Dec. 7, 1965 J. R. BIRD ETAL 3,222,165

NICKEL CHROMIUM BASE ALLOY PRODUCTS

Filed Nov. 24, 1959

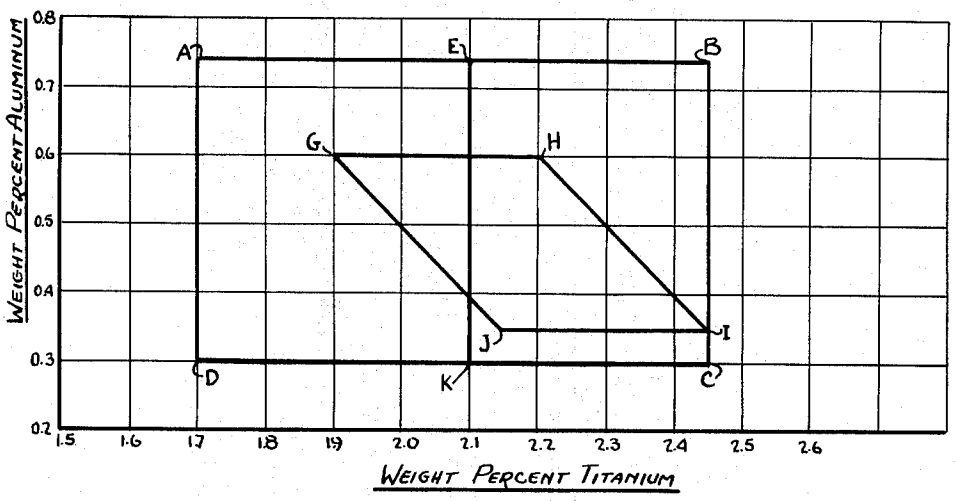


Fig. 2.

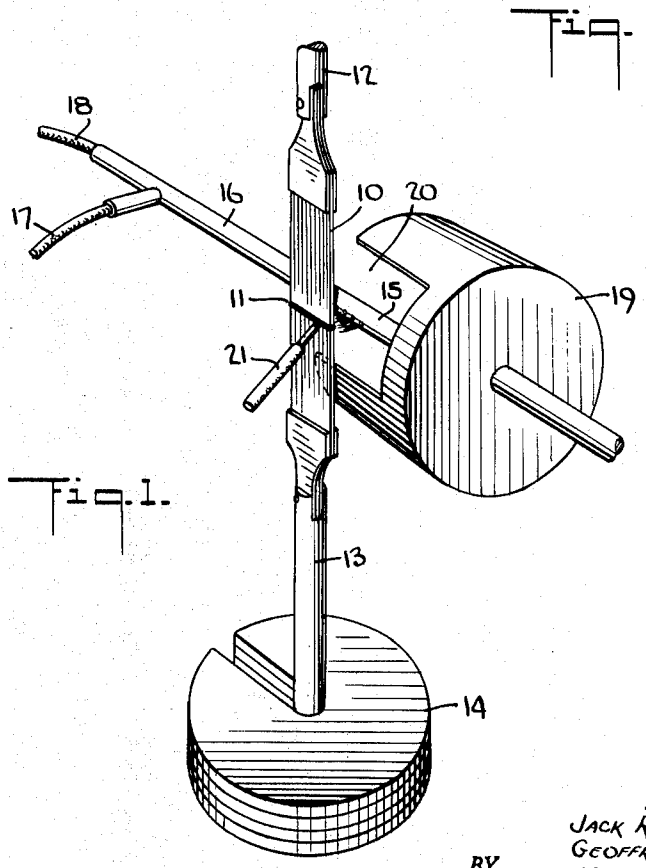


Fig. 1.

