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PROCESS OF PREHARDENING AUSTENITIC MANGANESE STEEL

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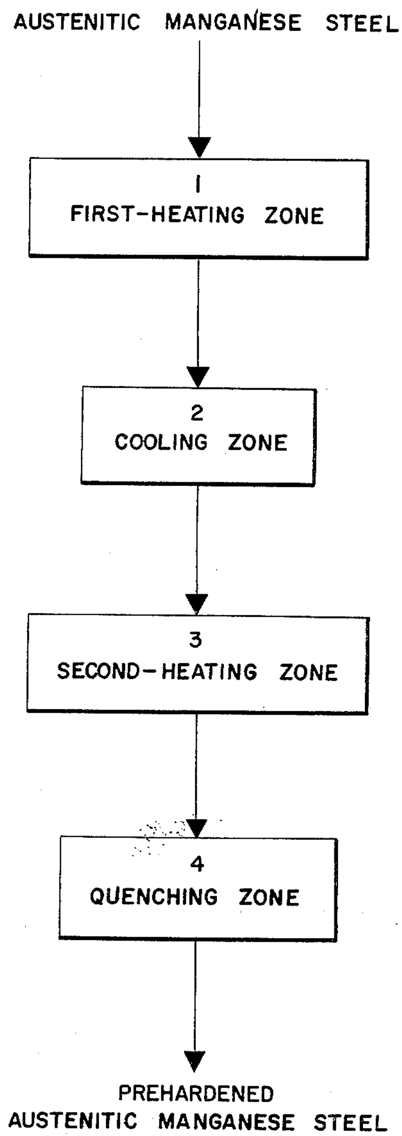

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PROCESS OF PREHARDENING AUSTENITIC MANGANESE STEEL

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This invention relates to a process of prehardening steel, and more particularly concerns a process for prehardening austenitic 10.00% to 14.00% high manganese steel before use to form a steel of superior hardness and ductility.

Austenitic manganese steel was invented by Sir Robert Hadfield in the latter part of the 19th century. This material usually has a chemical composition which includes:

Carbon	1.00% to 1.40%.
Manganese	10.00% to 14.00%.
Phosphorus	0.10% max.
Sulphur	0.01% to 0.03%.
Silicon	0.10% to 0.30%.

In the use of the Hadfield composition, it is conventional practice to vary this composition somewhat, as by varying the proportions given in his formula (for example, the carbon may be in the range of 0.65% to 1.40%, or the silicon may be 2.00%), or by adding supplementary ingredients such as nickel, chromium, vanadium, or molybdenum. But regardless of such changes, the steel does not lose its identity as Hadfield-type steel which is austenitic and non-magnetic, and the problem of hardening is still present in all these forms regardless of whether the material is cast or wrought.

Such a manganese steel composition is normally heat-treated by raising the temperature above the upper critical point until it becomes completely austenic and then quenching it in water. This temperature varies from 1800° to 1900° F. After this heat treatment, the material remains essentially austenitic. In this condition the material has approximately a yield strength of 55,000 to 75,000 p.s.i., an ultimate strength of 135,000 to 165,000 p.s.i., and an elongation of 35% to 60%. Such austenitic steel is inherently ductile to a high degree but lacks desired hardness since its hardness is usually only 180 to 215 Brinell.

The usual manner in which austenitic manganese steel attains its long-wearing characteristics is by work-hardening in use. Impact on manganese steel increases the surface hardness to about 450 to 600 Brinell, depending on the severity of the impact. The depth of work-hardening also increases wtih increasing severity of impact. For a great number of heavy duty operations, this work-hardened material is completely satisfactory and outwears any other material.

There are, however, a large number of applications wherein the severity of impact is not sufficiently great to cause immediate work-hardening. Consequently, there is substantial wear before a work-hardened surface is developed, or the part wears out without developing a substantial work-hardened surface.

Accordingly, it has been a problem to increase the initial hardness of the material before it is put into service, so that the opportunity for abrasive wear to occur before work-hardening developed would be minimized. There has been substantial work done to accomplish this result by utilizing shot peening, cold rolling, or by otherwise cold-working the material. However, prehardening by cold-working before use is generally unsatisfactory for many reasons, including lack of control of the degree and

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of the uniformity of the hardness produced, as well as the relatively high cost involved in such operations.

It is an object of this invention to overcome the aforementioned difficulties and problems.

It is another object of this invention to provide a process of prehardening austenitic manganese steel before use to form a steel which is of desired hardness without being brittle.

