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PROCESS OF HEAT-TREATING ALLOY STEEL

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1

This invention relates to metallurgy and, in particular, to ferrous metal alloys.

One object of this invention is to provide a process of heat-treating an alloy steel which will cause it to maintain its hardness and strength and resist wear, distortion and permanent size changes while operating at or being subjected to higher temperatures than are normally encountered in moving steel parts or those in contact with moving parts.

Another object is to provide such a process wherein the alloy steel may be heat-treated at substantially normal temperatures and with ordinary heat-treating equipment rather than by the expensive and rapidly deteriorating equipment at the high temperatures required for heat-treating high speed and other high alloy steels that possess high hardness at elevated temperatures.

Another object is to provide such a process resulting in an alloy steel which may be easily and rapidly carburized to give the surface a high carbon content and after heat treatment, a high surface hardness which will render it especially suitable for use in locations requiring a high order of wear-resistance, such as in bearings and especially anti-friction bearings, the alloy being capable of absorbing carbon readily from the gas, liquid or solid compounds ordinarily used in carburizing steel.

Another object is to provide a method of tempering such an alloy steel that decomposes the austenite by increments, thus controlling the extent of internal stresses and danger of cracking and damage to the strength of the parts treated.

This is a division of my co-pending application Serial No. 69,049, filed January 3, 1949, for Alloy Steel, now abandoned.

The ordinary carbon and alloy steels used in machine parts in contact under rolling or sliding movement, such as anti-friction bearings, lose their high hardness if subjected to excessive temperatures, that is, above 300 or 350° F. normally used for drawing or tempering such parts. Temperatures above the previous draw temperature temper or soften the parts so that they gall or seize in operation. Certain alloy steels do resist such softening, some as high as 1000° to 1200° F., but for reasons stated below they are used chiefly for tools and dies.

The essential alloying elements added to carbon steel to maintain high hardness or produce secondary hardness (an increase in hardness when tempering temperature is increased) are the carbide forming elements tungsten and molybdenum

2

used along with other carbide formers, chiefly chromium and vanadium. The complex alloy carbides formed by these elements require high heat treating temperatures, frequently 2200°–2400° F., to put them into solution and to develop secondary hardening power. The special furnaces and equipment required are expensive to maintain—factors which handicap these steels in a highly competitive market. Nickel is ordinarily not used, or is only occasionally used and then only to a limited amount, in such steels since it tends to retain, after quenching, an excessive amount of austenite, resulting in a structure with low indentation hardness as measured by the Brinell or Rockwell test. Although austenitic steels are file hard, they are subject to plastic flow and change of shape under pressure.

A high carbon content is necessary to develop high hardness. Hardness throughout may be desired for some purposes, but for other applications merely a high surface hardness is sufficient or may even be desirable. The carbide forming elements previously mentioned belong to the so-called Gamma loop closing group, or those which either prevent the absorption of carbon while the steel is in the solid condition or raise the temperature of its absorption beyond that possible to use in ordinary production carburizing furnaces. As such steels must be made by adding the carbon to the molten bath, they have a high carbon content all the way through, as originally made. High carbon, together with high alloy content, however, makes machining difficult and such steels are not easily processed by drilling, turning, shaping or the like and, indeed, require long, expensive annealing treatments to make these operations possible.

The alloy steel of the present invention is designed to eliminate these difficulties and provide a more practical alloy having the advantages set forth in the foregoing objects. The composition developed is the result of extensive research into the effects of the individual elements and the effect of combinations of two or more in numerous experimental melts of steel, as determined by tests on samples thereof.

The most suitable steel for attaining the objects of the present invention has been determined as one containing molybdenum, nickel and chromium as alloying elements. Molybdenum is an effective carbide forming element imparting secondary hardness or high hardness after tempering up to 1000° F. or higher, and at the same time it is the most readily available of such elements in time of national emergency. Nickel is

3

also an essential element in this steel. Nickel is an austenite forming element and increases carbon or carbide solubility at lower temperatures, offsetting the reverse effect of molybdenum and chromium.

Thus, the addition of nickel makes a higher alloy steel that can be carburized and heat treated at normal temperatures in ordinary production furnaces. The possibility of carburizing, in turn, permits the use of low carbon steels that can be more readily annealed, machined, cold formed, etc. These case hardened steels have the same advantages of the lower alloy case hardened steels, that is, a high carbon content, hard and wear resistant surface and a tough core. However, a steel made with high carbon content will possess the temperature resisting properties after suitable heat treatment, and may be used if processing difficulties are not too much of a handicap. Molybdenum and nickel in suitable amounts will produce a steel of good characteristics, but it has been found that the addition of chromium increases the hardness at any given temperature by a few points in Rockwell C hardness. Chromium also can be used to replace some of the molybdenum otherwise required, an advantage because of the greater cost of the latter.

The preferred composition of the non-ferrous ingredients of the alloy steel of this invention and the preferable range, as expressed as percentages of the total alloy, are as follows:

Composition		Range
	Percent	Percent
Nickel.....	3.00	1.00 to 4.00
Chromium.....	1.50	1.00 to 3.00
Molybdenum.....	5.00	2.00 to 6.00
Carbon.....	.15	0.05 to 0.30
Manganese.....	.50	0.20 to 1.00
Silicon.....	.30	0.10 to 0.75

The alloy of the present invention also contains phosphorus and sulphur as impurities which it is desired to keep below .025%. Aluminum or vanadium, or their oxides, used as grain refiners, may also be present in small amounts. The percentages of manganese and silicon are not critical but are listed as being present in all heat treatable steels to produce sound metal. Carbon is listed as that preferred for carburizing. It is not the intention, however, to limit this invention by requiring carburizing since, after suitable annealing, the alloy with high carbon content would be machined and subsequently hardened without carburizing.

