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Hoffmann

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[54] **METHOD FOR HEAT TREATING STEEL WIRE ROD**

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Related U.S. Application Data

[63] Continuation of Ser. No. 743,101, July 8, 1968, abandoned.

[52] **U.S. Cl.**.....**266/3 R,** 148/134, 148/145, 148/156

[51] **Int. Cl.**.....**C21d 9/52**

[58] **Field of Search**.....266/3 R; 148/134, 148/145, 156

[56] **References Cited**

UNITED STATES PATENTS

2,756,169	7/1956	Carson et al.	148/134
2,994,328	8/1961	Lewis	266/3 R X
3,011,928	12/1961	Kapec et al.	148/156

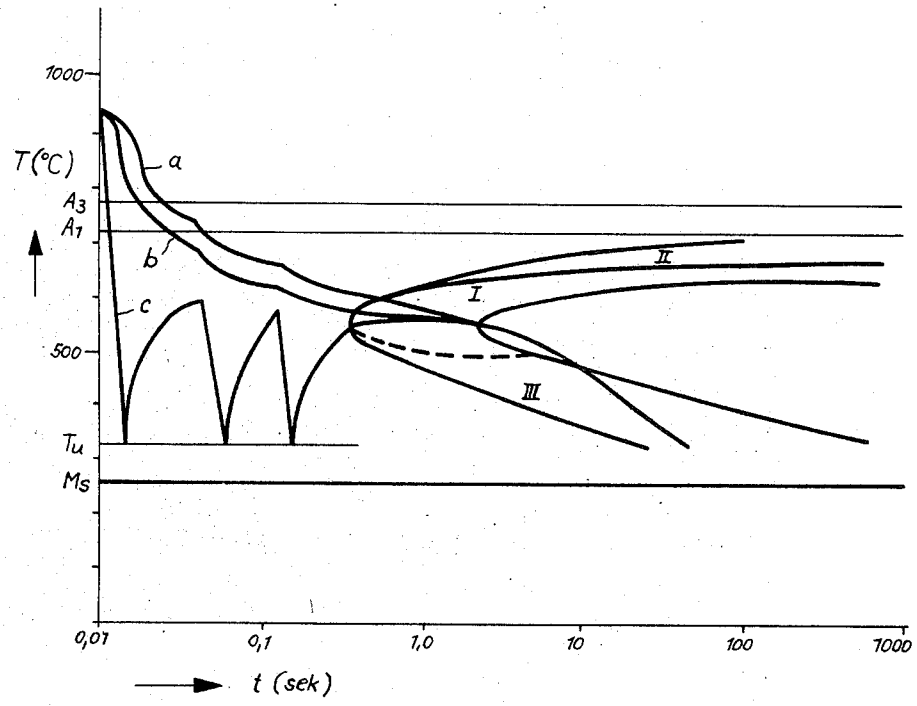
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[57] **ABSTRACT**

Patenting hot-rolled rod with alternate quenching and heat compensation stages before transformation; the quenching stations decrease logarithmically and the compensation stages increase logarithmically; the surface of the rod reaches is cooled down to below about 400°C, and the rod begins to transform in the pearlite zone before full temperature equalization, the rod being reeled when a substantial peripheral zone of the rod has been predominantly transformed to pearlite.

3 Claims, 2 Drawing Figures



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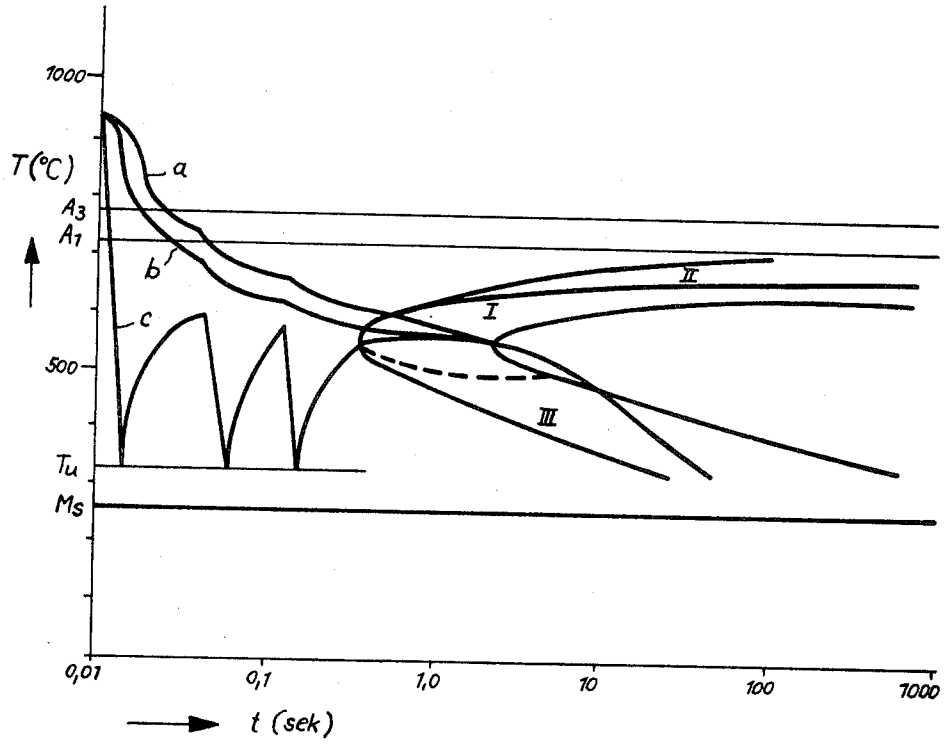


