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AUSTENITIC CHROMIUM-NICKEL-IRON
ALLOYHoward M. German, East Orange, N. J., assignor
to Driver-Harris Company, Harrison, N. J., a
corporation of New JerseyNo Drawing. Application January 1, 1944,
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6 Claims. (Cl. 75-128)

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This invention relates to a creep resistant alloy and more particularly to an austenitic chromium-nickel-iron alloy that is heat resistant, and which contains certain addition elements whereby the creep strength of the alloy is increased and the alloy is made less susceptible to checking or cracking when used where it is alternatively subjected to heating and cooling. This application is a continuation in part of my copending application Serial No. 446,932, filed June 13, 1942.

Austenitic alloys of chromium-nickel-iron are extensively used in the construction of trays or carriers employed for conveying metal parts through heat treating furnaces. These trays or carriers are subjected to severe usage, being constantly subjected first to the high temperature prevailing in the furnace and then to cooling at varied rates. As a result, checks or cracks develop in the castings from which the trays or carriers are formed.

I have found that the susceptibility of these alloys to checking or cracking in service is an inverse function of their creep strength. Castings having a high creep strength are less susceptible to cracking than those having a low creep strength. I have also found that the creep resistance of the castings is related to the solubility of their carbides; the greater the solubility, the lower the creep strength.

It has heretofore been proposed to increase the creep resistance of structural elements subjected in use to loads at elevated temperature by making them of austenitic chromium-nickel-iron-columbium alloys. While such alloys have greater creep strength than austenitic chromium-nickel-iron alloys heretofore used in casting structural elements subjected in use to loads at elevated temperature, I have found that greatly improved creep strength can be obtained by the addition of small amounts of molybdenum to such alloys.

While the present invention is not based on any particular theory, but upon performance of the alloy in actual tests, I believe that the results which I have obtained are due to the production of more insoluble carbides which prevents migration to the grain boundaries.

In the manufacture of austenitic alloys, the carbon present unites with other metals to form carbides. A certain amount of carbon is necessary in alloys of this type to give strength at high temperature and promote fluidity in casting. In the heretofore known austenitic chromium-nickel-iron alloys the carbides produced are soluble at high temperatures and they tend to migrate toward the grain boundaries. The addition of columbium to such alloys produces a less soluble carbide and therefore tends to prevent such migration. The result is an alloy having greater creep strength. Instead of adding columbium alone, however, I have found that

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when relatively small amounts of columbium or titanium and molybdenum are added, still less soluble carbides are formed. This not only results in greater creep strength and greater resistance to checking or cracking when the alloy is used in parts subjected alternately to high and low temperature, but also produces alloys of finer grain and therefore of greater strength.

I have also found that the presence of appreciable amounts of silicon and manganese produces an alloy of improved qualities. While the presence of silicon is generally believed to lower the creep strength of an alloy, I have found that this decrease in creep strength is overcome when the silicon is used in the presence of columbium or titanium and molybdenum or tungsten. At the same time the silicon contributes to the fluidity of the metal in casting, and permits use of smaller amounts of carbon. The presence of manganese, while not essential, also contributes to the production of an alloy of improved characteristics of the type disclosed.

In carrying out the invention the addition elements, titanium and molybdenum, may be added to any of the standard nickel-chromium-iron alloys. In the manufacture of trays or carriers employed in heat treating furnaces and in the manufacture of castings for structural elements subjected to loads under heat, an alloy of substantially 35 percent nickel, substantially 15 percent chromium and the balance iron is generally used.

The addition elements are added in relatively small amounts. As a general rule the amount of columbium or titanium added will vary from 0.5 percent to 3 percent. The amount of molybdenum added will vary from 0.5 percent to 3.5 percent. The total of columbium or titanium and molybdenum or tungsten should be greater than 2 percent. The silicon content may vary from 1.10 to 1.70 percent and the manganese may be present from 0.75 to 2.0 percent. Greater quantities of columbium and molybdenum may be present in the alloy, but I have found that when these elements are present in quantities greater than herein mentioned, the further addition does not result in a material increase in creep strength or resistance to cracking or checking when the alloy is subjected to alternate high and low temperature. In place of columbium I may employ titanium either in whole or in part and in place of molybdenum I may employ tungsten or vanadium. To demonstrate the greater creep strength of alloys of this type containing columbium and molybdenum as compared to the standard alloys or as compared to such alloys containing columbium alone, three heats were prepared. The first heat was a standard 35-15 nickel-chromium-iron alloy, the second heat was of standard analysis plus 2 percent of columbium,

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and the third heat, prepared in accordance with the present invention, was of standard analysis plus 2 percent of columbium and 2 percent of molybdenum. The analyses of these heats are as follows:

	I	II	III
Carbon.....	0.57	0.57	0.50
Manganese.....	1.09	1.10	1.18
Silicon.....	1.50	1.49	1.56
Nickel.....	35.83	36.19	35.58
Chromium.....	15.89	16.17	15.47
Columbium.....	None	1.91	2.03
Molybdenum.....	None	None	1.85
Iron.....	Balance	Balance	Balance

