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(54) **NiCrMoNb alloy with improved mechanical properties**

(57) A component made of an alloy including carbon at less than approximately 0.04 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.25 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about 4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, and the remainder being nickel. The alloy may then be subjected to heat treatment procedures such as annealing at a temperature of less than approximately 982 °C and a duration of less than approximately one hour and aging at a temperature between approximately 538 °C and 760 °C and a duration of up to approximately 100 hours. Methods of treating an alloy are also disclosed.

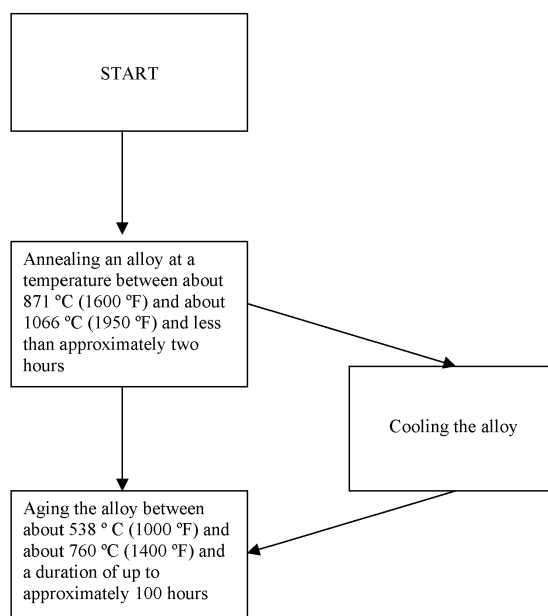


FIG. 3

Description**BACKGROUND OF THE INVENTION**

[0001] The embodiments of the present invention relate to an improved nickel-chromium-molybdenum- niobium (NiCrMoNb) alloy. Specifically, the embodiments relate to this improved NiCrMoNb alloy and its application to a wide range of advanced steam turbine components including, but not limited to, buckets and nozzles.

[0002] Components used in steam turbine assemblies are typically constructed of nickel-chromium, martensitic, or austenitic alloys. These alloys possess favorable high strength and corrosion resistance characteristics, which make them popular in industrial power generation applications. Furthermore, they typically possess high ultimate tensile, yield, and creep-rupture strengths making their continued use in applications over long periods of time possible.

[0003] "Alloy 625" is an example of a nickel-chromium based alloy that has a number of desirable properties for industrial steam turbine applications. The composition of Alloy 625 may vary slightly, with one particular manufacturer's composition specification by weight percentage of a minimum of 58.0 % nickel, between 20.0-23.0% chromium, a maximum of 5.0% iron, between 8.0-10.0% molybdenum, between about 3.15-4.15% niobium, a maximum of 0.10% carbon, a maximum of 0.50% manganese, a maximum of 0.50% silicon, a maximum of 0.015% phosphorous, a maximum of 0.015% sulfur, a maximum of 0.40% aluminum, a maximum of 0.40% titanium, and a maximum of 1.0% cobalt.

[0004] Many advances in steam turbine technology have come to fruition over the past several years which have led to next generation steam turbine assemblies featuring inlet temperatures in excess of 1050 °F. Early stage bucket and nozzle components of steam turbines are particularly susceptible to failure due to the increased temperatures related to advanced steam turbine assemblies. Alternatively, in combined cycle desalination plants, turbine stages operate at the early moisture region at high load and at elevated temperature during low load use. The desire for superior resistance to pitting, strength degradation, and stress corrosion cracking under these turbine moisture line conditions is becoming apparent. This broad range of challenging environments has provided unique obstacles to alloys in current use for steam turbine components.

[0005] Degradation due to sodium chloride, acid, and caustic deposition has been a significant concern for martensitic stainless alloys commonly used in steam turbine bucket applications. Furthermore, existing martensitic stainless blading alloys are not ideal for use in applications where temperatures exceed 1050 °F. Low temperature corrosion resistant alloys, such as Ti-6Al-4V, are not recommended as operating temperatures approach 1000 °F. Therefore, while many alloys may be used to address the conditions present in certain portions of turbine stages, they ultimately may require that design compromises be made in other regions of the turbine assembly, which can impact component reliability.

[0006] Heat treatments are methods that are used to alter and improve the metallurgical properties of compounds. These methods are often used to modify the characteristics of alloys. These alterations are accomplished through processes, such as annealing, precipitation hardening, aging, and quenching, where the end result is the enhancement of the compound's mechanical properties. In subjecting a compound to these external stressors, its microstructure is altered to conform to desired specified design characteristics.