INVENTORS
JACK R. BIRD
GEOFFREY W. MEETHAM
MARCUS A. WHEELER

BY Kenyon & Kenyon
ATTORNEYS

United States Patent Office

3,222,165

Patented Dec. 7, 1965

3,222,165

NICKEL CHROMIUM BASE ALLOY PRODUCTS

Jack Raymond Bird, Chellaston, Geoffrey William Meetham, Derby, and Marcus Alan Wheeler, Darley Abbey, England, assignors to Rolls-Royce Limited, Derby, England, a corporation of Great Britain

Filed Nov. 24, 1959, Ser. No. 855,076
Claims priority, application Great Britain, Nov. 26, 1958, 38,217/58; May 15, 1959, 16,721/59
2 Claims. (Cl. 75—171)

This invention relates to chromium-nickel base alloy products having advantageous welding characteristics. Specifically, such advantageous characteristics include the ability to withstand repeated, rapid, thermal cycling. Products embodying the invention also possess a relatively high ductility.

Claim is hereby made for the benefit of the filing date of patent applications, Serial No. 38,217 of 1958 filed in Great Britain on November 26, 1958, now Patent No. 3,038,174, and Serial No. 16,721 of 1959 filed in Great Britain on May 15, 1959, now Patent No. 3,109,156.

The advent of the jet age has led to ever-increasing requirements for materials of construction which can withstand relatively high temperatures. The initial materials used for these high temperature applications were chromium-nickel base alloys which were modified by addition of varying amounts of substituents designed to impart specific qualities or characteristics.

A development in the search for new high temperature materials of construction is described in U.S. Patent No. 2,712,498 which issued to H. E. Gresham and M. A. Wheeler on July 5, 1955. The basis of the foregoing patent was the discovery that certain important properties of high temperature alloys of the chromium-nickel base type are related, in a unique manner, to the amounts of each of three hardeners, aluminum, titanium and molybdenum, contained in the alloy. The amounts of the three hardeners which are necessary to achieve the desired properties are determined by computing "the balance factor," which is equal to the sum of the weight percent of molybdenum plus twice the weight percent of aluminum plus four times the weight percent of titanium. Thus, for example, in accordance with the data tabulated in the Gresham patent, it was established that the balance factor should be in the range of from 16 to 20 to impart a relatively high degree of creep strength to the alloy in question. The Gresham teaching indicates that an alloy having a balance factor less than approximately 16 is not suitable for use in applications requiring high creep strength.

Although the development of the alloys described above satisfied certain requirements in the manufacture of equipment ordinarily subject to relatively high temperatures, other difficulties in the field of high temperature design remain unsolved. Thus, for example, the production of the inner walls of jet pipes of modern gas turbine jet engines was hindered by the lack of a suitable material of construction. Such inner walls must be fabricated in a manner which will enable them to withstand repeated, rapid, thermal cycling up to temperatures of the order of 800° C. Such pipes are generally fabricated from alloy sheets which are welded to produce the desired shape. By virtue of the size of such pipes, which may be as large as 40 inches in diameter and 20 feet in length, the welds must possess a high degree of

strength and ductility to withstand the stresses arising from the severe thermal shocks continually encountered. Although a suitable heat treatment may improve the characteristics of the welded structure, such a procedure is impractical in view of the large dimensions of the jet pipes.

It has been discovered that chromium-nickel base alloys having a particular composition herein described will possess a relatively high degree of ductility in addition to being relatively resistant to the type of thermal cycling mentioned above. As in the alloy of the Gresham et al. patent, the present invention also involves the use but in another manner of the "balance factor." This factor, i.e., the sum of 1×percent Mo plus 2×percent Al plus 4×percent Ti serves, according to our discovery, as a critical indicia of the suitability of chromium-nickel base alloys for welded structures which must have high ductility and at the same time be able to resist without fracture a very large number of rapid and extreme temperature changes. According to the present invention, the balance factor must be maintained below a value of 16, rather than above 16 as taught by Gresham, et al.