It is another object of this invention to provide a process which is controllable so as to vary the degree of hardening and the degree of retained ductility of the steel.

It is another object of this invention to provide a process which uniformly produces an austenitic manganese steel product of predetermined uniform hardness.

It is a further object of this invention to provide a process which produces prehardened austenitic manganese steel which may be welded.

Other objects and advantages of this invention, including its simplicity and economy, as well as the ease with which it may be adapted to existing equipment, will further become apparent hereinafter, and in the drawing which shows diagrammatically the various zones through which the steel is conveyed in accordance with the process of this invention.

Although specific terms are used in the following description for clarity, these terms are not intended to define or limit the scope of the invention.

The present invention starts with austenite (which is inherently ductile but lacks desired hardness) and modifies it in essential particulars, first, by prehardening it (with accompanying loss of ductility) and then by reclaiming a part only of the original ductility without substantial loss of the hardness which has been imparted to the steel.

Turning now to the drawing, there is shown a first-heating zone 1, a cooling zone 2, a second-heating zone 3, and a quenching zone 4.

According to the present invention, fully austenitic 10.00% to 14.00% manganese steel is delivered to the first-heating zone 1, and there uniformly heated at a carefully-controlled predetermined degree of temperature, which is uniformly maintained, for a sufficient length of time to develop an acicular structure having carbide needles within the grains of the steel but with the boundaries of the grains being comparatively free of carbide precipitation.

The steel is then delivered to cooling zone 2 where it is slowly cooled to ambient temperature.

After the steel has been cooled, it is delivered to second-heating zone 3 where it is subjected to a temperature below the transformation point at which the steel would change completely into austenite. It is subjected to this temperature, which is uniformly maintained, for a sufficient length of time to diminish the size and round off the sharp points of the needles through a partial solution only of the previously precipitated carbides. After this is accomplished, the steel is delivered to quenching zone 4 where it is quickly quenched.

I have found that by heating the steel in the first-heating zone 1 to a predetermined temperature in the range between 1100° F. to 1300° F. and maintaining that temperature throughout the heat, satisfactory results are obtained. Best results have been obtained by heating the steel in the first-heating zone 1 to a temperature of 1200° F. plus or minus 25° F., and subjecting the steel in the first-heating zone 1 uniformly to this temperature for about six hours.

In cooling zone 2, the steel is slowly cooled to ambient temperature. Satisfactory results have been obtained when the cooling has lasted for a period of time between 10 to 48 hours.

In second-heating zone 3, the steel is heated to a temperature in the range of 1350° F. to 1500° F. to a predetermined temperature and maintained uniformly. In first-heating zone 1, carbide needles are formed in the steel, and in second-heating zone 3 these needles are partially dissolved to the extent of removing their sharp points and making the needles smaller and of approximately the shape of little round balls. These balls are just as hard as the needles, but because the balls are surrounded by ductile material, and because the sharp points of the needles have been eliminated, the steel has regained adequate ductility, that is, a part only of its original ductility sufficient to resist heavy impact in use. This is effected without substantial loss of the hardness imparted to the steel in the first-heating step.

The steel is subjected to the heat of the second-heating zone 3, which is maintained uniformly, for a period of time of not less than two hours, after which the steel is quickly quenched. This quenching is preferably accomplished by immersing the steel in water.

The Brinell hardness of the resulting product may be controlled by controlling the temperature of the second-heating zone 3. For example, it has been found that subjecting the steel in the second-heating zone 3 to a temperature of 1500° F. gives the resulting product a hardness of 300 Brinell, subjecting the steel in second-heating zone 3 to a temperature of 1450° F. gives a hardness of 350 Brinell, and subjecting the steel in second-heating zone 3 to a temperature of 1400° F. gives a hardness of 400 Brinell.

Example 1

A rolled-steel plate, such as is used by many asphalt plants for asphalt mixer liners, formed of fully austenitic 10.00% to 14.00% manganese steel is subjected to the process of this invention. This plate is delivered to first-heating zone 1, and is subjected to a predetermined temperature of substantially 1200° F. which is maintained uniformly for about six hours. After this, the rolled-steel plate is delivered to the cooling zone 2 where it is cooled slowly to ambient temperature for a period of ten hours.

Then the steel plate is delivered to second-heating zone 3 where it is heated to a predetermined temperature of substantially 1450° F. which is maintained uniformly for two hours. Next, the steel is delivered to quenching zone 4 for immediate quenching in water. The processed plate was found to have a hardness of 350 Brinell.

