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HEAT TREATMENT OF STEEL.

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This invention relates to heat treatment of steel and has particular reference to heat treatment of alloy steels such, for instance, as tool steels.

Steel and steel articles as at present manufactured are frequently defective by reason of a nonuniform distribution of carbon throughout the mass, involving an outer zone of decarburized steel, an inner central zone of a pearlitic nature and an intermediate zone of high-carbon steel. This zonic heterogeneity of structure is generally accompanied by a state of internal instability and has been found, in the case of rolled steel members, such as rails, to be mainly responsible for the commonly experienced disadvantages of corrugating and excessive wear and tear in use. A further disadvantage frequently associated with the presence of the aforesaid zoning of structure is the tendency to distortion of the steel member due to the existence of internal stresses and strains.

The defects referred to above may take place during any post-production heat treatment of steel. For example, in the case of an ingot, billet or the like, the defect may occur during heat treatment in the soaking pit or in the re-heating furnace if the steel be subjected to a process of reheating at any time. Indeed, under the conditions now prevailing in the art, practically any process of heat treatment to which steel or a steel article is subjected will result in the aforesaid uneven distribution of carbon and consequent zonic heterogeneity of structure with its accompanying ill effects upon the performance of the steel in use.

We have discovered that if the furnace atmosphere surrounding the steel during the heat-treatment thereof be one which has been rendered innocuous towards the steel as regards its oxidizing and decarburizing capacity by treatment with both an alkaline earth oxide such as lime and a substantially non-carburizing carbon-carrying material as hereinafter defined, the steel will not become decarburized by the heat-treatment and the zonic non-uniform distribution of carbon throughout the mass will not occur, or if these defects should occur, it would be only to a much reduced degree as compared with treatment in a normal heating atmosphere, that is to say, in an unmodified atmosphere such as would obtain without the use of the two reagents aforesaid, for example, in the case of furnace-treatment, such as would ordinarily obtain in a soaking-pit, reheating furnace or the like.

In the preceding paragraph reference has been made to "a substantially non-carburizing carbon-carrying material as hereinafter defined." We mean by this, a material consisting of a small proportion (e. g. about 10% or less) of free carbon in association with a sufficiency of inert and substantially incombustible matter, to render the mixture substantially non-carburizing towards the steel under the conditions of the heat-treatment thereof in which it is employed. Materials answering to this description, and which have been found to give satisfactory results, and which, moreover, can be specially recommended for reasons of economy, in that they are not costly materials, are boiler-ash and producer-ash and carburizing mixtures which latter have been used to such an extent as to be rendered more or less unsuitable for further use in carburizing, and which, for brevity, will be referred to herein, as "exhausted carburizing mixtures."

We have found that if, in the case, for example, of heat treatment of a steel ingot in a soaking pit, the heat treatment be effected in the presence of a mixture of two reagents aforesaid,—that is to say, for example, a mixture of lime and boiler-ash, an appropriate quantity of the mixture being added to the furnace and maintained therein during the treatment, the ingot will not become decarburized and rendered non-uniform in its structure as regards carbon distribution. Moreover, we have found that under these conditions the ingot, billet or the like, may be left in the soaking pit or other form of furnace practically indefinitely, at any rate for a much longer period than heretofore, without the deleterious effect on the steel of over-heating.

A further disadvantage, frequently, if not invariably, associated with heat treatment of steel as at present conducted, is the considerable formation of scale on the surface of the steel or steel article, due, of course, to oxidation by the surrounding atmosphere during

the heat treatment. We have found that this disadvantage, as well as those hereinbefore referred to, is very materially, if not entirely, overcome and that the steel or steel article heat-treated under the conditions characteristic of this invention will be substantially free from oxidation.

We have referred above to heat treatment of steel in a soaking pit. The novel effect, however, is obtainable in any process of heat treatment and is not confined to heat treatment within a heating chamber such as a furnace. For instance, it is possible in the case of the manufacture of steel rails where ordinarily the finished rail is transferred from the rolling mills to the hot banks after the last rolling operation and there allowed to cool, to secure complete homogeneity of structure and avoidance of the decarburization and oxidation, by burying the hot rail in a mixture of the two modifying reagents referred to above.

