WEAR RESISTANT ALLOY

Applicant: **EATON CORPORATION, Cleveland, OH (US)**

Inventors: **Michael James Warwick, Stoughton, WI (US); Sandra K. Schaefer, Marshall, MI (US); Jonn B. Nebbe, Clarion, IA (US)**

Appl. No.: 14/917,775

PCT Filed: Sep. 4, 2014

PCT No.: PCT/US2014/054153

Mar. 9, 2016

**Related U.S. Application Data**

Provisional application No. 61/877,438, filed on Sep. 13, 2013.

**Publication Classification**

Int. Cl.

*C22C 38/54* (2006.01)
*C22C 38/48* (2006.01)
*C22C 38/44* (2006.01)

**ABSTRACT**

An example of a wear resistant alloy consists essentially of from 0.15 wt. % to 0.30 wt. % C; up to 0.50 wt. % Mn; up to 0.02 wt. % P; up to 0.015 wt. % S; up to 0.50 wt. % Si; from 30.25 wt. % to 35 wt. % Ni; from 15.0 wt. % to 17.0 wt. % Cr; from 1.60 wt. % to 3.20 wt. % Ti; from 1.60 wt. % up to 2.50 wt. % Al; from 2.10 wt. % up to 3.20 wt. % Nb(Ta); up to 0.015 wt. % B; Mg present in an amount up to 0.050 wt. %; up to 0.50 wt. % Cu; up to 0.25 wt. % of Mo; up to 0.25 wt. % of W; up to 0.020 wt. % Ca; and a balance of Fe and inevitable impurities. The Ti+Nb(Ta) is greater than or equal to (>) 4.40 wt. %.
WEAR RESISTANT ALLOY
CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 61/875,438, filed on Sep. 13, 2013, which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] Engine exhaust valves are often subjected to temperatures exceeding 800°C, and the materials used to make the valves should exhibit strength, abrasion resistance, and corrosion/oxidation resistance. High temperature alloys have been used to form exhaust valves. Some high temperature alloys, including many superalloys and stainless steel alloys, are created with a variety of metals. Some of these alloys may be undesirable in terms of the manufacturing steps required to make them, the cost of the material(s), the durability or high temperature strength performance, the wear resistance performance, and/or the like.

[0003] SUMMARY

[0004] According to one example of the present disclosure, a wear resistant alloy consists essentially of from 0.15 wt. % to 0.50 wt. % C; up to 0.50 wt. % Mn; up to 0.02 wt. % P; up to 0.015 wt. % S; up to 0.50 wt. % Si; from 30.25 wt. % up to 35 wt. % Ni; from 15.0 wt. % up to 17.0 wt. % Cr; from 1.60 wt. % up to 3.20 wt. % Ti; from 1.60 wt. % up to 2.50 wt. % Al; from 2.10 wt. % up to 3.20 wt. % Nb(Ta); up to 0.015 wt. % B; Mg present in an amount up to 0.030 wt. %; up to 0.50 wt. % Cu; up to 0.25 wt. % of Mo; up to 0.25 wt. % of W; up to 0.020 wt. % Ca; and a balance of Fe and inevitable impurities. Ti+Nb(Ta) is greater than or equal to (≥) 4.40 wt. % of the alloy.

DETAILED DESCRIPTION

[0005] The present disclosure relates to an iron-nickel (Fe—Ni) based alloy. It is believed that the examples of the iron-nickel based alloy disclosed herein exhibit high hardness, high temperature strength, fatigue strength, and wear resistance characteristics. These characteristics allow the alloy(s) to be used in high temperature applications including, for example, turbine application parts, piston, valve, shaft, valve, and gas recycling valves. Other applications in which the alloy(s) may be used include, for example, turbine applications, fasteners, combustion chamber parts, exhaust system oxygen sensors, and other parts exposed to elevated temperatures, exhaust gas, and condensate environments.

[0006] Examples of the iron-nickel based alloy disclosed herein achieve high temperature mechanical properties through precipitation hardening and solid solution strengthening. The iron-nickel based alloy is developed by heat treatment sequences, which may involve a solution treatment to dissolve strengthening constituents, followed by aging heat treatments to precipitate phases in morphologies and distributions that will produce mechanical properties that are desirable for the alloy's intended use.

