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(54) HIGH STRENGTH NI-BASED SUPERALLOY

HOCHFESTE NI-BASIERTE SUPERLEGIERUNG

SUPERALLIAGE À BASE DE NI À HAUTE RÉSISTANCE

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(56) References cited:
EP-A1- 2 246 449
EP-A1- 2 940 174
WO-A1-2014/124626
WO-A2-2012/047352

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Description

[Technical Field]

[0001] The present invention relates to a high strength Ni-based superalloy having a high strength.

[Background Art]

[0002] A Ni-based superalloy shows excellent mechanical characteristics at high temperatures and is widely used as high-temperature members of aircraft jet engines, etc. In general, adding a small amount of Al, Ti as well as Nb and Ta to a Ni-based alloy brings about fine precipitation of a strengthening phase that is called a γ' (gamma prime) phase of $Ni_3(Al,Ti)$, or a γ'' (gamma double prime) phase of $Ni_3(Al,Ti,Nb)$ in crystal grains to express an excellent strength. For fuel consumption reduction and CO_2 emission reduction in civil aircraft jet engines in recent years, a technical tendency is toward an uncooled low-pressure turbine disk in jet engines. With such an uncooling technology, a low-pressure turbine disk has become desired to have a high strength at higher temperatures, and development of an alloy having an increased strength by increasing the amount of the above-mentioned strengthening phase therein is being made. However, with the increase in the precipitated phase, the hot workability of the alloy lowers, and therefore, the alloy becomes difficult to work into a desired shape. Accordingly, it is important to secure hot workability of an alloy while increasing the strength thereof.

[0003] A Ni-based superalloy generally contains large quantities of alloying elements, and in smelting the alloy, there may occur in any way, unevenness in compositional distribution, that is, micro-segregation. In the micro-segregated part, the solidus temperature is lower than that of the other part, and therefore, when overheated, the micro-segregated part may be partially melted to lower the hot workability of the alloy. Accordingly, before hot working, the alloy must be heat-treated under a suitable condition to relax the micro-segregation.

[0004] Heretofore, some proposes have been made for a Ni-based superalloy having excellent hot workability or a technique of improving the hot workability of a Ni-based alloy (Patent Documents 1 to 3).

[Background-Art Documents]

[Patent Documents]

[0005]

Patent Document 1: JP-A-2011-231410
Patent Document 2: JP-A-2007-332412
Patent Document 3: JP-T-2013-531739

[Summary of the Invention]

[Problems that the Invention is to Solve]

[0006] For example, Patent Documents 1 and 2 propose a Ni-based superalloy excellent in weldability and hot workability. However, these documents refer to nothing relating to hot workability from the viewpoint of the above-mentioned micro-segregation, and there is a possibility of absence of any suitable evaluation therein. Further, in these, the contents of Al and Ti capable of contributing to formation of a strengthening phase are smaller than those in the present invention, and therefore, a strengthening phase in an amount required by low-pressure turbine disks to which the present invention is intended to be applied could not be formed, that is, there is a possibility that the strength of the alloys may be insufficient. Also, Patent Documents 3 refers to nothing relating to the relationship between micro-segregation and hot workability, and it is unclear whether alloy production would be carried out under a suitable condition.

[0007] The present invention has been made in consideration of the above-mentioned situation, and an object thereof is to provide a Ni-based superalloy excellent in strength and hot workability.

[Means for Solving the Problem]

[0008] Namely, the present invention relates to the following (1) to (5).

(1) A high strength Ni-based superalloy having a composition including, in terms of % by mass:

C: 0.005 to 0.05%;
Fe: 0.1 to 2.0%;
Cr: 10 to 20%;
Co: 10 to 20%;
Mo: 1.0 to 8.0%;
W: 1.0 to 8.0%;
Ti: 0.1 to 2.0%;
Al: 2.0 to 4.5%; and
Nb: 0.1 to 2.0%,

with the balance being Ni and unavoidable impurities.
The composition of the high strength Ni-based superalloy further optionally includes, in terms of ppm by mass, at least one of:

P:30 to 100 ppm; and
B: 50 to 250 ppm.

The composition of the high strength Ni-based superalloy further optionally includes, in terms of % by mass, at least one of:

Mg: 0.01% or less; and
Zr: 0.01 to 0.50%.

(2) The high strength Ni-based superalloy according to (1), having a γ' phase amount at 700°C of 40 to 43% in terms of volume fraction.

(3) The high strength Ni-based superalloy according to (1) to (2), having a γ' phase amount at 1100°C or lower.

(4) The high strength Ni-based superalloy according to any one of (1) to (3), wherein a temperature range within which a reduction of area of the superalloy evaluated in a tensile test is 50% or more, is 120°C or higher.

(5) The high strength Ni-based superalloy according to any one of (1) to (4), which is used at a temperature of 600°C or higher.

