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HEAT TREATMENT FOR STEEL ALLOYS

Russell H. McCarroll and Gosta Vennerholm, Dearborn, Mich., assignors to Ford Motor Company, Dearborn, Mich., a corporation of Delaware

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This invention relates to a new and improved steel alloy and heat treatment therefor, and to castings made and treated in accordance therewith.

Much progress has been made in recent years in the development of so-called cast alloy steels which have made it possible to produce many previously forged steel parts as castings, thus greatly reducing the cost of manufacture of such parts. However, the use of the casting process has been limited in many cases because some steels, while having otherwise suitable physical properties, leave much to be desired in casting properties.

One of the principal objects of the invention is to provide a steel alloy that can be used for casting automotive and other parts previously requiring fabrication by forging or other relatively expensive methods.

Another object of the invention is to provide a steel alloy of a desired fairly high carbon content and heat treatment therefor capable of producing uniformly stronger and sounder steel castings than was heretofore attainable in castings having a somewhat similar carbon content.

Another object of the invention is to provide a steel alloy casting having an approximate eutectoid composition and in which the carbon in the casting is predominantly in the combined form.

Still another object of the invention is to provide a steel alloy of fairly high carbon content having casting properties improved by a relatively high silicon content, and containing carbon, silicon and manganese in such proportions as to produce an approximate eutectoid composition thereby reducing the tendency to hot tear and to produce dendrites and lines of weakness in the casting.

A further object of the invention is to make possible the production of cast steel articles having more satisfactory physical properties, such as increased tensile strength, elasticity, elongation, machineability, etc., than could be obtained with prior known steel alloys.

A still further object of the invention is to provide a novel heat treatment for the steel alloy which will prevent grain growth and break up the laminated carbides forming the perlite into small rounded individual particles or spheroids.

Other and further objects of the invention will be apparent from the following description:

Among the many parts which may be cast from the present alloy, instead of being forged, may be mentioned rear axle housings for trucks, furrow wheels, etc.

The various alloys comprising the present invention lie within the following range:

I

	Per cent
Carbon	0.75–1.20
Silicon	1.00–1.50
Manganese	0.50–1.00
Molybdenum (optional)	0.15–0.35

and the balance substantially iron (small amounts of phosphorus and sulfur, of course, being present).

In practice, for certain mechanical parts, it is preferred to maintain the composition within the following limits:

II

	Per cent
Carbon	0.90–1.10
Silicon	1.20–1.40
Manganese	0.60–0.80
Molybdenum (optional)	0.15–0.25
Phosphorus (maximum)	0.087

and the balance substantially iron.

As a specific example of a steel composition within the limits of Formulae I and II above, it has been found that desirable results in casting can be obtained with a steel having a specific analysis substantially as follows:

III

	Per cent
Carbon	1.00
Silicon	1.30
Manganese	0.70
Molybdenum (optional)	0.20

and the balance substantially iron.

Another highly desirable composition falling within the broad range of Formula I is as follows:

IV

	Per cent
Carbon	0.80–1.00
Silicon	1.20–1.40
Manganese	0.50–0.70
Molybdenum (optional)	0.15–0.25
Phosphorus (maximum)	0.06
Sulfur (maximum)	0.06

and the balance substantially iron.

A typical analysis falling within Formula IV and in which the carbon content is less than 1% is as follows:

V

	Per cent
Carbon	0.95
Silicon	1.35
Manganese	0.50
Molybdenum (optional)	0.17
Phosphorus (maximum)	0.06
Sulfur (maximum)	0.06

and the balance substantially iron.

It is to be noted from the foregoing formulae that the use of molybdenum is optional and may be omitted from the composition if desired.

In the above examples and ranges of the present steel alloy, the maximum specified range of carbon content is from 0.75% to 1.20%. Heretofore it has been considered advisable in actual practice to form articles or parts in this carbon range by the conventional forging or similar processes, because a casting process for such steel was considered commercially impracticable. It is, therefore, an important consideration that the improved casting properties of the present steel alloy make commercially practicable the extension of steel casting methods to a large and important class of high grade steel parts which previously required more expensive and elaborate methods for successful manufacture.

