United States Patent [19] McGurty
[11] 3,754,898
[45] Aug. 28, 1973

[54] AUSTENITIC IRON ALLOYS

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[22] Filed: Jan. 7, 1972

[21] Appl. No.: 216,297

[52] U.S. Cl. .... 75/122, 75/124, 75/125, 75/128 E
[51] Int. Cl. C22c 37/00, C22c 37/10
[58] Field of Search .... 75/128 E, 126 G, 75/124, 122, 125

[56] References Cited

UNITED STATES PATENTS

3,027,252	3/1962	McGurty	75/124
3,540,881	11/1940	White	75/124
3,298,826	1/1967	Wukusick	75/124
3,113,991	12/1963	Kleber	75/126 G
2,879,194	3/1959	Eichelberger	75/124

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[57] ABSTRACT

The production of an austenitic iron base alloy with relatively high aluminum and chromium content which forms an aluminum oxide protective film in the presence of yttrium and/or rare earth elements and has high temperature resistance.

5 Claims, No Drawings

AUSTENITIC IRON ALLOYS

My invention relates to high temperature, oxidation resistant austenitic iron alloys and more particularly to alloys of iron, nickel, aluminum and yttrium which have oxidation resistance based on the formation of an aluminum oxide protective film.

Because of its allotropic properties iron forms, depending on the addition of other alloying elements, two series of alloys, the ferritic and the austenitic which differ significantly in properties. Generally, ferritic alloys are magnetic, have low thermal expansion properties, poor high temperature strength and fair workability. The austenitic alloys are non-magnetic, have high thermal expansion properties, good high temperature strength and excellent workability.

Ferritic alloys which are oxidation resistant and which contain chromium, aluminum and yttrium are useful but have poor structural strength at high temperature and are difficult to produce economically in sheet form.

My invention of an austenitic alloy which readily forms an aluminum oxide film has greater strength at high temperature and is easily workable to produce standard products using conventional facilities presently employed in automotive and similar metal working shops.

In the ordinary automobile engine, exhaust gases which contain carbon monoxide, nitrogen oxides and hydrocarbon gas contaminants are present in harmful quantities.

The nitrogen oxide contamination can be minimized by adjusting the engine combustion conditions to realize less oxidizing combustion conditions. This resolution of the nitrogen oxide problem results in an even greater emission of carbon monoxide and hydrocarbon contaminants. However, if the combustion gases which exit from engines at temperatures of 1,400°F to 1,700°F are mixed with additional air in an automotive reactor connected to the engine exhaust ports, the carbon monoxide and hydrocarbon contaminants are oxidized to yield innocuous carbon dioxide and water vapor. Thus the gas which exhausts from an engine equipped with an exhaust reactor and operated under proper conditions such as a rich mixture and a retarded spark contains insignificant amounts of the carbon monoxide, nitrogen oxide and hydrocarbon contaminants.

The chemical reactions referenced above create increases in temperature to 1,700°–2,000°F and beyond. In my invention I have provided oxidation resistant alloys which are chemically stable at such temperatures, are workable, have strength and are economically feasible for high production.

High temperature technology is generally based on the use of metals which react with oxygen, nitrogen and/or other corrosive reactants at elevated temperatures to form a protective film which protects the base metal.

Iron, nickel and cobalt are useful as base metals for high temperature heat resistant alloys. Iron, nickel and cobalt react with oxygen at elevated temperatures and readily convert to the oxides. However, the oxides formed are chemically weak and are readily reduced by other high temperature metals. Thus when iron, nickel or cobalt alloys which contain other elements which are more reactive with oxygen are heated in an oxidizing atmosphere the addition elements when present in suitable concentration will preferentially oxidize at the surface of the metal. A barrier to further significant oxidation is obtained if the oxide film (of the additive metal) which forms is adherant and coherant.

Present day high temperature technology is thus based on the use of iron, nickel and cobalt base alloys which contain chromium and/or aluminum and whose oxidation resistance is dependant on the formation of aluminum oxide or chromium oxide protective films.

The aluminum oxide film, especially that which forms on alloys which contain small amounts (0.1 to 5.0 w/o) of yttrium or rare earth elements is the more protective of the base metals.

My invention consists of the production of an austenitic iron base alloy with high aluminum and chromium content so that in the presence of yttrium and/or rare earth elements an aluminum oxide protective film forms.