[Advantages of the Invention]

[0009] According to the present invention, it is possible to obtain a Ni-based superalloy having a high strength and excellent hot workability.
[0010] Furthermore, as a secondary effect, application of the alloy of the present invention to memebers of high-temperature instruments such as low-pressure turbine disks of jet engines and the like (for example, used at a temperature of 600°C or higher) brings about an effect of providing highly-efficient and environment-friendly instruments.

[Brief description of the drawings]

[0011]

[Fig. 1] Fig. 1 is a graph showing a relationship between a reduction of area and a temperature in the tensile test in Examples.
[Fig. 2] Fig. 2 is a graph showing a relationship between a reduction of area and a temperature in the tensile test in Examples.
[Fig. 3] Fig. 3 is a graph showing the temperature range within which the reduction of area is 50% or more in Examples.

[Modes for Carrying Out the Invention]

[0012] The following will explain the conditions defined in the present invention and the effects associated therewith. Every component is expressed by ratio by mass.
[0013] Here, "% by mass", "ratio by mass", and "ppm by mass" are the same as "% by weight", "ratio by weight", and

"ppm by weight", respectively.

C: 0.005 to 0.05%

[0014] C is an additive element to form a carbide to suppress crystal grain coarsening of the alloy, and to precipitate in a grain boundary to improve the high-temperature strength of the alloy; but when the content thereof is small, it is not effective for sufficiently improving the strength, and therefore, the content of C must be 0.005% or more. However, when the content thereof is too large, an excessive carbide may be formed to have a negative influence of decreasing the amount of other useful precipitates such as a γ'-phase, and therefore, the upper limit thereof is 0.05%. For the same reasons, the lower limit thereof is preferably 0.01% and the upper limit thereof is preferably 0.02%.

Fe: 0.1 to 2.0%

[0015] Fe is, when the content thereof is increased, effective for alloy cost reduction, but when Fe is incorporated excessively in an Nb-containing alloy, an intermetallic compound called a Laves phase is formed to cause worsening of material characteristics, for example, degradation of hot rollability, etc. Accordingly, the content of Fe is 0.1 to 2.0%. For the same reasons, the lower limit thereof is preferably 0.5% and the upper limit thereof is preferably 1.5%.

Co: 10 to 20%

[0016] Co is an element of improving the segregation property of the alloy by bringing the partition coefficient of alloying elements such as Al, Ti, Nb and W close to 1. When the alloy does not contain Co in an amount of 10% or more, the effect could not be sufficiently realized. On the other hand, when the content of Co is more than 20%, not only the forgeability is worsened but also a Laves phase may be readily formed, whereby, the matrix texture at a high temperature would be rather destabilized and the high-temperature texture stability would be worsened. Accordingly, the content of Co is limited to a range of 10 to 20%. For the same reasons, the lower limit thereof is preferably 12% and the upper limit thereof is preferably 16%.

Mo: 1.0 to 8.0%

[0017] Mo mainly dissolves in a matrix to strengthen it, and also dissolves in a γ' phase to substitute for the Al site in this phase to thereby increase the stability of the phase, and is therefore effective for increasing both high-temperature strength and texture stability. When the content of Mo is less than 1.0%, the above-mentioned effect is insufficient, but when the content thereof is more than 8.0%, a Laves phase may be readily formed, whereby the matrix texture at a high temperature would be rather destabilized and the high-temperature texture stability would be worsened. Accordingly, the content of Mo is limited to a range of 1.0 to 8.0%. For the same reasons, the lower limit thereof is preferably 2.0% and the upper limit thereof is preferably 6.0%.

W: 1.0 to 8.0%

[0018] Like Mo, W also dissolves in a matrix to strengthen it, and dissolves in a γ' phase to substitute for the Al site in this phase to thereby increase the stability of the phase, and is therefore effective for increasing both high-temperature strength and texture stability. However, when W is incorporated excessively, not only α-W precipitates to lower texture stability but also hot workability is also noticeably worsened. Accordingly, the content of W is limited to a range of 1.0 to 8.0%. For the same reasons, the lower limit thereof is preferably 2.0% and the upper limit thereof is preferably 6.0%.

Cr: 10 to 20%

[0019] Cr is an element necessary for enhancing oxidation resistance, corrosion resistance and strength of the alloy. Also, it combines with C to form a carbide, thereby enhancing high-temperature strength. However, too large content thereof invites destabilization of matrix and promotes the formation of harmful TCP phases such as a σ phase and α-Cr, resulting in adverse influences on ductility and toughness. Therefore, the content of Cr is limited to 10 to 20%. For the same reasons, the lower limit thereof is preferably 14% and the upper limit thereof is preferably 18%.

Ti: 0.1 to 2.0%

[0020] Ti mainly forms an MC carbide to suppress crystal grain coarsening of the alloy and also combines with Ni to precipitate a γ' phase, thereby contributing to precipitation strengthening of the alloy. However, when Ti is exceedingly incorporated, the stability of the γ' phase at a high temperature is lowered and an η phase is formed, thereby impairing strength, ductility, toughness, and high-temperature long-term texture stability. Therefore, the content of Ti is limited to a range of 0.1 to 2.0%. For the same reasons, the lower limit thereof is preferably 0.5% and the upper limit thereof is preferably 1.5%.

