US 20160145729A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2016/0145729 A1

(43) Pub. Date: May 26, 2016

JEONG et al.

(54) NI-BASED SUPERALLOY WITH EXCELLENT OXIDIZATION RESISTANCE AND CREEP PROPERTY AND METHOD OF MANUFACTURING THE SAME

(71) Applicant: **KOREA INSTITUTE OF MACHINERY AND MATERIALS**, Daejeon (KR)

(72) Inventors: **Hi-Won JEONG**, Gimhae-si (KR); **Young-Soo YOO**, Changwon-si (KR); **Seong-Moon SEO**, Changwon-si (KR); **Dae-Won YUN**, Gimhae-si (KR)

(21) Appl. No.: **14/564,686**

(22) Filed: **Dec. 9, 2014**

(30) **Foreign Application Priority Data**

Nov. 24, 2014 (KR) 10-2014-0164756

Publication Classification

(51) **Int. Cl.**

C22F 1/10 (2006.01)
B21B 3/00 (2006.01)
C22C 19/05 (2006.01)

(52) **U.S. Cl.**

CPC ***C22F 1/10*** (2013.01); ***C22C 19/055*** (2013.01); ***B21B 3/00*** (2013.01)

(57) **ABSTRACT**

The present disclosure relates to a Ni-based superalloy with excellent oxidation resistance and creep properties, which is suitable for parts of energy plants and chemical plants under a corrosive oxidative/reductive atmosphere, which stainless steel cannot withstand, through adjustment of alloy components and control of process conditions and a method of manufacturing the same. The Ni-based superalloy includes: chromium (Cr): 20~26 wt %, tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities.