Example 2

A rolled-steel plate, such as is used by the automobile industry for shot blast liners, formed of fully austenitic 10.00% to 14.00% manganese steel, is subjected to the process of this invention. The plate is delivered to first-heating zone 1 wherein it is subjected to a predetermined uniform temperature of substantially 1200° F. which is maintained uniformly for about six hours. Then the plate is delivered to cooling zone 2 where it is slowly cooled for ten hours to ambient temperature.

Then the steel plate is delivered to heating zone 3 wherein it is subjected to a predetermined uniform temperature of substantially 1500° F. which is maintained uniformly for two hours. Next, it is immediately quenched by being delivered to quenching zone 4 and submerged in water. The resulting hardness of the plate was found to be 300 Brinell.

Example 3

A rolled-steel plate, such as is used by steel companies for blast furnace bell liners, is formed of fully austenitic 10.00% to 14.00% manganese steel. The plate is subjected to the process of this invention by delivering it to heating zone 1 where it is subjected to a predetermined uniform temperature of approximately 1200° F. which is maintained uniformly for six hours. Then the plate is

delivered to cooling zone 2 where it is slowly cooled for a period of ten hours to ambient temperature.

Next, the plate is delivered to second-heating zone 3 wherein it is subjected to a predetermined uniform temperature of substantially 1400° F. which is maintained uniformly for two hours. Then the plate is immediately quenched by transferring it to quenching zone 4 and submerging it in water. The resulting hardness of the plate was found to be 400 Brinell.

It is to be noted in all of the above examples that the fully austenitic rolled steel is heated to a temperature of 1200° F. which is maintained uniformly in first-heating zone 1 for a sufficient length of time to develop an acicular structure having precipitated carbide needles within the grains of the steel. This structure forms uniformly within the grains, with some carbide precipitation forming on the grain boundaries but not in unwanted concentrations. Optimum precipitation of the needles of the acicular structure was obtained when the steel had been uniformly heated to 1200° F. which was maintained uniformly for a period of six hours. This acicular structure of the steel renders it very brittle although it has the quality of high hardness. But because of the brittle characteristic, the steel has no commercial value.

To eliminate unwanted brittleness, the second heat treatment is then applied to the steel in second-heating zone 3. A two-hour soak at 1450° F. (as in Example 1) is found to be satisfactory. After this soak, the material is immediately water-quenched from that temperature.

The purpose of the second heating is to partially dissolve the carbides by dissolving the sharp edges only of the acicular structure developed in the first-heating zone, thereby leaving an austenitic matrix with carbide precipitates uniformly distributed throughout the grains. These carbides are round or oblong with no sharp edges. The purpose of this second heating is not to establish an austenitic structure, nor is its purpose to dissolve carbides completely. The purpose of the second heating is only to sufficiently dissolve the sharp edges from each carbide precipitate in order to restore ductility without reducing hardness.

The ranges of temperature heretofore indicated for the first and second heats have been foundt suitable for the practice of the invention in connection with the usual Hadfield compositon of austenitic manganese steel referred to in column 1 hereof. It is to be noted that these indicated temperatures fall within the following limtis: in the first heat, above that at which ferrite goes into solution in the austenitic matrix but below the temperature at which carbide fully dissolves into the austenitic matrix, and in the second heat, higher than the temperature employed in the first heat but still within the limits of the temperature range of such first heat. If the usual Hadfield composition is varied somewhat in accordance with the conventional practice referred to in column 1 hereof, the ranges of temperatures employed in the first and second heats in practicing the present invention are varied within such limits in order to suit the changed composition.

The steel after being subjected to the process of the present invention has the following approximate physical characteristics:

Yield strength, 120,000 to 140,000 p.s.i.,
Ultimate strength, 135,000 to 165,000 p.s.i.,
Elongation in 2 inches, 10% to 16%.

The material has a hardness which may be varied from 300 to 400 Brinell. The material may be work-hardened in use to 450 to 600 Brinell. In all cases, the desired adequate ductility is retained in the material.

Steel which has been prehardened before use by the process of the present invention has been successfully used in blast furnace bells, woven screens (of a type which requires hardness and ductility), asphalt mixer liners, shot blast liners, skip tub liners, and receiving hopper liners.

While the hereinbefore discussed examples refer to the use of the inventive process with wrought steel, the process is equally applicable to articles of manganese steel produced by a cast process.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred embodiment, and various changes may be made within the skill of the art without departing from the spirit or scope of the invention, as defined in the subjoined claims.