[0007] Because next generation steam turbines feature challenging environments related to steam turbine bucket and nozzle applications, assemblies may benefit from the use of heat treated nickel based alloys. Therefore, a heat treated alloy that has a combination of excellent corrosion resistance and the ability to withstand the stressors of high temperature environments may be desirable.

BRIEF DESCRIPTION OF THE INVENTION

[0008] Embodiments of the present invention include a component formed by the process of annealing an alloy at a temperature of less than approximately 982 °C and a duration of less than approximately one hour, the alloy comprising carbon at less than approximately 0.04 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.25 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about 4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, and the remainder being nickel. The process also comprises aging the alloy at a temperature between approximately 538°C and 760 °C and a duration of up to approximately 100 hours.

[0009] Another embodiment of the invention includes a method of treating an alloy which may be applied to steam turbine components, the method comprising aging an alloy at a temperature of between about 538 °C to about 760 °C for a duration of less than approximately 100 hours, the alloy comprising carbon at less than approximately 0.04 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.25 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about

4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, and the remainder being nickel.

[0010] Embodiments of the present invention also include another method of treating an alloy which may be applied to steam turbine components, the method comprising providing an alloy comprising carbon at about 0.015 to about 0.035 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.15 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about 4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, boron at about 0.0 to about 0.005 weight percent, and the remainder being nickel. Annealing the alloy may then occur at a temperature of approximately 899 °C and a duration of approximately 1 hour. The method then comprises cooling the alloy and aging it at a temperature of approximately 677 °C and a duration of approximately 50 hours.

[0011] The above described and other features are exemplified by the following detailed description.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

FIG.1 is a graph plotting the ultimate tensile strength in kilo pound force per square inch versus temperature in degrees Fahrenheit. The graph is plotted for an as received alloy and the same alloy after being subjected to certain heat treatments.

FIG. 2 is a graph plotting 0.2% yield strength in kilo pound force per square inch versus temperature in degrees Fahrenheit. The graph is plotted for an as received alloy and the same alloy after being subjected to certain heat treatments.

FIG. 3 is a flow diagram illustrating a method of treating an alloy.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Embodiments of the present invention provide an alloy with improved yield strength, creep and stress relaxation characteristics, and excellent corrosion resistance in steam. It can be used for integrally coupled buckets (ICB), nozzles, or any other components of steam turbines.

[0014] The following definitions will apply for the entirety of this document. The term "Alloy 625" will refer to commonly manufactured nickel-chromium based alloys that have similar chemical compositions of embodiments of the present invention. The term "the alloy" will refer to the nickel-chromium based alloy meeting the composition specifications set forth in this document, prior to the application of heat treatment procedures. The terms "heat treated alloy" or "HTA" will refer to the nickel-chromium based alloy meeting the composition specifications set forth in this document, subsequent to the application of heat treatment procedures.

[0015] Alloy 625 is a nickel-chromium based alloy that is used in a wide array of applications such as industrial power generation, aerospace, and in the nuclear field. Alloy 625's versatility is derived from the stiffening effect of molybdenum and niobium on its nickel-chromium matrix. It possesses high strength and corrosion resistance as opposed to other available alloy alternatives. However, advanced turbine assemblies have imposed more demanding conditions than initially anticipated. Therefore, it has been found that Alloy 625 has the ability to meet the requirements imposed by modern steam turbine assemblies, when applied in conjunction with special heat treatments and process controls.

[0016] It has been found that a tightened chemistry and specific heat treatment process procedures provide an alloy that retains critical aspects of the deformed microstructure and produces gamma double prime (γ'') strengthening precipitates. These γ'' precipitates constitute an ordered nickel niobium phase in the alloy.

[0017] The chemistry of the alloy used in one embodiment of the present invention has an approximate maximum loading 0.04 weight percent (w/o) carbon (C), a maximum loading of 0.2 w/o manganese (Mn), a maximum loading of 0.25 w/o silicon (Si), a maximum loading of 0.015 w/o phosphorus (P), a maximum loading of 0.015 w/o sulfur (S), from about 20.0 to 23.0 w/o chromium (Cr), from about 8.5 to 9.5 w/o molybdenum (Mo), from about 3.25 to 4.00 w/o columbium (also referred to niobium) (Nb), a maximum loading of 0.05 w/o tantalum (Ta), from about 0.0 to 0.40 w/o titanium (Ti), from about 0.15 to 0.30 w/o aluminum (Al), a maximum loading of 0.005 w/o boron (B), from about 3.0 to 4.5 w/o iron (Fe), and all sub-ranges therebetween with the remainder being nickel (Ni).