Standard creep test pieces and castings for service tests were prepared from each of these heats. The creep resistance of cast heat resisting alloys of the 35-15 type is greatly increased by the presence of columbium but a far greater improvement is obtained by additions of columbium and molybdenum. The three alloys were tested at 1800° F. under 2000 pounds per square inch. The standard alloy entered the third period of creep within fifty hours from the beginning of the test. In the alloy containing 1.91 percent columbium the entrance into the final stage of creep did not occur for six hundred hours. The alloy containing 2.03 percent columbium and 1.85 percent molybdenum after fifteen hundred hours under stress had not entered the third stage of creep. I have found that the increase in creep resistance at 2000 p. s. i. is roughly eight-fold for the alloy containing columbium addition over the standard alloy and eighty-fold for the alloy containing the columbium-molybdenum addition.

As stated it appears that the creep resistance of these alloys is dependent upon the relative solubility of their carbides; the weakest exhibiting the greater solubility and less precipitation while the strongest develops the most voluminous precipitate and one which does not agglomerate readily by virtue of reduced solubility. In all, precipitation of carbides is accompanied by shrinkage which causes either negative creep or reduced rates of extension depending upon the value of the applied stress. The duration of this effect is extended in the alloys containing more of the heavy elements and which have reduced solubilities for their carbides.

In addition to the creep strength tests the three alloys were also submitted to tests on a production basis in which the trays or carriers employed in a heat treating furnace were made of such alloys. The No. II alloy containing the columbium addition showed less cracking and longer life than the No. I standard alloy. Castings of No. III alloy, however, showed considerably less cracking and longer life than the castings of the No. II alloy.

In the specific examples herein given the carbon content was roughly .50 percent. As stated, a certain amount of carbon is essential in these alloys for the production of carbides and the carbon content is preferably from 0.3 to 0.8 percent.

The alloys of the present invention may be prepared in the usual way for producing chromium-nickel-iron alloys. The addition elements are added preferably during the latter part of the melting period. Columbium and molybdenum may both be added as the pure elements or as the less expensive ferro-alloys. The alloy forming

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the subject matter of the present invention may be employed for any of the purposes for which the standard 35-15 nickel-chromium-iron alloys are now employed, such as the manufacture of structural elements subjected to loads at increased temperature in use and also in the manufacture of parts used particularly on conveyors passing through heat treating furnaces and alternately subjected to high temperature and quenching. The alloy is also particularly useful in the manufacture of parts of conveyor belts used in heat treating furnaces and which are alternately subjected to the heat of the furnaces and to quenching.

Throughout the specification and claims the expression "balance iron" means that except for the elements enumerated and iron the alloy is substantially free of other elements. It does not, however, exclude the presence of small amounts of other elements which do not materially affect the above described functions of titanium, tungsten and molybdenum. Other elements employed as deoxidizers in the melt, and generally used in slight excess, may likewise be present in substantially the same quantities.

I claim:

1. An austenitic chromium-nickel-iron alloy having high creep resistance at temperatures up to 1800° F. comprising substantially 35% nickel, substantially 15% chromium, 0.5 to 3.0% titanium, 0.5 to 3.5% of a metal from the group consisting of molybdenum and tungsten, 1.10 to 1.70% silicon, 0.75 to 2.0% manganese, 0.30 to 0.80% carbon, balance substantially all iron.

2. An austenitic chromium-nickel-iron alloy having high creep resistance at temperatures up to 1800° F. comprising substantially 35% nickel, substantially 15% chromium, 0.5 to 3.0% titanium, 0.5 to 3.5% molybdenum, 1.10 to 1.70% silicon, 0.75 to 2.0% manganese, 0.30 to 0.80% carbon, balance substantially all iron.

3. An austenitic chromium-nickel-iron alloy having high creep resistance at temperatures up to 1800° F. comprising substantially 35% nickel, substantially 15% chromium, 0.5 to 3.0% titanium, 0.5 to 3.5% tungsten, 1.10 to 1.70% silicon, 0.75 to 2.0% manganese, 0.30 to 0.80% carbon, balance substantially all iron.

4. An austenitic chromium-nickel-iron alloy having high creep resistance at temperatures up to 1800° F. comprising substantially 35% nickel, substantially 15% chromium, substantially 2% titanium, substantially 2% of a metal from the group consisting of molybdenum and tungsten, substantially 1.5% silicon, substantially 1.2% manganese, substantially 0.5% carbon, balance substantially all iron.

5. An austenitic chromium-nickel-iron alloy having high creep resistance at temperatures up to 1800° F. comprising substantially 35% nickel, substantially 15% chromium, substantially 2% titanium, substantially 2% molybdenum, substantially 1.5% silicon, substantially 1.2% manganese, substantially 0.5% carbon, balance substantially all iron.

6. An austenitic chromium-nickel-iron alloy having high creep resistance at temperatures up to 1800° F. comprising substantially 35% nickel, substantially 15% chromium, substantially 2% titanium, substantially 2% tungsten, substantially 1.5% silicon, substantially 1.2% manganese, substantially 0.5% carbon, balance substantially all iron.

HOWARD M. GERMAN.