[0007] In the disclosed alloys, the precipitation of a finely dispersed, stable and ordered intermetallic phase, (Fe, Ni), (Al, Ti, Nb), a crystal structure commonly referred to as gamma prime (γ'), contributes to the high temperature strength of the alloy. In addition, at least some of the carbon in the alloy(s) forms primary carbides (e.g., TiC and/or NbC) for enhanced wear resistance. It is to be understood that these carbides may be randomly precipitated in the alloy.

[0008] The example alloys disclosed herein include at least C, Ni, Cr, Ti, Al, Nb(Ta), Mg and Fe. As used herein, Nb(Ta) refers to niobium, which may be accompanied by a small amount of tantalum. Nb is often accompanied by Ta as a contaminant or an inevitable impurity because separating the two elements may be difficult. The notation Nb(Ta) recognizes that the measured niobium likely includes a small amount of tantalum. In addition, it is noted that while Ta and Nb behave similarly within the alloy, Ta is heavier and thus is not as effective as Nb pound for pound.

[0009] It is to be understood that when a lower limit for a range is not given (e.g., "up to X wt. % element"), the lower limit is 0 wt. %, and thus the particular element may not be present in the alloy. However, when it is stated that an element "is present in an amount up to X wt. %", the lower limit is greater than 0 wt. %, and at least some of the element is present in the alloy.

[0010] In some instances, particular element(s) may not be intentionally added to the alloy, but may be present in a small amount that equates to an inevitable impurity. For example, P, S, Mn, Si, W, Mo, and Cu are examples of classic inevitable impurities that may not be added to the alloy on purpose but are present nonetheless.

[0011] Examples of the disclosed alloy contain increased magnesium (Mg) or Mg and calcium (Ca) levels (compared to other high temperature alloys) which contribute to the alloy(s) having improved grain refinement. It is believed that the amount of Mg or Mg and Ca in the amounts disclosed herein have a desirable effect on grain refinement. It is also believed that the addition of magnesium, or combinations of magnesium and calcium, to the alloy(s) disclosed herein advantageously improve die life during forging. In an example, the die life may be increased by 15%.

[0012] The magnesium is present in the alloy in an amount up to 0.030 wt. %. Magnesium may also be present in smaller amounts, e.g., up to 0.020 wt. % or up to 0.010 wt. %. As examples, the magnesium may be present in a range from 0.010 wt. % up to 0.020 wt. %, or in a range from 0.020 wt. % up to 0.030 wt. %. As previously mentioned, it is believed that the magnesium helps improve at least grain refinement and die life. In addition, the Mg may be added while other elements (e.g., C, Ni, Cr, Ti, Al, Nb(Ta), and Fe) of the alloy remain unchanged, which improves the grain refinement without affecting the phase balance of the alloy.

[0013] In some examples, calcium is added to the alloy, and in other examples calcium is not included in the alloy. When present, calcium may be included in the alloy in an amount up to 0.020 wt. % maximum. The maximum amount of calcium may also be lower, e.g., up to 0.015 wt. %, or up to 0.010 wt. %. It is believed (as noted above), that calcium also helps improve grain refinement.

[0014] Carbon may be present in the alloy in an amount ranging from 0.15 wt. % up to 0.30 wt. %. The alloy may also contain smaller ranges of carbon, examples of which include from 0.16 wt. % up to 0.30 wt. %, from 0.15 wt. % up to 0.25 wt. %, from 0.15 wt. % up to 0.20 wt. %, or from 0.15 wt. % up to about 0.17 wt. %. As mentioned above, at least some of the carbon combines with niobium (i.e., Nb(Ta)) and titanium to form primary carbide grains. The formation of primary carbides may occur during ingot solidification. Generally, as the percentage of carbon goes down, so will the percentage of
primary carbides. The carbide grains positively influence the adhesive and abrasion wear resistance of the alloy.

