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HEAT TREATMENT OF CAST-IRON ROLLS

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This invention relates to chill cast iron rolls having a definite chill, and more particularly to heat treatment of such rolls to improve their resistance to spalling.

The term "chill cast iron rolls having a definite chill" issued herein to refer to definite chilled iron rolls as defined in Metals Handbook (1939 ed.) at page 1183, and to distinguish them from grain and sand cast rolls as described at page 1184. Definite chilled iron rolls are characterized by possessing a substantially homogeneous chilled white iron area of substantial depth, below which there is a secondary chill of mottled iron which merges into the unchilled body of the roll. It is further characteristic of this type of roll that there is a relatively sharp and readily identified line of demarcation between the white iron and the mottled chills. Grain rolls likewise possess primary and secondary chills but there is no distinct line of demarcation between them; the two merge into one another in such manner that it is ordinarily not possible to distinguish any boundary between them. In grain rolls finely divided graphite is present in the chilled portions.

Both definite chilled iron rolls and grain rolls have properties adapting them to particular uses, and both have been used widely. Ordinary definite chilled iron rolls possess excellent wear resistance due to the hardness of the white iron surface, but because the white iron area is so hard throughout its depth these rolls are less resistant to spalling than grain rolls, for instance in stands prior to the finishing stands of hot strip mills. On the other hand, grain rolls are better adapted to resist spalling than definite chilled rolls, but the graphitic carbon present is in the form of stringers which are generally aligned with the dendritic structure so the directional properties are more or less emphasized, which means that the chill structure of these rolls will be stronger in one direction than in another. Also, grain rolls require special alloying elements, such as nickel, chromium and molybdenum, which are of strategic importance at the present time, and special balancing of the compositions is required to produce the typical grain roll structure.

An object of the present invention is to provide heat treated chill cast iron rolls having a definite chill whose resistance to spalling is better than that of the same rolls without heat treatment, and which may be produced by a simple heat treatment without objectionable added expense from both plain carbon and alloy cast irons of the types used for making rolls of this class.

Another object is to provide heat treated cast iron rolls embodying the advantages just stated and whose wear resistance is not objectionably decreased.

Yet another object is to provide heat treated cast iron rolls having a definite chill which not only embody the foregoing objects but in which the structure of the chill is regulable by the heat treatment to effect desired properties therein.

Still another object is to provide a method of heat treating chill cast iron rolls having a definite chill which improves the spalling resistance of the rolls and is applicable both to plain carbon and to alloy iron rolls.

Other objects will appear from the following description.

It is characteristic of chill cast iron rolls having a definite chill that the white iron of the chill contains substantial amounts of massive cementite. In accordance with the present invention such rolls are heated to a temperature and for a time such as to decompose massive cementite in the chill with production of graphitic carbon, but a particular feature of the invention is that only a relatively small proportion of the massive cementite is decomposed in this manner. Thus there is retained in the outer, or white iron, chill a large part, and most suitably the major proportion, of the original massive cementite. The graphitic carbon which is formed by decomposition of massive cementite is dispersed uniformly throughout the chill in the form of fine nodules, which is of particular advantage and a feature of the invention. Stated otherwise, the roll is heat treated to decompose a restricted portion of the massive cementite and produce a grain type structure in the chill.

In this manner the definite chill is converted to a structure which resembles that of a grain type roll although, of course, the definite chill remains as such, i. e., the sharp line of demarcation between the primary and secondary chills remains unaffected. The graphitic carbon acts to toughen the chill and to increase its resistance to spalling, in which respect the heat treated roll resembles grain type rolls. Also, by retaining most of the massive cementite undecomposed, the wear resistance of the chill may be kept substantially unimpaired.

Rolls heat treated in this manner are superior to grain type rolls in two respects. First, the graphitic carbon is largely nodular in form and distributed uniformly throughout the chill so that the directional properties of the chills of grain type rolls are avoided. Second, in the chill of grain rolls the graphitic carbon particles gradually increase in size and the chill becomes progressively softer passing from the roll surface inwardly. In rolls produced under the present invention the properties of the primary chill are more uniform than those of grain type rolls so that the benefits of grain type rolls may be had with greater effective chill depths.