[0018] The chemistry of the alloy used in another embodiment of the present invention is a loading from about 0.015-0.035 weight percent (w/o) carbon (C), a maximum loading of 0.2 w/o manganese (Mn), a maximum loading of

0.15 w/o silicon (Si), a maximum loading of 0.01 w/o phosphorus (P), a maximum loading of 0.002 w/o sulfur (S), from about 20.0 to 23.0 w/o chromium (Cr), from about 8.5 to 9.5 w/o molybdenum (Mo), from about 3.25 to 4.00 w/o columbium (also referred to niobium) (Nb), a maximum loading of 0.05 w/o tantalum (Ta), from about 0.20 to 0.40 w/o titanium (Ti), from about 0.15 to 0.30 w/o aluminum (Al), a maximum loading of 0.005 w/o boron (B), from about 3.0 to 4.5 w/o iron (Fe), and all sub-ranges therebetween with the remainder being nickel (Ni).

[0019] An embodiment of the heat treatment procedure may include annealing the alloy and subsequently aging it to form γ' precipitates. The annealing heat treatment may be at a temperature of less than approximately 982 °C (1800 °F) and a duration of less than approximately one hour. The aging heat treatment may occur at a temperature of between approximately 538 °C (1000 °F) to 760 °C (1400 °F) for times up to 100 hours.

[0020] Treating the alloy at temperatures lower than 538°C, or greater than 760 °C, which requires either extended heat treatment time in the low temperature regime (greater than 100 hours) or very short heat treatment time at the high temperature regime (less than 10 hours) with uncertainty of achieving greater than 90 ksi yield strength that is needed for the ICB applications, for example. The problem with these heat treatment processes is that they create a dual phase structure of γ' and δ (the less desirable equilibrium phase) at high temperatures (greater than 760 °C) and not creating γ' at the lower aging temperatures (less than 538 °C). Temperatures less than 538 °C require long aging times to produce equivalent strength while temperatures greater than 760 °C are complicated by δ formation.

[0021] An exemplary embodiment of the heat treatment process procedure may be used after any metal forming process but is specific to bar, plate, sheet or forged products. After thermomechanical processing into the requisite component shape, the aging heat treatment to produce HTA is performed, whereby the alloy is either given a low temperature anneal (less than 954 °C (1750 °F) for less than 1 hour) or no anneal prior to heat treatment in the range of 538 °C (1000 °F) to 760 °C (1400 °F) for times up to 100 hours. In the specific case of round bar, the heat treatment sequence can include the following steps: bar forming followed by mill anneal at 954 °C (1750 °F) for 30 minutes, or any suitable time and temperature heat treatment at less than 982 °C (1800 °F), or no mill anneal, followed by heat treatment at 677 °C (1250 °F) for 50 hours.

[0022] Another exemplary embodiment may include annealing, cooling, and aging the alloy. Annealing may be at a temperature of approximately 899 °C (1650 °F) for a duration of less than approximately 1 hour. The alloy may then be cooled by a variety of means, including but not limited to, quenching or air cooling. The alloy may be quenched in water or any other suitable medium. Finally, aging may be at a temperature of approximately 677 °C and a duration of approximately 50 hours.

[0023] The heat treatments of the alloy are used to impart secondary strength through retention of the dislocation substructure (via component forming operation) and γ' precipitate development. The composition of the alloy is similar to the chemistry specified in AMS5666F (SAE Standards) but is more precise. This more precisely defined chemistry window provides uniformity in manufacture of the alloy.

[0024] AMS5666F provides a loose framework for defining the limits of the alloy's chemistry. A preferred chemistry as specified above for the alloy allows use of it for many applications, including but not limited to, high pressure/intermediate pressure (HP/IP) buckets, low pressure (LP) buckets, and Integrated Water and Power Plant (IWPP) last stage buckets. Embodiments of the present invention are suitable for steam applications and because retention of the dislocation substructure produced during mechanical deforming processing and γ' strengthening precipitates, HTA possesses additional yield strength and stress relaxation capability.

[0025] In order to maximize γ' strengthening precipitates, the carbon level must be below 0.04 w/o. In contrast, the maximum carbon limit for AMS5666F is 0.1 w/o. A carbon level in excess of 0.04 w/o interferes with γ' formation by using solute from the matrix, primarily Nb (niobium, also called columbium), to form carbide. In addition, Nb must be sufficient to form γ' (i.e., Ni_3Nb with an ordered body centered tetragonal crystal structure which is coherent with the γ Ni matrix) and Al and Ti (i.e., 0.35 to 0.70 w/o: Al+Ti) must be present in sufficient quantities as both can substitute for Nb in the γ' precipitate lattice.