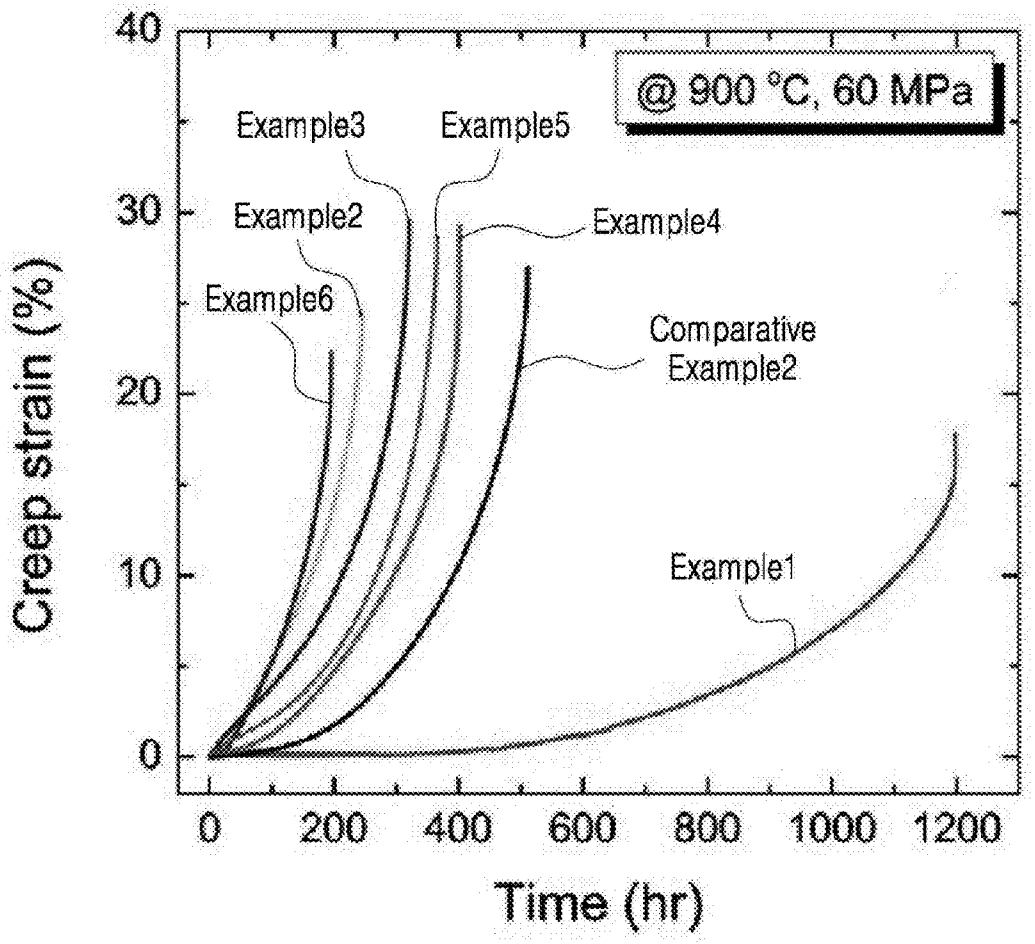


Fig. 1

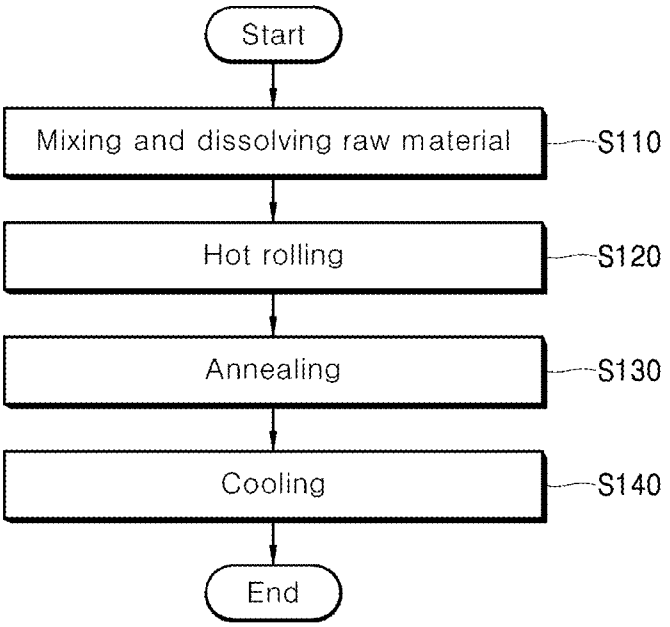

Start
Mixing and dissolving raw material
S110
Hot rolling
S120
Annealing
S130
Cooling
S140
End

Fig. 2

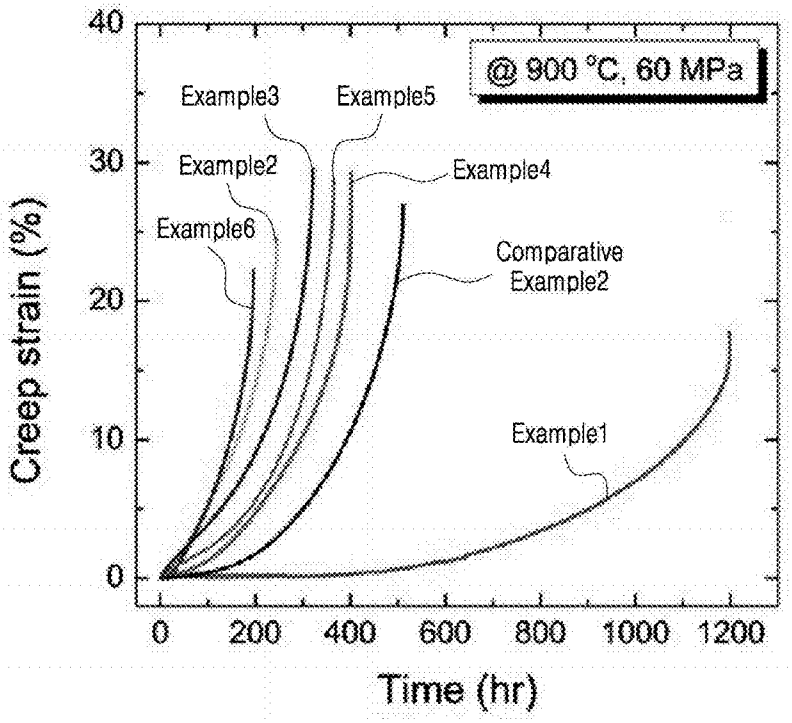

@ 900 °C, 60 MPa
Example3
Example5
Example2
Example4
Example6
Comparative Example2
Example1
Creep strain (%)
Time (hr)
0
10
20
30
40
0
200
400
600
800
1000
1200