The above examples illustrating the composition of the present steel alloy are characterized by their relatively high silicon content and also a relatively increased manganese content, although to a lesser extent. It has been found that if the above specified ranges and specific examples are followed an approximate eutectoid composition is maintained which reduces the tendency to precipitate material forming dendrites and planes of weakness, and, therefore, the casting properties of the steel are materially improved. The essential thing is that with the ratios disclosed there is a substantial balance of elements assuring an approximate eutectoid composition in the carbon range of 0.75% to 1.20%, and this is accomplished mainly because of the relatively high silicon content, there being a greater percentage of silicon than carbon.

Although the present alloy, so far as the carbon content is concerned, falls within the range which is generally termed tool steel, the effect of the alloying elements, especially high silicon and relatively high manganese, give the alloy exceptionally good casting properties. Especially noticeable is the high hot metal strength which reduces the tendency to hot tear and also the tendency to form dendrites which would result in a weakening of the casting. Probably the greatest objection to the prior materials lies in the fact that the dendrites, hot tears or planes of weakness, do not always show up during machining or assembly, or even when given severe production tests, for example, a drop test on a truck rear axle housing.

It will be seen from the ranges and specific compositions set forth herein, that, as a general proposition, the sum of the amounts of silicon and manganese is approximately twice that of the carbon. It will also be noted that the amount of silicon is approximately twice that of the manganese. Thus, there is more or less definite relationship between the amounts of silicon, manganese and carbon entering into the composition. As a specific comparison, and considering Formula III as illustrative, it will be noted that the manganese is 0.70%, the silicon is 1.30% and that their sum makes a total of 2.00%. When this sum is compared with that of the carbon content, namely, 1.00%, it is apparent that the total amount of manganese and silicon is twice that of the carbon. It will also be noted that the 1.30% silicon is approximately twice that of the manganese, which is 0.70%. However, it will be understood that reasonable variations in the proportions and in the relationships set forth can be made without destroying the casting advantages and physical characteristics of the steel alloy.

Castings made of the steel alloys disclosed herein are preferably heat treated in a continuous type furnace (not requiring illustration herein) differing from the conventional type mainly in the respect that the furnace is made in two sections, thereby making it possible to provide a heat treatment with an interposed air quench as described below.

In accordance with the present invention, the castings are introduced into the first section of the furnace on a conveyor and are gradually brought up to a temperature of about 1725° F., the time required to reach this temperature being about two hours. The castings are permitted to remain or "soak" in the furnace at this temperature for about one hour, and are then removed from the first section of the furnace and rapidly air cooled to below the critical temperature, that is, to about 1200° F., the air cooling or quenching being effected in the relatively short period of approximately fifteen minutes. The effect of a rapid cooling upon the structure at this high temperature is very pronounced, in that it not only produces a pronounced equalization of the cast structure, but also prevents grain growth.

After the rapid air quenching, the conveyor carries the castings into the second portion of the furnace where they are reheated to approximately 1400° F. in one hour, and held between 1400° F. and 1460° F. for a period of about two and one-half hours, after which the temperature of the castings is lowered to approximately 1300° F. at the rate of 25° F. per hour. The castings are then permitted to cool in air from 1300° F. to atmospheric temperature.

The second portion of the heat treatment cycle, namely, that in which the metal is reheated to 1400° F. and held at about such temperature for a substantial period of time, is of vital importance, as the spheroidization takes place during this period. The spheroidization process consists of a breaking up of the laminated carbides forming the perlite into small rounded individual particles or spheroids.

The foregoing heat treatment produces a fine substantially uniform distribution of the carbides resulting in a much tougher and stronger material than would be the case where a coarse lamellar perlite predominates with each lamella constituting a plane of weakness. Stated differently, the present heat treatment provides a fine spheroidized matrix characterized by a complete absence of primary graphite and with any temper-carbon present of almost sub-microscopic size.