[0026] The aging heat treatment is used to form the γ' in the matrix prior to steam turbine operation in order to increase yield strength prior to bucket or nozzle component manufacture. Because Alloy 625 is not specifically an age hardenable alloy, the heat treatment temperature used to form γ' must be such that sufficient time is available to nucleate and grow the γ' , while at the same time not producing the equilibrium δ phase (also Ni_3Nb but with an orthorhombic crystal structure). In addition, the time and temperature for γ' formation must not be too high, less than 760 °C (1400 °F), or too long, greater than 100 hours, to adversely affect the dislocation substructure (i.e., the reduction of free dislocations in the γ Ni matrix). For operating temperatures less than 649 °C (1200 °F), once γ' has been formed through the aging heat treatment, the phase is relatively stable for long times and will not revert to the less desirable δ phase during operation. As such, strength is high from the beginning of the manufacturing process and remains at this high level throughout.

[0027] Although embodiments of the present invention are not directed to any particular steam turbine component, use of embodiments of the present invention for integral cover buckets (ICBs) create the need to take special considerations regarding alloy characteristics into account. Stress-relaxation for any alloy used in the ICB design is critically important because the contacting force between the buckets in the row (at the points of contact) is the force that holds

them in place during operation. For any ICB application, a certain level of stress is required to keep the buckets in contact with each other for the duration of their usage life. Certain alloys, like 10Cr steels have excellent yield strength and good creep resistance, but when tested for stress-relaxation, the strength drops off rapidly, falling below that threshold stress level for efficient bucket-to-bucket contact for the early hours of operational bucket life. The 10Cr steel very quickly loses its strength at normal operating conditions of ICBs.

[0028] Tests were performed on as received Alloy 625, HTA, and 10Cr Steel. In summary, 10Cr steel relaxes too quickly for the ICB bucket application at standard operating conditions. Alloy 625 although providing improved performance relative to 10Cr steel, is not sufficient to meet target ICB lifetimes. The heat treated alloy meets the desired specified design requirements.

[0029] Not wanting to be bound by theory, it is thought that HTA alleviates the problem of failing to meet target ICB lifetime through retention of the dislocation substructure achieved during prior forming operations and via precipitation of γ' . The precipitation of γ' and the retention of a high dislocation density from the manufacturing process insure adequate yield strength for bucket insertion during manufacture and stress-relaxation capability during steam turbine operation to meet design requirements of the ICB component.

[0030] The heat treated alloy allows the use of ICB buckets in both high temperature (steam temperatures between 582 and 649 °C) and low temperature (corrosion resistance in addition to stress-relaxation capability) steam turbine offerings with concomitant improvement in overall turbine efficiency. The heat treated alloy provides for a desired operational life of the ICB component in these steam turbines under normal operating conditions. It also allows ICB buckets to be used in the first 2-3 bucket rows in the HP/IP of steam turbines at temperatures in excess of 582 °C for prolonged operating times and in low pressure rows of in an Integrated Water and Power Product.

[0031] The formation of γ' and dislocation retention are critical to this invention. Chemistry, while still within the nominal range of AMS5666F, is tightened for critical elements C, Nb, Al and Ti, to insure sufficient γ' is available for strength. The heat treatment window provides latitude to form γ' without concomitant loss in strength due to dislocations reduction.

EXAMPLES

[0032] Heat treatments of Alloy 625 were conducted where samples were obtained from five different sources. Table 1 lists the compositions of four samples A-D, along with the minimum and maximum approximate amounts of elements in HTA for an embodiment of the present invention. Table 2 lists the compositions of five samples A-E, along with the minimum and maximum approximate amounts of elements in HTA for another embodiment of the present invention.

Table 1

Element	Min	Max	A	B	C	D
Ni	Balance		60.40	61.89	61.50	61.34
Cr	20.00	23.00	22.15	21.73	21.75	21.01
Mo	8.5	9.50	9.08	8.82	8.69	8.65
C	0.0	0.04	0.029	0.020	0.020	0.057
Mn	0.0	0.20	0.20	0.08	0.07	0.07
P	0.0	0.015	0.005	0.007	0.007	0.014
S	0.0	0.015	0.001	0.001	0.001	0.0003
Si	0.0	0.25	0.21	0.08	0.06	0.245
Fe	3.0	4.5	3.71	3.42	3.68	4.43
Nb	3.25	4.00	3.49	3.37	3.47	3.44
Ta	0.0	0.05	<0.01	<0.01	<0.01	<0.01
Co	0.0	1.00	0.18	0.12	0.21	0.11
Al	0.15	0.30	0.17	0.22	0.26	0.22
Ti	0.20	0.40	0.29	0.24	0.28	0.26