Nickel may be present in the alloy in an amount ranging from 30.25 wt. % up to 35 wt. %. The alloy may also contain smaller ranges of nickel, examples of which include from 30.25 wt. % up to 34.50 wt. %, from 31.0 wt. % up to 35.0 wt. %, from 32.0 wt. % up to 35.0 wt. %, from 33.0 wt. % up to 35.0 wt. %, or from 34.0 wt. % up to 35.0 wt. %. Nickel is mutually soluble with iron. Nickel may be added to stabilize the austenitic matrix (gamma) and to promote the formation of the gamma prime phase/crystal structure, which improves the high temperature strength of the alloy. Nickel can also promote the formation of a gamma double prime (eta) crystal structure (i.e., Ni3Nb), which also contributes to the high temperature strength of the alloy. Nickel can also form a brittle eta (eta) phase with titanium as Ni3Ti. Carefully balancing aluminum (Al), titanium (Ti), and niobium (Nb(Ta)) with nickel (Ni) will prevent the eta phase from forming.

In addition, it is believed that relatively low amounts and tight ranges for the carbon and the relatively high amount of Nb(Ta) (as compared to other known alloys) in the examples disclosed herein increase the gamma prime phase and the gamma double prime phase, and thus increase the strength of the alloy disclosed herein.

In some examples of the alloy, cobalt may also be substituted for at least some of the nickel. Cobalt can be substituted for nickel in the gamma phase (leading to improved creep strength), which allows more nickel to form the gamma prime phase.

Chromium may be present in the alloy in an amount ranging from 15.0 wt. % up to 17.0 wt. %. Chromium provides solid solution strengthening to the alloy matrix, and also forms a tenacious oxide for oxidation resistance. This tenaceous oxide is believed to be present at the surface of the alloy, which advantageously inhibits high temperature oxidation formation and minimizes corrosion and wear rates in addition to oxidation rates. Chromium present above 20 wt. % forms a sigma (sigma) or an alpha prime (alpha) phase, which may precipitate at exhaust service temperatures. This precipitation can hinder the wear resistance of the alloy, and thus chromium is present in an amount that is within the given range of 15.0 wt. % up to 17.0 wt. %.

Aluminum may be present in the alloy in an amount ranging from 1.60 wt. % up to 2.50 wt. %. The alloy may also contain smaller ranges of aluminum, examples of which range from 1.65 wt. % up to 2.30 wt. %, from 1.60 wt. % up to 2.20 wt. %, from 1.60 wt. % up to 2.00 wt. %, or from 1.60 wt. % up to 1.80 wt. %. Aluminum can be combined with nickel to precipitate the gamma prime phase, and thus may be considered the principle ingredient for the gamma prime crystal structure. In addition, aluminum provides some high temperature oxidation protection. It has been found that adding aluminum in amounts outside the range provided herein may be undesirable. For example, when aluminum is added in an amount below 1.60 wt. %, the gamma prime phase becomes unstable and can transform to the eta phase (Fe,Ni3)(Ti,Al) phase, which can degrade the alloy’s mechanical properties. Furthermore, adding aluminum in an amount above 3 wt. % may diminish the high workability of the alloy. In addition, gamma prime with a high level of aluminum has little lattice strain mismatch with the gamma matrix, and thus adds little strengthening capability. As such, it is desirable to include aluminum in the amounts given herein.

Titanium may be present in the alloy in an amount ranging from 1.60 wt. % up to 3.20 wt. %. The alloy may also contain smaller ranges of titanium, examples of which include from 2.40 wt. % up to 3.20 wt. %, from 2.20 wt. % up to 2.60 wt. %, from 1.90 wt. % up to 2.30 wt. %, or from 1.60 wt. % up to 1.80 wt. %. It is believed that the lattice strain mismatch of aluminum with the gamma matrix may be improved with the addition of titanium. Titanium also increases the anti-phase boundary energy of the gamma prime crystal structure. If titanium is present below 1.5 wt. %, the solution temperature of the gamma prime phase is believed to be too high. In addition, a titanium-to-aluminum ratio above 1.5 or a titanium content that is too high may cause the eta phase to develop precipitate at temperatures above 700°C. Conversely, if the titanium-to-aluminum ratio is below 1.0 the alloy has a sluggish age hardening response. As mentioned above, at least some of the titanium also combines with carbon to precipitate the primary carbides which contribute to wear resistance.