As will be readily appreciated from the foregoing, the term "normal atmosphere" as used above denotes the atmosphere which ordinarily surrounds a steel member in any of the normal processes in the art of heat treatment of steel by direct contact with hot furnace gases, and is not limited to the furnace atmosphere of a soaking pit, re-heating furnace and the like.

Furthermore, it is immaterial whether the heat treatment be one which involves a raising of temperature of the steel or a lowering of temperature.

It has been found that for the best results it is important that the alkaline earth oxide should be employed in a certain definite proportion in relation to the carbon-carrying material. Thus, it has been found that the relative amounts of the two reagents should be such that the quantity of oxide employed is equivalent to from 10% to 50% by weight of the combined quantities of oxide and carbon-carrying material, and the carbon-content of the carbon-carrying material should be such that the quantity of free carbon present is equivalent to from 4% to 20% by weight of the aforesaid combined quantities.

We have also found in our investigations that the novel effects characteristic of the invention can be enhanced by conducting the heat treatment of the steel in a modified furnace atmosphere as aforesaid and in the presence of material, such, for example, as scrap steel plates, (say, scrap steel known in the art as tin plate) steel wire spools or spirals, scrap steel of any description, for example, steel turnings, filings, mill cuttings, etc. which is readily oxidizable, is unreactive deleteriously upon the steel under heat treatment at the temperature employed, and is of such form as will enable it to present to the surrounding atmosphere an area of oxidizable surface which is large relatively to the mass of the material. The degree of decarburization and scale formation appears to be approximately proportional to the surface area of metal exposed. Consequently, a false, increase of area, such as would be provided by the presence of material of above type, will reduce the degree of possible oxidization of the steel per unit of area and correspondingly also the extent of decarburization.

According to a further feature of the invention, therefore, steel is heat treated in a modified atmosphere as aforesaid in the presence of material, such, for example, as that referred to above, which is readily oxidizable, is unreactive deleteriously upon the steel under heat treatment at the temperature employed, and is of such form as will enable it to present to the surrounding atmosphere an area of oxidizable surface which is large relatively to the mass of the said material.

It is to be appreciated that the process of the present invention is a process which depends upon certain specific chemical interactions as between the furnace gases and the constituents of the steel of the member under treatment. It is, therefore, to be distinguished from processes of simple annealing, normalizing, refining and the like, which, in general, are processes involving only transformations of a physical nature. The following will, perhaps, make this clear.

If a mass of steel is heated it behaves more or less like an open sponge, and the furnace gases by which the steel is heated tend to penetrate into the interior of the mass and either rob the steel of a proportion of its carbon by attacking the iron carbide components of the steel, or deposit carbon which combines with the ferrite present in the steel. The net result of this action of the furnace gases upon the steel depends upon the amount of free carbon or free oxygen present in the gases and varies with a definite effect according to which of the two predominates. It has been determined, however, that the degree and intensity of action of the gases upon the steel is dependent to a considerable extent upon the presence of certain hydrocarbon constituents of the gases. It has been found as the result of our investigations that these hydrocarbon constituents act as accelerating agents or catalyzers in relation to the steel-attacking components of the furnace gases. These investigations lie behind the present invention, and we have found that by the special means hereinbefore stated, both the accelerating action of the hydrocarbon constituents of the gas, and also the action of the steel-attacking constituents, can be prevented, or at any rate neutralized, with the result that a rail or other steel-member may be produced which is free from the oxidation decarburizing and kindred defects hereinbefore mentioned.

