

1

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## METHOD OF DECARBURIZING FERROUS MATERIALS

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The present invention relates to an improved method of decarburizing ferrous materials and more particularly to such a method whereby the carbon content is reduced to a specific low level without an excessive time requirement.

The mechanical and magnetic properties of iron, iron-silicon alloys, and other ferrous materials are improved by removing the last traces of carbon, for example, by reducing the carbon to below 0.002 weight percent. Low carbon steels and iron-silicon alloys are presently decarburized by heating in hydrogen, in mixtures of hydrogen and water vapor and other similar decarburizing gases. Maximum efficiency is sought by heating the material in a decarburizing atmosphere at the maximum temperature to which the specific alloy may be heated without austenite formation.

In the case of an ordinary low carbon sheet steel containing 0.05 weight percent carbon, the optimum temperature is approximately 725° C. In a 3/4 percent silicon-iron sheet containing 0.05 weight percent carbon the optimum temperature may be about 775° C. Above these temperatures, austenite forms in these materials and because carbon is much more soluble in austenite than in ferrite, much of the carbon tends to segregate in the austenite where it diffuses very slowly. Thus, the rate of decarburization is slowed down. In view of austenite formation, it is present practice to carry out the entire decarburization at a single temperature.

Iron and its alloys may exist in two allotropic modifications: the body-centered-cubic crystalline form (ferrite) and the face-centered-cubic crystalline form (austenite), or, in alloys, as a mixture of the two. The constitution of a given alloy is a function of its composition and the temperature. In general, austenite exists at high temperatures and the ferrite at low temperatures. The rate of diffusion of carbon is much greater in the ferrite or lower temperature form. It would be desirable to shorten the time period for decarburization of ferrous material to specific low carbon contents. Secondly, it would be advantageous to reduce the carbon content of ferrous materials below the present commercial practice limits of 0.002 weight percent carbon without an excessive time requirement.

It is an object of my invention to provide an improved method of decarburizing ferrous materials.

It is another object of my invention to provide an improved method of decarburizing ferrous materials in which present process time is shortened.

It is a further object of my invention to provide an improved method of decarburizing ferrous materials in which the carbon content is reduced below 0.002 weight percent without an excessive time requirement.

In carrying out my invention in one form, a method of decarburizing a ferrous material containing carbon up to 0.05 weight percent comprises heating the material in a decarburizing atmosphere to an initial temperature below any austenite formation to reduce the carbon content thereof at this temperature and as the carbon content is reduced to below the maximum solubility limit of carbon in ferrite, raising the temperature of the material to at least one additional higher temperature below any austenite formation to reduce further the carbon content.

These and various other objects, features and advantages of the invention will be better understood from the following description.

2

In iron-carbon alloys, iron-silicon-carbon alloys, and other ferrous materials the temperature at which austenite forms first on heating is a function of the carbon content of the specific alloy. In iron-carbon alloys with a carbon content above approximately 0.05 weight percent, austenite forms at all temperatures above about 725° C. If the carbon content is reduced to about 0.01 weight percent, austenite does not form on heating until about 825° C. As the carbon content is reduced further and approaches zero percent, then the temperature at which austenite forms first on heating approaches 910° C., the temperature of the ferrite to austenite phase transformation in pure iron.

I discovered that decarburization of ferrous material should be commenced at an initial temperature below austenite formation and as the carbon content of the material is reduced, the material should be heated to subsequently higher temperatures below austenite formation and maintained at each of these higher temperatures to reduce the carbon content to a specific low value. The rate at which the temperature of decarburization is raised will be governed by the maximum carbon content at the center of thickness of the material being decarburized, and the phase diagram of the particular material. I found it possible by this method to reduce the carbon content to a specific low value in shorter time or to reduce the carbon content below the level of 0.002 weight percent which is now practicable without a prohibitive increase in the time of decarburization. This method of decarburizing might also be practiced by passing a thin strip or wire continuously through a furnace having a gradient in temperature with the material entering at the low temperature end and being removed from the high temperature end.

For example, in present practice an iron-carbon alloy of 0.040 inch in thickness containing 0.05 weight percent of carbon is decarburized in a mixture of hydrogen and water vapor at a single temperature of 725° C. for a period of seventy-six minutes. This decarburization treatment reduces the carbon content of the iron-carbon alloy from approximately 0.05 weight percent of carbon to 0.001 weight percent. Similarly, if a 3/4 percent silicon-iron sheet containing 0.05 weight percent of carbon is decarburized in a mixture of hydrogen and water vapor at a single temperature of 725° C. for seventy-six minutes, the carbon content is reduced to 0.001 weight percent.

