cooling curves are shown comparing prior art applications with those in accordance with this invention. The abscissa is time in seconds and the ordinate is temperature in degrees centigrade. Curve (a) represents a continuous cooling process with air cooling. In this case, no undesirable martensite structure is produced. However, the cooling time is much too long. Curve (b) also shows a continuous cooling process, but with liquid cooling. A shorter cooling time is obtained, but the result is a final product containing martensite. Curve (b1) is the core and (b2) is the outside temperature of the coil. Curve (c), according to the invention, represents an intermittent cooling with a short cooling time and, at the same time, a larger quantity of perlite as compared to ferrite as was the case with curve (a). Here, curve (c1) represents the core temperature, and curve (c2) the outside temperature of the coil.

Referring to FIGS. 2 and 3, reel 10 carries winding drum 12, on which wire 13 is wound up to form coil 15 by means of spooling device 14, all in well known manner. Coil 15 is partly surrounded by cooling basin 16, which is shown in section in FIG. 4; in this cooling basin, manifold or manifolds 17 are located equipped with nozzles 18 spraying fan-shaped jets 19 of cooling liquid. As can be seen in FIG. 4, three spaced cooling spray manifolds 17 are provided, and cooling basin 16 serves to catch cooling liquid 20 dripping from coil 15. Therefore, coil 15 is not inserted into the cooling liquid.

In the embodiment of FIG. 5, however, no cooling manifolds are provided, but the level of cooling bath 21 is high enough in cooling basin 25 that coil 15 always has a portion 22 of its circumference immersed in the cooling bath 21.

During operation, wire 13 is spooled by means of spooling device 14 on winder drum 12 of reel 10. In the case illustrated in FIG. 4, the wire is exposed, for example, to three spaced-apart fan-shaped jets 19, which determine that portion of the total circumferential extent of coil 15 exposed to cooling at any one time, and as a consequence the total cooling time. Nozzles 18 remain at all times at a precise spaced interval 24 from wire 13. In this connection, provision is made for moving spool 10 away from the manifolds 17 as additional layers are wound in order to maintain the same spacing.
24. The structure for this movement is not shown for clarity. The part of the circumferential extent of coil 15 between the nozzle spray areas 19, including the upper semicircular part of the coil projecting from the cooling basin, are located in static air zones and, therefore, are not cooled. These zones determine the alternating non-cooling compensating time intervals. During these compensating intervals, the heat radiates out from the inside of the coil and reheats the cooled surface portions of coil 15. Because of this, uniform cooling of the entire cross-section of the coil is obtained.

In the arrangement of FIG. 5, no nozzles are provided. The coil is cooled, therefore, only in the lower circumferential segment 22 of coil 15, which extends into cooling bath 21. This determines cooling time. The remaining circumferential extent of coil 15 remains uncooled in the static air zone, which determines the intermittent non-cooling time interval.

As purely illustrative of the invention herein, one may note the following Example I in which a wire having a diameter of 10 mm was cooled down from 900°C during rolling on the horizontal reel as shown in the embodiment of FIGS. 2 and 4. It is to be understood, however, that this example is being presented with the understanding that it is to have no limiting character on the broad disclosure of the invention as generally set forth herein and as directed to men skilled in the art.

**EXAMPLE I**

The final rolling speed $V_R$ for this 10 mm diameter wire was 20 meters per second, which is conventional on a modern refined carbon steel train. The refined steel was rolled onto the reel so that the individual windings of the coil were spaced apart about 2 mm. Several layers were superimposed onto the reel. As stated above, with the final rolling speed of 20 m/sec, and a reel diameter of 1 meter, the time taken to roll one layer with 2 mm spacings was 12 seconds.

During rolling onto the reel, the wire was cooled in accordance with the invention, by intermittent water-air cooling. 20% of the circumferential extent of the wound coil was exposed to the cooling water spray, while the remaining 80% was not. This non-exposed surface represented the compensation time, where the temperature between the surface and core of the coil were equalized.

The ratio between compensation time $A$ and cooling $K$ is 4:1. The quantity of water utilized was 0.15 liters per minute per each square centimeter of surface exposed. Thus, the indication of $A/K$ ratio and water quantity $1/\text{min} \times \text{cm}^2$ specifies cooling speed of the coil surface and the temperature differential between the coil surface and core coil. The wire length was selected to result in a coil having 4 superimposed layers. The rolling lasted 48 secs. Sixty seconds after starting (12 secs. after terminating the formation of the coil) the cooling device was turned off. The wire temperature had been reduced to 550°C.

Further cooling was accomplished by exposure to stagnant ambient air although it should be understood that it is within the purview of the invention to apply intermittent cooling until a desired temperature is reached. In this instance the temperature was reduced to about 100°C in ambient air. This procedure was repeated with the same parameters on four bundles having four different carbon contents and structural tests were taken of the resulting products which are shown in FIGS. 6-9 inclusive. These tests revealed the desired structure of perlite and ferrite discussed above in various portions of the four bundles tested.