Alloys which contain 4 w/o aluminum, 20 or 25 w/o nickel and 5, 10 and 15 w/o chromium plus 1 w/o yttrium were found to be austenitic and readily workable hot or cold. The oxide film formed on these austenitic alloys on exposure to air at elevated temperatures (1,800°–2,300°F) was a thin aluminum oxide film which is also protective of the ferritic Fe-Cr-Al-Y alloys. I found austenitic iron base alloys containing Ni, Cr, Al, and Y to have superior oxidation resistance due to the formation of a thin aluminum oxide film which is adherent, non-spalling and highly protective of the base metal.

The exact compositional limits for defining the range of alloys which possess the required austenite stability and aluminum oxide protective film oxidation resistance may generally be defined as having 16 to 45 w/o Ni, 4 to 25 w/o Cr, 3½ w/o to 5½ w/o aluminum and 0.1 to 5 w/o Y. I found the most useful composition to be the following: Fe-20 percent Ni-10 percent Cr-4 percent Al-1 percent Y.

The function of the alloying additions in the oxidation resistant alloys is as follows: The nickel with the help of chromium is added to the alloy to obtain the desired austenitic structure. The aluminum content with the help of the chromium and yttrium contents provides the superior oxidation resistance.

For economic reasons it is desirable to limit the nickel content of commercial alloys.

It is well known that manganese, carbon, nitrogen and copper like nickel promote austenite stabilization. I have found that the content in my alloys of strategic and expensive nickel can be lowered to below 15 percent without loss of austenite stability by the addition to the alloy of manganese and copper. The Fe-15w/o Ni-10w/o-Cr-4w/oAl-5w/oMn-1w/oCu-1w/oY was found to possess the desired austenite stability and the excellent strength and oxidation resistance typical of the non-manganese and copper containing alloys.

I have found based on phase stability and oxidation resistance, useful alloys would fall within the following composition range Fe-10- to 45 w/o Ni-4 to 25 w/o Cr-3½ to 5½ w/oAl-0.1 to 5 w/oY, and contain 0-20w/o Mn-0 to 0.5 w/oC-0 to 0.5 w/oN and/or 0 to 1w/o Cu as a partial substitution of the austenite stabilizing nickel content.

It is well known in the art that carbon and nitrogen in small amounts (less than 0.4 w/o) and molybdenum, tungsten, columbium, tantalum, titanium, zirconium and hafnium in larger amounts added to austenitic iron base alloys such as the stainless steels improve the high temperature strength of the austenite structure. Evaluations were conducted to determine the effectiveness of such strengthening additions for improving the properties of these new austenitic alloys. In addition to high temperature strength the effects of the additions on austenite stability and oxidation resistance were also determined. Examples of the effectiveness of such strengthening additions are shown in Table I.

TABLE I

Effects of Alloy Additions to Fe-Cr-Ni-Al-Y ti Base Alloys on Stress Rupture Strength at 1800°F

Alloy Composition in (w/o)	stress rupture 3000 psi stress	Time (Hrs.) 4000 psi stress
Fe-10Cr-20Ni-4Al-1Y	1	
Fe-10Cr-20Ni-4Al-4W-1Y	8	
Fe-10Cr-20Ni-4Al-4Mo-1Y	7	
Fe-10Cr-25Ni-4Al-4-W-1Y	26	3.7
Fe-10Cr-25Ni-4Al-4Mo-1Y	26	2.8
Fe-10Cr-25Ni-4Al-4Mo-4W-1Y		4.2
Fe-10Cr-20Ni-4Al-2W-2Mo-1Cb 0.2C-0.2N-1Y	27	
Fe-10Cr-25Ni-4Al-2W-2-Mo-1Cb 0.2 C-0.2N-1Y	30	
Fe-10Cr-15Ni-4Al-5Mn-1Cu-1Y	12	
Fe-10Cr-20Ni-4Al-5Mo-1Y	14	
Fe-10Cr-30Ni-4Al-5Mo-1Y	8	
Fe-10Cr-35Ni-4Al-5Mo-1Y	4	

Additions of molybdenum and tungsten alone and in combination are effective to improve the strength in this regard.

