

UNITED STATES PATENT OFFICE

2,664,369

METHOD OF SOFTENING LOW-CARBON
MEDIUM-ALLOY STEELJohn M. Kiefer, Jr., Bedford, Ohio, assignor to
United States Steel Corporation, a corporation
of New JerseyNo Drawing. Application August 6, 1951,
Serial No. 240,613

1 Claim. (Cl. 148—21.5)

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This invention is concerned with softening low-carbon medium-alloy steel. Such steel has a carbon content of less than 20% and may contain from 3 to 10% of one or more alloys of the class consisting of chromium, nickel, molybdenum, and manganese, which elements are soluble in iron in such amounts and which have the common property of slowing down the decomposition of austenite.

The preferred manner of softening similar steels is to heat them to temperatures in the vicinity of 1850° F. followed by slow cooling. This is a rather expensive treatment and requires considerable equipment due to the long time required for cooling at a sufficiently slow rate to obtain the desired effect. I have discovered that steels of this type can be rendered as soft or softer by austenitizing at a low temperature as hereinafter described and quenching as they can be by the foregoing treatment.

In softening such steel by the method of the present invention, the steel is heated to a temperature slightly above its A_{e1} temperature, i. e., not more than about 50° F. above the A_{e1} temperature and soaking at such temperature for a sufficient time to equalize the temperature and dissolve substantially all the carbides. By such heating, just about sufficient austenite is produced to dissolve therein about all the carbides that are in the steel, while the remainder of the structure remains untransformed and relatively stable as ferrite which is relatively unhardenable by quenching. A_{e1} temperature of the steel is determinable, in so far as this method is concerned, by austenitizing a sample of the steel under question, quenching it violently to render it martensitic, whereby it has a highly stressed metastable structure, and then reheating the steel to various temperatures, in the vicinity where the A_{e1} temperature is anticipated, and quenching until the first appearance of untempered martensite in a background of martensite tempered by reheating. The temperature where untempered martensite is first discernible may be taken as the A_{e1} temperature of the steel. Due to the accuracy of control required and necessary, it is preferred to the A_{c1} point for obtaining the limited transformation desired although as an alternative method the steel may be heated to just above its A_{c1} point and immediately withdrawn from the furnace to achieve the desired transformation.

Between such temperatures and the higher temperatures where the steel becomes as wholly austenitic as it can be made, there is a range

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where the steel's structure includes both ferrite and austenite which are both relatively stable for relatively long periods of time, the amount of ferrite being greatest and the amount of austenite being the smallest at a temperature just barely above the A_{e1} and A_{c1} temperatures depending on the method of heating, and the austenite increasing in proportion to the ferrite with increasing temperatures until the steel acquires its maximum possible amount of austenite and has little or no ferrite. In practicing the present invention, the particular temperature to which the steel is heated theoretically depends upon the specific amount of carbides it contains, the best temperature being that producing just sufficient austenite to with time dissolve all of the carbides, while the remainder of the steel's structure remains ferritic and untransformed by the heating.

While it is necessary to allow some time for the austenite to dissolve all of the carbides, in commercial work this time is usually provided to an adequate degree by the time required for the steel to soak at the temperature just above the A_{e1} point to assure its attaining this temperature throughout. Upon all the carbides being dissolved in the austenite, the steel's structure is predominantly a two-phase structure consisting largely of ferrite with the balance austenite, the carbides being largely dissolved in the latter, as described. Furthermore, it is ordinarily sufficient to heat steel of the type with which this invention is concerned to just as little above its A_{e1} temperature as can be done while assuring that the steel has actually been heated above its A_{e1} temperature so that it has acquired at least some austenite. In such a steel this usually provides a structure consisting of from 10 to 40% austenite with the balance untransformed ferrite. The ratio of these phases does not change when commercially practicable soaking times are considered, it being possible to hold the steel at temperature for several hours without any great change occurring in the ratio between the relatively smaller amount of austenite and the greater amount of ferrite prevailing when the temperature was first attained.

