United States Patent Office

2,892,703

Patented June 30, 1959

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2,892,703

NICKEL ALLOY

Walter F. Furman, New York, N.Y., and Harvey T. Harrison, Scottdale, Pa., assignors to The Duraloy Company, Scottdale, Pa., a corporation of Delaware

No Drawing. Application March 5, 1958
Serial No. 719,204

4 Claims. (Cl. 75—128)

This invention relates to ferrous alloys and ferrous alloy articles for use at high temperatures, referring especially to alloy articles suitable for use in applications where high strength at elevated temperatures is required.

The trend in modern engineering is towards the utilization of high temperatures for many and diverse operations. As an example, chemical processes are conducted today at high temperatures, a notable instance being in the field of petroleum refining. Alloys with high strength at elevated temperatures are also required as furnace parts in the form of supports and channels of one kind or another in which processes are operated at high temperatures. Such furnaces may contain tubes, either cast or wrought, or rolls that act as conveyors for parts moving through the furnaces, or they may contain metal trays that are constantly being brought in and out of the furnace with frequent heating and cooling resulting in drastic changes in temperatures. In some instances, ends of metal tubes, usually referred to in the art as reactor tubes, are operated in such fashion that one end is hot and the other is cool. In this case the necessity for having available metal that will withstand temperature variations as well as rapid changes in temperature is a requirement that is difficult to meet.

The aforementioned furnaces and furnace parts that have been used successfully in commercial processes in the past have been produced from alloys that contain in addition to chromium substantial proportions of nickel. Invariably, these alloys have contained anywhere from about 30% to 60% nickel. It is a well known fact that in recent years the industrial demands for nickel have been at least equal to, and in some cases in excess of, availability.

This state of affairs has created an unfavorable condition in regard to the economic use of alloys at the high temperatures. It has brought stress on the users of high-nickel-content alloys to such an extent that substitutes have been tried with resulting unsatisfactory service and increased cost in operation. The supply of nickel has not increased to such an extent that it is a free commodity, and continued hardship will confront both the producers and users of the high-nickel-content alloys in order to obtain materials of construction that are economically suited for high temperature applications.

Other applications in which high-nickel alloys are used are in such devices as superchargers, gas turbines, jet propulsion apparatus, and the like, and it is necessary in these instances for the materials to withstand deterioration at high temperatures and under high mechanical stress without failure due to excess deformation or cracking.

Usually the temperatures involved in all such types of applications are in excess of 1200° F., and in many instances the temperatures generally exceed 1500° F. Typical of the compositions that have been used in such applications are alloys containing from 15% to 20% of chromium and from 35% to 60% of nickel, the remainder being iron with minor percentages of other constituents such as carbon, manganese, silicon and impurities such as phosphorous and sulphur.

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The principal object of this invention is to provide new ferrous alloys which contain much less than about 30% of nickel and which will successfully resist oxidation and will withstand high applied stresses at temperatures of from about 1200° F. to somewhat in excess of about 1500° F.

This object is attained by the present invention which provides alloys of new compositions and properties. The principal ingredients of the alloys of this invention are carbon, chromium, nickel, manganese, nitrogen and columbium with adequate percentages of silicon for quality purposes, and incidental impurities, such as phosphorous and sulphur.

It is important that certain of these elements should be present in the proper proportions and percentages. The nickel should not be less than about 15% nor more than about 25% and the combined chromium and nickel content should range between about 25% and about 50%, and the manganese should range between about 5% and about 15%. When columbium and nitrogen are present in certain percentages in alloys containing those percentages of chromium, nickel and manganese, the alloys will have high temperature strength quite comparable with that of prior high chrome, high nickel alloys containing from 35% to 60% of nickel. And even when the nickel content is as low as 10% or 15%, the present alloy will have high temperature strength heretofore thought to be impossible to attain in alloys of that low nickel content. This new and unexpected high temperature strength is traceable in large part to the presence of the three elements, high manganese, columbium and nitrogen, as is indicated by the fact that when either columbium or nitrogen is omitted, the high temperature strength is greatly reduced.

In alloys of the foregoing composition it is to be understood that the remainder of the composition is iron with usual impurity amounts of sulphur and phosphorous, medium carbon, and moderate amounts of silicon.

This invention is also embodied in alloys having the following intermediate composition range within the foregoing broad range:

Carbon	From about .30% to about .50%.
Chromium	From about 15% to 25% maximum.
Nickel	From about 10% to about 25%.
Manganese	From about 5% to about 15%.
Silicon	From about .9% to about 1.5%.
Nitrogen	From about .05% to about .5%.
Columbium	From about .75% to about 1.5%.

the remainder being iron with not more than about .05% of each of phosphorous and sulphur.

A narrower and preferred range of ingredients is as follows:

Carbon	From about .30% to about .50%.
Chromium	From about 19% to about 22%.
Nickel	From about 19% to about 22%.
Manganese	From about 8% to about 11%.
Silicon	From about .9% to about 1.5%.
Nitrogen	From about .05% to about .5%.
Columbium	From about .75% to about 1.5%.

the remainder being iron with not more than about .04% of each of phosphorous and sulphur.

A preferred alloy has the following composition:

Carbon	About .38%.
Chromium	About 21.4%.
Nickel	About 20.6%.
Manganese	About 9.30%.
Silicon	About .94%.
Nitrogen	About .20%.
Columbium	About 1.02%.

with the remainder being iron with not more than about .025% of phosphorous and not more than about .022% of sulphur.