Niobium (i.e., Nb(Ta)) may be present in the alloy in an amount ranging from 2.10 wt. % up to 3.20 wt. %. The alloy may contain smaller ranges of Nb(Ta), examples of which include from 2.10 wt. % up to 2.40 wt. %, from 2.40 wt. % up to 2.80 wt. %, from 2.60 wt. % up to 3.00 wt. %, from 2.80 wt. % up to 3.20 wt. %, or from 2.90 wt. % up to 3.00 wt. %. In some instances, it may be desirable to utilize an even higher amount of Nb(Ta). As previously mentioned, niobium (when used in the amounts disclosed herein) promotes formation of the gamma prime phase and/or the gamma double prime phase. As mentioned above, both structures promote strength. Niobium is also attributed to increasing the coherency between gamma prime and gamma double prime crystal structures, limiting gamma prime grain coarsening, improving weldability, and improving sulfidation corrosion resistance. In addition to forming the gamma prime phase, niobium also forms primary carbides, which impart wear resistance.

In the examples disclosed herein, the alloy includes a minimum amount of the carbide forming elements of Nb(Ta) and Ti. The minimum amount may be desirable in order to react all of the carbon to form carbides, and to have enough Nb(Ta) and/or Ti to form the gamma prime phase and/or the gamma double prime phase. In one example, the total amount of niobium and titanium (i.e., Nb(Ta)+Ti) is greater than or equal to 4.40 wt. %. In another example, the amount of Nb(Ta) plus Ti is greater than or equal to 4.50 wt. %, and in still another example, the amount of Nb(Ta) plus Ti is greater than or equal to 4.60 wt. %.

The alloy may also include up to 0.50 wt. % copper. The alloy may also contain copper in smaller maximum amounts, examples of which include up to 0.35 wt. %, 0.25 wt. %, 0.15 wt. %, or even as low as 0.010 wt. %. Copper may be beneficial for sulfidation corrosion resistance. However, if too much copper is present, it can in some instances hinder high temperature oxidation protection. Some examples of the alloy also exclude copper.

The alloy may also include molybdenum, tungsten, and/or manganese. Up to 0.25 wt. % of each of molybdenum and tungsten may be present in the alloy. In some examples, the maximum amount of molybdenum may be up to 0.20 wt. %, 0.15 wt. %, 0.10 wt. %, or 0.010 wt. %. In some examples, the maximum amount of tungsten may be up to 0.15 wt. %, 0.10 wt. %, or 0.002 wt. %. In small amounts (whether intentionally added or included as inevitable impurities), both molybdenum and tungsten can provide solid solution strengthening to the alloy matrix and can provide resistance to
creep when the alloy is exposed to elevated temperatures. Up to 0.50 wt. % of manganese may be included in the alloy. Manganese provides solid solution strengthening to the matrix, and can also aid in deoxidizing the melt. Excessive amounts of any of these elements may be undesirable because they stabilize ferrite.

The ingots may be scarfed and subjected to forging and rolling to form a bar.

Some specific examples of the alloys disclosed herein are shown in Table 1. It is to be understood that all of the amounts are shown in wt. %.