Al: 2.0 to 4.5%

[0021] Al combines with Ni to precipitate a γ' phase, thereby contributing to precipitation strengthening of the alloy. However, when the content thereof is too large, the γ' phase aggregates at grain boundaries and is coarsened, thereby drastically impairing mechanical properties at a high temperature and also lowering hot workability. Therefore, the content of Al is limited to 2.0 to 4.5%. For the same reasons, the lower limit thereof is preferably 3.0% and the upper limit thereof is preferably 4.0%.

Nb: 0.1 to 2.0%

[0022] Nb is an element that stabilizes the γ' phase and contributes to strength enhancement, but when Nb is exceedingly incorporated, the precipitation of the η phase, the σ phase, and the Laves phase that are harmful phases is promoted, thereby remarkably lowering texture stability. Therefore, the content ofNb is limited to 0.1 to 2.0%. For the same reasons, the lower limit thereof is preferably 0.5% and the upper limit thereof is preferably 1.5%.

P: 30 to 100 ppm

[0023] P is considered to have an effect of reducing local strain accumulation near grain boundaries to prevent creep deformation by depositing precipitates containing P at grain boundaries, thereby lowering the minimum creep speed and prolonging the creep rupture time. However, when P is exceedingly incorporated, there is a possibility that grain boundary segregation of P becomes excessive to lower the consistency of the grain boundaries, thereby causing ductility reduction and the like. Therefore, when P is incorporated according to the necessity, it is desirable that the lower limit of the content of P is 30 ppm and the upper limit thereof is 100 ppm. For the same reasons, the lower limit thereof is more preferably 40 ppm and the upper limit thereof is more preferably 80 ppm.

B: 50 to 250 ppm

[0024] B segregates at grain boundaries to contribute to high-temperature characteristics, and is therefore incorporated according to the necessity. However, when the content thereof is too large, B may readily form borides thereof and would rather bring about intergranular embrittlement. Accordingly, when B is incorporated according to the necessity, the content of B is preferably 250 ppm or less. For sufficiently realizing the above-described effect, the content thereof is preferably 50 ppm or more, and for the same reasons as above, the lower limit thereof is more preferably 100 ppm and the upper limit thereof is more preferably 200 ppm.

Mg: 0.01% or less

[0025] Mg mainly combines with S to form a sulfide and enhances hot workability, so that Mg is incorporated according to the necessity. However, when the content thereof is too large, the grain boundaries are contrarily embrittled and hot workability decreases. Accordingly, when Mg is incorporated according to the necessity, the content of Mg is preferably 0.01% or less. Incidentally, for sufficiently exhibiting the above-described effect, the lower limit of the Mg content is preferably 0.0005% or more.

Zr: 0.01 to 0.50%

[0026] Zr segregates at grain boundaries to contribute to an improvement in high-temperature characteristics, so that Zr is incorporated according to the necessity. However, when Zr is exceedingly incorporated, the hot workability of the alloy is lowered. Accordingly, when Zr is incorporated according to the necessity, the content of Zr is preferably 0.50% or less. In order to obtain the above-described effect, it is preferable to incorporate Zr in an amount of 0.01% or more.

γ' phase amount at 700°C being 40 to 43% in terms of volume fraction.

[0027] When the γ' phase amount at 700°C in terms of volume fraction is appropriate, a desired strength can be realized. When it is lower than 40%, the strength would be too low and desired characteristics of members could not be satisfied. On the other hand, when it is more than 43%, the strength would be excessive to lower the toughness of members. Accordingly, it is desirable that the γ' phase amount at 700°C is 40 to 43% in terms of volume fraction.

[0028] The γ' phase amount in terms of volume fraction may be controlled by varying the balance of Al and Ti that are the constituent elements of the γ' phase.

γ' phase solution temperature being 1100°C or lower.

[0029] When the γ' phase solution temperature is 1100°C or lower, the temperature range within which the alloy exhibits good hot workability can be expanded to lower temperatures, thereby enabling effective bloom-forging at lower temperatures. The γ' phase solution temperature can be controlled by varying the balance of Al and Ti that are the constituent elements of the γ' phase.

[0030] Temperature range within which reduction of area is 50% or more being 120°C or higher.

[0031] In the present invention, the temperature range that realizes excellent hot workability is expanded, and in a one-time bloom-forging step, a cast structure can be more effectively destroyed. When the temperature range is less than 120°C, the temperature range capable of realizing excellent hot workability may narrow, and multiple bloom-forging steps would be necessary for sufficiently destroying a cast structure, thereby resulting in cost increase. Hot working can be carried out, for example, in a temperature range of 900°C to 1150°C. However, in the present invention, the temperature range for hot working is not limited to the above-described temperature range.

[0032] The temperature range within which the reduction of area is 50% or more is preferably 120°C or higher, and the temperature range can be controlled by varying the balance of Al and Ti that are the constituent elements of the γ' phase, and the balance of Cr, Mo and Nb that are micro-segregation elements.

