CONTINUOUS ANNEALING FURNACE

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Filed: Jan. 10, 1974

Foreign Application Priority Data
Jan. 11, 1973 Japan

U.S. Cl................. 266/3 R; 148/156; 266/6 R; 432/59

Int. Cl...................... C21d 9/48

Field of Search.............. 65/114; 134/65, 114; 148/156; 266/3 R; 432/8, 59

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ABSTRACT

In a continuous annealing for steel strip furnace comprising recrystallization heating zone, rapid cooling zone, carbon precipitation treating zone and final cooling zone, improved facilities characterized in that said rapid cooling zone is divided into a gas-jet cooling zone and a water-quenching zone and an alternate path for said steel strip is provided parallel with said water quenching zone such that the said strip may bypass said water quenching zone if necessary for a required rapid cooling rate.

3 Claims, 3 Drawing Figures
CONTINUOUS ANNEALING FURNACE

The present invention relates to improvements of a continuous annealing furnace comprising a recrystallization heating zone, a rapid cooling zone, a carbon precipitation treating zone and a final cooling zone, and more particularly, a new rapid zone divided into a gas-jet cooling zone and water-quenching zone and an alternate path for the travelling steel strip is provided parallel with said water-quenching zone.

Continuous annealing art for cold rolled mild steel strip was developed for a mother steel of tin-plating and has been used widely in the field. Such a conventional art of continuous annealing usually comprises a recrystallization heating zone, a slow cooling zone, and the final cooling zone which offers an extremely short annealing time and uniform materials. However, the art is defective in that the steel sheet after annealing was

1. hard,
2. had inferior strain aging property, and
3. had inferior formability.

These defects have previously been considered to be unavoidable. In other words, it was considered impossible to obtain a material suitable for press-forming. With this in mind, research was conducted for a process and an apparatus which would facilitate production of materials for press-forming while effectively maintaining the characteristics of continuous annealing. One example of the manifestation of such research was U.S. Pat. No. 2,832,711.

The art disclosed in the above U.S. Pat. No. 2,832,711 concerns a continuous annealing process for soft steel strips which passes the said strips through a furnace comprising a heating zone, a rapid cooling zone and a holding zone continuously. That is to say, the strips are heated to 1,250°C to 1,300°C in the heating zone, rapidly cooled to below 1,000°C in the rapid cooling zone and then are maintained for at least 30 seconds within a temperature range of 800°C to 1,000°C. According to this art, it is true that such defects as above-mentioned of the continuous annealing were removed to a considerable degree, but it is also true that these defects have not yet been overcome sufficiently when comparison is made of the steel sheets for commercial press forming purposes manufactured in accordance with the ordinary batch type annealing process. It is particularly known that the former is far inferior to the latter in respect of the yield point and press formability.

Applicants proposed the process disclosed in their copending U.S. patent application Ser. No. 373,744, filed June 26, 1973, in order to eliminate these defects. The art disclosed in the said application indicated that the above-mentioned defects could be eliminated at once if the starting temperature of rapid cooling after recrystallization heating and said cooling rate were selected to be within a specific range. More particularly, when said rapid cooling rate of 30°C/sec. to 200°C/sec. should be required, said starting temperature is selected from the range of 650°C to 850°C, while when said cooling rate of more than 200°C/sec. is required said starting temperature is from 500°C to 600°C. Such a combination of the above heat cycle is selected mainly depending upon the thickness of steel strip. However, in a commercial scale plant, which is different from a pilot plant, these heating cycles are necessarily accompanied by various difficulties when being put into actual practice, which difficulties would not be apparent from experiments on said pilot plant. The present inventors have taken note of such difficulties and have made a successful development of an entirely novel continuous annealing system to realize the above annealing cycle.

Thus, the present invention has been developed to obtain the highest mechanical properties of steel sheet by a continuous annealing process with ease and stability. The features of the present invention lie in the dividing of a rapid cooling zone following a carbon precipitation treating zone into a gas-jet cooling zone and a water-quenching zone and the providing of an alternate path for the travelling strip parallel with said water-quenching zone.

An object of the present invention is to provide improved continuous annealing facilities wherein passage of a travelling steel strip is changeable according to the required rapid cooling rate.

Another object of the present invention is to provide improved continuous annealing facilities capable of performing the most suitable heat cycle, including the required rapid cooling rate to obtain excellent mechanical properties.

Other objects and advantages will be apparent from the following description and the accompanying drawings in which:

FIG. 1 shows a fundamental structure of the continuous annealing furnace according to the present invention;

FIG. 2 is a schematic view of the inner structure for the gas-jet cooling zone in FIG. 1;

FIG. 3 shows an outline of the water-quenching zone and an alternate path provided parallel with said zone in FIG. 1.