One method of decarburizing a ferrous material in accordance with my invention is to employ an iron-carbon alloy of 0.040 inch in thickness containing 0.05 weight percent of carbon. The alloy is heated in a furnace containing a decarburizing atmosphere of a mixture of hydrogen and water vapor at an initial temperature of 725° C., which is below austenite formation, for a period of 16 minutes after which time the carbon content at the center of thickness is reduced to approximately 0.025 weight percent. The temperature is then raised to 825° C. and maintained at this temperature for an additional period of 6 minutes to reduce the carbon content to 0.0125 weight percent. Finally, the temperature is raised to 880° C. for a period of 8 minutes to reduce the carbon content of the alloy to 0.001 weight percent. The decarburization is accomplished within a period of thirty minutes. The upper temperature limit is set by the alpha to gamma phase transformation at 910° C.

Another example of my method of decarburizing ferrous materials is to employ a 3/4 percent silicon-iron sheet containing 0.05 weight percent of carbon. The alloy is heated in a furnace containing a mixture of hydrogen and water vapor at an initial temperature of 725° C. for a period of 16 minutes after which the carbon content is approximately 0.025 weight percent. The temperature is then raised to 1100° C. and maintained at this temperature for

3

a period of 3 minutes to reduce the carbon content to 0.001 weight percent. The total decarburizing time is 19 minutes. In the case of  $3\frac{1}{4}$  percent silicon iron no upper temperature limit exists after the carbon content is reduced below 0.03 weight percent.

It will be noted in my above first example that the present method of decarburizing a ferrous material reduced the carbon content of an iron-carbon alloy from 0.05 weight percent to 0.001 weight percent within a period of 30 minutes. Thus, it is possible to reduce the carbon content to a specific low value of 0.001 weight percent which has not been practicable in present practice without a prohibitive increase in the time of decarburization to 76 minutes. My second example discloses the decarburization of a  $3\frac{1}{4}$  percent silicon-iron sheet from a carbon content of 0.05 weight percent to 0.001 weight percent within a period of 19 minutes. Thus, it will be seen that the present invention may be employed to shorten the time in present decarburization practice which would require 76 minutes.

While other modifications of this invention and variations of method which may be employed within the scope of the invention have not been described, the invention is intended to include such that may be embraced within the following claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of decarburizing a ferrous material containing carbon up to 0.05 weight percent which comprises heating said material in a decarburizing atmosphere to an initial temperature below any austenite formation to reduce the carbon content thereof at this temperature, and as the carbon content is reduced to below the maximum solubility limit of carbon in ferrite, raising the temperature of said material to at least one additional higher temperature below any austenite formation to reduce further the carbon content.

2. A method of decarburizing a ferrous material containing carbon up to 0.05 weight percent which comprises heating said material in a decarburizing atmosphere to at least two higher temperatures below any austenite formation to reduce the carbon content thereof at each of these

4

temperatures, the heating at the first of said higher temperatures reducing the carbon content to below the maximum solubility limit of carbon in ferrite, each subsequent heating at a higher temperature taking place as the carbon content is reduced by the previous heating.

3. A method of decarburizing a ferrous material containing carbon up to 0.05 weight percent which comprises heating said material in a decarburizing atmosphere to an initial temperature below any austenite formation to reduce the carbon content thereof at this temperature, and as the carbon content is reduced to below the maximum solubility limit of carbon in ferrite, raising the temperature of said material to subsequently higher temperatures below any austenite formation to reduce further the carbon content at each of the subsequently higher temperatures, each such heating at a subsequently higher temperature taking place as the carbon content is reduced by the previous heating.

4. A method of decarburizing a ferrous material containing carbon up to 0.05 weight percent which comprises heating said material in a decarburizing atmosphere to a series of progressively higher temperatures below any austenite formation to reduce the carbon content thereof at each of the progressively higher temperatures, the heating at the first of said series of subsequently higher temperatures reducing the carbon content to below the maximum solubility limit of carbon in ferrite, and each subsequent heating at a higher temperature taking place as the carbon content is reduced by the previous heating.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

2,534,141 Morrill et al. Dec. 12, 1950

##### OTHER REFERENCES

Carpenter et al.: Metals, volume 1, Oxford University Press, 1939, pages 743 to 751 particularly relied on.

"A Mechanism of the Surface Decarburization of Steel," W. A. Pennington, transactions of the A.S.M., volume 37, 1946, pages 48-109. Pages 48, 83, 86-89 particularly relied upon.