The amounts to be used of steel shavings, scrap steel plate, steel wire spools, spirals etc.

and lime or other alkaline earth oxide and exhausted carburizing mixture or other carboniferous material employed will be found to depend upon circumstances in any given case. Thus, the amounts will be found to vary with the type of steel under treatment, that is to say, with the analysis of the steel, particularly in relation to its liability to oxidation, the weight of steel in any one furnace, the area of steel exposed to the gases in relation to the volume of gases supplied to the furnace, the design of the furnace, and lastly, the actual chemical composition of the furnace gases themselves. As will be appreciated, the aforesaid are all variable factors and as they all have a bearing upon the actual amounts of scrap steel or the like to be employed in any given case, it will be at once understood that it is practically impossible to stipulate a rule governing the amounts of the materials to be employed. In actual practice it is a simple matter for a workman operating the process to determine by judgment or trial and adjustment the appropriate amounts to be used. Moreover, there are certain indications in the actual furnace practice of the process, such as the appearance of the flame from the furnace and the general appearance of the furnace, which would guide the operator in determining whether sufficient of the modifying reagents is being used. The use of the modifying reagents involves the presence in the furnace of a reducing atmosphere and, generally speaking, therefore, the appearance of the furnace would be a ready guide as to whether the quantity in use of the modifying reagents is sufficient.

If an exhausted carburizing mixture is used, a suitable mixture is one which, prior to its use as a carburizing agent, was composed of three parts of powdered beech charcoal, two parts of powdered horn charcoal and two parts of powdered animal charcoal, and which has been used to such an extent as to render it unsuitable for further use in carburizing.

The special heat treatment constituting the present invention has been found to be utilizable, not only for the purpose of avoiding the structural defects hereinbefore referred to during the manufacture of a steel article, but also for the removal of such defects after manufacture. It has been found that if steel or a steel article, defective as aforesaid by reason of decarburization and zonic heterogeneity of structure, be heat treated preferably through a range of temperatures embracing the change-points of the steel in an atmosphere modified according to the present invention, the defects will be materially, if not entirely, removed, the structure being rendered uniform throughout as regards carbon distribution, and the carbon content of the steel being restored to what it would have been had not decarburization taken place in the previous heat treatment to which the steel had been subjected.

The invention is capable of wide application and is moreover susceptible to extensive variation in the matter of proportions, temperatures, and other conditions of its use.

The following is a detailed example illustrating the invention in its application to the manufacture of steel billets for various purposes.

In normal works practice as hitherto carried out, the steel ingot has been stripped and heated in furnace pits prior to rolling. The time of heating in the pits has varied from 6 to 10 hours, according to works exigencies. At the end of the period the ingot has been passed through the blooming and rolling mills until the required section had been obtained, and thereafter to the hot shears, where bottom and top crops were taken, and finally to the stores.

In applying the process of this invention a mixture was prepared consisting of one part by weight of lime and eight parts by weight of boiler ash carrying about 10% of combustible carbon. This mixture was left to dry for two days before application. No particular efforts was made to reduce this mixture to any definite size mesh.

The mixture was spread to a depth of 6″ on the floor of the furnace before firing the latter. On top of the bed so formed steel turnings were spread to the depth of another 2″. On charging each ingot four shovelsful of the mixture were thrown on to the ingots, together with two shovelsful of the turnings. In addition to this, material was thrown on to the lip of the gas inlet ports so that the incoming gases had to pass through the small heap of the material left at the end of the ports. After heating under these conditions the ingot was treated in the normal way, viz passed through the blooming and rolling mills, cropped at each end, and passed to stores.

The approximate loss of weight between the metal charged in the pits and the finished billets, including crops, was before the application of the process in the region of 4% by weight. The following are representative figures of ingots taken from a batch treated under this invention:—

Medium carbon steel.

State of ingot when charged	Time (in hours) in the pits.	Weight charged (kgs.).	Weight after rolling.			Losses.		Remarks.
			Billets.	Crops.	Total.	In kgs.	In per cent.	
Cold	6.30	1821	1615	195	1810	11	0.59	Billets 150 m/m
Hot	10.20	1417	1312	97	1409	8	0.565	
Hot	10.0	1400	1310	90	1400	0.0	0.0	

In addition, steel so treated showed greater

freedom from ingot defects, and in general was of better quality.