Further improved results can be obtained, particularly with the alloy set forth in Formula II using the following heat treatment, in which the castings are introduced into the first section of the furnace on a conveyor and are gradually brought up to a temperature of about 1725° F., in

about two hours. The castings are permitted to remain or "soak" in the furnace at this temperature for about one and one-half hours, and are then removed from the first section of the furnace and rapidly cooled to below the critical temperature, that is, to about 1200° F., the air cooling or quenching being effected in the relatively short period of approximately fifteen minutes. After the rapid air quenching the conveyor carries the castings into the second portion of the furnace where they are reheated to approximately 1430° F. in one hour, and held at substantially this temperature for a period of about one and one-half hours, after which the temperature of the castings is lowered to about 1350° F. in about one and one-half hours. The castings are then held at about 1350° F. for a period of about three and one-half hours and are then allowed to cool to about 1200° F. in about one and one-half hours. Thereafter, the castings are permitted to cool in air from 1200° F. to room temperature.

The present alloy has superior casting qualities relative to other steel alloys of both low carbon, say .30% to .60% and higher carbon, say 1.50% or thereabouts. In addition to the improved foundry quality of the metal over other cast alloys, the present metal can be satisfactorily heat treated, as specified, to obtain a metal ranging in tensile strength from about 65,000 to 120,000 pounds per square inch, with elongation properties of from 9% to 20% and with a modulus of elasticity of over 29,000,000 pounds per square inch. The high modulus of elasticity is of utmost importance as other cast alloys of a similar type have a modulus of from as low as 23,000,000 to a maximum of 28,000,000 pounds per square inch.

Because of the approximate eutectoid composition of the present steel alloy, it is possible to take the utmost advantage of the carbon content in heat treatment without either precipitating quantities of free cementite particles, which cause increase in hardness and brittleness, or, when annealing, without producing quantities of free temper carbon which also weakens the material. It is also true that where lower tensile strength but higher ductility is desired, the material reacts remarkably well to annealing treatments of the short cycle malleable type resulting in an extremely tough and ductile casting with elongation in excess of 20% and a tensile strength of over 65,000 pounds per square inch. Also by applying a so-called spheroidizing treatment comprising a prolonged heating near the critical temperature followed by slow cooling, a material of exceptionally high tensile strength of over 110,000 pounds per square inch and an elongation of about 10% is obtainable, thus making it possible to replace large numbers of expensive low carbon steel castings as well as forgings at a considerable saving and improvement in properties.

It will be noted that the present invention is characterized by the fact that a steel casting is produced, as contradistinguished from malleable iron, such for example as exhibited in the patent to Edmunds No. 2,069,717 dated February 2, 1937. For example, steel castings made in accordance with the present invention are characterized by a higher elastic limit, greater machineability, tensile strength, freedom from dendritic planes of weakness, etc.

This application is a continuation-in-part of our copending application Serial No. 414,210 filed October 8, 1941, and entitled "Steel alloys," which in turn is a continuation-in-part of our co-pending application Serial No. 351,123 filed August 3, 1940, and entitled "Steel."

While certain specific compositions and ranges of the alloy have been set forth herein, and while specific temperatures and times have been given for the heat treatment of the alloy, it will be understood that reasonable departures may be made from both the composition and heat treatment without departing from the spirit or scope of the invention.

We claim:

1. The method of heat treating a steel casting having substantially the following composition: carbon ranging from 0.75% to 1.20%, silicon ranging from 1.00% to 1.50%, manganese ranging from .50% to .10%, and the balance being substantially iron, which comprises heating said casting to a temperature of about 1725° F. in two hours, maintaining said casting at approximately said temperature for a period of about one hour, cooling said casting from said temperature to about 1200° F. in fifteen minutes, reheating said casting to about 1400° F. in one hour, maintaining said reheated casting at a temperature of between about 1400° F. and 1460° F. for about two and one-half hours, cooling said casting to a temperature of about 1300° F. at the rate of about 25° F. per hour, and then allowing said casting to cool from about 1300° F. to atmospheric temperature in air.

