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METHOD OF HEAT TREATMENT

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This invention relates to a method of heat treatment. More particularly it is concerned with a method of heat treating ferritic steel or iron alloy articles while in contact with austenitic steel or alloy, in such a manner to remove carbon and such other elements as are hereinafter named which migrate from ferrite to austenite.

In the present method, a purification takes place which improves certain desirable properties of the articles so treated. More specifically, for example, by heat treating 28% chromium steel tubing while in contact with iron filings, a condition is achieved wherein ferrite is in equilibrium with austenite. It has been found that the austenitized iron filings absorb carbon and other elements from the 28% chromium ferritic steel rendering it stable against embrittlement by carbide precipitation in high temperature service.

In further explanation of the background of this invention, certain observations on the migration of carbon and other light elements such as nitrogen, boron and oxygen which are capable of solid solution in iron alloys of ferritic character reveal a strong tendency for these elements to diffuse in a direction toward contacting alloys of austenitic character. It has also been found that it is immaterial whether such contact as referred to be established by mechanical means, fusion, or by mixture of phases of microscopic proportions, such elements as carbon will migrate out of the ferrite and into the austenite. Carbon and other light elements are known to assume interstitial solid solution in iron alloys; i. e., positions other than those occupied at the regular space lattice points assumed by the metals atoms. While in the ferritic space lattice, the interstitial solubility is small, interstitial solubility in the austenite space lattice on the other hand is comparatively large. For example, in the latter connection, the solid solution of carbon in ferrite is of the order of a few hundredths of a percent, while the austenities will hold carbon in solid solution in concentrations of the order of two percent. The greater capacity of the austenite for the solid solution of carbon and the other interstitially dissolved elements named seems to render it capable of subtracting the same elements from interstitial solution in the ferrite lattice where they are less commodiously accommodated. It is as though austenite placed in contact acts as a blotter for carbon and other light elements.

The rate of migration of the light elements from ferrite to austenite, being a solid diffusion process, is dependent primarily upon time and temperature. Other factors such as stress, metal

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working and inherent structure are secondary influences upon the rate of migration. The most rapid migration of carbon, nitrogen and other light elements from ferrite to austenite seems to occur at the highest temperature at which these phases remain in equilibrium. In the case of ferrite of low alloy content, such a temperature will not exceed that of the A_1 transformation. In the case of the more highly alloyed ferrites, such a limiting temperature may be the lower of the two melting points represented by the ferrite and austenite phases. The time necessary for austenite to substantially subtract the interstitial alloy content of the ferrite, may vary from days to minutes, depending upon the limiting temperature at which the two phases remain in equilibrium.

Evidence of the ability of austenite to subtract carbon from ferrite has been shown by study of actual photomicrographs, in which the fusion line of a deposit of an austenitic steel containing 25% of chromium, 20% of nickel, upon a ferritic steel of low alloy content was clearly shown as freshly deposited. The same structure after a period of aging at a temperature slightly below the A_1 point, reveals that carbon had diffused across the fusion line from the ferrite to the austenite, while in another photomicrograph a microstructure of an austenitic steel, containing 18% of chromum, 8% of nickel, and 3% of molybdenum was shown, which, although nominally an austenitic steel, the microstructure was characterized by lakes of ferrite in a matrix austenite. After a period of exposure to elevated temperature, a further micrographic study showed that carbon had migrated from the ferrite, giving rise to a precipitate of carbide in the austenite upon cooling. In additional photomicrographic studies, it has been shown that with more prolonged aging the carbon had been dispersed to an extent no longer occasioning the carbide precipitate but the subtraction of carbon from the ferrite phase was demonstrated by the softening which had occurred in this phase.

It has been discovered that this characteristic migration of hardening and embrittling impurities from ferrites toward austenites can be made the basis of a process for the purification of ferritic alloys and for the purpose of improving physical properties such as toughness, stability, corrosion resistance, etc. In the latter connection, for example, by simply contacting a ferritic material or metal article with a suitable encasement of austenite, later to be removed, and exposing same for a sufficient time at a suitably

elevated temperature, the desired removal of impurity is accomplished. It should be appreciated that such purification procedure might be employed to real advantage in the manufacture of sheets, strips, tubes, rods, vessels, containers and the like, to the enhancement of whatever properties such treatment would accomplish.

In contradistinction to the novel heat treatment hereinabove described, it is realized of course that plain carburizing has been used in the past, but the instant invention differs from such method in that carburizing is accomplished by diffusing carbon into the article while heated to its austenitizing range. In this invention however, the article is heated in such a range as will not cause austenitization while the article is kept in contact with austenitized material which serves to wtihdraw carbon and other elements hereinabove mentioned.

Furthermore, actual test results have shown that if ordinary carbon steel articles be heated in contact with iron-manganese alloy filings at a temperature below the A_1 point for the carbon steel, but above such transformation temperature for the filings, a purified case is produced upon the carbon steel having enhanced toughness, corrosion resistance, magnetic susceptibility and other characteristics associated with carbon free and nitrogen free iron.