The hot steel may now be cooled to permit its handling, and any rate of cooling may be used without making the steel hard and brittle. In the case of many shapes ordinary air cooling is satisfactory. However, quick cooling of some sort is generally desirable in the interest of saving time and if desired, the steel may be quenched. An actual quenching is of advantage since it keeps the elements from diffusing into the ferrite and

it transforms the relatively small amount of austenite included in the structure of the steel so that this portion becomes a hard constituent such as fine pearlite or martensite which is hence more easily spheroidized by tempering. This does not harden the steel but in fact softens it, because the amount of ferrite is so large that it overbalances the amount of austenite resulting from the desired heating. This is the reason why it is desirable in the case of the present invention to select a temperature that is only very slightly above the A_{e1} temperature, since this provides for maximum retention of the ferrite and the production of just sufficient austenite to dissolve most of the carbides. The type of steel to which this invention is applicable contains a sufficiently small amount of carbides to make it practicable to follow what has been discussed, but in the case of materially higher carbon contents it becomes necessary to produce so much austenite, by going to a suitable higher temperature, as to leave so little untransformed ferrite that the steel is actually hardened.

The improved results obtained by my improved method of softening low-carbon medium-alloy steel are aptly shown by the following tests conducted with specimens of hot-rolled and normalized SAE 3312 steel containing:

	Percent
Carbon	0.15
Manganese	.38
Silicon	.23
Nickel	3.95
Chromium	1.40

This steel had an A_{e1} temperature of 1240°F . and in the normalized condition a Brinell hardness of 382. Normalized specimens of the steel were heated to the temperatures tested in the following Table A, held at such temperatures for 20 minutes and air cooled with the following results:

Table A

Temperature:	Brinell hardness
$1,100^{\circ}\text{F}$	258
$1,250^{\circ}\text{F}$	238
$1,275^{\circ}\text{F}$	255
$1,300^{\circ}\text{F}$	265
$1,350^{\circ}\text{F}$	352
$1,450^{\circ}\text{F}$	475

Similar results were obtained on AISI 2315 steel containing:

	Percent
Carbon	0.14
Manganese	.45
Silicon	.25
Nickel	3.75

This steel had a Brinell hardness in the hot-rolled and normalized condition of 159 and an A_{e1} temperature of 1215°F . Specimens thereof were heated to the following temperatures and held at the temperatures indicated for 2 hours and air cooled with the results shown in the following Table B:

Table B

Temperature:	Brinell hardness
$1,180^{\circ}\text{F}$	143
$1,220^{\circ}\text{F}$	120
$1,275^{\circ}\text{F}$	131

In both the foregoing cases the specimens were normalized prior to treatment to insure uniformity of results. However, such prior treatment is not essential to attainment of the objects of this invention.

The foregoing data shows that instead of the expected hardening due to the formation of hard transformation products such as martensite or fine pearlite, the steel is actually softened if treated in accordance with this invention. As a result of such treatment, the steel has a structure consisting mainly of ferrite, so that the steel has the ductility and malleability imparted by this structure, which overbalances the minor amount of hardened structure. In commercial work, this hardened structure will usually be a hardened metastable form of stressed ferrite and carbides, such as martensite or fine pearlite. This structure can be spheroidized relatively easily by conventional spheroidizing treatment if further softening is desired.

This is a continuation-in-part of my copending application, Serial No. 107,377, filed July 28, 1949, now abandoned which was a continuation of my prior application, Serial No. 523,365 filed February 21, 1944, now abandoned.

I claim:

A method of softening low-carbon medium-alloy steel containing less than .20% carbon and from 3 to 10% of at least one of the alloying elements, chromium, nickel, molybdenum and manganese, which includes heating the steel to a temperature just above its A_{e1} temperature to produce just enough austenite to dissolve therein about all its carbides while the remainder of its structure remains untransformed and relatively stable as ferrite; holding at such temperature for a sufficient time to dissolve substantially all of the carbides in said austenite, and then quenching the steel at a rate wherein the austenite with the dissolved carbides will transform to a hard constituent composed of a hardened metastable form of stressed ferrite and carbides, whereupon the cool steel is mainly unhardened due to its being composed principally of ferrite which overbalances the minor amount of the hard constituent.

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Number	Name	Date
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