Fig. 3

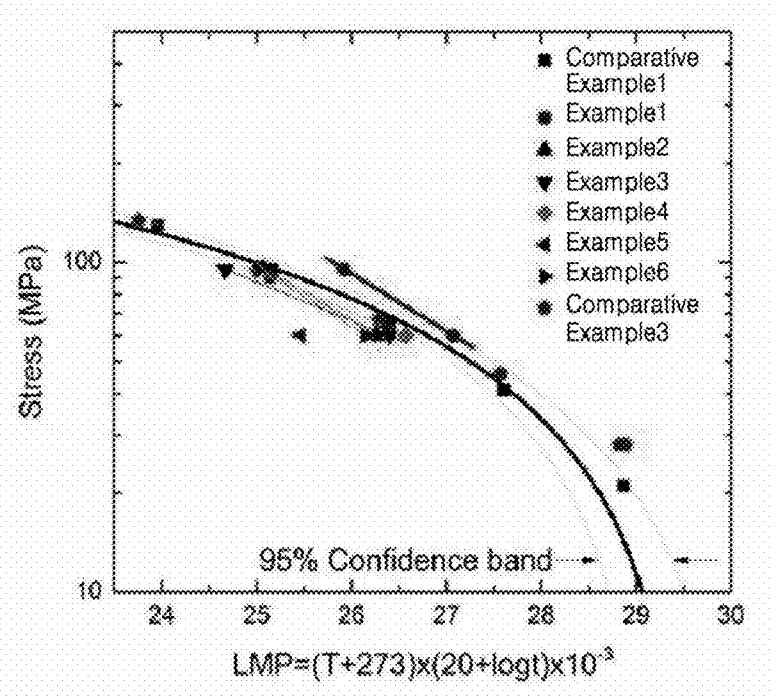
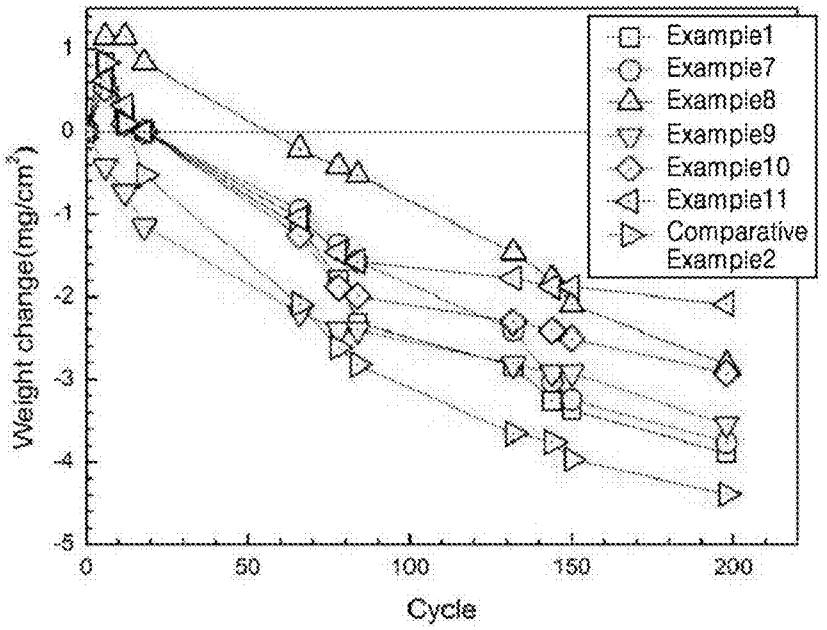

Comparative Example1
Example1
Example2
Example3
Example4
Example5
Example6
Comparative Example3
95% Confidence band
Stress (MPa)
100
10
24
25
26
27
28
29
30
LMP=(T+273)x(20+logt)x10-3

Fig. 4


Exampie1
Exampie7
Exampie8
Exampie9
Exampie10
Exampie11
Comparative Exampie2
Weight change(mg/cm²)
Cycle
1
0
-1
-2
-3
-4
-5
0
50
100
150
200

NI-BASED SUPERALLOY WITH EXCELLENT OXIDIZATION RESISTANCE AND CREEP PROPERTY AND METHOD OF MANUFACTURING THE SAME

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Korean patent application no. 10-2014-0164756, filed on Nov. 24, 2014, entitled "Ni-BASED SUPERALLOY WITH EXCELLENT OXIDIZATION RESISTANCE AND CREEP PROPERTY AND METHOD OF MANUFACTURING THE SAME", which is hereby incorporated by reference in its entirety into this application.

BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to a Ni-based superalloy and a method of manufacturing the same, and more particularly, to a Ni-based superalloy with excellent oxidization resistance and creep properties, which is suitable for parts of energy plants and chemical plants under a corrosive oxidative/reductive atmosphere, which stainless steel cannot withstand, through adjustment of alloy components and control of process conditions, and a method of manufacturing the same.

[0004] 2. Description of the Related Art

[0005] Superalloys refer to alloys which are mainly aimed at withstanding use at high temperature, and heat resistant steels refer to alloy steels which exhibit stable mechanical properties and good corrosion resistance even at high temperature.

[0006] Among wrought Ni-based superalloys, examples of commercially available alloys with good corrosion resistance and creep properties include Haynes 230 and Alloy 617, both of which can be used for long periods of time while exhibiting good phase stability up to about 650° C. In particular, in power generation equipment such as A-USC (Advanced-Ultra supercritical) equipment, the temperature of main steam can be increased from existing 650° C. to 700~760° C. for reduction of carbon dioxide emission and energy efficiency. Since commercially available alloys are difficult to use at 700~760° C., there is a need for novel alloys having good creep properties.

[0007] In addition, commercially available alloys have a problem in that the alloys cannot exhibit good creep properties and good oxidization resistance at the same time.

[0008] In the related art, Korean Patent Publication No. 10-1998-022301 (issued on Jul. 6, 1998) discloses Ni-based superalloys for casting.