[0033] The Ni-based alloy of the present invention is controlled to have a composition including, in terms of % by mass, C: 0.005 to 0.05%, Fe: 0.1 to 2.0%, Cr: 10 to 20%, Co: 10 to 20%, Mo: 1.0 to 8.0%, W: 1.0 to 8.0%, Ti: 0.1 to 2.0%, Al: 2.0 to 4.5%, and Nb: 0.1 to 2.0%, with the balance being Ni and unavoidable impurities. The composition may further include according to the necessity, in terms of ppm by mass, at least one of P: 30 to 100 ppm, and B: 50 to 250 ppm, and also according to the necessity, at least one of Mg: 0.01% or less, and Zr: 0.01 to 0.50%.

[0034] The Ni-based alloy of the present invention can be produced according to an ordinary smelting method and, as the invention, the smelting method is not particularly limited.

[0035] After smelted, the Ni-based alloy may be subjected to diffusion heat treatment. In this embodiment, an ingot of 5 tons or more is expected in smelting. In the present invention, although the size of products is not specifically limited, the effect of improving hot workability for large-size members of 5 tons or more brings about especially favorable results.

[0036] Diffusion heat treatment can be carried out under the condition at 1200°C for 50 hours or more. For preventing cost increase, the treatment time is preferably 100 hours or less.

[0037] In the present invention, diffusion heat treatment may be omitted.

[0038] The Ni-based alloy may be worked for forging or the like, according to the necessity. The condition in working is not specifically limited in the present invention.

[0039] In working the Ni-based alloy of the present invention, the γ' phase amount at 700°C is 40 to 43% in terms of volume fraction, the γ' phase solution temperature is 1100°C or lower, and the temperature range within which the reduction of area of the alloy in a tensile test is 50% or more, is 120°C or higher; and the alloy realizes good hot workability.

[0040] In this embodiment, an Ni-based superalloy that has improved hot workability and contains a sufficient amount of a strengthening phase to secure the strength thereof can be obtained. The strength is, for example, 1050 MPa or more at 750°C, but is not limited thereto.

[0041] The above-described Ni-based alloy is favorably used in the field where a temperature of 600°C or higher is expected, such as low-pressure turbine disks of jet engines and gas turbine disks for high-efficiency power generation.

[Examples]

[0042] Examples of the present invention are described with reference to the tables and the drawings given herein.

[0043] The material was a 25-kg round ingot produced according to a vacuum induction melting method, and nine invention alloys and one comparative alloy were produced. The chemical components (with the balance being unavoidable impurities) of the invention alloys and the comparative alloy are shown in Table 1.

[0044] The γ' phase amount at 700°C and the γ' phase solution temperature of the invention alloys and the comparative alloy are calculated using a general-purpose thermodynamic calculation software (Thermo-Calc). Table 2 collectively shows them.

[0045] For solving the unevenness of the compositional distribution owing to micro-segregation that is generally expected in a Ni-based superalloy, these materials were, except some samples, subjected to diffusion heat treatment at 1200°C for 50 hours, and then the test materials were machined to give tensile test pieces.

[Table 1]

Sample No.	Chemical Composition of Invention Alloy and Comparative Alloy (mass%, but mass ppm for B and P)												
	Ni	Fe	Cr	Co	Mo	W	Al	Ti	Nb	C	B	Zr	P
Comparative Alloy	Bal.	0.9	15.4	13.8	3.8	4.1	2.2	3.8	0.7	0.016	170	-	50
Invention Alloy 1	Bal.	0.5	14.3	12.3	2.9	5.8	4.0	1.2	0.8	0.016	102	0.01	55
Invention Alloy 2	Bal.	0.9	17.5	13.4	2.0	4.9	3.7	0.5	1.2	0.017	198	0.01	40
Invention Alloy 3	Bal.	1.0	15.7	15.3	5.9	2.8	3.6	1.5	0.9	0.012	154	0.03	48
Invention Alloy 4	Bal.	0.8	16.1	14.2	4.0	3.9	3.6	1.0	0.5	0.014	183	0.06	69
Invention Alloy 5	Bal.	1.3	15.2	15.8	3.9	4.8	3.3	1.3	1.2	0.011	133	0.12	41
Invention Alloy 6	Bal.	1.5	17.8	13.0	4.0	2.0	3.1	1.2	1.4	0.019	117	0.48	80
Invention Alloy 7	Bal.	1.0	16.0	13.2	5.0	4.0	3.7	1.2	1.2	0.015	-	-	-
Invention Alloy 8	Bal.	1.0	16.0	13.2	5.0	4.0	3.7	1.2	1.2	0.015	-	0.03	-
Invention Alloy 9	Bal.	1.0	16.0	13.2	5.0	4.0	3.7	1.2	1.2	0.015	120	-	70

[0046] The tensile test was performed as follows.