Fig. 1

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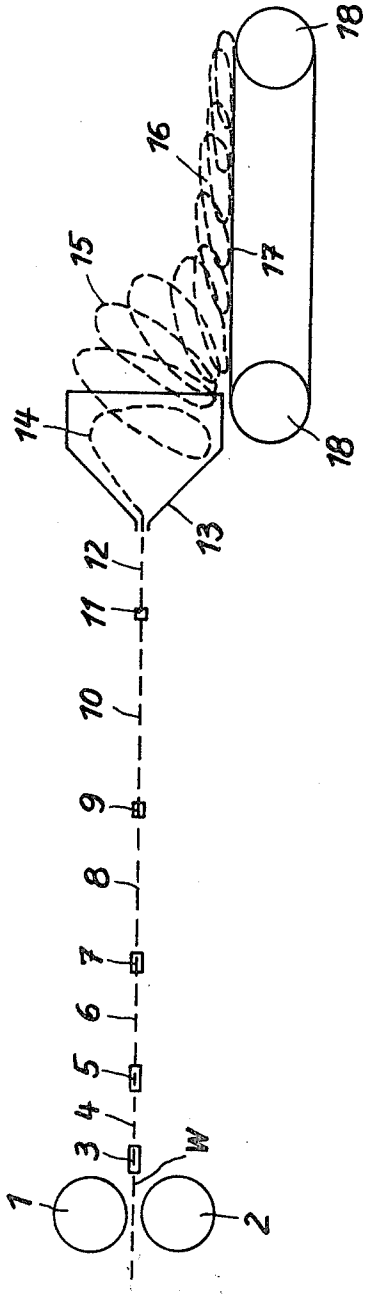


Fig. 2

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METHOD FOR HEAT TREATING STEEL WIRE ROD

This application is a continuation of Ser. No. 743,101, filed July 8, 1968, and now abandoned.

The invention relates to an apparatus for heat treating of hot, patentable steel rod (for instance rod having a carbon content of more or slightly more than 0.4 percent by weight) from the rolling temperature, in which after the rod leaves the last stand of a rod mill, the surface is quenched in successive stages and reheated by temperature compensation with its internal cross-section, and subsequently transformed in the pearlite transformation range.

According to the present invention, there is provided an apparatus for heat treating hot, patentable steel rod after the rod leaves the last stand of a rod mill, comprising means for quenching the surface of the rod to a temperature of about 70°C above the martensite transformation temperature in each of a number of successive quenching stages and allowing the surface of the rod to be reheated after each quenching stage by heat from the center zone of the rod so that the rod enters the pearlite transformation zone when temperature compensation is still occurring between the center and peripheral zones of the rod and with an average temperature of about 600° to about 650°C and the temperature of the rod surface is raised to above the upper bainite temperature before transformation begins, and reeling the rod when a substantial peripheral zone of the rod is predominantly transformed to a pearlitic structure.

Preferably, said peripheral zone has a radial thickness of about 10 to about 20 percent of the rod diameter. Hot rolled rods usually have a diameter of between 5 and 12.7 millimeter, and in the case of a thick rod, said peripheral zone may have a radial thickness of about 10 percent of the rod diameter whereas in the case of a thin rod, said peripheral zone may have a radial thickness of about 20 percent of the rod diameter. Preferably, the rod is reeled when the peripheral zone has been 50 to 70 percent transformed to a pearlitic structure.

