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PROCESS OF ANNEALING LOW CARBON STEEL

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This invention relates to processes of annealing low carbon steels and particularly to processes of annealing such steels after cold working by heating to a subcritical annealing temperature and subsequently cooling.

In the continuous annealing of low carbon steel strip in modern strip and tinplate mills, the annealing cycle imposes a limit upon the linear speeds of the annealing lines, and the attainment of the speeds at present in use has only been made possible by the utilisation of large and extremely costly furnaces and equipment. Between one-half and one mile of strip may be enclosed in such an annealing furnace together with the inlet and exit loopers. In addition, the extremely fine grain of the continuous annealed product limits the range of uses to which it can be put, continuously annealed blackplate, for example, may be employed only for products normally made from tempers 4, 5 and 6, and thicker sheet and strip are similarly restricted in their use.

It is an object of the invention to provide a process of annealing low carbon steel, applicable to the continuous annealing of steel strip or blackplate, which makes it possible to maintain existing speeds in continuous annealing with smaller and simpler furnaces, or alternatively to increase existing throughput speeds with the furnaces of the sizes at present in use. It is a further object of the invention to provide a process of annealing which is capable of providing a metallurgically improved quality of continuous annealed sheet or blackplate.

In one known time-temperature annealing cycle used in continuous annealing treatment, the material is first heated to 760°C, this temperature being reached after 25 seconds in the heating zone of the furnace. The material then soaks at this temperature in a soaking zone for 10½ seconds, after which it is cooled. Cooling takes place in three stages: a slow cool lasting 15 seconds from 670°C to 425°C, a fast cool lasting 8½ seconds from 425°C to 115°C, and a forced air cool lasting 11 seconds from 115°C to 50°C; this time-temperature cycle is shown by a dashed line in the single FIGURE of the accompanying drawing in which temperature in °C is plotted against time (in seconds). With reference to such a time-temperature cycle, it has now been found that:

(1) By heating up cold-reduced, low carbon steel to the subcritical annealing temperature, which is at or about 780°C, rapidly, that is in less than half the heating time required in the known annealing cycle, the ultimate grain size after recrystallisation appears to be greater than when the material is heated up at the relatively slower rate of the known cycle.

(2) Further, since the heavily cold worked material recrystallises almost instantaneously when the subcritical annealing temperature is reached, holding the metal at annealing temperatures for any period up to 10 minutes does not appreciably increase the grain size. Hence, the soaking period of the known annealing cycle is superfluous.

(3) The major time portion of the known time-temperature cycle is taken up by cooling. For example, 92½ seconds out of a total cycle time of 143 seconds are taken up by cooling from 425°C to 60°C. Metallurgically, this part of the cycle has a relatively minor role in the annealing process since it actually plays no part in the recrystallisation which is the major softening mechanism. The relatively slow controlled cooling has been thought to be necessary to avoid the hardening effects that occur when low carbon steels are rapidly cooled or quenched from temperatures above 300°C. On the other hand, the metal must remain inside the furnace for an excessively long time so that the speed of the throughput is limited by the length of the furnace which is already very long, and if a breakage occurs with this excessive length of blackplate or strip within the furnace, 2 to 16 hours are required to retread the furnace.

It has now been found that the time required for the cooling portion of the annealing cycle can be radically reduced by rapidly quenching the steel after recrystallisation and removing any increased hardness due to quenching by an age softening treatment. According to the present invention, therefore, there is provided a process of annealing cold worked low carbon steel which comprises the step of rapidly quenching the steel from a subcritical annealing temperature and thereafter carrying out an age softening treatment.

The two operations of quenching and age softening can be carried out separately, that is by quenching to room temperature and subsequently carrying out the age softening treatment, or they can be combined by quenching the steel to the age softening temperature and holding it at this temperature until softening occurs. The latter, however, is to be preferred from both a practical viewpoint, that is it does not necessitate re-heating of the steel to the softening temperature, and from a metallurgical viewpoint, in that the most consistent results are obtained and quench ageing does not occur.

Such quenching and age softening is capable of giving a product whose quality is at least as good as that produced in known continuous systems employing large furnaces, while the cost of the age softening equipment is relatively much smaller and there is considerably saving in space.

The quenching and age softening may be carried out as soon as the effects of work hardening have been removed by recovery or recovery and recrystallisation of the comparatively slow heating and soaking periods of a known annealing cycle. It is preferred, however, to effect quenching and age softening after rapid heating of the steel to the subcritical annealing temperature, i.e. recrystallisation temperature, as this gives rise to a large grain size and enables the soaking periods of the known annealing cycle to be eliminated thus making possible a further increase in the speed of a continuous or semi-continuous annealing line, or alternatively a reduction in the size of the furnace. As stated above, rapid heating of the steel to the recrystallisation temperature involves heating in less than half the time required in the known annealing cycle. It is, in fact, preferred to effect heating to this temperature in from 1 to 10 seconds.