[0047] Based on the Japanese Industrial Standards, JIS Z 2241:2011, each test piece had a diameter in the parallel part of 6 mm and a mark-to-mark distance of 30 mm. The test temperature range was 950 to 1225°C, and the following method was employed for avoiding the influence to be provided by the difference in the crystal grain size. Specifically, in the case where the test temperature was 1150°C or higher, the test piece was kept at the test temperature for 30 minutes and then subjected to the tensile test. In the case where the tensile temperature was lower than 1150°C, the test piece was once kept at 1150°C for 30 minutes, then cooled down to the test temperature, and further kept at the test temperature for 15 minutes to thereby stabilize the temperature thereof, and thereafter subjected to the tensile test. The strain speed in the tensile test was 3×10^{-2} s^{-1} in every case.

[0048] In this description, the contents of JIS Z 2241:2011 are hereby incorporated by reference.

[Table 2]

Sample No.	γ' Phase Amount at 700°C (vol.%)	γ' Phase Solution Temperature (°C)
Comparative Alloy	38.6	1114
Invention Alloy 1	42.1	1092
Invention Alloy 2	42.5	1093
Invention Alloy 3	41.8	1093
Invention Alloy 4	41.9	1093
Invention Alloy 5	42.0	1093
Invention Alloy 6	43.1	1094
Invention Alloy 7	42.1	1092
Invention Alloy 8	42.2	1092
Invention Alloy 9	42.1	1092

[0049] As in Table 2, all the invention alloys have a larger γ' phase amount at 700°C, from 42.0 to 43.1%, than the comparative alloy. In addition, the γ' phase solution temperature in the invention alloys is lower than that in the comparative alloy, that is, lower than 1100°C.

[0050] Fig. 1 and Fig. 2 each show a relationship between a reduction of area and a temperature of the invention alloys and the comparative alloy. The maximum reduction of area is almost the same between the invention alloys and the comparative alloy, but the temperature range within which the reduction of area is 50% or more is broader for the invention alloys than that for the comparative alloy. The broader temperature range means that the forgeable temperature range is broad and the hot workability of the alloy is good.

[0051] Fig. 3 shows the temperature range within which the reduction of area is 50% or more for the invention alloys and the comparative alloy. The temperature range for the comparative alloy is 120°C, but all the invention alloys shown in Fig. 3 show a temperature range higher than that for the comparative alloy. Accordingly, it becomes clear that the invention alloys are excellent in hot workability.

Claims

1. A high strength Ni-based superalloy having a composition comprising, in terms of % by mass:

   C: 0.005 to 0.05%;
   Fe: 0.1 to 2.0%;
   Cr: 10 to 20%;
   Co: 10 to 20%;
   Mo: 1.0 to 8.0%;
   W: 1.0 to 8.0%;
   Ti: 0.1 to 2.0%;
   Al: 2.0 to 4.5%; and
   Nb: 0.1 to 2.0%,

   with the balance being Ni and unavoidable impurities,
   wherein the composition further optionally comprises, in terms of ppm by mass, at least one of:

   P:30 to 100 ppm; and
   B: 50 to 250 ppm.

   and wherein the composition further optionally comprises, in terms of % mass, at least one of:

   Mg: 0.01% or less; and
   Zr: 0.01 to 0.50%.

2. The high strength Ni-based superalloy according to claim 1, having a γ' phase amount at 700°C of 40 to 43% in terms of volume fraction.

3. The high strength Ni-based superalloy according to claim 1 or 2, having a γ' phase amount at 1100°C or lower.

4. The high strength Ni-based superalloy according to any one of claims 1 to 3, wherein a temperature range within which a reduction of area of the superalloy evaluated in a tensile test is 50% or more, is 120°C or higher.

5. The high strength Ni-based superalloy according to any one of the claims 1 to 4, which is used at a temperature of 600°C or higher.

Patentansprüche

1. Hochfeste Ni-basierte Superlegierung mit einer Zusammensetzung, die in Ma% Folgendes umfasst:

   C: 0,005 bis 0,05 %
   Fe: 0,1 bis 2,0 %
   Cr: 10 bis 20 %
   Co: 10 bis 20 %
   Mo: 1,0 bis 8,0 %
   W: 1,0 bis 8,0 %
   Ti: 0,1 bis 2,0 %
   Al: 2,0 bis 4,5 %, und
   Nb: 0,1 bis 2,0 %

   wobei der Rest Ni und unvermeidbare Verunreinigungen sind,
   wobei die Zusammensetzung des Weiteren optional hinsichtlich Massen-ppm mindestens eines aus Folgendem umfasst:

   P: 30 bis 100 ppm; und
   B: 50 bis 250 ppm,

und wobei die Zusammensetzung des Weiteren optional hinsichtlich Ma% mindestens eines aus Folgendem umfasst: Mg: 0,01 % oder weniger, und Zr: 0,01 bis 0,50 %.

2. Hochfeste Ni-basierte Superlegierung nach Anspruch 1 mit einer γ'-Phasenmenge bei 700 °C von 40 bis 43 % hinsichtlich Volumenanteil.