BRIEF SUMMARY

[0009] It is an aspect of the present invention to provide a Ni-based superalloy with excellent oxidization resistance and creep properties, which is suitable for parts of energy plants and chemical plants under a corrosive oxidative/reductive atmosphere, which stainless steel cannot withstand, through adjustment of alloy components and control of process conditions, and a method of manufacturing the same.

[0010] In accordance with an aspect of the present invention, provided is a Ni-based superalloy with excellent oxidization resistance and creep properties, which includes chromium (Cr): 20~26% by weight (wt %), tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities.

[0011] In accordance with another aspect of the present invention, provided is a method of manufacturing a Ni-based superalloy with excellent oxidization resistance and creep properties, including: (a) preparing an alloy by mixing and dissolving raw materials including chromium (Cr): 20~26 wt %, tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities; (b) hot rolling the alloy; (c) annealing the hot rolled alloy; and (d) cooling the annealed alloy.

[0012] The Ni-based superalloy with excellent oxidization resistance and creep properties and the method of manufacturing the same according to the present invention can enhance creep properties by lowering the amounts of chromium (Cr) and silicon (Si), and improve oxidization resistance by excluding Fe while increasing the amount of manganese (Mn), thereby improving oxidization resistance and creep properties at the same time.

[0013] In addition, the Ni-based superalloy manufactured by the method according to the present invention exhibits excellent oxidization resistance and creep properties even at a high temperature of 700° C. or more through adjustment of alloy components and control of process conditions, and thus is suitable for parts of energy plants and chemical plants under a corrosive oxidative/reductive atmosphere, which stainless steel cannot withstand.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The above and other aspects, features and advantages of the invention will become apparent from the detailed description in conjunction with the accompanying drawings, in which:

[0015] FIG. **1** is a flowchart of a method of manufacturing a Ni-based superalloy in accordance with one embodiment of the present invention;

[0016] FIG. **2** is a graph showing creep strain over time for samples prepared in Examples 1 to 6 and Comparative Example 2;

[0017] FIG. **3** is a graph showing creep results for samples prepared in Examples 1 to 6 and Comparative Examples 1 and 3; and

[0018] FIG. **4** is a graph showing cyclic oxidation property results for samples prepared in Example 1, Examples 7 to 11 and Comparative Example 2.

DETAILED DESCRIPTION

[0019] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It should be understood that the present invention is not limited to the following embodiments and may be embodied in different ways, and that the embodiments are given to provide complete disclosure of the present invention and to provide thorough understanding of the present invention to those skilled in the art. The scope of the present invention is limited only by the accompanying claims and equivalents thereof. Like components will be denoted by like reference numerals throughout the specification.

[0020] Hereinafter, a Ni-based superalloy with excellent oxidization resistance and creep properties and a method of manufacturing the same according to embodiments of the invention will be described with reference to the accompanying drawings.

[0021] Ni-Based Superalloy

[0022] The Ni-based superalloy according to the present invention includes chromium (Cr): 20~26 wt %, tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities.

[0023] The Ni-based superalloy may further include 0.001~0.015 wt % of boron (B).

[0024] Furthermore, the Ni-based superalloy has a yield strength (YS) of 195~300 MPa, a tensile strength (TS) of 420~580 MPa, and an elongation (El) of 35~55% under temperature conditions of 700° C., and has a yield strength (YS) of 160~200 MPa, a tensile strength (TS) of 235~300 MPa, and an elongation (El) of 48~59% under high temperature conditions of 900° C.

[0025] In development of the Ni-based superalloy with excellent oxidation resistance and creep properties according to the present invention, it was considered that decrease in chromium (Cr) content has an advantage in terms of improvement of creep properties, whereas increase in chromium (Cr) content has an advantage in terms of improvement of oxidation resistance. In this regard, the inventor has established an optimal composition range of chromium (Cr) which allows improvement in both oxidation resistance and creep properties at the same time. In addition, the inventor has found that appropriate amounts of tungsten (W) and molybdenum (Mo) can enhance creep properties, whereas an excess of tungsten (W) and molybdenum (Mo) causes deterioration in creep properties.

[0026] Thus, based on the established optimal composition ratio of alloy components, the present invention can enhance creep properties by lowering the amounts of chromium (Cr) and silicon (Si), and improve oxidation resistance by excluding Fe while increasing the amount of manganese (Mn), thereby improving oxidation resistance and creep properties at the same time.

[0027] As a result, the Ni-based superalloy with excellent oxidation resistance and creep properties according to embodiments of the present invention exhibits good oxidation resistance and creep properties even at high temperatures of 700° C. or more through adjustment of alloy components and control of process conditions, and thus is suitable for parts of energy plants and chemical plants under a corrosive oxidative/reductive atmosphere, which stainless steel cannot withstand.

[0028] Hereinafter, each component of the Ni-based superalloy according to the present invention will be described in detail in terms of functions and content thereof.