A fairly wide range of temperatures are suitable for the age softening treatment and the temperature chosen will depend upon the degree of softening it is desired to attain as the higher the temperature the greater the degree of softening. It has been found that 200°C is about the minimum temperature at which age softening can be carried out and suitable temperatures are from 200°C to about 450°C. At temperatures from 200°C to about 250°C, age softening may be effected in air as substantially no oxidation of the steel occurs at these temperatures; above 250°C age softening should be carried out in a non-oxidising atmosphere as the amount of oxidation which would occur in air at these temperatures would be sufficient to interfere with subsequent operations, such as tinning. The minimum time of holding at the softening temperature in order to obtain a product with stable mechanical properties depends on the
softening temperature; at lower temperatures longer holding times are required than at higher softening temperatures. Thus at 200° C., a holding time of 30 to 50 minutes is required, while at about 300° C., from 15 to 30 minutes is required. Within these limits of holding time, the degree of softening can be varied by choice of holding time, the shorter the holding time, the smaller being the degree of softening.

The age softening treatment is conveniently carried out by coiling the steel as soon as it reaches the desired softening temperature; due to its bulk and shape in coil form, the steel in most cases cools slowly enough to have sufficient time for complete age softening to occur. If a longer holding time is required, the rate of cooling of the coiled material may be retarded by extraneous means.

A typical annealing cycle according to the present invention is illustrated, by way of example only, by the full line curve in the accompanying drawing. This annealing cycle was applied to the continuous treatment of cold worked blackplate having a thickness of 0.014 inch moving at 500 feet per minute. The blackplate was first heated to 700° C. in 5 seconds and then immediately quenched to 300° C. in 5 seconds and was then immediately cooled at the latter temperature, the coil being located in a non-oxidising atmosphere. The coil of black plate was allowed to cool slowly in the non-oxidising atmosphere for from 15 to 30 minutes. At the end of this time, its Vickers hardness was 105-115 D.P.N., while the Vickers hardness of the same blackplate which had been annealed by the known annealing cycle shown by the dashed curve in the accompanying drawing was 115 D.P.N.

Instead of quenching the steel immediately it reaches the recrystallisation temperature, a slow cool from the recrystallisation temperature (i.e. about 700° C.) to about 600° C. taking from 3 to 4 seconds, can be effected before quenching. This slow cool makes it easier to obtain the desired degree of softening with the lower age softening temperatures, for example from 200° to 250° C., and is therefore advantageous in enabling the age softening treatment to be carried out without a non-oxidising atmosphere, and thus with simpler plant.

The capital costs of a continuous annealing furnace for low carbon steels, together with the difficulties attendant upon the threading of long lengths of steel through a furnace, may be reduced to a marked extent by use of the present invention. At the same time, the invention is not restricted to continuous annealing; for example, it can be adapted to semi-continuous and batch annealing of heavily cold worked low carbon steel.

What I claim is:

1. A process for the continuous high speed annealing of cold-reduced low carbon steel strip suitable for the production of tinplate, which process comprises the steps of rapidly heating the steel to a subcritical annealing temperature of about 700° C., whereby recrystallisation of the steel is effected, quenching the steel from the annealing temperature in not more than 5 seconds to a temperature of from 200° to 250° C., coiling the strip at the latter temperature, and maintaining the coiled strip within said temperature range for from 30 to 50 minutes.

2. A process according to claim 1, in which the steel is heated up to the subcritical annealing temperature in from 1 to 10 seconds and said rapid quenching is carried out immediately the steel reaches said temperature.

3. A process according to claim 1, in which the steel is cooled from the subcritical annealing temperature to about 600° C. in from 3 to 4 seconds prior to said rapid quenching.

4. A process for the continuous high speed annealing of cold-reduced low carbon steel strip suitable for the production of tinplate, which process comprises the steps of rapidly heating the steel to a subcritical annealing temperature of about 700° C., whereby recrystallisation of the steel is effected, quenching the steel from the annealing temperature in not more than 5 seconds to a temperature of from 250° C. to 450° C., coiling the strip at the latter temperature, and maintaining the coiled strip in a non-oxidising atmosphere within said temperature range for from 15 to 30 minutes.

5. A process according to claim 4, in which the steel is heated up to the subcritical annealing temperature in from 1 to 10 seconds and said rapid quenching is carried out immediately the steel reaches said temperature.

6. A process according to claim 4, in which the steel is cooled from the subcritical annealing temperature to about 600° C. in from 3 to 4 seconds prior to said rapid quenching.

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