References being made to the attached drawings, the fundamental structure of the present invention and the heat cycles corresponding thereto are shown in FIG. 1. A strip 1 is fed out of pay-off reel 2 and enters cleaning line 3. Although not shown, there are usually provided a cutter and a welder between said pay-off reel 2 and said cleaning line 3. In said cleaning line, such impurities as oils used in a cold reducing operation are removed from the strip 1. The strip 1 is then made to pass through a looping tower 4 and goes into recrystallization heating zone 5. The strip is heated up to 710°C or thereabout and plastic strain caused by said cold reducing operation is removed therefrom. The strip is then maintained at about the same temperature for a suitable period of time in order to encourage growth of recrystallized grains and solution of carbon from out of carbide in the steel. The strip 1 then enters gas-jet cooling zone 6 which is one component of the present invention. The strip in the said cooling zone is forcibly cooled down to the required temperature by the jet stream of atmospheric gas, at which time the water-quenching is started in the following stage. In this instance, the strip is cooled by the jet stream of the said atmospheric gas to a temperature of 500°C to 600°C, at which time said water-quenching is started. In said water-quenching zone 7, a rate of above 200°C/sec. is used for the travelling strip. Such a high rate quench will cause said strip to reach room temperature instantly. The strip 1 is then processed through pickling, neutralizing, rinsing and drying and then is sent into carbon precipitation treatment zone 8. In this zone, said strip is reheated to a temperature of 400°C to 500°C.
and is held for a predetermined period of time, that is, more than 30 seconds at least within said temperature range. Said solute carbon by the above gas-jet cooling and water-quenching is precipitated during the said period. This brings about mechanical properties not inferior to those of the ordinary batch type annealing process although the process used is a continuous annealing process. The strip 1 thus processed enters final cooling zone 9 and is cooled down to room temperature and is subjected to a light reduction of about 1 percent by temper rolling stand 11 via a looping tower 10 and then finally coiled by the tension reel 12.

In the above continuous annealing system according to the present invention as has been explained in detail heretofore, one example of the inner structure of said gas-jet cooling zone 6 is illustratively shown in FIG. 2. The strip 1 sent into said gas-jet cooling zone as it comes out of the recrystallization heating zone changes its direction by helper rolls 13 and travels between gas-jet headers 14. The jet stream of atmospheric gas being jetted from a group of orifices 15, which is provided on said headers with an interval therebetween, cools the strip down to a predetermined temperature at which time the water-quenching is started. The strip then enters the water-quenching zone 7 via seal rolls 16. In such a gas-jet cooling system as mentioned above, the atmospheric gas-jet being jetted to the strip 1 is exhausted out of the zone by duct pipe 17 and is cooled to about the room temperature by a gas cooler (not shown) and pressurized by a blower (not shown) and again introduced into the said headers 14. In this case, there are dampers 18 provided at the inlet of the said headers 14, which act to control the gas flow. Control of the gas flow by the said dampers 18 will facilitate the control of cooling rate of said travelling strip 1. The lower limit of the cooling rate by the atmospheric gas-jet naturally is determined by the production efficiency as a continuous annealing line. The upper limit thereof is automatically determined by the cooling efficiency of the atmospheric gas being used. At the same time, the scale of said continuous annealing time is determined by the distribution of time to the respective zones of said line while consideration is given to quality of materials. The selection of an optimum cooling rate within such upper and lower limits may be arbitrarily made depending upon thickness of the travelling strip, by the control of the said dampers every time a need arises.

With the present invention as heretofore explained, it is readily possible to obtain the heat cycle (as aforementioned) of the continuous annealing process which will impart the same degree of press formability as that obtained from the ordinary batch type annealing. For instance, when the temperature of the strip at the delivery side of said recrystallization heating zone 5 is set up at 700°C., the temperature at the entry side of said water-quenching zone 7 is set up to 550°C.; the difference between the temperatures is 150°C. When annealing capacity of the employed continuous annealing furnace is 60 t/hr or thereabout and a strip of 0.8 mm thick and x 1,000 mm width was passed through the line, then the speed thereof is about 3 m/min. Under these conditions the above-mentioned temperature difference of 150°C. is to be cooled down by natural cooling and then there would be required an excessive length of said cooling zone, which would be elongated to at least 450 m of the strip length, between the said recrystallization heating and water-quenching zones. This is because the natural cooling rate is 1°C./sec at most. Naturally, the furnace having such a long cooling zone is extremely impractical. If an atmospheric gas having suitable cooling capacity was to be selected, then control of said cooling rate along with use of damper means 18 becomes quite easy, and utility of design, structure and operation of the said atmospheric gas cooling zone is far superior to that of the above-mentioned device. Even if an ordinary atmospheric gas was to be employed, there will be no difficulties to obtain a cooling rate of 15°C./sec, while the strip length in the cooling zone as aforementioned will be only about 30 m long. It is, therefore, self-evident that the gasjet cooling zone to let the said strip stay becomes quite short. It is clear that the use of an atmospheric gas having more than 30°C./sec cooling capacity, furthermore, will simplify said zone. The ease and stability in the cooling rate control in accordance with the present invention device promotes unparalleled utility in actual operations. For instance, not all the strips being passed through the continuous annealing furnace are the same in size. That is to say, coils of different thickness and widths are usually connected one after the other in actual operations. Even in such cases, there are no difficulties of the present invention in the controlling of said cooling rate. The same is true of the cases where the line speed changes during the time while the strip is traveling. In other words, it is possible to maintain the constant temperature at which the following water-quenching is started. It is needless to say that this will result in the uniformity and stability of the press formability of the steel sheets. The actual control of such a cooling rate is very easy. For instance, the temperature of a travelling strip is detected at a suitable point just before the water-quenching zone and the detected value is converted into electric signals, etc., so as to automatically adjust the degree of the damper opening. Such an adjusting mechanism exhibiting a high precision and stability is readily available in the market, which may be applied to the present invention without any difficulties.