3. Hochfeste Ni-basierte Superlegierung nach Anspruch 1 oder 2, die eine γ'-Phasenmenge bei 1100 °C oder niedriger aufweist.

4. Hochfeste Ni-basierte Superlegierung nach einem der Ansprüche 1 bis 3, wobei ein Temperaturbereich, innerhalb dessen eine Brucheinschnürung der Superlegierung, die in einem Zugversuch evaluiert wird, 50 % oder mehr beträgt, 120 °C oder höher ist.

5. Hochfeste Ni-basierte Superlegierung nach einem der Ansprüche 1 bis 4, die bei einer Temperatur von 600 °C oder höher verwendet wird.

Revendications

1. Superalliage haute résistance à base de Ni ayant une composition comprenant, en termes de % en masse :

C : de 0,005 à 0,05 % ;
Fe : de 0,1 à 2,0 % ;
Cr : de 10 à 20 % ;
Co : de 10 à 20 % ;
Mo : de 1,0 à 8,0 % ;
W : de 1,0 à 8,0 % ;
Ti : de 0,1 à 2,0 % ;
Al : de 2,0 à 4,5 % ; et
Nb : de 0,1 à 2,0 %,

le reste étant du Ni et des impuretés inévitables,
la composition comprenant en outre éventuellement, en termes de ppm en masse, l'un au moins parmi :

P : de 30 à 100 ppm ; et
B : de 50 à 250 ppm.

et la composition comprenant en outre éventuellement, en termes de % en masse, l'un au moins parmi :

Mg : 0,01 % ou moins ; et
Zr : de 0,01 à 0,50 %.

2. Superalliage haute résistance à base de Ni selon la revendication 1, ayant une quantité de phase γ' à 700 °C de 40 à 43 % en termes de fraction volumique.

3. Superalliage haute résistance à base de Ni selon la revendication 1 ou 2, ayant une quantité de phase γ' à 1 100 °C ou moins.

4. Superalliage haute résistance à base de Ni selon l'une quelconque des revendications 1 à 3, où une plage de température dans laquelle une réduction de la surface du superalliage évaluée lors d'un essai de traction est de 50 % ou plus, est de 120 °C ou plus.

5. Superalliage haute résistance à base de Ni selon l'une quelconque des revendications 1 à 4, qui est utilisé à une température de 600 °C ou plus.