Once the transformation of the peripheral zone has occurred in the manner described, the remaining heat content of the center zone is not able to transmit a high enough degree of heat to the peripheral zone as to cause the pearlite to be transformed back into austenite, which would involve the risk of renewed martensite formation. On the other hand, the peripheral zone prevents the spontaneous cooling of the center zone, which has not yet undergone transformation, by contact between the surface of the rod and the cold portions of the reel (or conveyor); such spontaneous cooling would result in the formation of martensite in the core.

Additional protection against too much heat being withdrawn from the metal when the surface comes into contact with the cold portions of the reel is afforded by the thin layer of scale which forms on the surface of the rod during cooling. This offers substantial resistance to the conduction of heat and thus also favors a transformation process which avoids the formation of martensite or bainite.

The method performed by the apparatus of the invention whereby the surface of the rod is cooled in intermittent stages down 400°C or less can be used directly after the rolled rod leaves the finishing stand of the rod mill. Due to the strong cooling effect which has to be employed, the first stage of quenching produces a structure which is exceedingly fine-grained because of the foregoing deformation. This results in a shift of the time-temperature transformation curves for the beginning and end of the pearlite transformation in such a way that pearlite transformation begins and finishes very early. This means that it is possible considerably to shorten the cooling system which follows directly after the finishing stand and to make it of a length corresponding to the product of the rolling speed and a time of about 0.6 to about 0.7 seconds. When, for example, the rolling speed is 50 m/s, the cooling system only need be between 30 and 42 meters in length. Once the peripheral zone of the rod has entered the zone of pearlite transformation, the rod may be laid in non-concentric turns or coiled without any risk of the local formation of undesirable structures in the peripheral zone. The contact between the surface of the rod and the cooler portions of the reel thus no longer has any effect and instead almost the whole of the resulting structure is sorbitic.

In the cooling system, which may operate by the alternate effects of water and air, there is now no formation of martensite, in spite of the fact that the surface temperature of the rod is near that of martensite transformation. This is due to the fact that the center zone of the rod still contains a sufficient amount of heat that it is able to reheat the surface before the next water-cooling stage to such a degree that even during water cooling the temperature never drops below the point of martensite transformation. Once the average cross-sectional temperature of the wire rod has reached 600° – 650°C, pearlite transformation commences in the peripheral zone. The intermittent cooling to below 400°C and to a temperature of about 70°C above the martensite transformation temperature results not only in the cooling time being substantially shortened but also in the fact that, as a result of the shift in the pearlite transformation range, conditions favor optimum cooling during this shorter period.

The apparatus comprises a series of alternate water and air cooling units through which the rod is arranged to pass, for positioning after the last stand of a rod mill but before a reel, the cooling effect of the water cooling units becoming less (for instance the water cooling units becoming shorter) in the direction of travel of the rod according to a logarithmic relationship and the air-cooling units becoming longer in the direction of travel of the rod according to a logarithmic relationship, the overall length of the cooling units being equal to the product of the rod speed and a time of about 0.6 to about 0.7 seconds. According to the present invention, there is in addition provided a combination of a rod mill, apparatus according to the invention and a reel, for rolling, heat treating and reeling hot, patentable steel rod.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a time-temperature transformation diagram; and

FIG. 2 is a schematic elevation of apparatus in accordance with the invention.

FIG. 1 could illustrate the transformation of any of the steels EN 42 and EN 42 B to EN 42 I (British quality); EN 42 B corresponds to DIN 11221 (German