The steel of the present invention can be made in the usual production melting furnaces for higher alloy content steels which, because of certain components of their alloy content, particularly chromium, are ordinarily electrically heated in arc or induction furnaces. The steel is preferably made according to fine grained practice to permit direct quenching from carburizing temperature, although reheating after carburizing may be employed. Carburizing may be done by means of any of the commercial carburizing compounds, gaseous, liquid or solid, within the usual commercial range of 1650° to 1800° F. with the latter preferred, especially when the alloy content is toward the high side of the range. The steel carburizes nearly as rapidly as the commercial carburizing steels of lower alloy content. The actual time depends on the depth of the case (or surface layer) required by the design of the part. Parts are cooled from the carburizing temperature, or after reheating to a similar range, at

4

a rate to provide an austenite structure in the case or surface layer. This can be done by oil quenching or cooling in air. Air cooling in sizes up to 2" round has been employed. Very large sizes, however, would require an oil quench. The alloy content is balanced so that austenite will be retained when the steel is cooled, but not so stable that it will not be converted to martensite on tempering or require excessive time to do so.

Because of the plastic flow of the austenite and the highly stable austenite produced as a result of the nickel content, the tempering procedure is an important part of this invention and differs from that usually employed. According to the present invention, austenite is converted to martensite or other constituents of high Rockwell hardness by multiple treatments in the range of 600 to 1200° F. One treatment may result in high hardness, but requires an excessively long time, especially with the alloy content at the high limits, and leaves the martensite in an untempered, highly stressed, brittle condition. To avoid this at least two and preferably several tempering treatments are required. Less total time is required by several short treatments than by fewer longer treatments. Between treatments the steel is cooled to approximately room temperature but the time at room temperature is not critical. By a choice of tempering temperature and time at heat, any desired percent of the austenite can be decomposed in any one treatment. The next treatment tempers the martensite formed, hence the stresses produced and the danger of cracking can be precisely controlled. This treatment also produces a part relatively free from distortion of shape.

Parts treated in this manner, according to the present invention, with five tempering treatments of two hours each at 1000° F. will have a final hardness in the range of 55 to 65 Rockwell C hardness, depending on the actual analysis, within the range of this invention. Further repetitions or very long holds at 1000° F. will produce only a minor drop in hardness in the order of 1 to 5 points Rockwell C. Parts tempered five 2 hour periods at 1000° F. are very stable in hardness when reheated to lower temperatures, for example, parts 60Rc remained unchanged when given single treatments up to 60 hours or repeated treatments totalling 100 hours at 900° F. The structure of the case or surface layer, as quenched, is austenite and carbide. After tempering this becomes carbide and martensite or other hard decomposition products. For maximum stability of hardness and size over extended periods of time, austenite is completely decomposed by the tempering treatments. If the operating temperature of the part is considerably below the tempering temperature employed, complete decomposition of the austenite is not necessary, but the major portion must be decomposed to develop high Rockwell hardness and prevent plastic flow under pressure.

What I claim is:

1. A process of heat-treating an alloy steel essentially consisting of approximately 3.00% nickel, approximately 1.50% chromium, approximately 5.00% molybdenum, approximately 0.15% carbon, approximately 0.50% manganese, approximately 0.30% silicon, the remainder substantially all iron, said heat-treating process comprising carburizing the steel within the temperature range of 1650° to 1800° F., air or liquid quenching the steel after carburizing, alternately and repeatedly heating the steel to a temperature

5

within the temperature range of 600° to 1200° F. and cooling the steel to approximately room temperature between successive heatings to convert the austenite to martensite a portion at a time whereby to prevent excessive hardness, stress and size changes during each such heating and cooling step, so that the surface of the steel possesses, at high operating temperatures, high hardness and resistance to wear such as required by parts in contact under rolling or sliding movement.

2. A process of heat-treating an alloy steel essentially consisting of 1.00% to 4.00% nickel, 1.00% to 3.00% chromium, 2.00% to 6.00% molybdenum, 0.05% to 0.30% carbon, 0.20% to 1.00% manganese, 0.10% to 0.75% silicon, the remainder substantially all iron, said heat-treating process comprising carburizing the steel within the temperature range of 1650° to 1800° F., air or liquid quenching the steel after carburizing, alternately and repeatedly heating the steel to a temperature within the temperature range of 600° to 1200° F. and cooling the steel to approximately room temperature between successive heatings to convert the austenite to martensite a portion at a time whereby to prevent excessive hardness, stress and size changes during each such heating and cooling step, so that the surface of the steel possesses,

6

at high operating temperatures, high hardness and resistance to wear such as required by parts in contact under rolling or sliding movement.

3. An alloy steel article produced by the process of claim 1.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,012,765	Marthourey	Aug. 27, 1935

FOREIGN PATENTS

Number	Country	Date
445,651	Great Britain	Apr. 16, 1936

OTHER REFERENCES

"Molybdenum in Steel," Sec. 11, page 2, by Climax Molybdenum Co., 1938.

"Transactions of the American Society for Metals," vol. 27, 1939, pages 1042-1045.

"Tool Steels" by Gill et al., pages 451, 501, 510, published by American Society for Metals, 1944.