Fig. 1

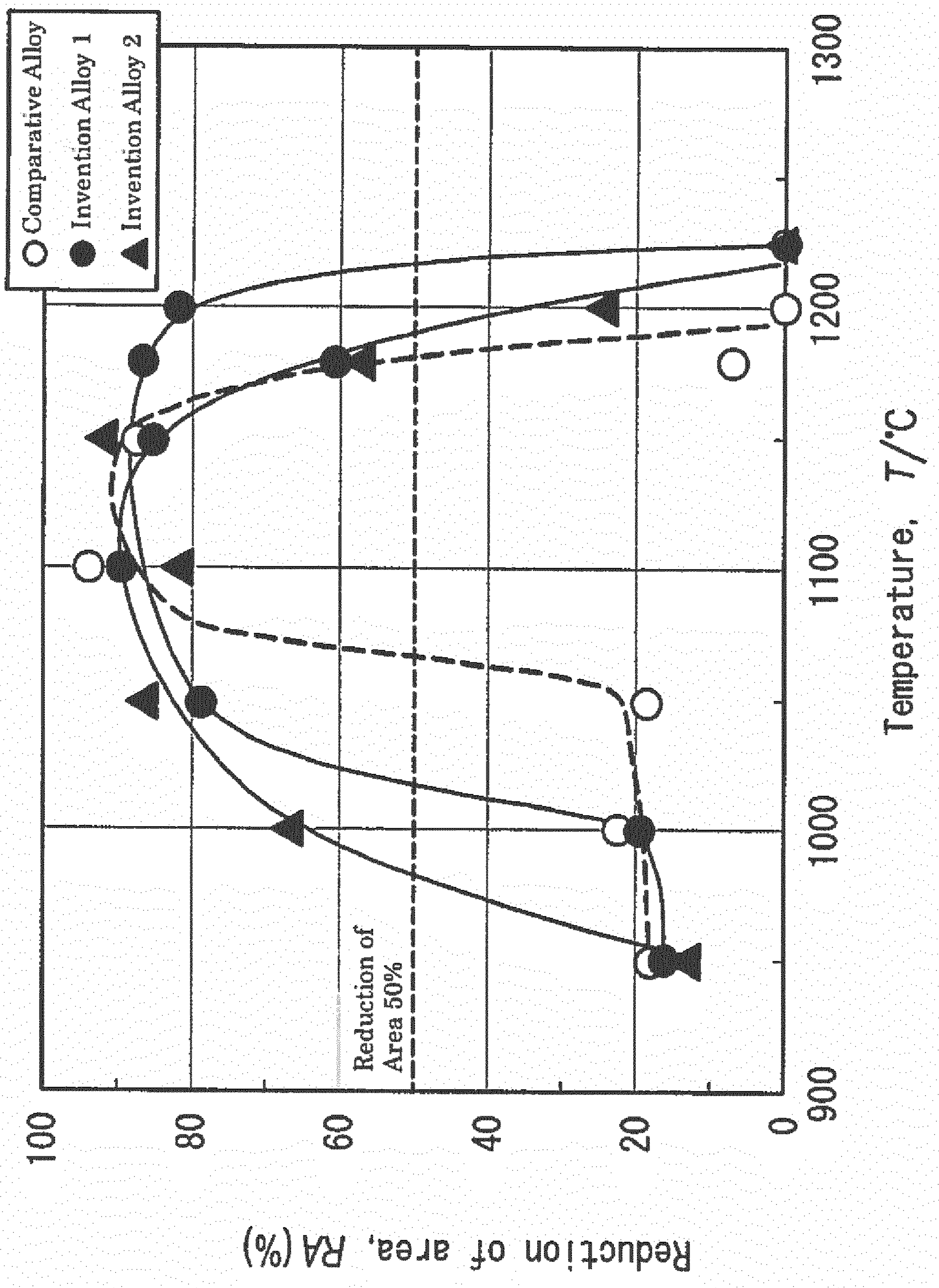

○ Comparative Alloy
● Invention Alloy 1
▲ Invention Alloy 2
Reduction of Area 50%
Reduction of area, RA (%)
0
20
40
60
80
100
Temperature, T/°C
900
1000
1100
1200
1300