Physical properties of the preferred composition are shown in the following table:

	1,400° F.	1,600° F.
Short Time High Temperature Properties:		
Tensile Strength (p.s.i.)	54,100	30,600
Elongation in 2"	11.5	14.0
Reduction in Area	10.4	37.8
Room Temperature Physical Properties:		
Yield Point (p.s.i.)	53,250	
Tensile Strength (p.s.i.)	83,750	
Elongation in 2"	11.0	
Reduction in Area	12.6	
Stress rupture at 1,600° F. and 7,000 p.s.i. load:		
Time in Hours to Rupture	1,103 Hrs.	
Air Oxidation Resistance at 1,800 °F	.0097696 inch per year.	

The air oxidation resistance factor is determined in the customary way, that is, by exposing the specimen to the specified temperature for a prolonged period of time and then removing the oxidized surface portions of the specimen and determining the depth of penetration in inches and then calculating the amount of such penetration which would be obtained if the specimen were subjected to the same temperature for a year.

Alloys embodying this invention are stronger at both room temperature and at elevated temperatures, and are more resistant to air oxidation, than alloys which have been used extensively heretofore to resist high temperatures and which contained a much higher nickel content. Since it was generally believed that a high nickel content was required to confer high heat resisting properties on the alloy, it is a surprising and unobvious discovery that even better properties at high temperatures can be obtained by this invention wtih greatly reduced amounts of nickel.

It is to be understood that many different alloys may be made within the limits of the foregoing broad composition ranges and that each such alloy will embody the present invention and will, at least to an appreciable extent, possess the above-stated properties.

All of the test results described in the foregoing tables have been obtained on cast samples, but it should be pointed out that this in no way limits the invention as all of these alloys are capable of being hot worked into various and sundry items such as billets, forgings, bars, sheet, and strip. It should be understood that when it is necessary to produce such items for fabrication into equipment serving at temperatures of about 1200° F., this practice is also included and forms a part of the invention.

Alloys embodying the present invention may be made either from virgin metal or scrap metal. A convenient way to make these alloys is to select scrap metal of the chrome-nickel types and to proportion such scrap in a manner to obtain the above-specified chrome-nickel contents. Since the chrome-nickel scrap contains iron and iron contains such elements as carbon and impurity amounts of phosphorous and sulphur, the desired amounts of iron and such elements may be provided by proportioning the chrome-nickel scrap or adding iron or iron containing alloys. The manganese may be in the form of ferro-manganese. The nitrogen may be conveniently added in the form of high nickel bearing ferro-chrome alloy. All these metals may be melted down at the same time.

Having thus described this invention in such full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains to make and use the same, and having set forth the best mode contemplated of carrying out this invention, we state that the subject-matter which we regard as being our invention is particularly pointed out and distinctly claimed in what is claimed, it being understood that equivalents or modifications of, or substitutions for, parts of the above specifically described embodiments of the invention may be made without departing from the scope of the invention as set forth in what is claimed.

What is claimed is:

1. A nickel chrome iron alloy having a tensile strength above about 50,000 pounds per square inch at 1400° F., an air oxygen resistance of less than about .010 inch per year at 1800° F., and a resistance to rupture for about 1100 hours under a stress of about 7000 pounds per square inch applied at about 1600° F. and consisting essentially of not less than about 10% or more than about 25%, of nickel sufficient chromium not exceeding about 25% to bring the combined nickel and chromium content to between about 25% and about 50%, between about 5% and about 15% of manganese, between about .75% and about 1.5% of columbium, between about .05% and about .5% of nitrogen, the remainder being moderate amounts of silicon and iron containing medium carbon and usual impurity amounts of sulphur and phosphorous.

2. A nickel chrome iron alloy having a tensile strength above about 50,000 pounds per square inch at 1400° F., an air oxygen resistance of less than about .010 inch per year at 1800° F., and a resistance to rupture for about 1100 hours under a stress of about 7000 pounds per square inch applied at about 1600° F. and consisting essentially of between about .30% and about .50% of carbon, between about 15% and about 25% of chromium, between about 10% and about 25% of nickel, between about 5% and about 15% of manganese, between about .9% and about 1.5% of silicon, between about .75% and about 1.5% of columbium, and between about .05% and about .5% of nitrogen, the remainder being iron with not more than about .05% of each of sulphur and phosphorous.

3. A nickel chrome iron alloy having a tensile strength above about 50,000 pounds per square inch at 1400° F., an air oxygen resistance of less than about .010 inch per year at 1800° F., and a resistance to rupture for about 1100 hours under a stress of about 7000 pounds per square inch applied at about 1600° F. and consisting essentially of between about .30% and about .50% of carbon, between about 19% and about 22% of chromium, between about 19% and about 22% of nickel, between about 8% and about 11% of manganese, between about .9% and about 1.5% of silicon, between about .75% and about 1.5% of columbium, and between about .05% and about .5% of nitrogen, the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

4. A nickel chrome iron alloy having a tensile strength above about 50,000 pounds per square inch at 1400° F., an air oxygen resistance of less than about .010 inch per year at 1800° F., and a resistance to rupture for about 1100 hours under a stress of about 7000 pounds per square inch applied at about 1600° F. and consisting essentially of .38% of carbon, about 21.4% of chromium, about 20.6% of nickel, about 9.3% of manganese, about .94% of silicon, about 1.02% of columbium, and about .20% of nitrogen, the remainder being iron with not more than about .04% of each of sulphur and phosphorous.

No references cited.