In accordance with the present invention, it has been determined that a definite correlation exists between the welding characteristics of a nickel-chromium base alloy which contains by weight approximately 19 to 23% chromium, 12 to 25% cobalt, 3 to 8.6% molybdenum, 1.7 to 2.45% titanium, 0.3 to 0.74% aluminum, 0.2 to 0.6% manganese, 0.1 to 0.5% silicon, and small amounts of impurities with the balance essentially nickel—and the balance factor of the alloy. Specifically, it has been determined that such balance factor should be less than 16 in order to impart desirable welding characteristics to the alloy.

The invention will be more readily understood when taken in conjunction with the drawings in which:

FIG. 1 is a perspective view of an apparatus suitable for use in testing the thermal shock resistance of a weld in a specimen, and

FIG. 2 is a graph defining by weight percent of aluminum and weight percent of titanium, the alloys which are the subject of the present invention.

Referring to FIG. 1, there is shown an apparatus which may be used to subject a weld in a specimen to repeated, rapid thermal cycling. Shown in FIG. 1, is specimen **10** which consists of two pieces of sheet material joined by weld **11**. Specimen **10** is suspended from rod **12** and in turn supports weight **14** which is attached by rod **13**. A plurality of jet flames emanate from burner **15** which is connected by pipe **16** to air and gas sources, numbered **17** and **18**, respectively. Cylinder **19**, having open space **20** on its periphery, is rotated about burner **15** by means, not shown, at an appropriate speed so that weld **11** is exposed to the flame for a small period of time. For the balance of the cycle, the jet flame is prevented from impinging on weld **11** by the walls of cylinder **19**, and accordingly, the temperature of the weld decreases during this relatively long period of time. Thermocouple **21** continuously measures the temperature of weld **11**, and such temperature information is transmitted to a temperature recording device, not shown.

FIG. 2 is a graph defining the alloys which are the subject of this invention. As may be seen, the coordinates of the graph are weight percent aluminum and weight percent titanium. Because of the impracticability of illustrating a three-component system on a plane surface, the molybdenum content of the alloy has not been indicated, although it is to be understood that this percentage will always be equal to a value in the range of from 3.0 to 8.6 % by weight.

The rectangular area formed by joining joints A, B, C and D in FIG. 2 includes all of the possible combinations of aluminum and titanium suitable for use in the alloys of this invention. As stated above, the specific percentages of aluminum, titanium and molybdenum must be chosen so that the balance factor is equal to a figure less than 16.

The aluminum content of the alloys of the present invention is of considerable importance. If the aluminum content exceeds 0.74%, the ductility of the alloy falls and its welding properties are adversely affected due to skin formation. On the other hand, if the aluminum content is substantially less than 0.3% the resistance of the alloy to deformation under stress falls off to a low value (e.g. deformation of more than 1.0% strain after 100 hours at a temperature of 775° C. under a stress of 7.8 tons per square inch.

Manganese and silicon both serve to strengthen the alloy and also improve its welding properties. Thus 0.2 to 0.6% manganese and 0.1 to 0.5% silicon enable the alloy to flow better and also prevent bubble formation during argon arc welding. Such bubble formation is undesirable in that it reduces the strength of the weld.

Cobalt is present preferably in the range of from 18 to 21% whereas the molybdenum content is preferably in the range from 5.5 to 6.5%.

Particularly satisfactory alloys for use in the manufacture of the aforementioned jet pipes may be fabricated from alloys having an aluminum-titanium content within the parallelogram formed by joining points G, H, I and J as shown in FIG. 2, provided such alloys also have a balance factor less than 16.

The various alloys represented by points within the delineated areas of FIG. 2 may contain, in addition to aluminum, titanium, molybdenum and the other elements specified above, impurties such as carbon, iron, boron, zirconium and sulfur in small amounts, the balance of the alloy being made up of nickel.

Carbon and iron are usually unavoidably present and should be maintained below 0.06% and 1.0% respectively. Boron and zirconium are preferably to be avoided, but may be present in amounts up to 0.02% for boron and 0.5% for zirconium. Sulfur also is to be avoided but may be present in amounts up to 0.01% but preferably below 0.005%.