[0029] Chromium (Cr)

[0030] Chromium (Cr) serves to improve corrosion resistance and oxidation resistance. However, an excess of chromium can cause formation of carbides or topologically close packed (TCP) phases.

[0031] Thus, chromium (Cr) is preferably present in an amount of 20~26 wt % based on the total weight of the Ni-based superalloy. If the content of chromium (Cr) is less than 20 wt %, there can be a problem in terms of corrosion resistance. If the content of chromium (Cr) exceeds 26 wt %, creep properties can be deteriorated, and a TCP phase, which has an adverse influence on mechanical properties, can be produced when exposed to high temperature for long time.

[0032] Tungsten (W)

[0033] Tungsten (W) is an element which improves high temperature strength and creep strength by solid-solution strengthening.

[0034] Tungsten (W) is preferably present in an amount of 13~17 wt % based on the total weight of the Ni-based superalloy. If the content of tungsten (W) is less than 13 wt %, it is difficult to obtain the aforementioned effects of tungsten. If the content of tungsten (W) exceeds 17 wt %, there can be a problem of deterioration in toughness and flexibility as well as reduction in phase stability.

[0035] Molybdenum (Mo)

[0036] Molybdenum (Mo) is a solid-solution strengthening element and serves to improve high temperature tensile properties and creep properties. In addition, molybdenum (Mo) is bound to carbon to form M_6C type carbides at grain boundaries, thereby suppressing grain growth.

[0037] Molybdenum (Mo) is preferably present in an amount of 1~5 wt % based on the total weight of the Ni-based superalloy. If the content of molybdenum (Mo) is less than 1 wt %, there can be a problem in that the solid-solution strengthening effect can hardly be obtained due to too low amount of molybdenum and creep properties can be deteriorated. If the content of molybdenum (Mo) exceeds 5 wt %, hot workability can be deteriorated and a TCP phase is likely to be formed.

[0038] Manganese (Mn)

[0039] Manganese (Mn) serves to improve oxidation resistance of alloys.

[0040] Manganese (Mn) is preferably present in an amount of 0.1~1.0 wt % based on the total weight of the Ni-based superalloy. If the content of manganese (Mn) is less than 0.1 wt %, improvement in creep property can be insignificant due to too low amount of manganese. If the content of manganese (Mn) exceeds 1.0 wt %, there is a problem of deterioration in workability and oxidation resistance.

[0041] Silicon (Si)

[0042] Like manganese (Mn), silicon (Si) also improves oxidation resistance of alloys.

[0043] Silicon (Si) is preferably present in an amount of 0.1~0.6 wt % based on the total weight of the Ni-based superalloy. If the content of silicon (Si) is less than 0.1 wt %, improvement in oxidation resistance can be insignificant due to too low amount of manganese. If the content of silicon (Si) exceeds 0.6 wt %, oxidation resistance can be improved, but creep properties can be sharply deteriorated.

[0044] Aluminum (Al)

[0045] Aluminum (Al) is an element forming austenite (γ'), which is a main reinforcing phase of the Ni-based superalloy, and contributes to improvement in oxidation resistance.

[0046] Aluminum (Al) is preferably present in an amount of 0.1~10 wt % based on the total weight of the Ni-based superalloy. If the content of aluminum (Al) is less than 0.1 wt %, the aforementioned effects of aluminum are not obtained. If the content of aluminum (Al) exceeds 1.0 wt %, an excess of γ' phase is precipitated, causing deterioration in workability.

[0047] Lanthanum (La)

[0048] Lanthanum (La) serves to improve oxidation resistance.

[0049] Lanthanum (La) is preferably present in an amount of 0.01~0.06 wt % based on the total weight of the Ni-based superalloy. If the content of lanthanum (La) is less than 0.01 wt %, the aforementioned effects of lanthanum can hardly be obtained due to too low amount of lanthanum. If the content of lanthanum (La) exceeds 0.06 wt %, there can be a problem of deterioration in oxidation resistance due to interaction with boron (B).

[0050] Carbon (C)

[0051] Carbon (C) is bound with tungsten (W), molybdenum (Mo), chromium (Cr), and the like to form carbides in the form of MC, M_6C, or $M_{23}C_6$, and contributes to refinement of grains. In addition, carbon forms carbides at grain boundaries, thereby enhancing strength of the grain boundaries.

[0052] Carbon (C) is preferably present in an amount of 0.01~0.20 wt % based on the total weight of the Ni-based superalloy. If the content of carbon (C) is less than 0.01 wt %, the strength enhancing effect can hardly be obtained due to insufficient formation of carbides. If the content of carbon (C) exceeds 0.20 wt %, an excess of carbides is formed, thereby causing deterioration in flexibility, workability, and the like.

[0053] Boron (B)

[0054] Boron (B) is segregated at grain boundaries to improve strength of the grain boundaries, and to suppress grain growth, thereby improving creep properties.