It is anticipated that this method of heat treatment might be applied to any combination of carbon or alloy steel remaining in its ferrite phase while a contacting ferrous or other medium is applied at a temperature effecting its (the contacting medium's) equilibrium in austenite phase. This condition establishes the possibility of applying the principle of the heat treatment described to a large field of ferritic alloys for the accomplishment of many diverse ends.

Investigations of the strain-aging and blue metal phenomena of steel have shown that the effect is governed to a large degree by the dissolved nitrogen content. It has been shown that the brittle shortcomings of Bessemer steels are due in a large measure to this cause. Treatment of Bessemer steel and articles made thereof by the method herein described may be used to correct such brittle tendency.

Great stress is laid by steel makers upon the importance of "killing" steel with aluminum, titanium and other agents to cure such various shortcomings as strain, aging and brittlement, "Krupp krankheit," crystallization, poor impact strength, low temperature embrittlement, etc. The additions of such elements in the steelmaking process are effective by virtue of their affinity for nitrogen, immobilizing it against precipitation upon cleavage planes, through the formation of non-metallic inclusion complexes. By the use of the heat treatment hereinabove described, nitrogen is removed, accomplishing the same end as the steelmakers' addition agents or "killers" without the undesirable effect of incurring the inclusions which are known to promote directional properties, instability of carbide in elevated temperature service, loss of resistance to corrosion and erosion, etc.

The application of the heat treatment herein described to the production of a case upon a ferritic steel article purified of carbon and nitrogen tends to raise the temperature of the start of the heating transformation from A_1 for the eutectoid containing core to the higher A_3 point in the case.

Useful applications may be made of such a

change in character. For instance, it is known that the resistance of a steel gun barrel to firing erosion could be improved if the carbon content of the steel were lowered and the transformation temperature raised. However, to lower the carbon content of the steel would reduce the strength and elasticity below the requirements of the firing pressure, but if by treating the bore by a process which would leave a thin case of iron-alloy purified of carbon and nitrogen, with the body of the barrel intact in its physical properties, enhancement of firing erosion resistance and consequently an increase in the gun life would be effected.

It is noteworthy of the heat treatment hereinabove described that it does require heating the article treated through a critical point with the dimensional changes that result therefrom. Thus it is plain that the treatment may be applied to accurately finished parts and surfaces without disturbing dimensions, as in other subcritical treatments for steel articles, as for instance, nitriding. It might be stated surrounding of the article to be treated with the contacting agent prevents oxidation of the surface of said article, which is an obvious advantage.

Another respect in which the method of heat treatment herein described may be employed to unique advantage concerns the adjusting of surface carbon contents to ideal concentrations. After the surface of the article has been purified, it may continue to be heat treated without contact with the austenitizing contact agent, until the core carbon diffuses towards the surface in desired concentration below that of the original concentration. As an example of the utility of such a treatment, the case of articles manufactured from the 11% to 14% chromium stainless steels, and irons may be cited. For certain kinds of corrosion resisting surfaces it is desirable to have a low carbon content stainless steel. Frequently the carbon content used represents a compromise between that which is low enough to permit of the best corrosion resistance and the minimum necessary to establish the requisite response to heat treatment and physical properties. By means of the present invention it becomes possible to process a stainless steel article having an adequate carbon content to establish core strength and a low enough carbon content at the surface to present high resistance to corrosion. A particular advantage in applying this type of treatment in adjusting the carbon content in the surface of a stainless steel article, accurately finished to dimensions, as for instance a valve seat or disc or both, is that the processing is carried on at a temperature below the critical transformations, thus not disturbing dimensions or shape of the article.

It might furthermore be stated that the method or principle of heat treatment herein covered has applications in the field of powder metallurgy. For instance, if it is the object to purify a ferritic iron powder of carbon, nitrogen and other like elements, in order to enhance magnetic or other properties, it may be admixed with another powder in austenite phase and the mixture heat treated at a temperature below the A_1 point of the ferritic powder. Separation of the purified powder from the austenitic contacting powder may then be accomplished by magnetic separation and the purified powder may then be used either as such or for the manufacture of articles by powder metallurgy techniques.

It should of course be realized that the detailed

method of heat treatment may vary substantially from the description hereinabove set forth which is only an example of the application of this invention and therefore the scope of this invention should be measured by the breadth of the claims appended hereto.

I claim:

1. In a process of the character described, the steps consisting of contacting an article of ferrous material with a ferrous contacting material to purify the ferrous article of interstitially dissolved elements, the contact taking place in a range of elevated temperatures below the A_1 transformation point of the said ferrous article and above the A_1 transformation point of the said ferritic contacting material for a period of time during which a substantial rate of migration of an interstitially dissolved element having lower solubility in ferrite than in austenite is attained from the ferrite to the austenite, the said ferrous contacting material being austenitic at the treating temperature whilst the said ferrous article remains ferritic.