standard). FIG. 1 shows, in the usual manner, the transformation curves and the transformation temperatures A_3, A_1 and M_s. Pearlite transformation takes place in zone I, ferrite transformation in zone II and bainite (intermediate stage) transformation in zone III. Pearlite transformation commences at a temperature of about 600° after about 0.6 seconds, due to the fine-grain formation of the structure obtained as a result of the strong cooling effect. The rod leaves the finishing stand at a temperature of about 950°C. Three temperature curves illustrate what occurs during the cooling process effected directly the rod leaves the mill. Curve *a* represents the temperature of the rod core, curve *b* the average temperature of the rod as a whole and curve *c* the surface temperature. For reasons of clarity only three successive quenching processes are illustrated. Generally a greater number of successive cooling processes will be possible, more quenching operations being feasible in the case of small diameter rods than in that of large-diameter rods, because of the more rapid equalization of temperature between the core and the periphery. At each quenching stage the metal is cooled to temperature T_u which, as already mentioned, is below 400°C and is about 70°C above the martensite transformation temperature M_s. During the following air-cooling stage, the effect of which is much weaker, the surface temperature rises due to the flow of heat from the center to the surface of the rod, and is then recooled. A complete equalization of temperature between the core and periphery does not occur since this would require more time. The temperature of the core, as illustrated by curve *a* and the average temperature as illustrated by curve *b* have an approximately logarithmic shape which is slightly wavy in accordance with the varying conditions of cooling at the surface of the rod. The last cooling stage in the system may have its effect shortly before pearlite transformation commences since transformation does not require that the temperature of the core, the average temperature of the rod as a whole, and the surface temperature should closely approximate. It is sufficient that the surface temperature be, as shown in the drawing, increased (by the process of temperature equalization which results from the higher temperature of the core) just to the point which ensures that the metal does not pass through the bainitic transformation zone III. It is, of course, possible also to advance the last quenching stage so that the three temperatures develop almost uniformly or reach almost the same value before entering the lower pearlite zone.

After pearlite transformation has commenced in zone I and a peripheral zone of the rod equal to 10 to 20 percent of the rod diameter has undergone a 50 – 70 percent transformation, it is possible to lay the wire rod in loops or coil or reel it, as already described, without incurring the risk of undercooling causing martensite or bainite formation in the peripheral zone. Thorough tests, during which portions of rod were quenched immediately laying or coiling commenced in order to effect transformation of the residual austenite, confirmed that the peripheral zone was only composed of pearlite, with the possibility of some ferrite. The more intensive cooling of the peripheral zone made it possible to achieve, in addition to a fine-grain structure, a considerable increase in the buckling resistance of the rod, thus improving guidance of the rod.

In order to achieve the cooling effect desired, it is sufficient and also advisable that the surface of the rod be reheated after each water-cooling stage to a temperature which is below 600°C and that the following quenching process commences at this temperature.

As already mentioned, the cooling system comprises alternating water and air cooling units. FIG. 2 shows this cooling system, which follows a rod mill finishing stand having rolls **1** and **2.** The layout was designed on the basis of a final rolling speed of 40 meters/sec. and an overall throughput time of 0.6 sec. The total length of the cooling system is 24m.

The rolling stand is directly followed by a cooling tube **3** from which water is conveyed on to the rolled material W, shown as a broken line; this is followed by an air-cooling unit **4.** This in turn is followed by another water-cooling unit **5** succeeded by an air-cooling unit **6.** If we assume that the cooling effect in the individual units is proportional to the length shown in the diagram we arrive at the fact that, in view of the decreasing temperatures shown in FIG. **1,** the length of the cooling system units shown in the drawing at the odd numbers steadily decreases as the rod passes through the cooling system. The individual water-cooling units **3,5,7,9** and **11** are of logarithmically related lengths. Conversely, in view of the gradual reduction in the heat content of the rod, the time required for reheating increases — a fact which has been taken into account from the point of view of the cooling system in that these air-cooling units **4,6,8,10** are of logarithmically increasing length. The final air-cooling unit **12** is, on the other hand, somewhat shorter in order to compensate for the extra air cooling which still takes place in the laying reel **13.**

In the reel **13,** the rod W is shifted out of its horizontal path so as to form loops **14** which tip forwards over an edge surface (not shown in detail in the drawing) and out of the reel so as to tilt and drop downwards, as illustrated by loop **15.** They are then conveyed forward by the belt **17** in successive and partly over-lapping loops **16,** to which end the conveyor belt **17** is passed over rollers **18,** at least one of which is driven.

I claim:

1. Apparatus for heat treating hot, patentable steel rod whose temperature is initially above the A_3 transformation point, as the rod issues from the last stand of a rod mill, the apparatus comprising a series of at least three successive water cooling units and at least three successive air cooling units arranged as alternate water and air cooling units through which the rod is adapted to pass, the cooling effect of the water cooling units becoming less in the direction of travel of the rod according to a logarithmic relationship and the air cooling units becoming longer in the direction of travel of the rod according to a logarithmic relationship, the overall length of the cooling units being equal to the product of the rod speed and a time of about 0.6 to about 0.7 seconds.

2. Apparatus as claimed in claim **1,** wherein the water cooling units become shorter in the direction of travel of the rod according to a logarithmic relationship.

3. Apparatus as claimed in claim **1** in combination with a reel, for rolling, heat treating and reeling hot, patentable steel rod.

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