The invention is applicable to the treatment of definite chilled cast iron rolls made from any

of the plain carbon cast irons which are used for that purpose, such, for example, as those reported as typical in Metals Handbook at page 1183. An example of such a plain carbon cast iron roll is one containing 2.90 per cent of carbon, 0.24 per cent of manganese, 0.5 per cent of phosphorus, 0.65 per cent of silicon, and 0.09 per cent of sulfur. The benefits of grain type rolls may thus be had without the use of alloying elements. However, it is equally applicable to the various alloy cast irons which are used for making definite chill cast iron rolls, such as the simple molybdenum cast irons which are made by adding, for example, 0.2 to 0.3 Mo to the plain cast irons. Some of the alloy compositions applicable are indicated at page 1183 of Metals Handbook, and specific examples of analyses actually used are as follows:

C	Cr	Mn	Mo	Ni	P	Si	S
Per-cent	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*	*Per-cent*
3.30	0.72	0.4	0.4	------	0.08	0.85	0.065
3.01	0.75	0.18	0.2	4.8	0.5	0.38	0.09
3.15	0.50	0.21	0.2	2.0	0.45	0.55	0.106

Heating above the lower critical temperature will cause decomposition of the massive cementite, but the exact temperature at and the time during which the roll is heated will depend in part upon the composition of the roll and in part upon the results to be produced. Thus, some compositions graphitize more readily than others, and with such rolls lower temperatures or shorter heating times suffice for the production of a given result than in the case of less easily graphitized rolls. For example, nickel is generally considered to favor graphitization, and rolls made from nickel cast irons can generally be treated for shorter times and at lower temperatures, either or both, to obtain a desired amount of graphitization, than would be the case with chromium cast irons because chromium tends to retard graphitization. These effects of alloying elements are, of course, well understood in the art.

The temperature and time will be correlated, as indicated above, so that only a part of the massive cementite is decomposed, i. e., the temperature and time will be so balanced as to avoid graphitization of a large part or all of the massive cementite. I have found that particularly desirable results are to be had by heating under such conditions as to cause the pearlitic cementite to be spheroidized. Another factor which will in general control the time and temperature of treatment is that for most purposes the decomposition of the massive cementite should be restricted to avoid substantial decrease of the chill hardness, whereby to maintain high wear resistance.

As exemplifying the application of these facts to the products of the present invention, I have found that satisfactory results in the case of the simple molybdenum alloy cast irons are to be had by heating the rolls from 16 to 32 hours at 1500° F. Generally equivalent results may be had by the use of higher temperatures and shorter heating times, for example, by heating from 4 to 16 hours at 1600° F. Lower temperatures might be used, for instance 1300° F., although in such cases the time of treatment is usually too long to be practical except in the case of cast irons which are easily graphitized.

These factors may be described further with reference to the treatment of a definite chilled iron roll containing 2.95 per cent of carbon, 0.23 per cent of manganese, 0.17 per cent of molybdenum, 0.67 per cent of silicon, and 0.095 per cent of sulfur. As cast the clear chill of this roll was ¾ inch deep. Samples were cut from the roll and packed in iron turnings in air-tight metal capsules and heated at different temperatures for different times. In the as-cast condition the chill consisted of lamellar pearlite within islands of ferrite distributed through massive cementite. No graphitic carbon appeared in the white iron portion of the chill. Upon being heated at 1300° F. for 64 hours traces of graphitization were observed, and spheroidization of the lamellar pearlite had occurred. Substantially the same result was obtained by heating 32 hours at 1400° F. or 4 hours at 1500° F., and somewhat more graphitic carbon was produced by heating 8 hours at 1500° F. However, when the samples were heated 16 hours at 1500° F. there was diminution in the amount of spheroidized cementite and lamellar pearlite reappeared in a new form. Up to this time the pearlite was wholly within the ferrite islands, but now it extended across the islands to touch the massive cementite. When specimens were heated 32 and 64 hours at 1500° F., or from 4 to 64 hours at 1600° and 1700° F., no spheroidized cementite was present (at least in substantial amount) and lamellar pearlite was uniformly present in the reformed structure just described.

Upon heating 64 hours at 1400° F. the graphitization was considerable. Appreciable graphitization occurred after 16 hours at 1500° F. as well as after 4 hours at 1600° F. A substantial proportion of the massive cementite was decomposed after 32 hours at 1500° F., and ferrite appeared about the graphite nodules, while the graphitization was quite extensive after 64 hours at 1500° F. Likewise, extensive graphitization occurred after 8 hours at 1600° F., and it became progressively greater with increase in time of heating until at 64 hours the massive cementite had largely disappeared. The results of heating at 1700° F. for 4 to 64 hours were generally like those at 1600° F. except that, as would be expected, the graphitization was more vigorous.

