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# Fe-Cr-Ni ALLOYS

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This invention relates to alloys containing iron, nickel and chromium. The use of such alloys precipitation hardened by titanium for high temperature service is known and various proposals for the manufacture of such precipitation hardened alloys have been made, see for example, U. S. Patent No. 2,519,406.

In practice it is generally accepted that these alloys precipitation hardened by titanium require to have an exceedingly low carbon content, i. e. less than 0.05%, otherwise the desirable nickel-titanium precipitation hardening complexes are suppressed at the expense of relatively inert titanium carbide.

The basis of the present invention is the use of small percentages of niobium and/or tantalum in iron-nickel-chromium alloys precipitation hardened by titanium. One advantage of this is that, owing to the strong carbide-forming powers of niobium and/or tantalum, somewhat higher carbon contents may be used where necessary (for example, to facilitate melting) while maintaining satisfactory mechanical and creep strengths.

According to the present invention, alloys consist of the following constituents in the amounts by weight as stated in the following ranges:

| | Percent |
|---|---|
| Carbon | up to 0.15 |
| Nickel | 20–26 |
| Chromium | 11–15 |
| Cobalt | 0–2 |
| Niobium and/or Tantalum | 0.2–0.8 |
| Molybdenum | 2.3–3.3 |
| Titanium | 1.5–2.5 |
| Iron and impurities | Balance |

The usual deoxidisers, manganese, silicon, calcium, aluminum, etc. may be present but the total amount should not normally exceed 3%.

A more restricted range for carbon is 0.08%–0.15% and still further restricted range is 0.06%–0.13%. Alloys according to this invention may be solution treated in the temperature range 1,000° C. to 1,250° C. and age-hardened in the temperature range 600° C. to 700° C.

An example of an alloy which is designated by the reference L. 1107 according to this invention is:

| | Percent |
|---|---|
| Carbon | 0.07 |
| Silicon | 0.5 |
| Manganese | 0.7 |
| Nickel | 23 |
| Chromium | 13.5 |
| Cobalt | 1.0 |
| Molybdenum | 2.7 |
| Tantalum | 0.3 |
| Niobium | 0.2 |
| Titanium | 2.4 |
| Iron and impurities | Balance |



Such an alloy when solution treated at 1100° C., and suitably age-hardened in the temperature range 650–750° C. has the following properties:

| | | |
|---|---|---|
| 0.1% proof stress | tons/sq. in. | 44 |
| Maximum stress | do | 69 |
| Elongation | percent | 18 |
| Reduction of areas | do | 25 |

When tested at 28 tons/sq. in., at 600° C., and 16 tons/sq. in. at 700° C. this alloy had a life of 1577 hours and 543 hours respectively.

The following are examples of further alloys in accordance with this invention, the amounts being by weight percent:

| | Wex 603 | L. 1365 | L. 1366 |
|---|---|---|---|
| Carbon | 0.05 | 0.11 | 0.15 |
| Silicon | 0.64 | 0.20 | 0.73 |
| Manganese | 0.72 | 0.78 | 0.89 |
| Nickel | 23.3 | 25.2 | 25.4 |
| Chromium | 13.1 | 12.8 | 13.6 |
| Cobalt | | 0.88 | 0.52 |
| Molybdenum | 2.60 | 2.36 | 2.30 |
| Tantalum | 0.35 | 0.41 | 0.33 |
| Niobium | 0.49 | 0.49 | 0.46 |
| Titanium | 1.52 | 1.96 | 1.84 |
| Iron and Impurities | Balance | Balance | Balance |

These alloys, after being solution treated and age-hardened substantially as in the case of alloy L. 1107, were mechanically tested at room temperature and gave the following results:

| Alloy | 0.1% Proof Stress, Tons/sq. in. | Maximum Stress, Tons/sq. in. | Elongation, Percent |
|---|---|---|---|
| Wex 603 | 43.3 | 68.6 | 26 |
| L. 1365 | 46.5 | 74.0 | 16 |
| L. 1366 | 45.0 | 71.6 | 22 |

Stress-rupture tests have been carried out at 600° C. and 700° C. on these three alloys with the following results:

| Alloy | Rupture Time at 28 Tons/sq. in., 600° C., hours | Rupture Time at 16 Tons/sq. in., 700° C., hours |
|---|---|---|
| Wex 603 | 167 | 72 |
| L. 1365 | 115 | 74 |
| L. 1366 | 138 | 101 |

It will be seen from these results that in the presence of niobium and tantalum the high proof stress at room temperature and the high maximum stress is not diminished by the presence of carbon up to 0.15%. The same remarks apply to the rupture stress at 600 and 700° C.

It may be observed that the superior creep-rupture properties of the alloy L. 1107 are attributed to the higher titanium content of the alloy. Such a high titanium content is suitable where high creep strength is of importance but contents of the order of 1.8%–2% are preferred for easy manipulation where the room temperature proof strength is the more important property being sought. It will be noted that the figure of 44 tons per square inch for the 0.1% proof stress of alloy L. 1107 was no better than the corresponding values for alloys L. 1365 and L. 1366, i. e. alloys within a titanium range of 1.8–2%,

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is:

1. Alloys consisting of the following constituents in the amounts by weight as stated in the following ranges:

| | Percent |
|---|---|
| Carbon | 0.05–0.15 |
| Nickel | 20–26 |
| Chromium | 11–15 |
| Cobalt | 0–2 |
| At least one metal of the group consisting of niobium and tantalum | 0.2–0.8 |
| Molybdenum | 2.3–3.3 |
| Titanium | 1.5–2.5 |
| Iron and impurities | Balance |

2. Alloys as claimed in claim 1 in which the range of carbon is 0.08–0.15%.

3. Alloys as claimed in claim 1, in which the range of carbon is 0.06–0.13%.



4. Alloys as claimed in claim 1, in which the range of titanium is 1.8–2%.

5. Alloys as claimed in claim 1, in which the usual deoxidisers, manganese, silicon, calcium, aluminum are present in usual proportions.

6. Alloys as claimed in claim 5, in which the elements referred to are present in a total amount not exceeding 3%.

7. Alloys according to claim 1, which have been solution treated in the temperature range 1,000° C. to 1,250° C. and age-hardened in the temperature range 600° C. to 700° C.

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