In another application of the invention a batch of steel files were treated to harden the steel.

First, one batch of files were hardened by the ordinary treatment in a gas-fired muffle furnace. The files on completion of the treatment were heavily scaled and were characterized moreover by local zones of decarburization.

A second batch of files were then taken and heat-treated in the same gas-fired muffle under exactly the same conditions but in the presence of a mixture of 2 parts of lime and 3 parts of exhausted carburizer containing about 15% of free carbon when introduced into the furnace, this mixture being disposed in the muffle in a bed on the bottom thereof approximately six inches deep and the files being placed upon this bed. At the conclusion of the hardening process the files were removed and found to be properly hardened, free from scale and free from soft spots, that is to say, areas of decarburization.

Similarly, tool steel was heat-treated in an electric furnace for the purpose of hardening the steel both with and without modification of the furnace atmosphere according to the present invention. Without modification, that is to say, heat treatment of the tool steel in the ordinary way, resulted in considerable oxidation and local decarburization of the steel. The same treatment repeated on another batch of the same steel in the presence of a mixture of lime and boiler ash, the latter component carrying about 15.6% of combustible carbon, and the two components being present in approximately the relative proportions of 40:60, resulted in proper hardening of the steel with complete avoidance of scale formation and decarburization of the steel. The aforesaid mixture of lime and boiler ash was disposed as a bed of approximately 4 inches in depth upon the bottom of the furnace and after the steel had been placed in the furnace a further charge of the mixture was introduced loosely around the steel in the space between the steel and the walls of the furnace. In addition to the mixture of lime and boiler ash there was present in the furnace a quantity of steel turnings. These were intermixed with the lime and boiler ash in the bed of the latter upon the floor of the furnace and the space around the sides and above the top of the steel under treatment was occupied by steel spirals suspended from the sides and the top of the furnace. The spirals were suspended at intervals of approximately 4 inches across the underside of the top of the furnace. Further steel scrap was thrown into the furnace at intervals during the treatment.

The invention has been found to be particularly successful in the heat treatment of armour plate, for example, for purposes of hardening and toughening the same.

As stated before, the invention is applicable to heat treatment in any type of furnace whether electric, gas-fired or furnaces of the open-hearth type.

We claim:—

1. In processes of heat treatment of steel wherein the steel is heated by direct contact with furnace gases, effecting the treatment in and by hot furnace gases which have been rendered substantially innocuous towards the steel as regards their oxidizing and decarburizing capacity by treatment with a mixture of an alkaline earth oxide and a carbon-carrying material consisting of carbon in association with a sufficiency of ash to render the material substantially non-carburizing towards the steel.

2. In processes of heat treatment of steel wherein the steel is heated by direct contact with furnace gases, effecting the treatment in and by hot furnace gases which have been rendered substantially innocuous towards the steel as regards their oxidizing and decarburizing capacity by treatment with both an alkaline earth oxide and a carbon-carrying ash which has been produced by the partial combustion of a carbonaceous material and which contains an insufficiency of residual combustible carbon to render the ash materially carburizing towards the steel.

3. In processes of heat treatment of steel wherein the steel is heated by direct contact with furnace gases, effecting the treatment in and by hot furnace gases which have been rendered substantially innocuous towards the steel as regards their oxidizing and decarburizing capacity by treatment with both an alkaline earth oxide and a substantially non-carburizing carbon-carrying material as herein defined, the quantity of oxide employed being equivalent to from 10% to 50% by weight of the combined quantities of the oxide and the carbon-carrying material and the carbon content of the carbon-carrying material being such that the quantity of free carbon present is equivalent to from 4% to 20% by weight of the aforesaid combined quantities.

4. In processes of heat treatment of steel wherein the steel is heated by direct contact with furnace gases, effecting the treatment in and by hot furnace gases which have been rendered substantially innocuous towards the steel as regards their oxidizing and decarburizing capacity by treatment with both lime and a carbon-carrying ash which has been produced by the partial combustion of carbonaceous material, the quantity of lime employed being equivalent to from 10% to 50% by weight of the combined quantities of the lime and the ash and the carbon content of the ash being such that the quantity of free

carbon present is equivalent to from 4% to 20% by weight of the aforesaid combined quantities.