Alloys of the present invention may be melted in air or in vacuo and then rolled into sheet form in the customary manner. The sheets are then preferably heat treated by solution treating and thereafter aged for 4 to 16 hours at a temperature in the range of from 700° C. to 800° C. Line EK, which bisects rectangle ABCD in FIG. 2, divides the alloy of this invention into two groups according to the method of heat treatment thereof. Alloys which aluminum-titanium content is such that they fall within rectangle AEKD may be treated by a process comprising solution treating the alloy from 10 to 30 minutes at a temperature in the range of from 1080 to 1120° C. Alloys whose aluminum titanium content brings them within rectangle EBCK may be treated by a process comprising solution treating the alloy from 10 to 15 minutes of from 1050° C. to 1100° C. The alloys of the present invention having aluminum-titanium contents falling within parallelogram GHIJ of FIG. 2 may be solution treated for 10 to 15 minutes at a temperature in the range of 1060° C. to 1180° C.

Described in detail below are two illustrative examples of the present invention:

Example 1

An alloy according to the invention was fabricated into sheet form. Its composition was as follows:

	Weight percent
Chromium	21.00
Titanium	2.12
Aluminum	0.45
Cobalt	20.00
Manganese	0.40
Silicon	0.30
Molybdenum	6.1
Iron	0.50
Carbon	0.04
Sulfur	0.005
Nickel	Balance

The percentages of aluminum and titanium in this example fall within the preferred area of parallelogram GHIJ of FIG. 2. The balance factor for this alloy is 15.48.

The alloy was solution treated, argon arc-welded and then aged to form a specimen similar to that designated by the numeral **10** in FIG. 1.

The specimen so prepared was appropriately placed in a testing apparatus similar to that shown in FIG. 1. The gas flames emanating from burner **15** were controlled in conjunction with the speed of rotation of cylinder **19** so that the welded area was subjected to thermal cycling from a temperature of approximately 20° C. to a temperature of approximately 775° C. The welded area was exposed to the flames for approximately ten seconds in every minute. During such thermal cycling, the specimen was stressed at a constant load of approximately 7.8 tons per square inch by appropriately adjusting weight **14**.

The specimen prepared as described above withstood 1,410 heating and cooling cycles before failure.

The ductility of the welded section was also tested. A standard size tensile test specimen was prepared from the alloy of composition set forth above. Such standard size test piece was approximately 0.75 inch wide and had a parallel section 3 to 3.5 inches long which was streamlined into ends 1.25 inches wide.

The standard test piece was stressed, after ageing, with the weld at right angles to the axis of pull. The test was conducted at a temperature of 775° C. and stress continually applied until fracture. The elongation measured when cold on a 1.0 inch gauge length across the weld was found to be 23%.

Example 2

An alloy according to the invention was fabricated into sheet form. Its composition was as follows:

	Weight percent
Chromium	21.00
Titanium	1.75
Aluminum	0.45
Cobalt	20.00
Manganese	0.40
Silicon	0.30
Molybdenum	6.00
Iron	0.50
Carbon	0.04
Sulfur	0.005
Nickel	Balance

The composition of this alloy is identical to that of the alloy of Example 1 except for the molybdenum, aluminum and titanium percentages.

The percentages of alumina and titanium in this example fall within rectangle ABCD but outside the preferred area of parallelogram GHIJ. The balance factor for this alloy is 13.9.

The alloy was tested in the manner described in Example 1. The welded specimen withstood 1,020 heating and cooling cycles before failure. Elongation before fracture was found to be 11%.

Another alloy, alloy X, was prepared with the following composition:

	Weight percent
Chromium	21.00
Titanium	2.41
Aluminum	0.51
Cobalt	20.00
Manganese	0.40
Silicon	0.30
Molybdenum	6.00
Iron	0.50
Carbon	0.04
Sulfur	0.005
Nickel	Balance

The composition of this alloy is identical to that of the alloy of Example 1, except for the molybdenum, aluminum and titanium percentages.