Table 2

Element	Min	Max	A	B	C	D	E
Ni	Balance		60.40	61.89	65.49	61.50	61.34
Cr	20.00	23.00	22.15	21.73	20.92	21.75	21.01
Mo	8.50	9.50	9.08	8.82	8.38	8.69	8.65
C	0.015	0.035	0.029	0.020	0.012	0.020	0.057
Mn	0.0	0.2	0.2	0.08	0.03	0.07	0.07
P	0.0	0.010	0.005	0.007	<0.005	0.007	0.014
S	0.0	0.002	0.001	0.001	0.0005	0.001	0.0003
Si	0.0	0.15	0.21	0.08	<0.05	0.06	0.245
Fe	3.0	4.5	3.71	3.42	1.28	3.68	4.43
Nb	3.25	4.00	3.49	3.37	3.34	3.47	3.44
Ta	0.0	0.05	<0.01	<0.01	<0.02	<0.01	<0.01
Co	0.0	0.25	0.18	0.12	0.18	0.21	0.11
Al	0.15	0.30	0.17	0.22	0.18	0.26	0.22
Ti	0.20	0.40	0.29	0.24	0.07	0.28	0.26
B	0.0	0.005	0.0	0.0	0.0	0.0	0.0025
Cu	0.0	0.0	0.0	0.0	0.02	0.0	0.06
Zr	0.0	0.0	0.0	0.0	0.0	0.0	<0.01
W	0.0	0.0	0.0	0.0	0.0	0.0	0.12
V	0.0	0.0	0.0	0.0	0.0	0.0	0.03

[0033] Tensile and creep strength and stress-relaxation were measured for the as received (i.e., mill annealed, prior to heat treatment) alloy and for material given a specific heat treatment of 50 hours at 677 °C, hereinafter referred to as HT2. Another heat treatment applied to the as received alloy, hereinafter referred to as HT1, included annealing the alloy at 899 °C (1650 °F) for one hour, water quenching the alloy, and aging the alloy at 677 °C (1250 °F) for fifty hours. Another heat treatment applied to the as received alloy, hereinafter referred to as HT4, included annealing the alloy at 899 °C (1650 °F) for one hour, air cooling the alloy, and aging the alloy at 677 °C (1250 °F) for fifty hours.

[0034] Yield strength, creep life and stress-relaxation response were evaluated for each heat treated Alloy 625. The room temperature yield strength (mean) for the as received alloys subjected to heat treatments (samples A-D of Table 1) were at least 99 ksi, well above the nominal 60 ksi minimum of low solution annealed Alloy 625. At the operating temperature of the 1000 MW steam turbine (600 °C), stress relaxation at 0.25% strain for four samples was sufficient to provide 100,000 hour life for the ICB. Non heated treated samples did not provide sufficient life at 0.25% strain at 600 °C. Creep strength of HTA was improved over the non heat treated Alloy 625.

[0035] Of the tested samples, the main chemistry difference is carbon level in heat D of Table 1, which is above the maximum threshold of 0.04 weight percent. It is required that the carbon level be at 0.04 weight percent, or lower, preferably equal to, or lower than, 0.03%. At levels above 0.03%, and certainly at levels above 0.04%, the carbon tends to form carbide with solute elements rather than be available for use in the strengthening precipitates. Furthermore, the embodiment of the present invention articulated in Table 2 includes a narrowed silicon weight percentage range. The silicon weight percentage range was narrowed in order to minimize the formation of lava phase, a secondary detrimental phase.

[0036] The effect of HT 1, 2, and 4 on ultimate tensile strength of an alloy is shown in FIG. 1. Significant improvements between the ultimate tensile strength of the as received alloy and the heat treated alloy are apparent. The heat treatment that produced the most significant improvements was HT1. HT1 produced an improved room temperature UTS of approximately 30 ksi and an improved operating condition temperature UTS of approximately 20 ksi.

[0037] The effect of HT 1, 2, and 4 on 0.2% yield strength of an alloy is shown in FIG. 2. Once again, significant improvements between the yield strength of the as received alloy and the heat treated alloy are apparent. HT1 produced an improved room temperature yield strength of approximately 40 ksi and an improved operating condition temperature

yield strength of approximately 60 ksi.

[0038] FIG. 3 is a flow diagram illustrating a method of treating an alloy, as embodied by the invention.

[0039] The terms "first," "second," and the like, herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another, and the terms "a" and "an" herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item. The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context, (e.g., includes the degree of error associated with measurement of the particular quantity). The suffix "(s)" as used herein is intended to include both the singular and the plural of the term that it modifies, thereby including one or more of that term (e.g., the metal(s) includes one or more metals). Ranges disclosed herein are inclusive and independently combinable (e.g., ranges of "up to about or approximately 25 w/o, or, more specifically, about or approximately 5 w/o to about or approximately 20 w/o", are inclusive of the endpoints and all intermediate values of the ranges of "about 5 w/o to about 25 w/o," etc and sub-ranges therebetween).