The data shown in Table I illustrate the desirable strength advantage of the low nickel manganese containing alloy (Fe-10Cr-15Ni-4Al-5Mn-1Cu-1Y) as compared to the higher nickel non-manganese containing composition (Fe-10Cr-20Ni-4Al-1Y).

Based on austenite phase stability, oxidation resistance and high temperature strength useful alloys would fall within the following composition range Fe-8 to 45 w/o Ni-4 to 25 w/o Cr-3½ to 5½ w/o Al-0.1 to 5 w/o Y and 0.5 to 20 w/o Mn-0.1 to 1 w/o Cu 0.1 to 10 w/o W and/or Mo-0.1 to 2 percent Cb and/or Ta, Ti, Zr, or Hf and 0.05 to 0.5 w/o carbon and/or nitrogen.

I have in my invention found that austenitic alloys containing iron, nickel, aluminum and yttrium have superior oxidation resistance because of the formation of an aluminum oxide protective film and are high temperature oxidation resistant, have good strength along with workability compared to oxidation resistant ferritic alloys.

I have found that additions of manganese and/or copper, carbon and nitrogen provides austenitic alloys of lower nickel content and higher strength than the base Fe-Ni-Cr-Al-Y compositions. Further additions to the base Fe-Ni-Cr-Al-Y alloy of additions which are effective for improving the strength of stainless steel alloys such as molybdenum, tungsten, manganese, columbium, carbon and/or nitrogen are significantly advantageous for increasing the high temperature strength of the Fe-Ni-Cr-Al-Y alloys.

It is well known that the rare earth elements have an effect similar to yttrium for decisively improving the protective qualities of aluminum oxide protective films in terms of non-spalling properties and effectiveness as a nitrogen barrier. However, the most protective aluminum oxide films are formed on alloys which contain yttrium alone or in combination with small additions of the rare earth metals and/or actinide metals. It is recognized that the yttrium content of my alloys may be partially substituted or wholely replaced by rare earth metal or actinide metal additions without loss of excellent oxidation resistance.

Although the present invention has been described in preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand. Such modifications and variations are considered to be within the purview and scope of the invention and appended Claims.

I claim:

1. An austenitic alloy of iron, nickel, chromium, aluminum and yttrium consisting essentially of 20.0 weight percent of nickel, 10.0 weight percent chromium, 4.0 weight percent of aluminum and 1.0 weight percent yttrium and the balance consisting essentially of iron.

2. An austenitic alloy of iron, nickel, chromium, aluminum, and yttrium consisting essentially of 16 to 45 weight percent of nickel, 4 to 25 weight percent of chromium, 3.5 to 5.5 weight percent aluminum, 0.1 to 5 weight percent yttrium and the balance consisting essentially of iron.

3. An austenitic alloy of iron consisting essentially of nickel, chromium, aluminum, manganese, copper and yttrium which consists of 15.0 weight percent of nickel, 10.0 weight percent of chromium, 4.0 weight percent aluminum, 5.0 weight percent manganese, 1.0 weight percent copper, 1.0 weight percent yttrium and the balance consisting essentially of iron.

4. An austenitic alloy of iron consisting essentially of nickel, chromium, aluminum, yttrium and containing additions of manganese, carbon, nitrogen and copper as a partial substitution of the austenite stabilizing nickel content within the following ranges, 10.0 to 45.0 weight percent nickel, 4 to 25.0 weight percent chromium, 3.5 to 5.5 weight percent aluminum, 0.1 to 5.0 weight percent yttrium and containing 0. to 20 weight percent manganese, 0. to 0.5 weight percent carbon, 0. to 0.5 weight percent nitrogen and/or 0. to 1 weight percent copper with the balance iron.

5. An austenitic iron base alloy as described in claim 4 having improved high temperature strength and including iron, 8 to 45 weight percent nickel, 4 to 25 weight percent chromium, 3.5 to 5.5 weight percent aluminum, 0.1 to 5 weight percent yttrium, and contain 0. to 20 weight percent manganese, 0. to 0.5 weight percent carbon, 0. to 0.5 weight percent nitrogen, 0 to 1 weight percent copper, and/or as a partial substitution of the austenite stabilizing nickel content and for increased high temperature strength 0.1 to 10 weight percent tungsten and/or molybdenum, and/or 0.1 to 2 weight percent columbium and/or tantalum, titanium, zirconium or hafnium.

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