[0055] Boron (B) is preferably present in an amount of 0.001~0.015 wt % based on the total weight of the Ni-based superalloy. If the content of boron (B) is less than 0.001 wt %, the creep property enhancing effect can hardly be obtained due to too low amount of boron. If the content of boron (B) exceeds 0.015 wt %, there is a problem of deterioration in oxidation resistance due to interaction with lanthanum (La) which serves to improve oxidation resistance.

[0056] Method of Manufacturing Ni-Based Superalloy

[0057] FIG. **1** is a flowchart of a method of manufacturing a Ni-based superalloy in accordance with one embodiment of the present invention.

[0058] Referring to FIG. **1**, a process of manufacturing a Ni-based superalloy according to one embodiment of the invention includes preparing an alloy by mixing and dissolving raw materials (**S110**), hot rolling (**S120**), annealing (**S130**), and cooling (**S140**).

[0059] Mixing and Dissolving Raw Materials

[0060] In operation of preparing an alloy by mixing and dissolving raw materials (**S110**), the raw materials are mixed and dissolved, wherein the raw materials include chromium (Cr): 20~26 wt %, tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities. Here, an alloy in which these components are uniformly mixed may be prepared by mixing and dissolving the raw materials in a molten metal.

[0061] In this operation, the alloy may further include boron (B): 0.001~0.015 wt %.

[0062] Hot Rolling

[0063] In operation of hot rolling (**S120**), the prepared alloy is subjected to hot rolling.

[0064] Here, hot rolling is preferably performed at a reduction rate of 40~80% and at 1100~1250° C. If the hot rolling temperature is less than 1100° C., there can be a problem in that the alloy is likely to suffer from cracking during hot rolling. Further, the hot rolling temperature exceeds 1250° C., there can be a problem in that it is difficult to control microstructure of the alloy due to grain coarsening of the alloy.

[0065] In addition, if the reduction rate in hot rolling is less than 40%, it is difficult to ensure a structure having both uniformity and fineness. If the reduction rate in hot rolling exceeds 80%, there is a problem in that hot rolling takes a long time, thereby causing low yield.

[0066] Annealing

[0067] In operation of annealing (**S130**), the hot rolled alloy is subjected to annealing.

[0068] Annealing may include solution annealing the hot rolled alloy at 1200~1280° C., and aging the solution annealed alloy at 700° C.~850° C. Aging is optionally performed depending upon the composition of the alloy.

[0069] Preferably, after solution annealing in which the hot rolled alloy is maintained in a high temperature range of 1100~1280° C. for 5~180 minutes, aging is carried out in a middle temperature range of 700~850° C. for 4~8 hours.

[0070] Here, when solution annealing is performed out of the range from 1100~1280° C., precipitates are not sufficiently dissolved to provide desired properties. Preferably, solution annealing is performed for 5~180 minutes, which allows carbide and γ' precipitate phases within the alloy to be sufficiently dissolved in the alloy without causing grain growth.

[0071] In addition, aging is preferably performed at 700~850° C. for 4~8 hours such that the γ' precipitate phases in the alloy are uniformly distributed in a matrix and the carbides are precipitated at grain boundaries to allow sufficient aging without change in a structure even when exposed to the same aging temperature range.

[0072] Cooling

[0073] In operation of cooling (**S140**), the annealed alloy is subjected to cooling.

[0074] Here, cooling may be performed to room temperature by water cooling or air cooling. Room temperature may range from 1° C. to 40° C., without being limited thereto.

[0075] Although not shown in FIG. **1**, the method of manufacturing a Ni-based superalloy with good oxidation resistance and creep properties according to the embodiment may further include additional annealing (not shown) after cooling (**S140**).

[0076] In operation of additional annealing, the cooled alloy is subjected to additional annealing at 950~1100° C. for 0.5~4 hours. As a result, additional annealing after cooling (**S140**) can provide reinforced grain boundaries. Here, as additional annealing is performed, solid-solution strengthening alloy components such as carbon (C), chromium (Cr), and the like, produce precipitates to cause loss of solution strengthening effects. However, an additional precipitation strengthening effect resulting from additional annealing can counterbalance loss of the solution strengthening effects, thereby causing change in mechanical properties.

[0077] If the additional annealing temperature and time are out of the range as set forth above, stable precipitation cannot accomplished, which hinders production and growth of the precipitates. As a result, the desired effects cannot be sufficiently obtained.

[0078] The Ni-based superalloy manufactured through the above procedure can enhance creep properties by lowering the amounts of chromium (Cr) and silicon (Si), and improve

oxidation resistance by excluding Fe while increasing the amount of manganese (Mn), thereby improving oxidation resistance and creep properties at the same time.

[0079] Moreover, the Ni-based superalloy manufactured by the method of the invention exhibits excellent oxidation resistance and creep properties even at a high temperature of 700° C. or more through adjustment of alloy components and control of process conditions, and thus is suitable for parts of energy plants and chemical plants under a corrosive oxidative/reductive atmosphere, which stainless steel cannot withstand.