2. In a process of the character described, the steps consisting of contacting an article of ferrous material with a ferrous contacting material to purify the ferrous article of carbon, the contact taking place in a range of elevated temperatures below the A_1 transformation of the said ferrous article and above the A_1 transformation point of the said ferrous contacting material for a period of time during which a substantial rate of migration of interstitially dissolved carbon is effected from the ferrite to the austenite, the said contacting material being austenitic at the treating temperature whilst the said ferrous article remains ferritic.

3. In a process of the character described, the steps consisting of contacting an article of ferrous material with a ferrous contacting material to purify the ferrous article of nitrogen, the contact taking place in a range of elevated temperatures below the A_1 transformation of the said ferrous article and above the A_1 transformation point of the said ferrous contacting material for a period of time during which a substantial rate of migration of an interstitially dissolved nitrogen is attained from the ferrite to the austenite, the said ferrous contacting material being austenitic at the treating temperature whilst the said ferrous article remains ferritic.

4. In a process of the character described, the steps consisting of contacting an article of ferrous material with a ferrous contacting material to purify the ferrous article of carbon and nitrogen, the contact taking place in a range of elevated temperatures below the A_1 transformation of the said ferrous article and above the A_1 transformation point of the said ferrous contacting material for a period of time during which a substantial rate of migration of interstitially dissolved carbon and nitrogen are attained from the ferrite to the austenite, the said ferrous contacting material being austenitic at the treating temperature whilst the said ferrous article remains ferritic.

5. In a process of the character described, the steps consisting of contacting an article of ferrous material with an austenitic material to purify the ferrous article of interstitially dissolved elements, the contact taking place in a range of elevated temperatures at which the ferritic phase of the said article remains in equilibrium with the austenitic phase of the said contacting material for a period of time during which a substantial migration of an interstitially dissolved element having lower solubility in ferrite than in austenite is attained from the said article contacted to the said contacting material.

6. In a process of the character described, the steps consisting of contacting an article of ferrous material with an austenitic material to purify the ferrous article of carbon, the contact taking place in a range of elevated temperatures at which the ferritic phase of the said article remains in equilibrium with the austenitic phase of the said contacting material for a period of time during which a substantial rate of migration of interstitially dissolved carbon is attained from the said article contacted to the said contacting material.

7. In a process of the character described, the steps consisting of contacting an article of ferrous material with an austenitic material to purify the ferrous article of nitrogen, the contact taking place in a range of elevated temperatures at which the ferritic phase of the said article remains in equilibrium with the austenitic phase of the said contacting material for a period of time during which a substantial migration of interstitially dissolved nitrogen is attained from the said article contacted to the said contacting material.

8. In a process of the character described, the steps consisting of contacting an article of ferrous material with an austenitic material to purify the ferrous articles of carbon and nitrogen, the contact taking place in a range of elevated temperatures at which the ferritic phase of the said article remains in equilibrium with the austenitic phase of the said contacting material for a period of time during which a substantial migration of interstitially dissolved carbon and nitrogen are attained from the said article contacted to the said contacting material.

9. A process of the character described, the steps consisting of contacting at the processing temperature a ferritic article with an austenitic material to purify the ferritic article to the extent of enhancing its physical and chemical properties comprising heat treatment and solid diffusion whereby migration of interstitial elements is effected from the ferritic phase of the article to the austenitic phase of the material contacted and at a range of elevated temperatures in which these two phases remain in equilibrium with each other and at which a substantial rate of migration of interstitially dissolved elements having lower solubility in ferrite than in austenite is attained.

10. A process of the character described, the steps consisting of contacting at the processing temperature a ferritic article with an austenitic material to purify the ferritic article to the extent of enhancing its physical and chemical properties comprising heat treatment and solid diffusion whereby migration of carbon is effected from the ferritic phase of the article to the austenitic phase of the material contacted and at a range of elevated temperatures in which these two phases remain in equilibrium with each other and at which a substantial rate of migration of carbon is attained.

11. A process of the character described, the steps consisting of contacting at the processing temperature a ferritic article with an austenitic material to purify the ferritic article to the extent of enhancing its physical and chemical properties comprising heat treatment and solid diffusion whereby migration of nitrogen is effected from the ferritic phase of the article to the

austenitic phase of the material contacted and at a range of elevated temperatures in which these two phases remain in equilibrium with each other and at which a substantial rate of migration of nitrogen is attained.

12. A process of the character described, the steps consisting of contacting at the processing temperature a ferritic article with an austenitic material to purify the ferritic article to the extent of enhancing its physical and chemical properties comprising heat treatment and solid diffusion whereby migration of carbon and nitrogen is effected from the ferritic phase of the article to the austenitic phase of the material contacted and at a range of elevated temperatures in which these two phases remain in equilibrium with each other and at which a substantial rate of migration of carbon and nitrogen is attained.

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