These data indicate how time and temperature of heating may be correlated to decompose a small amount of massive cementite in accordance with this invention, and to regulate the structure produced. It is to be borne in mind that for most purposes the graphitization should not proceed far enough to greatly lower the hardness, and the relation of hardness to treatment may be understood from the following data obtained with the same specimens and which should be read in the light of the foregoing data to obtain fully the benefits of the invention:

Treatment	Hardness ½" below surface Rc
As cast	42
1300° F.—64 hrs.	42
1400° F.—4 to 32 hrs.	41
1400° F.—64 hrs.	38
1500° F.—4 to 16 hrs.	40
1500° F.—32 hrs.	36
1500° F.—64 hrs.	29
1600° F.—8 hrs.	40
1600° F.—32 hrs.	30
1600° F.—64 hrs.	25
1700° F.—4 hrs.	37
1700° F.—8 hrs.	31
1700° F.—16–64 hrs.	18–13

As will be understood by those familiar with the

subject, these data indicate the extent and progression of graphitization. Generally speaking, hardnesses of at least 35, and preferably 38, Rc at 0.5 inch below the roll surface are desirable, at least for hot strip mill service ahead of the finishing stands. Such hardness is easily attained, as appears, and in fact, hardnesses approaching the as-cast chill hardness may be had in combination with decomposition of sufficient massive cementite to produce a grain type structure and sufficient nodular graphite to improve materially the resistance to spalling which is the gist of this invention. Moreover, my work showed that the effect of this heat treatment was quite uniform throughout the depth of the clear chill, which is of course desirable from the standpoint of the roll user.

I have found furthermore, on comparing furnace and air cooling, that the rate of cooling from 1500° F. has little effect on the resulting hardness, at least up to 32 hours heating. Furnace cooling from 1600° F. or 1700° F., however, produces lower hardness than with air cooling. The actual structures and hardnesses reported above were of air cooled samples.

I have found further that the time and temperature of graphitization can be reduced by preheating the roll for a few hours at a temperature below the graphitizing temperature, and where the iron has absorbed hydrogen in melting its retarding effect on graphitization may be overcome by such a pretreatment.

According to the provisions of the patent statutes, I have explained the principle and method of practicing my invention and have described what I now consider to represent its best embodiments. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. That method of treating a chilled cast iron roll having a definite chill containing massive cementite which comprises heating said roll at a temperature and for a time to decompose a relatively small portion of said cementite and produce graphitic carbon distributed through the chill in finely divided nodular form and thereby increasing the toughness and spall resistance of the roll.

2. That method of treating a chilled cast iron roll having a definite chill containing massive cementite which comprises heating said roll at a temperature above the graphitizing temperature for a time to decompose a portion of said cementite and produce graphitic carbon in finely divided nodular form distributed through the chill in which the major proportion of said cementite remains undecomposed, and thereby increasing the toughness and spall resistance of the roll.

3. That method of treating a chilled cast iron roll having a definite chill containing massive cementite which comprises heating said roll at a temperature above the graphitizing temperature and for a time to decompose a minor proportion of said cementite and produce graphitic carbon in finely divided nodular form distributed through the chill in which the major proportion of said cementite remains undecomposed, said decomposition being insufficient to lower the chill hardness substantially, and thereby increasing the toughness and spall resistance of the roll without substantial impairment of its wear resistance.

4. A heat treated chilled cast iron roll having a definite chill containing a substantial amount of massive cementite together with graphitic carbon in finely divided nodular form distributed therethrough, and characterized by improved toughness and spall resistance as compared with an as-cast chilled roll of the same composition produced in the same manner.

5. A heat treated chilled cast iron roll having a definite chill containing the major proportion of the as-cast massive cementite and having graphitic carbon in finely divided nodular form distributed therethrough as the result of decomposition of a portion of said cementite by heat treatment, and being thereby of increased toughness and spall resistance as compared with an as-cast chilled roll of the same composition produced in the same manner.

6. A heat treated chilled cast iron roll having a definite chill containing a substantial proportion of the as-cast massive cementite and graphitic carbon in finely divided nodular form distributed therethrough as the result of a decomposition of part of said as-cast cementite by heat treatment, the hardness of said chill being not greatly lower than the hardness as cast, and the roll being of increased toughness and spall resistance and of equal wear resistance as compared with an as-cast chilled roll of the same composition produced in the same manner.

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