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METHOD OF IMPROVING ABRASION RESISTANCE OF ALLOYS

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The invention relates to a method of improving the abrasion resistance of iron-base alloys containing chromium and to articles, composed of such alloys, having superior resistance to abrasion.

The abrasion, or wearing away, of metal articles during service in industry causes large monetary losses, involving shutdowns and labor and replacement costs. To combat abrasion, many special "wear-resistant" alloys have been developed. However, the importance of the problem is such that efforts continue to be made either to develop new wear-resistant materials or to improve the wear resistance of already known materials.

One material that has been used to some extent in applications where resistance to abrasion is required is an iron-base alloy containing about 12% to 30% chromium and 1.5% to 3% carbon, the remainder principally iron. Generally this alloy is used in the cast or wrought condition, but under some conditions of use it is heat treated before use, either to develop maximum hardness (by heating it at a temperature between about 900° C. and 1000° C. and cooling it in air or by an oil quench) or to develop maximum toughness (by heating it at about 700° C. to 800° C. and cooling it in air). The abrasion resistance of this alloy is good, but improvement is desirable.

The present invention has for one of its objects a method of improving the wear resistance of iron-base alloys containing chromium and carbon. Another object of the invention is an abrasion resistant article composed of such alloys treated to impart thereto superior resistance to abrasion.

In accordance with the invention, these objects are achieved by a heat treatment adapted to produce in such alloys a physical structure such that the alloys are rendered extremely resistant to abrasion. Specifically, the invention comprises a method of improving the abrasion-resistance of high chromium-high carbon iron-base alloys, which method consists in heating such alloys at a temperature above about 1100° C. but below the melting point of the alloys, and thereafter cooling them at a rate sufficient to permit retention in the alloys at ordinary room temperatures of a predominantly austenitic structure. The most preferable range is 1200° C. to 1300° C. The invention also includes abrasion-resistant articles composed of high chromium-high carbon iron-base alloys, which articles are in the condition resulting from the heat treatment just described.

The alloys to which the heat treatment of the invention is most suitably applied contain about 10% to 40% chromium and 1% to 4% carbon, the remainder principally iron. Generally, to attain the desired structure by the heat treatment, the chromium content should be at least about 12% if the carbon content is near the low end of the range given, and if both the chromium content and the carbon content are near the low ends of their respective ranges, the presence of one or more austenite-promoting elements may be necessary in order to achieve this result.

The temperature at which the iron-chromium-carbon alloys under discussion are heated in the practice of the invention is considerably higher than the temperature at which the same alloys are heated in the usual treatment designed to develop their greatest hardness. Microscopic, magnetic, and X-ray diffraction tests indicate that when such alloys are cooled in air or quenched in oil from the high temperatures employed in the heat treatment of the invention, they have a predominantly austenitic structure. Although the hardness of the alloys after this treatment is less than the maximum hardness that may be developed, the wear-resisting properties of the alloys are far superior to those of similar alloys treated to develop maximum hardness. A possible explanation for this may be that austenite, although itself relatively soft, is unstable and breaks down under conditions of use to a structure that is extremely resistant to abrasion.

In the practice of the invention an article to be treated may be heated in any conveninet manner. Generally, it will be most convenient to heat the entire article in a furnace. On occasion it may be desirable that it be heated electrically by induction or resistance heating, and if the greatest degree of wear resistance is desired only locally, the heat treatment may be locally applied, as by an oxy-fuel gas torch. In all cases, to develop the greatest degree of wear resistance, the cooling rate should be sufficiently rapid to permit retention of an austenitic structure in the alloy of which the article is composed. Generally, for articles having sections no greater than about ½ inch in thickness, cooling in still air is sufficiently rapid for the purpose. Articles hav-

ing heavier sections are preferably cooled more rapidly, as by an air blast or by quenching in a suitable liquid. Ordinarily, it is unnecesary that the articles be quenched in water, and too-rapid quenching should be avoided as it may cause cracking.

As already pointed out, the heat treatment of the invention is applicable in general to iron-base alloys containing 10% to 40% chromium and 1% to 4% carbon, the remainder principally iron. The greatest degree of abrasion resistance is obtained by the invention in alloys containing 12% to 30% chromium and 1.5% to 3% carbon, remainder iron and, as incidental impurities, up to about 3% silicon and 5% manganese. The heat treatment is also effective to enhance the wear resistance of high chromium alloys of the kind described, modified by the presence of minor proportions, say between about 0.1% and 5%, of the elements nickel, copper, cobalt, molybdenum, tungsten, vanadium, boron and nitrogen sometimes added to these alloys to improve their physical properties. I have particularly observed that about 0.5% to 3% vanadium imparts a substantial improvement in the strength of the cast and heat treated alloys, as measured by the standard transverse strength and deflection tests for cast iron. The presence of any of these elements with the exception of boron and vanadium makes possible the use of slightly lower heat treating temperatures than are required for the ordinary high chromium-high carbon alloys. Similarly, temperatures near the lower end of the range recited may be used for the heat treatment of alloys containing not more than about 14% chromium, but in all cases the temperature of the heat treatment is above that employed for maximum hardening and is above about 1050° C.

In tests of the effectiveness of the heat treatment of the invention the abrasion resistance of alloys subjected to different heat treatments was compared. A "Rotoblast" cleaning machine provided with a revolvable wheel much like a paddle wheel, having eight blades, was used for these tests. In operation, the wheel revolves at high speed, throwing an abrasive material, such as steel grit, against a surface to be cleaned. The blades are called upon to withstand exceptionally severe conditions of wear.