The quenching system in the present invention comprises fundamentally a gas-jet cooling zone and a water-quenching zone. In order that the said system may have mechanical properties not inferior to the products manufactured by the batch annealing system, a temperature of 500° to 600°C. should be given as the best suited requirements for starting quenching. However, it is also true that the same degree of utility may not be expected of every thickness of annealing strips. That is to say, this is incomparably effective for a strip having more than about 0.6 mm thickness, but a strip with a thickness thinner than the above, i.e. one with 0.5 mm thickness, causes rapid appearances of defective shapes. Such defects as herein mentioned appear as a pocket-like shape and are confirmed to have been caused by the uneven quenching. Naturally, such defective shapes need to be avoided. In the case of thin strip as mentioned above, the present invention provides an alternate path parallel to a water-quenching zone through which the strip can be passed without going through said water quenching zone. Accordingly, the gas-jet cooling zone 6 and carbon precipitation treatment zone 8 are connected directly with each other. Such an example is shown in FIG. 3. The travelling strip 1 at the delivery side of the gas-jet cooling zone 6 is changed in respect of its directions by helper.
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rolls 19 and enters protective duct 20 and then is sent to the carbon precipitation treatment zone 8 directly. Numerous experiments have confirmed that it is possible to obtain another optimum quenching rate of above 30°C/sec, thus having eliminated any fears that this was not possible. This is because of the fact that said cooling rate is accelerated as the thickness is decreased and atmospheric gas having higher cooling capacity is employed. In this case, the temperature at which quenching is started should be selected from among the range of 650°C to 850°C, the case being different from the use of the said water-quenching zone. This temperature leads to the setting up of the recrystallization heating temperature and is easily realizable. In the carbon precipitation treatment zone (8), the treatment temperature of below 500°C and about 350°C are considered optimum. For instance, when said rapid cooling was to be started at 700°C and the temperature at the entry side of the carbon precipitation treatment zone 8 was to be made 490°C, said rapid cooling range in said gas-jet cooling zone will be 210°C. Such lowering of temperatures of the travelling strip is quite easily obtained because of the above-mentioned reasons and its control is also freely performed by the automatic adjustment of said dampers 18. When the gas-jet cooling zone and the carbon precipitation treatment zone were directly connected in a way as aforementioned, there is no chance for the travelling strip to be cooled down to the room temperature as is the case with the use of water-quenching zone, since the control of the rapid cooling rate in said gas-jet cooling zone is so easy as had been explained heretofore. Accordingly, said required temperature in the carbon precipitation treatment zone is stably held without the need of reheating, and only the slow cooling or the holding of at least above 30 seconds from 490°C to 350°C remains to be performed. It goes without saying that this is also easily practiced. Thus, the stable production of thin strip of less than about 0.5 mm with excellent properties comparable to those of the steel sheets produced by the ordinary batch type annealing process without giving rise to defective shapes becomes possible with ease.

In the present invention, as has been explained, it is possible to use such cooling mechanisms as a water jacket system or a gas jacket system in place of the gas-jet cooling zone following the recrystallization heating zone. However, each of these systems is confirmed to present considerable difficulties in their cooling capacity or temperature control. Therefore, it is recommended that a direct cooling mechanism by the jetting of atmospheric gas is the best in the present invention.

We claim:
1. In a continuous annealing furnace for steel strip comprising a recrystallization heating zone, a rapid cooling zone, a carbon precipitation treating zone and a final cooling zone, improved facilities characterized in that said rapid cooling zone is divided into a gas-jet cooling zone and a water-quenching zone and an alternate path for said steel strip is provided parallel with said water-quenching zone such that the said strip may by-pass the said water quenching zone if necessary for a required rapid cooling rate.
2. Improved facilities as set forth in claim 1 wherein when the thickness of said travelling strip is more than about 0.6mm, said gas-jet cooling zone and then said water-quenching zone are employed as said rapid cooling zone.
3. Improved facilities as set forth in claim 1 wherein when the thickness of said travelling strip is less than about 0.5mm, only said gas-jet cooling zone is employed as said rapid cooling zone and said zone is connected directly to said following carbon precipitation treating zone through said alternate path provided parallel with said water-quenching zone.

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