The chemical analyses of the four different steel qualities are shown as follows:

**Steel 1:** C 0.15%, Mn 0.40%, Si 0.22%, P 0.024%, S 0.022%, Cr 0.37%

**Steel 2:** C0.33%, Mn 0.50%, Si 0.25%, P 0.026%, S 0.014%, Cr 0.07%

**Steel 3:** C 0.43%, Mn 0.62%, Si 0.26%, P 0.028%, S 0.014%, Cr 0.07%

**Steel 4:** C 0.75%, Mn 0.65%, Si 0.24%, P 0.024%, S 0.014%, Cr 0.07%

Moreover, the bundles cooled according to the invention with respect to stress values and malleability in tensile strength tests taken from various points in each bundle or coil formed. The results of these tests are noted below:

**Steel 1:**
- $\sigma_y = 48 \text{ kg/mm}^2$
- $\delta_y = 19%$
- $\sigma_{sp} = 38 \text{ kg/mm}^2$
- $\psi = 69%$

**Steel 2:**
- $\sigma_y = 63 \text{ kg/mm}^2$
- $\delta_y = 20%$
- $\sigma_{sp} = 40 \text{ kg/mm}^2$
- $\psi = 60%$

**Steel 3:**
- $\sigma_y = 73 \text{ kg/mm}^2$
- $\delta_y = 16%$
- $\sigma_{sp} = 50 \text{ kg/mm}^2$
- $\psi = 60%$

**Steel 4:**
- $\sigma_y = 114 \text{ kg/mm}^2$
- $\delta_y = 9%$
- $\sigma_{sp} = 77 \text{ kg/mm}^2$
- $\psi = 33%$

Thus, as can be seen from the above information, the cooling method herein shortens the time required for cooling down from 900°C to about 600°C as compared to air cooling, and simultaneously avoids most of the scaling formation. Moreover, improved structure is obtained obviating the further processing required with conventional air cooling.

It should be understood that it is within the purview of this invention to vary the cooling, non-cooling time intervals, as desired, depending upon the size of the wire coils, the thickness of the wire, and the materials comprising the wire. For example, by selecting a larger or smaller number of cooling fluid manifolds, the cooling process can be varied at will by changing the circumferential extent of cooling time versus non-cooling time. Furthermore, the same variance can be obtained by lesser or greater insertion of the coil into the cooling medium. Thus, the invention can be adapted at will and varied according to technological requirements.

While the methods and arrangements of apparatus herein disclosed form preferred embodiments of this invention, this invention is not limited to those specific methods and arrangements of apparatus, and changes may be made therein without department from the scope of this invention which is defined in the appended claims.

We claim:

1. A process for cooling wire emerging hot rolled from the output stand of a rolling mill train; the steps which comprise...
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a. winding said wire into coil form on a winding drum;
b. said winding drum having an axial length longer than the diameter of said wire being coiled for accommodating a plurality of windings of said wire in a single layer on said drum;
c. winding a plurality of layers of said wire on said drum;
d. simultaneously with said winding, applying liquid cooling medium to a portion of the circumferential extent of each outermost layer of coiled wire as it is progressively wound on said drum; and e. exposing the remainder of said circumferential extent of said outermost layer of coiled wire to ambient air.

2. A process as recited in claim 1, which includes a. discontinuing the application of cooling liquid medium to said wound coil; and b. subjecting said coil to a continuous ambient air cooling after said applying step.

3. A process as recited in claim 1, in which a. said winding step is carried out by controlling the placing of said individual windings of each layer on said drum.

4. A process as recited in claim 1, in which a. said applying step is carried out by continuously maintaining an equal spacing between the source of liquid cooling medium and the last layer applied to said coil.

5. A process as recited in claim 1, in which a. said applying step is delayed until the beginning of the formation of the second layer of said wire coil.

6. A process as recited in claim 1, in which a. the axis of said winder drum is horizontal.

7. A process as recited in claim 1, in which a. said applying step is carried out at a plurality of spaced-apart intervals around the circumference of said wound coil of wire.

8. A process as recited in claim 7, in which a. the size of said spaced intervals is varied directly in relation to the cross-section size of said wire.

9. A process as recited in claim 5, in which a. said applying step is carried out by applying said cooling medium simultaneously to the full longitudinal extent of a portion of the circumference of said outermost layer of wound coil.

10. A process as recited in claim 7, in which a. the size of said spaced intervals is varied depending upon the characteristics of said wire being wound and the speed of said winding step.

11. A process as recited in claim 7, in which a. said applying step is carried out with a plurality of nozzles extending longitudinally of said wound coil, said nozzles being positioned at a plurality of spaced intervals around the circumference of said wound coil.

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