[0040] While various embodiments are described herein, it will be appreciated from the specification that various combinations of elements, variations or improvements therein may be made by those skilled in the art, and are within the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A component formed by a process of:

annealing an alloy at a temperature of less than approximately 982 °C and a duration of less than approximately one hour, the alloy comprising carbon at less than approximately 0.04 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.25 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about 4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, and the remainder being nickel; and
aging the alloy at a temperature between about 538 °C and about 760 °C and a duration of up to approximately 100 hours.

2. The component according to claim 1, wherein the alloy further comprises boron at approximately 0.0-0.005 weight percent.

3. The component according to claim 1 or claim 2, wherein aging the alloy is at a temperature of approximately 677 °C and a duration of approximately 50 hours.

4. The component according to any preceding claim, wherein the alloy has a room temperature yield strength of greater than 90 kilo pound force per square inch (ksi).

5. The component according to any preceding claim, wherein the alloy comprises γ' phase precipitates of tri-nickel-niobium (Ni_3Nb).

6. The component according to any preceding claim, wherein the alloy is free of δ phase tri-nickel-niobium Ni_3Nb precipitates.

7. The component according to any preceding claim, wherein annealing the alloy is at a temperature of less than approximately 954 °C.

8. The component according to claim 7, wherein annealing the alloy is at a temperature of less than approximately 899 °C

9. The component according to any preceding claim, wherein the process further includes:

cooling the alloy subsequent to annealing.

10. A method of treating an alloy, the method comprising:

aging an alloy at a temperature of between about 538 °C to about 760 °C for a duration of less than approximately 100 hours, the alloy comprising carbon at less than approximately 0.04 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.25 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about 4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, and the remainder being nickel.

11. The method of claim 10, wherein the alloy further comprises boron at approximately 0.0-0.005 weight percent.

12. The method of claim 10 or claim 11, wherein aging the alloy is at a temperature of approximately 677 °C and a duration of approximately 50 hours.

13. The method of any one of claims 10 to 12 further comprising:

annealing the alloy at a temperature of less than approximately 982 °C for a duration of less than approximately 1 hour prior to aging.

14. The method of claim 13, wherein annealing the alloy is at a temperature of less than approximately 954° C.

15. The method of claim 14, wherein annealing the alloy is at a temperature of less than approximately 899 °C.

16. The method of any one of claims 10 to 15 further comprising:

cooling the alloy subsequent to annealing.

17. A method of treating an alloy, the method comprising:

providing an alloy comprising carbon at about 0.015 to about 0.035 weight percent, manganese at about 0.0 to about 0.2 weight percent, silicon at about 0.0 to about 0.15 weight percent, phosphorus at about 0.0 to about 0.015 weight percent, sulfur at about 0.0 to about 0.015 weight percent, chromium from about 20.0 to about 23.0 weight percent, molybdenum from about 8.5 to about 9.5 weight percent, niobium from about 3.25 to about 4 weight percent, tantalum at about 0.0 to about 0.05 weight percent, titanium from about 0.2 to about 0.4 weight percent, aluminum from about 0.15 to about 0.3 weight percent, iron from about 3.0 to about 4.5 weight percent, boron at about 0.0 to about 0.005 weight percent, and the remainder being nickel;
annealing the alloy at a temperature of approximately 899 °C and a duration of approximately 1 hour;
cooling the alloy;
aging the alloy at a temperature of approximately 677 °C and a duration of approximately 50 hours.