<table>
<thead>
<tr>
<th>Element</th>
<th>Example 1</th>
<th>Example 2</th>
<th>Example 3</th>
<th>Example 4</th>
<th>Example 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.16-0.30</td>
<td>0.15-0.30</td>
<td>0.15-0.25</td>
<td>0.15-0.20</td>
<td>0.15-0.17</td>
</tr>
<tr>
<td>Mn</td>
<td>≤0.50</td>
<td>≤0.50</td>
<td>≤0.50</td>
<td>≤0.50</td>
<td>≤0.15</td>
</tr>
<tr>
<td>P</td>
<td>≤0.02</td>
<td>≤0.02</td>
<td>≤0.02</td>
<td>≤0.02</td>
<td>≤0.01</td>
</tr>
<tr>
<td>S</td>
<td>≤0.015</td>
<td>≤0.015</td>
<td>≤0.01</td>
<td>≤0.005</td>
<td>≤0.001</td>
</tr>
<tr>
<td>Si</td>
<td>≤0.50</td>
<td>≤0.50</td>
<td>≤0.50</td>
<td>≤0.50</td>
<td>≤0.10</td>
</tr>
<tr>
<td>Ni</td>
<td>30.25-34.50</td>
<td>31.0-35.0</td>
<td>32.0-35.0</td>
<td>33.0-35.0</td>
<td>34.0-35.0</td>
</tr>
<tr>
<td>Cr</td>
<td>15.0-17.0</td>
<td>15.0-17.0</td>
<td>15.0-17.0</td>
<td>15.0-17.0</td>
<td>15.0-17.0</td>
</tr>
<tr>
<td>Ti</td>
<td>2.40-2.80</td>
<td>2.20-2.60</td>
<td>1.90-2.30</td>
<td>1.60-2.00</td>
<td>1.60-1.80</td>
</tr>
<tr>
<td>Al</td>
<td>1.65-2.30</td>
<td>1.60-2.50</td>
<td>1.60-2.20</td>
<td>1.60-2.00</td>
<td>1.60-1.80</td>
</tr>
<tr>
<td>Nb(Ta)</td>
<td>2.10-2.50</td>
<td>2.40-2.80</td>
<td>2.60-3.00</td>
<td>2.80-3.20</td>
<td>2.90-3.20</td>
</tr>
<tr>
<td>Ti + Nb(Ta)</td>
<td>≥4.50</td>
<td>≥4.60</td>
<td>≥4.50</td>
<td>≥4.40</td>
<td>≥4.50</td>
</tr>
<tr>
<td>B</td>
<td>0.015</td>
<td>0.005-0.015</td>
<td>0.005-0.015</td>
<td>0.005-0.015</td>
<td>0.01-0.015</td>
</tr>
<tr>
<td>Mg</td>
<td>&gt;0.03</td>
<td>&gt;0.02</td>
<td>0.01-0.02</td>
<td>0.02-0.03</td>
<td>0.01-0.02</td>
</tr>
<tr>
<td>Cu</td>
<td>≤0.50</td>
<td>≤0.35</td>
<td>≤0.25</td>
<td>≤0.15</td>
<td>≤0.01</td>
</tr>
<tr>
<td>Mo</td>
<td>≤0.25</td>
<td>≤0.20</td>
<td>≤0.15</td>
<td>≤0.10</td>
<td>≤0.01</td>
</tr>
<tr>
<td>W</td>
<td>≤0.25</td>
<td>≤0.25</td>
<td>≤0.15</td>
<td>≤0.10</td>
<td>≤0.002</td>
</tr>
<tr>
<td>Ca</td>
<td>None</td>
<td>&gt;0.01</td>
<td>&gt;0.015</td>
<td>&gt;0.02</td>
<td>0.01-0.02</td>
</tr>
<tr>
<td>Fe</td>
<td>balance</td>
<td>balance</td>
<td>balance</td>
<td>balance</td>
<td>balance</td>
</tr>
</tbody>
</table>

Some examples of the alloy may include boron, zirconium, or a combination thereof. When included, each of these elements may be present in the alloy in an amount up to 0.015 wt. %. Boron, zirconium, or the combination thereof may be present in smaller ranges, such as from 0.005 wt. % up to 0.015 wt. %, or from 0.010 wt. % up to 0.015 wt. %. Boron and/or zirconium help strengthen grain boundaries and improve creep. In some instances, zirconium may be more desirable than boron, because it is believed that boron can be incorporated into the gamma prime phase. However, if either boron or zirconium is used in a higher amount, incipient melting may occur.

In some examples, non-metals may also be present in the alloy. As mentioned above, some of the non-metals are present as inevitable impurities. In an example, up to 0.01 wt. % or 0.02 wt. % phosphorus may be present in the alloy; up to 0.001 wt. %, 0.005 wt. %, or 0.010 wt. %, or 0.015 wt. % sulfur may be present in the alloy; and up to 0.10 wt. % of 0.50 wt. % silicon may be present in the alloy.

Some additional metals, such as hafnium, which have similar chemical properties as titanium, can be incorporated in the gamma prime crystal structure. When included, the amount is up to 0.2 wt. %.

In any of the examples disclosed herein, the balance of the alloy is iron, either alone or with incidental/inevitable impurities. The inevitable impurities may include those already discussed, as well as trace amounts of oxygen and nitrogen, as they may not be controlled.