The claimed invention:

1. A process of prehardening austenitic manganese steel to form a steel of superior hardness and ductility, comprising heating austenitic manganese steel to a temperature above that at which ferrite goes into solution in the austenitic matrix and below the temperature at which carbide fully dissolves into the austenitic matrix, in order to precipitate carbide needles within the grains of the steel, allowing the steel to cool to ambient temperature, heating the steel to a higher temperature than that in the first said heating step but within the first said heating range, in order to diminish the size and round off the sharp points of said carbide needles, and quenching the steel.

2. A process of prehardening austenitic manganese steel to form a steel of superior hardness and ductility, comprising the steps of heating austenitic manganese steel to a temperature in the range between 1100° F. to 1300° F. to precipitate carbide needles within the steel, allowing the steel to cool to ambient temperature, heating the steel to a temperature in the range of 1350° F. to 1500° F. to diminish the size and round off sharp points of the carbide needles, and quenching the steel.

3. The process defined in claim 2, wherein said steel in said first-heating step is heated to a uniform temperature of approximately 1200° F., and the steel contains 1.00% to 1.40% carbon.

4. The process defined in claim 2, wherein said steel is subjected to said first-heating step for about six hours.

5. The process defined in claim 2, wherein said steel is slowly cooled for 10 to 48 hours to ambient temperature in said cooling step between said first and second heats.

6. The process defined in claim 2, wherein said steel is subjected to said second-heating step for more than two hours.

7. The process defined in claim 2, wherein said quenching is accomplished by immersing said steel in water.

8. A process of prehardening 10.00% to 14.00% manganese steel before use to form a steel of superior hardness and ductility, comprising heating said steel at approximately 1200° F. and uniformly maintaining the temperature for about six hours to develop an acicular structure having needles within the grains but with the boundaries of the grains being comparatively free of varbide precipitation, slowly cooling said steel for 10 to 48 hours to ambient temperature, heating the steel to a temperature of about 1450° F. and uniformly maintaining the temperature for at least two hours to diminish the size and round off sharp points of said needles, and then water-quenching said steel, whereby to form a prehardened manganese steel.

9. A process of prehardening 10.00% to 14.00% manganese steel before use to form a steel of superior hardness and ductility and a Brinell hardness of substantially 300, comprising heating said steel at approximately 1200° F. and uniformly maintaining the temperature for about six hours to develop an acicular structure having needles within the grains but with the boundaries of the grains being comparatively free of carbide precipitation, slowly cooling said steel for 10 to 48 hours to ambient temperature, heating the steel to a temperature of about 1500° F. and uniformly maintaining the temperature for at least two hours to diminish the size and round off sharp points of said needles, and then water-quenching said steel, whereby to form a prehardened manganese steel with a Brinell hardness of substantially 300.

10. A process of prehardening 10.00% to 14.00% manganese steel before use to form a steel of superior hardness and ductility and a Brinell hardness of substantially 400, comprising heating said steel at approximately 1200° F. and uniformly maintaining the temperature for about six hours to develop an acicular structure having needles within the grains but with the boundaries of the grains being comparatively free of carbide precipitation, slowly cooling said steel for 10 to 48 hours to ambient temperature, heating the steel to a temperature of substantially 1400° F. and uniformly maintaining the temperature for at least two hours to diminish the size and round off sharp points of said needles, and then water-quenching said steel, whereby to form a prehardened manganese steel with a Brinell hardness of substantially 400.

11. A process of prehardening before use austenitic 10.00% to 14.00% manganese steel, having carbon in the range of 1.00% to 1.40%, to form a steel of superior hardness and ductility, consisting of heating said manganese steel at approximately 1200° F. and uniformly maintaining the temperature for about six hours, slowly cooling said steel for 10 to 48 hours to ambient temperature, heating the steel to a temperature of about 1450° F. and uniformly maintaining the temperature for at least two hours, and then water-quenching said steel, whereby to form a prehardened manganese steel.

12. Prehardened austenitic manganese steel having a composition which includes carbon 0.65% to 1.40%, manganese 10.00% to 14.00%, phosphorus up to 0.10%, sulphur 0.01% to 0.03%, silicon 0.10% to 2.00%, said steel being non-magnetic and having an elongation in two inches of 10% to 16%, a hardness in the range of 300 to 400 Brinell, and an austenitic matrix with rounded carbide particles dispersed therethrough.

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