Examples

[0080] Hereinafter, the present invention will be described with reference to some examples. However, these examples are given by way illustration only and should not be construed in any way as limiting the invention.

[0081] Descriptions of details apparent to those skilled in the art will be omitted herein.

[0082] 1. Manufacture of Sample

[0083] Samples of Examples 1 to 11 and Comparative Examples 1 to 3 were prepared according to compositions as listed in Table 1 and process conditions as listed in Table 2.

TABLE 1

(unit: wt %)

	Cr	W	Mo	Mn	Si	Al	La	C	B	Fe	Co	Ti	Ni
Example 1	21	14	2	0.7	0.2	0.2	0.02	0.1	0.015	—	—	—	Bal.
Example 2	26	16	2	0.8	0.3	0.5	0.02	0.1	0.015	—	—	—	Bal.
Example 3	23	14	4	0.1	0.5	0.2	0.02	0.1	0.015	—	—	—	Bal.
Example 4	21	14	2	0.7	0.2	0.2	0.04	0.04	0.005	—	—	—	Bal.
Example 5	26	16	2	0.8	0.3	0.5	0.02	0.16	0.005	—	—	—	Bal.
Example 6	23	14	4	0.1	0.5	0.2	0.04	0.04	0.005	—	—	—	Bal.
Example 7	21	14	2	0.7	0.2	0.5	0.02	0.1	0.015	—	—	—	Bal.
Example 8	21	14	2	0.7	0.2	0.8	0.02	0.1	0.015	—	—	—	Bal.
Example 9	21	14	2	0.7	0.5	0.2	0.02	0.1	0.015	—	—	—	Bal.
Example 10	21	14	2	0.7	0.5	0.5	0.02	0.1	0.015	—	—	—	Bal.
Example 11	21	14	2	0.7	0.5	0.8	0.02	0.1	0.015	—	—	—	Bal.
Comparative Example 1	22	14	2	0.5	0.4	0.3	0.02	0.1	0.015	3	5	—	Bal.
Comparative Example 2	22	14	2	0.5	0.4	0.3	0.02	0.1	0.015	1.5	—	—	Bal.
Comparative Example 3	22	—	9	—	—	1.2	—	0.07	—	1	12.5	0.3	Bal.

TABLE 2

	Hot rolling temperature (° C.)	Reduction rate (%)	Solution annealing temperature (° C.)	Solution annealing time (min)
Example 1	1150	57	1135	60
Example 2	1150	58	1135	60
Example 3	1150	59	1135	60
Example 4	1150	61	1135	60
Example 5	1150	62	1135	60
Example 6	1150	59	1135	60
Example 7	1200	58	1135	60
Example 8	1200	61	1135	60
Example 9	1200	63	1135	60
Example 10	1200	64	1135	60
Example 11	1200	59	1135	60
Comparative Example 1	1150	56	1135	60
Comparative Example 2	1150	62	1135	60

TABLE 2-continued

	Hot rolling temperature (° C.)	Reduction rate (%)	Solution annealing temperature (° C.)	Solution annealing time (min)
Comparative Example 3	1150	55	1135	60

[0084] 2. Evaluation of Mechanical Properties

[0085] Table 3 shows evaluation results of mechanical properties of the samples prepared in Examples 1 to 11 and Comparative Examples 1 to 3.

TABLE 3

	700° C.			900° C.		
	YS (° C.)	TS (° C.)	EL (%)	YS (° C.)	TS (° C.)	EL (° C.)
Example 1	266	543	35.1	191	293	51.3
Example 2	302	583	38.1	160	240	59.8
Example 3	279	547	34.5	180	262	66.8
Example 4	193	423	55.4	161	235	54.6

TABLE 3-continued

	700° C.			900° C.		
	YS (° C.)	TS (° C.)	EL (%)	YS (° C.)	TS (° C.)	EL (° C.)
Example 5	234	482	36.0	167	242	63.4
Example 6	234	490	39.8	176	259	48.4
Example 7	268	550	36.2	198	296	50.2
Example 8	271	561	35.2	201	302	50.6
Example 9	261	538	38.3	188	291	53.1
Example 10	270	544	34.1	195	301	54.1
Example 11	253	536	31.2	185	288	50.1
Comparative Example 1	252	593	62.1	199	280	96.5
Comparative Example 2	240	531	59.2	185	252	89.9
Comparative Example 3	241	553	78.9	175	253	96.5

[0086] Referring to Tables 1 to 3, it can be seen that all of the samples of Examples 1 to 11 exhibited a yield strength (YS) of 195~300 MPa, a tensile strength (TS) of 420~580 MPa and an elongation (El) of 35~55% under temperature conditions of 700° C., and satisfies a yield strength (YS) of 160~200 MPa, a tensile strength (TS) of 235~300 MPa and an elongation (El) of 48~59% under high temperature conditions of 900° C.