The alloy disclosed herein can be prepared using conventional methods. The elemental materials may be melted by vacuum induction, air induction melting, arc melting or argon-oxygen decarburization, electroslag remelting (ESR), or combinations thereof. In an example, air melting techniques are utilized. The melted materials are then cast into ingots, which are then exposed to a soaking treatment.

It is to be understood that the ranges provided herein include the stated range and any value or sub-range within the stated range. For example, a range from about 2.10 wt. % up to 3.20 wt. % should be interpreted to include not only the explicitly recited limits of about 2.10 wt. % up to 3.20 wt. %, but also to include individual values, such as 2.25 wt. %, 2.5 wt. %, 3 wt. %, 3.1 wt. %, etc., and sub-ranges, such as from about 2.3 wt. % to about 3.1 wt. %, from 2.5 wt. % to about 2.9 wt. %, etc.

Reference throughout the specification to “one example”, “another example”, “an example”, and so forth, means that a particular element (e.g., feature, structure, and/or characteristic) described in connection with the example is included in at least one example described herein, and may or may not be present in other examples. In addition, it is to be understood that the described elements for any example may be combined in any suitable manner in the various examples unless the context clearly dictates otherwise.

In describing and claiming the examples disclosed herein, the singular forms “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise.

While several examples have been described in detail, it will be apparent to those skilled in the art that the disclosed examples may be modified. Therefore, the foregoing description is to be considered non-limiting.

What is claimed is:

1. A wear resistant alloy, consisting essentially of:
   from 0.15 wt. % up to 0.30 wt. % C;
   up to 0.50 wt. % Mn;
   up to 0.02 wt. % P;
   up to 0.015 wt. % S;
   up to 0.50 wt. % Si;
   from 30.25 wt. % up to 35 wt. % Ni;
   from 15.0 wt. % up to 17.0 wt. % Cr;
   from 1.60 wt. % up to 3.20 wt. % Ti;
   from 1.60 wt. % up to 2.50 wt. % Al;
   from 2.10 wt. % up to 3.20 wt. % Nb(Ta);
   up to 0.015 wt. % B;
Mg present in an amount up to 0.030 wt.%; up to 0.50 wt. % Cu; up to 0.25 wt. % of Mo; up to 0.25 wt. % of W; up to 0.020 wt. % Ca; and a balance being Fe and inevitable impurities;

wherein Ti+Nb(Ta) is 4.40 wt. %.

2. The alloy as defined in claim 1 wherein:
the C is present in an amount ranging from 0.16 wt. % up to 0.30 wt. %;
the Ni is present in an amount ranging from 30.25 wt. % up to 34.50 wt. %;
the Ti is present in an amount ranging from 2.40 wt. % up to 3.20 wt. %;
the Al is present in an amount ranging from 1.65 wt. % up to 2.30 wt. %;
the Nb(Ta) is present in an amount ranging from 2.10 wt. % up to 2.40 wt. %;
Ca is not present; and
Ti+Nb(Ta)=4.50 wt. %.

3. The alloy as defined in claim 1 wherein:
the Ni is present in an amount ranging from 31.0 wt. % up to 35.0 wt. %;
the Ti is present in an amount ranging from 2.20 wt. % up to 2.60 wt. %;
the Nb(Ta) is present in an amount ranging from 2.40 wt. % up to 2.80 wt. %;
the Mg is present in an amount up to 0.020 wt. %; the Cu is present in an amount up to 0.35 wt. %; the Mo is present in an amount up to 0.20 wt. %; the W is present in an amount up to 0.25 wt. %; the Ca is present in an amount up to 0.010 wt. %; and
the B is present in an amount ranging from 0.005 wt. % up to 0.015 wt. %; and
Ti+Nb(Ta)=4.60 wt. %.

4. The alloy as defined in claim 1 wherein:
the C is present in an amount ranging from 0.15 wt. % up to 0.25 wt. %;
the S is present in an amount up to 0.010 wt. %; the Ni is present in an amount ranging from 32.0 wt. % up to 35.0 wt. %;
the Ti is present in an amount ranging from 1.90 wt. % up to 2.30 wt. %;
the Al is present in an amount ranging from 1.60 wt. % up to 2.20 wt. %;
the Nb(Ta) is present in an amount ranging from 2.60 wt. % up to 3.00 wt. %;
the Mg is present in an amount ranging from 0.010 wt. % up to 0.020 wt. %; the Cu is present in an amount up to 0.25 wt. %; the Mo is present in an amount up to 0.15 wt. %; the W is present in an amount up to 0.15 wt. %; the B is present in an amount ranging from 0.005 wt. % up to 0.015 wt. %; and
the Ca is present in an amount up to 0.015 wt. %; and
Ti+Nb(Ta)=4.50 wt. %.