2. The method of heat treating a steel casting having substantially the following composition: carbon ranging from .9% to 1.10%; silicon ranging from 1.20% to 1.40%; manganese ranging from .6% to .8%; molybdenum ranging from .15% to .25%; and the balance being substantially iron, which comprises heating said casting to a temperature of about 1725° F. in two hours, maintaining said casting at approximately said temperature for a period of about one hour, cooling said casting from said temperature to about 1200° F. in fifteen minutes, reheating said casting to about 1400° F. in one hour, maintaining said reheated casting at a temperature of between about 1400° F. and 1460° F. for about two and one-half hours, cooling said casting to a temperature of about 1300° F. at the rate of about 25° F. per hour, and then allowing said casting to cool from about 1300° F. to atmospheric temperature in air.

3. The method of heat treating a steel casting having substantially the following composition: carbon about 1.0%; silicon about 1.30%; manganese about .70%; and the balance being substantially iron, which comprises heating said casting to a temperature of about 1725° F. in two hours, maintaining said casting at approximately said temperature for a period of about one hour, cooling said casting from said temperature to about 1200° F. in fifteen minutes, reheating said casting to about 1400° F. in one hour, maintaining said reheated casting at a temperature of between 1400° F. and 1460° F. for about two and one-half hours, cooling said casting to a temperature of about 1300° F. at the rate of about 25° F. per hour, and then allowing said casting to cool from about 1300° F. to atmospheric temperature in air.

4. The method of heat treating a steel casting having substantially the following composition: carbon ranging from .80% to 1.00%; silicon ranging from 1.20% to 1.40%; manganese ranging from .50% to .70%; and the balance being substantially iron, which comprises heating said casting to a temperature of about 1725° F. in two

hours, maintaining said casting at approximately said temperature for a period of about one hour, cooling said casting from said temperature to about 1200° F. in fifteen minutes, reheating said casting to about 1400° F. in one hour, maintaining said reheated casting at a temperature of between about 1400° F. and 1460° F. for about two and one-half hours, cooling said casting to a temperature of about 1300° F. at the rate of about 25° F. per hour, and then allowing said casting to cool from about 1300° F. to atmospheric temperature in air.

5. The method of heat treating a steel casting having substantially the following composition: a carbon about .95%; silicon about 1.35%; manganese about .50%; and the balance being substantially iron, which comprises heating said casting to a temperature of about 1725° F. in two hours, maintaining said casting at approximately said temperature for a period of about one hour, cooling said casting from said temperature to about 1200° F. in fifteen minutes, reheating said casting to about 1400° F. in one hour, maintaining said reheated casting at a temperature of between about 1400° F. and 1460° F. for about two and one-half hours, cooling said casting to a temperature of about 1300° F. at the rate of about 25° F. per hour, and then allowing said casting to cool from about 1300° F. to atmospheric temperature in air.

6. The method of heat treating a steel casting having substantially the following composition: carbon ranging from .9% to 1.10%; silicon ranging from 1.20% to 1.40%; manganese ranging from .6% to .8%; molybdenum ranging from .15% to .25%; and the balance being substantially iron, which comprises heating said casting to a temperature of about 1725° F. in about two hours, maintaining said casting at approximately said temperature for a period of about one and one-half hours, cooling said casting from said temperature to about 1200° F. in about fifteen minutes, reheating said casting to about 1430° F. in one hour, maintaining said heated casting at said temperature of 1430° F. for about one and one-half hours, cooling said casting to about 1350° F. in about one and one-half hours, holding said casting at said temperature of 1350° F. for three and one-half hours, cooling said casting from about 1350° F. to 1200° F. in about one and one-half hours, and then allowing said casting to cool from about 1200° F. to atmospheric temperature in air.

RUSSELL H. McCARROLL.
GOSTA VENNERHOLM.