[0087] On the other hand, it can be seen that the samples of Comparative Examples 1 to 3 exhibited yield strength (YS) and tensile strength (TS) as measured at 700° C. and 900° C., which were not much different than those of Examples 1 to 11. Thus, it can be seen that, despite not including cobalt (Co), the samples of Examples 1 to 11 exhibited similar mechanical properties in terms of high temperature strength to those of the samples of Comparative Examples 1 to 3.

[0088] FIG. **2** is a graph showing creep strain over time for samples prepared in Examples 1 to 6 and Comparative Example 2.

[0089] In FIG. **2**, results of creep testing under conditions of 900° C. and 60 MPa show that the samples of Examples 2 to 6 had a shorter creep life than that of Comparative Example 2, which is a commercially available alloy. On the other hand, the samples of Example 1 had a final creep life of 1199 hours, which is about three times that of Comparative Example 2.

[0090] FIG. **3** is a graph showing creep property results for the samples of Examples 1 to 6 and Comparative Examples 1 and 3. In the graph showing stress according to LMP (Larson-Miller Parameter), a higher stress value at the same LMP indicates better creep properties.

[0091] In FIG. **3**, it could be ascertained that the samples of Examples 2 to 6 did not exhibit better creep properties than those of Comparative Examples 1 and 3, whereas the sample of Example 1 exhibited better creep properties than those of Comparative Examples 1 and 3.

[0092] FIG. **4** is a graph showing cyclic oxidation property results for samples of Example 1, Examples 7 to 11 and Comparative Example 2, and more specifically, showing results obtained by a cyclic oxidation test in which the alloy samples of Example 1, Examples 7 to 11, and Comparative Example 2 were maintained at 1150° C. for 15 minutes, followed by maintaining the alloy samples at room temperature for 5 minutes.

[0093] In FIG. **4**, it can be seen that all of samples in Example 1, Examples 7 to 11 and Comparative Example 2 tended to linearly decrease in weight over time. As a result, it can be seen that the samples of Example 1 and Examples 7 to 11 exhibited substantially similar oxidation resistance to the sample of Comparative Example 2, which is a commercially available alloy.

[0094] Although some embodiments have been described herein, it should be understood by those skilled in the art that these embodiments are given by way of illustration only, and that various modifications, variations, and alterations can be made without departing from the spirit and scope of the invention. Therefore, the scope of the invention should be limited only by the accompanying claims and equivalents thereof.

LIST OF REFERENCE NUMERALS

[0095] **S110**: Mixing and dissolving raw material
[0096] **S120**: Hot rolling
[0097] **S130**: Annealing
[0098] **S140**: Cooling

What is claimed is:

1. A Ni-based superalloy with excellent oxidation resistance and creep properties, comprising: chromium (Cr): 20~26 wt %, tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities.

2. The Ni-based superalloy according to claim **1**, further comprising: 0.001~0.015 wt % of boron (B).

3. The Ni-based superalloy according to claim **1**, having a yield strength (YS) of 195~300 MPa, a tensile strength (TS) of 420~580 MPa, and an elongation (El) of 35~55%, under temperature conditions of 700° C.

4. The Ni-based superalloy according to claim **1**, having a yield strength (YS) of 160~200 MPa, a tensile strength (TS) of 235~300 MPa, and an elongation (El) of 48~59%, under high temperature conditions of 900° C.

5. A method of manufacturing a Ni-based superalloy with excellent oxidation resistance and creep properties, comprising:

(a) preparing an alloy by mixing and dissolving raw materials comprising chromium (Cr): 20~26 wt %, tungsten (W): 13~17 wt %, molybdenum (Mo): 1~5 wt %, manganese (Mn): 0.1~1.0 wt %, silicon (Si): 0.1~0.6 wt %, aluminum (Al): 0.1~1.0 wt %, lanthanum (La): 0.01~0.06 wt %, carbon (C): 0.01~0.20 wt %, and the balance of nickel (Ni) and unavoidable impurities;
(b) hot rolling the alloy;
(c) annealing the hot rolled alloy; and
(d) cooling the annealed alloy.

6. The method according to claim **5**, wherein the alloy further comprises 0.001~0.015 wt % of boron (B).

7. The method according to claim **5**, wherein hot rolling is performed at a reduction rate of 40~80% and at 1100~1250° C.

8. The method according to claim **5**, wherein annealing the hot rolled alloy comprises:

(c-1) solution annealing the hot rolled alloy at 1200~1280° C.; and
(c-2) aging the solution annealed alloy at 700~850° C.

9. The method according to claim **5**, further comprising:
additionally annealing the cooled alloy at 950~1100° C. for 0.5~4 hours after cooling the annealed alloy.

* * * * *