5. In processes of heat treatment of steel wherein the steel is heated by direct contact with furnace gases, effecting the treatment in and by hot furnace gases which have been rendered substantially innocuous towards the steel as regards their oxidizing and decarburizing capacity by treatment with both an alkaline earth oxide and a substantially non-carburizing carbon-carrying material as herein defined and with a material which is readily oxidizable, is infusible and unreactive upon the steel under heat treatment at the temperature employed and is of such form as will enable it to present to the surrounding atmosphere an area of oxidizable surface which is large relatively to the mass of the infusible material.

6. In processes of heat treatment of steel wherein the steel is heated by direct contact with furnace gases, effecting the treatment in and by hot furnace gases which have been rendered substantially innocuous towards the steel as regards their oxidizing and decarburizing capacity by contact with a false area of oxidizable surface provided by a mass of scrap steel of extended superficial area, and by treatment with both lime and a carbon-carrying ash which has been produced by the partial combustion of a carbonaceous material, the quantity of lime employed being equivalent to from 10% to 50% by weight of the combined quantities of the lime and ash and the carbon-content of the ash being such that the quantity of free carbon present is equivalent to from 4% to 20% by weight of the aforesaid combined quantities.

7. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of material which renders it substantially innocuous toward the alloy as regards its oxidizing and decarburizing and recarburizing properties.

8. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of material containing an alkaline earth oxide and a reducing agent.

9. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of material containing an alkaline earth oxide and carbon.

10. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of material containing an alkaline earth oxide and carbon, the material being substantially non-carburizing toward the alloy.

11. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of an alkaline earth oxide and a carbonaceous material, the quantity of the alkaline earth oxide employed being equivalent to at least 10% by weight of the combined quantities of the oxide and carbonaceous material.

12. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of an alkaline earth oxide and a carbonaceous material, the quantity of combustible carbon present in the carbonaceous material being equivalent to at least 4% by weight of the combined quantities of the oxide and the carbonaceous material.

13. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of an alkaline earth oxide and a carbonaceous material, the quantity of the alkaline earth oxide being equivalent to from 10 to 50% by weight of the combined quantities of the oxide and the carbonaceous material.

14. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of an alkaline earth oxide and a carbonaceous material, the carbon content of the carbonaceous material being such that the quantity of combustible carbon present is equivalent to from 4 to 20% by weight of the combined quantities of the oxide and the carbonaceous material.

15. The process of rendering innocuous the atmosphere in which an iron alloy is being heated, which comprises subjecting the atmosphere to the action of an alkaline earth oxide and a carbonaceous material, the quantity of the alkaline earth oxide being equivalent to from 10 to 50% by weight of the combined quantities of the oxide and the carbonaceous material, and the carbon content of the carbonaceous material being such that the quantity of combustible carbon present is equivalent to from 4 to 20% by weight of the said combined quantities.

16. In the process of rendering innocuous the atmosphere in which an iron alloy is being heated, the steps comprising subjecting the atmosphere to the action of a mixture of alkaline earth oxide and a carbonaceous material, and prolonging the effective life of said mixture by adding a material which is readily oxidizable and unreactive upon the alloy at the temperature employed and which presents a large surface area as compared with that of the alloy.

17. In the process of rendering innocuous the atmosphere in which an iron alloy is being heated, the steps comprising subjecting the atmosphere to the action of a mixture of alka-

line earth oxide and a carbonaceous material, and prolonging the effective life of said mixture by adding a material which is readily exidizable and unreactive upon the alloy at the temperature employed and which presents a large surface area as compared with that of the alloy, said material also serving to prevent decarburization of the iron alloy in case the carbonaceous material becomes ineffective.

In testimony whereof we have signed our names to this specification.

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