The percentages of aluminum and titanium in alloy X fall within rectangle ABCD. The balance factor for alloy X is 16.66.

Alloy X was tested in the manner described in Example 1. The welded specimen withstood 510 heating and cooling cycles before failure. Elongation before fracture was found to be 8%.

The characteristics of the three alloys described are summarized in Table I.

Table I

	Example 1	Example 2	Alloy X
Molybdenum, percent	6.1	6.00	6.00
Titanium, percent	2.12	1.75	2.41
Aluminum, percent	0.45	0.45	0.51
Balance factor	15.48	13.9	16.66
Thermal cycles to failure	1,410	1,020	510
Elongation before fracture, percent	23	11	8

It is noted from the data of Table I that the alloys of Examples 1 and 2 were far more resistant to thermal cycling than alloy X. The only differences in composition between the three alloys were in the amounts of molybdenum, aluminum and titanium contained therein. As shown in Table I, alloy X has a balance factor of 16.66 and thus lies outside the scope of this invention whereas the alloys of Examples 1 and 2 have balance factors below 16 in accordance with the present teachings. The threefold advantage in thermal cycling resistance of the alloy of Example 1 over alloy X is all the more remarkable in view of the small differences in the respective aluminum-titanium-molybdenum percentages between the two alloys. Results such as these clearly confirm the uniqueness and indispensability of the "balance factor" as an indicia of high temperature properties.

It is noted from Table I that the alloy of Example 1, which falls within the preferred area of parallelogram GHIJ as a result of its aluminum-titanium-content is superior to the alloy of Example 2 with respect to both

resistance to thermal cycling and ductility as determined by elongation before fracture.

Although the test welds described in the examples above were produced by argon arc welding techniques, other types of welding may be employed. In instances of welding relatively thick sheets or shapes, a filler rod having the same composition as the sheets being welded may be satisfactorily employed.

In the compositions described above, no attempt was made to specifically list each and every impurity which may be present in alloys of the type under consideration. The common impurities and their effects are well known in the art. Thus, for example, small amounts of residuals which result from the addition of de-oxidizers may be present in addition to the impurities specified above. Additionally, occluded gases may be present in trace amounts.

The primary use of the alloys of this invention is in the fabrication of articles of manufacture which are subsequently to be welded. Such articles of manufacture include each and every shape and structure which may be fabricated from the inventive alloys such as, for example, sheet, strip, beam, rod, bar and wire. However, the advantages of the present invention may also be realized by joining one of the alloys disclosed above to structures of other materials of construction in a manner which assures that the weld is composed essentially of the alloy.

It is to be understood that the examples described above are merely intended as illustrative of the present invention and variations may be made within the skill of the art without departing from the spirit and scope of this invention.

We claim:

1. A formed metal article having a weld therein, the metal of said article and of said weld consisting by weight essentially of approximately 21.00% chromium, 20.00% cobalt, 6.1% molybdenum, 2.12% titanium, 0.45% aluminum, 0.40% manganese, 0.30% silicon, and the balance nickel, apart from impurities and residuals from de-oxidizers.

2. A formed metal article having a weld therein, the metal of said article and of said weld consisting by weight essentially of approximately of 21.00% chromium, 20.00% cobalt, 6.00% molybdenum, 1.75% titanium, 0.45% aluminum, 0.40% manganese, 0.30% silicon, and the balance nickel apart from impurities and residuals from deoxidizers.

References Cited by the Examiner

UNITED STATES PATENTS

2,712,498	7/1955	Gresham et al.	75—171
2,747,993	5/1956	Johnson	75—171
2,781,264	2/1957	Gresham et al.	75—171
2,805,154	9/1957	Moore	75—171

FOREIGN PATENTS

532,000	10/1954	Belgium.

DAVID L. RECK, *Primary Examiner.*

RAY K. WINDHAM, NATHAN MARMELSTEIN, MARCUS U. LYONS, *Examiners.*