Fig. 2

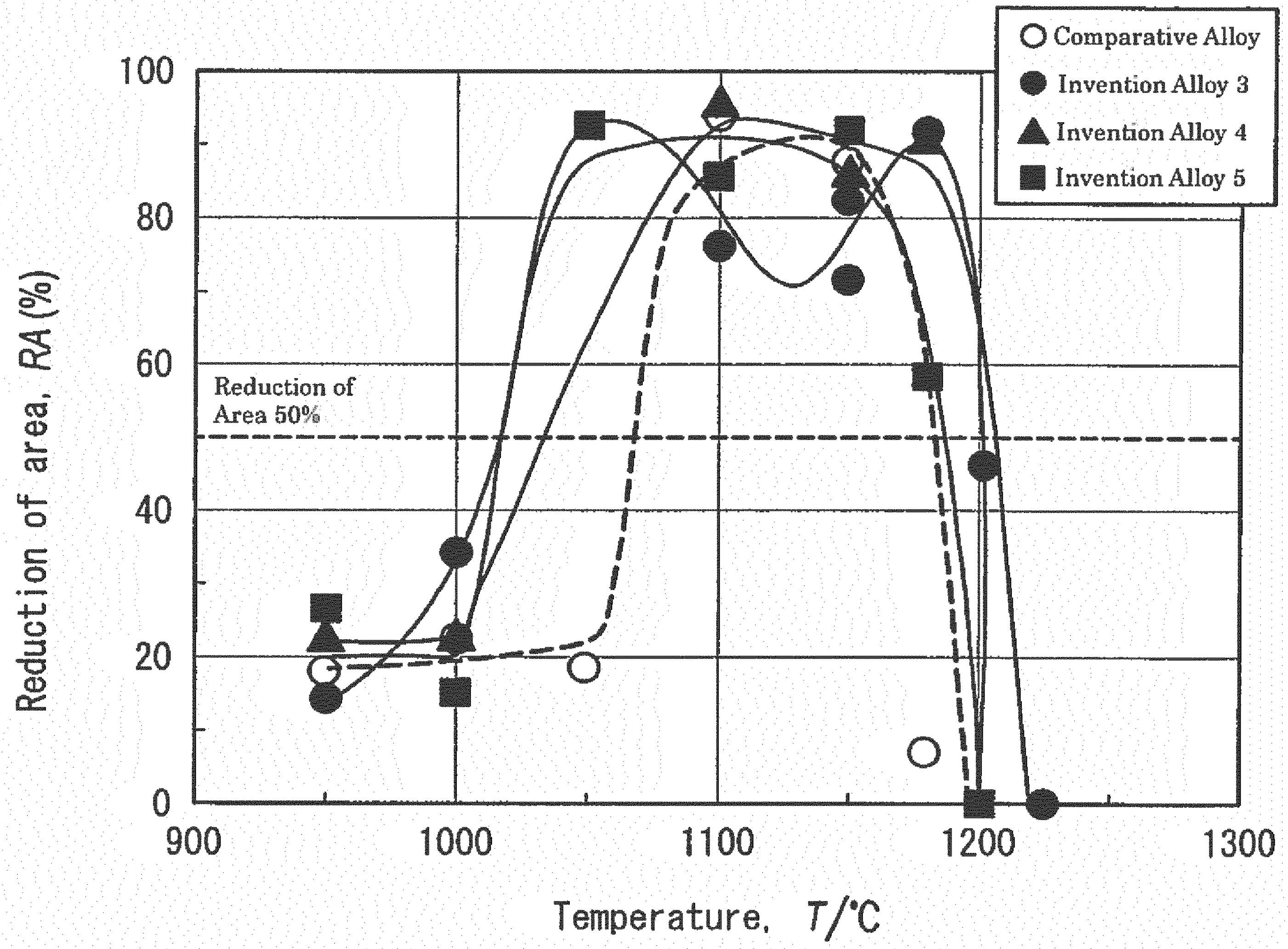
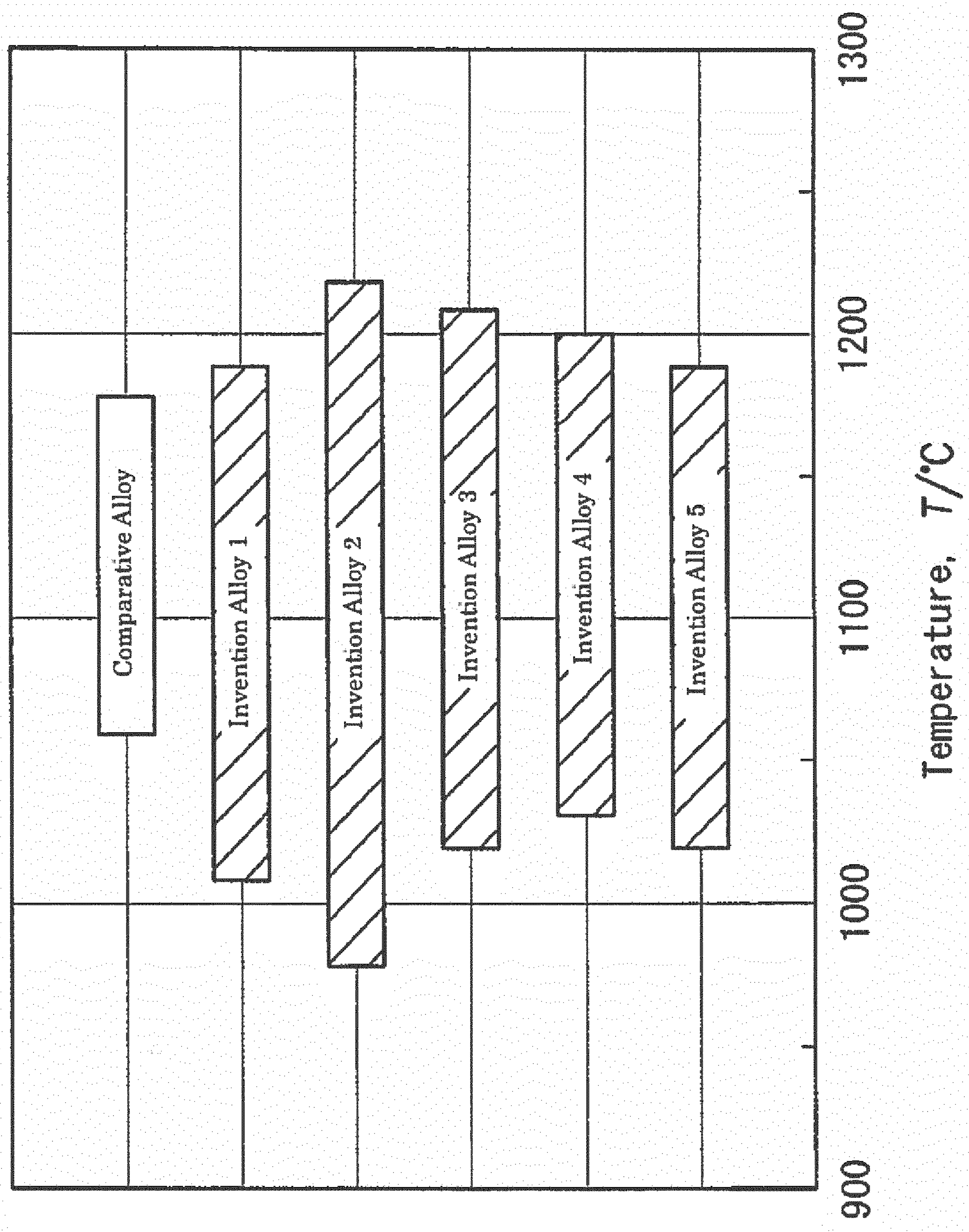

○ Comparative Alloy
● Invention Alloy 3
▲ Invention Alloy 4
■ Invention Alloy 5
Reduction of Area 50%
100
80
60
40
20
0
900
1000
1100
1200
1300
Reduction of area, RA (%)
Temperature, T/°C

Fig. 3


Comparative Alloy
Invention Alloy 1
Invention Alloy 2
Invention Alloy 3
Invention Alloy 4
Invention Alloy 5
900
1000
1100
1200
1300
Temperature, T/°C

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2011231410 A **[0005]**
- JP 2007332412 A **[0005]**
- JP 2013531739 T **[0005]**