5. The alloy as defined in claim 1 wherein:
the C is present in an amount ranging from 0.15 wt. % up to 0.20 wt. %;
the S is present in an amount up to 0.005 wt. %; the Ni is present in an amount ranging from 33.0 wt. % up to 35.0 wt. %;
the Ti is present in an amount ranging from 1.60 wt. % up to 2.00 wt. %; the Al is present in an amount ranging from 1.60 wt. % up to 2.00 wt. %; the Nb(Ta) is present in an amount ranging from 2.80 wt. % up to 3.20 wt. %; the Mg is present in an amount ranging from 0.020 wt. % up to 0.030 wt. %; the Cu is present in an amount up to 0.15 wt. %; the Mo is present in an amount up to 0.10 wt. %; the W is present in an amount up to 0.10 wt. %; the Ca is present in an amount up to 0.020 wt. %; the B is present in an amount ranging from 0.005 wt. % up to 0.015 wt. %; and
Ti+Nb(Ta)=4.40 wt. %.

6. The alloy as defined in claim 1 wherein P, S, Mn, Si, Cu, W, and Mo are present as the inevitable impurities.

7. The alloy as defined in claim 1 wherein Zr is substituted for B and is present in an amount ranging from 0.005 wt. % to 0.015 wt. %.

8. The alloy as defined in claim 1 wherein Co is substituted for Ni.

9. The alloy as defined in claim 1 wherein:
the C is present in an amount ranging from 0.15 wt. % up to 0.17 wt. %; the Mn is present in an amount up to 0.15 wt. %; the P is present in an amount up to 0.01 wt. %; the S is present in an amount up to 0.001 wt. %; the Si is present in an amount up to 0.10 wt. %; the Ni is present in an amount ranging from 34.0 wt. % up to 35.0 wt. %; the Ti is present in an amount ranging from 1.60 wt. % up to 1.80 wt. %; the Al is present in an amount ranging from 1.60 wt. % up to 1.80 wt. %; the Nb(Ta) is present in an amount ranging from 2.90 wt. % up to 3.00 wt. %; the Mg is present in an amount ranging from 0.010 wt. % up to 0.020 wt. %; the Cu is present in an amount up to 0.010 wt. %; the Mo is present in an amount up to 0.010 wt. %; the W is present in an amount up to 0.002 wt. %; the Ca is present in an amount ranging from 0.010 wt. % up to 0.020 wt. %; the B is present in an amount ranging from 0.010 wt. % up to 0.015 wt. %; and
Ti+Nb(Ta)=4.50 wt. %.

10. The alloy as defined in claim 1 wherein:
the C is present in an amount ranging from 0.15 wt. % to about 0.17 wt. %; the Mn is present in an amount up to 0.15 wt. %; the P is present in an amount up to 0.01 wt. %; the S is present in an amount up to 0.001 wt. %; the Si is present in an amount up to 0.10 wt. %; the Ni is present in an amount ranging from 34.0 wt. % up to 35.0 wt. %; the Ti is present in an amount ranging from 1.60 wt. % up to 1.80 wt. %; the Al is present in an amount ranging from 1.60 wt. % up to 1.80 wt. %; the Nb(Ta) is present in an amount ranging from 2.90 wt. % up to 3.00 wt. %; the Mg is present in an amount up to 0.010 wt. %; the Cu is present in an amount up to 0.010 wt. %; the Mo is present in an amount up to 0.010 wt. %;
the W is present in an amount up to 0.002 wt. %;
the Ca is present in an amount up to 0.010 wt. %;
the B is present in an amount up to 0.015 wt. %; and
Ti+Nb(Ta) ≥ 4.50 wt. %.

11. The alloy as defined in claim 1 wherein primary carbides present in the alloy are randomly precipitated.