18. The method of claim 16 or claim 17, wherein cooling the alloy may be by quenching or air cooling.

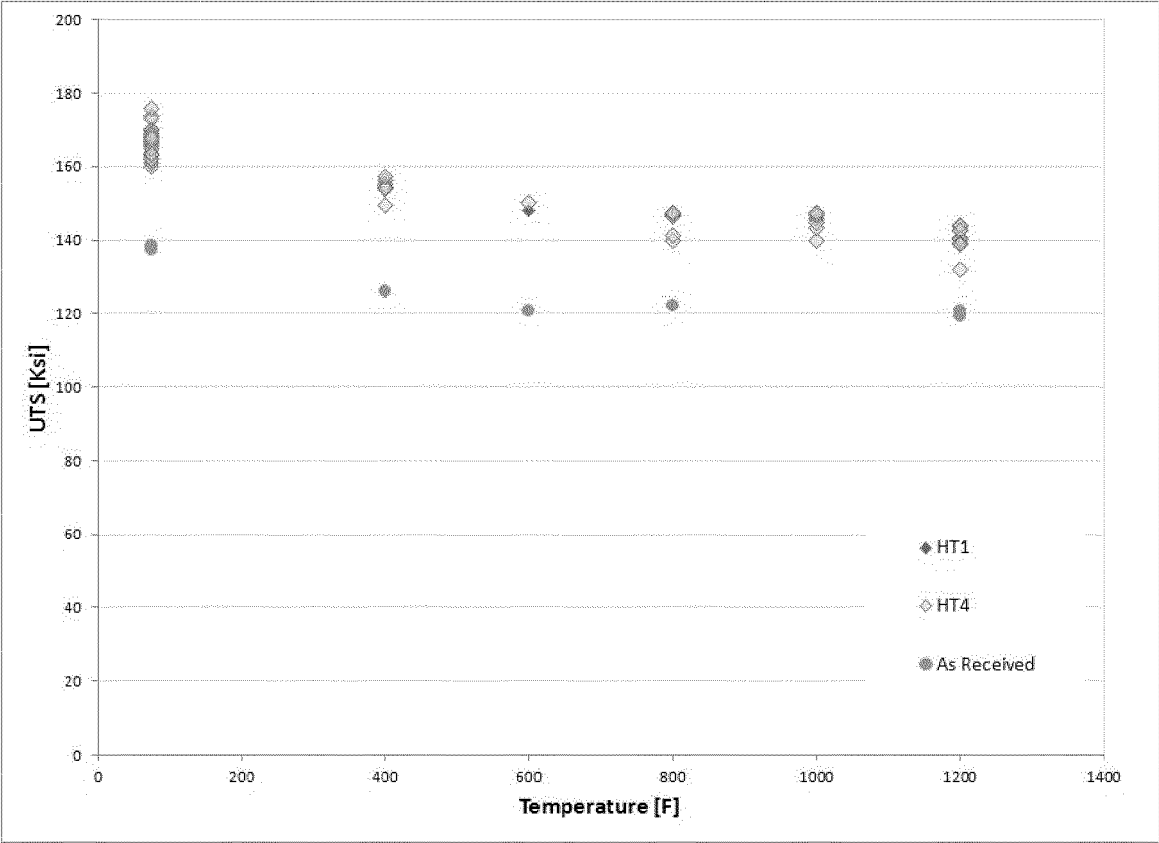


FIG. 1

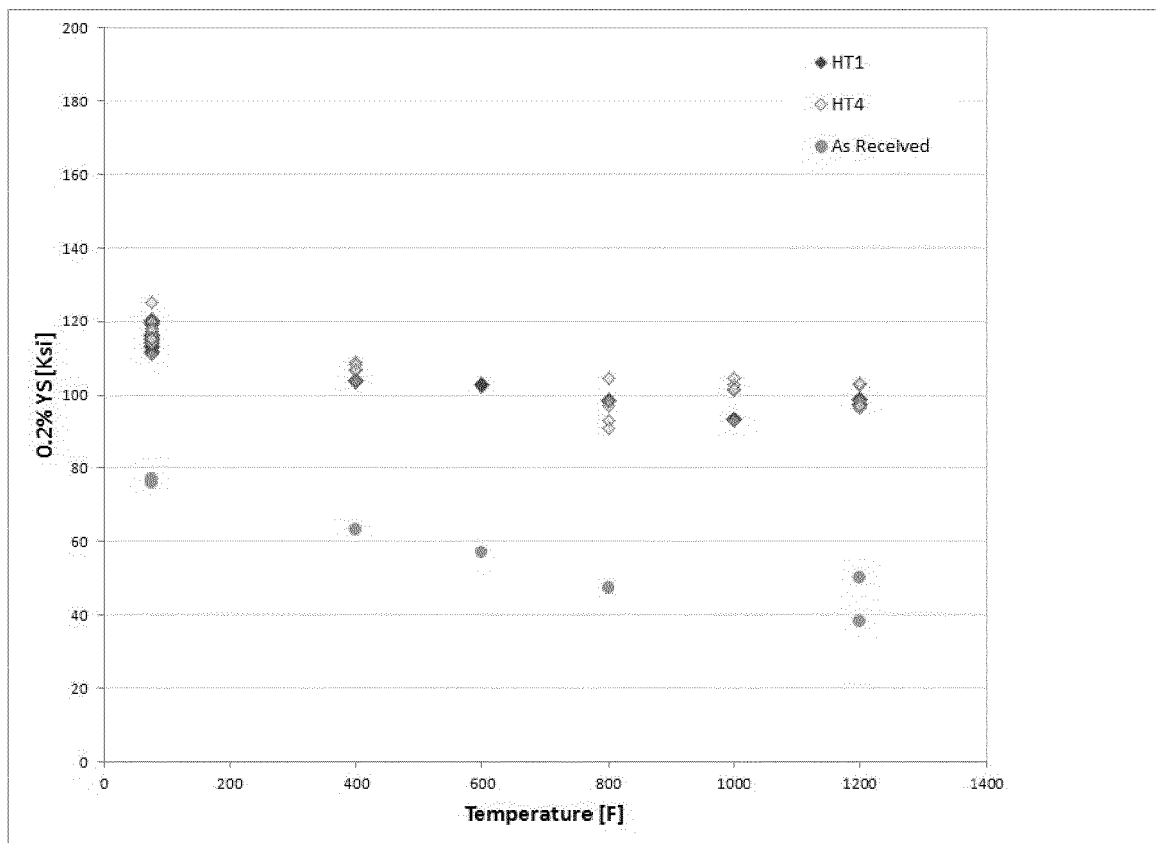


FIG. 2

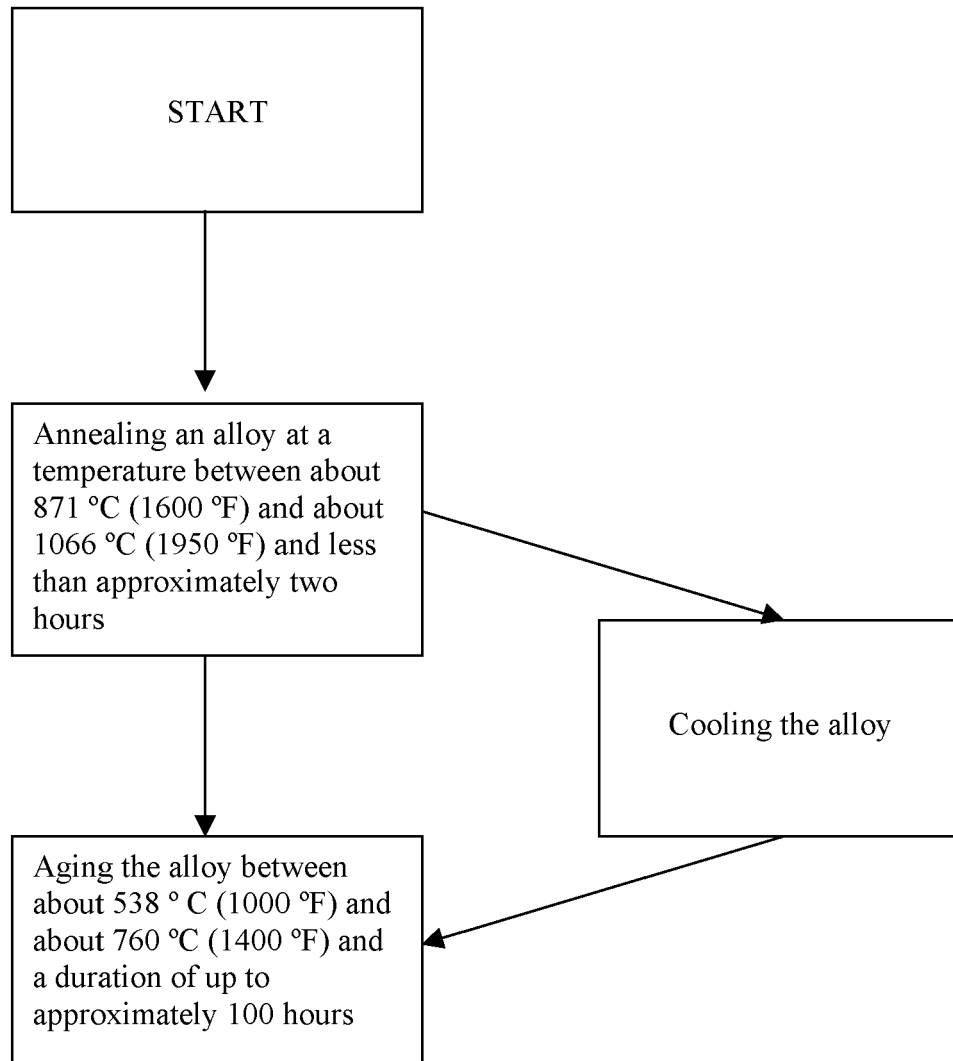


FIG. 3



EUROPEAN SEARCH REPORT

Application Number
EP 11 18 3638

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 24 January 2012	Examiner Brown, Andrew
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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24-01-2012

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82