The tests were conducted by using blades cast of the several materials to be tested. Each blade was weighed before being placed in the machine, the machine was used to produce an abrasive blast for a measured period of time, and the blades were again weighed. The loss in weight of a blade caused by the abrasive action of the steel grit in the normal operation of the machine is a measure of the wear resistance of the blade. Results obtained in some of these tests are set forth in the following tables. All of the heat-treated blades were cooled in still air from the treatment temperatures indicated.

First test

[Blades composed of alloy containing 1.57% C; 18.24% Cr; rest Fe: test run for 672 minutes]

Blade	Heat treatment	Rockwell "C" hardness	Weight loss
			Grams
1	None	45	225.6
2	1 hour @ 1,000° C	61	115.0
3	15 hours @ 700° C	37	426.6
4	1 hour @ 1,200° C	49	58.2

Second test

[Blades composed of alloy containing 3% C; 29.69% Cr; rest Fe; test run for 1180 minutes]

Blade	Heat treatment	Rockwell "C" hardness	Weight loss
			Grams
5	1 hour @ 1,000° C	63	113.5
6	½ hour @ 1,200° C	61	8.0

Third test

[Blades composed of alloy containing 2.69% C; 25.85% Cr; rest Fe]

Blade	Heat treatment	Hardness	Duration of test	Weight loss
				Grams
7	None	49	1,690	93.9
8	2 hours @ 1,000° C	55	1,690	188.4
9	2 hours @ 1,100° C	51	5,140	203.9
10	1 hour @ 1,200° C	52	5,140	164.3
11	1 hour @ 1,250° C	52	5,140	155.3

In the third test blades 7 and 8 failed by penetration; that is, a hole was worn through these blades. Blade 6, tested in the second test, was subsequently given a life test, which continued for 12,628 minutes before the blade was penetrated.

These tests demonstrate that in alloys of the kind tested, mere hardness is not a reliable criterion of wear resistance. Blades heat treated to develop maximum hardness were more readily worn than blades given the heat treatment of the invention, despite the fact that the latter blades were considerably softer. The heat treatment of the invention, which provides an important increase in the wear resistance of the alloys, is conducted at a temperature higher than that used for maximum hardening.

Although particular examples of the application of the invention to particular alloys have been given herein, the invention is not limited to such examples. It is applicable both to cast alloys, which usually have a chromium content near the higher end of the range given, and to wrought alloys which usually have chromium contents near the lower end of the range, generally about 12% to 14%.

I claim:

1. A method of improving the resistance to abrasion of iron-base alloys containing about 10% to 40% chromium and about 1% to 4% carbon, the remainder principally iron, which method consists in heating said alloys at a temperature above the temperature range at which alloys of such composition are customarily heated to develop maximum hardness and between about 1100° C. and their melting point and thereafter cooling said alloys at a rate sufficiently rapid to permit the retention in said alloys at ordinary room temperature of a predominantly austenitic structure.

2. A method of improving the resistance to abrasion of iron-base alloys containing about 10% to 40% chromium and about 1% to 4% carbon, the remainder principally iron, which consists in heating said alloys at a temperature above the temperature range at which alloys of such composition are customarily heated to develop maximum hardness and between about 1100° C. and 1300° C. and thereafter cooling said alloys at a rate sufficiently rapid to permit the retention in said alloys at ordinary room temperatures of a predominantly austenitic structure.

3. A method of increasing the resistance to abrasion of iron-base alloys containing about 10% to 40% chromium and 1% to 4% carbon, 0.5% to 3% vanadium, silicon up to 3%, manganese up to 5%, the remainder substantially iron, which method consists in heating said alloys at a temperature above the temperature range at which alloys of such composition are customarily heated to develop maximum hardness and between about 1200° C. and 1300° C. and thereafter cooling said alloys in air.

4. An abrasion-resistant article composed of an iron-base alloy containing about 10% to 40% chromium, 1% to 4% carbon, and the remainder principally iron, said article being in the condition resulting from heating it at a temperature above the temperature range at which alloys of such composition are customarily heated to develop maximum hardness and between about 1100° C., and the melting point of the alloy of which it is composed, and thereafter cooling it at a rate sufficiently rapid to permit the retention at ordinary room temperatures of a predominantly austenitic structure in the alloy.

5. An abrasion-resistant article composed of an iron-base cast alloy containing about 12% to 30% chromium, about 1.5% to 3% carbon, 0.1% to 5% molybdenum, and the remainder principally iron, said article being in the condition resulting from heating it at a temperature above the temperature range at which alloys of such composition are customarily heated to develop maximum hardness and between about 1100° C. and 1300° C. and thereafter cooling it at a rate sufficiently rapid to permit the retention at ordinary room temperatures of a predominantly austenitic structure in the alloy of which it is composed.

6. An abrasion-resistant article composed of a cast alloy containing about 12% to 30% chromium, about 1.5% to 3% carbon, and the remainder iron and incidental impurities, said article being in the condition resulting from heating it at a temperature above the temperature range at which alloys of such composition are customarily heated to develop maximum hardness and between about 1200° C. and 1300° C. and thereafter cooling it at a rate sufficiently rapid to permit the retention at ordinary room temperatures of a predominantly austenitic structure in said alloy.

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