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METHOD OF HEAT TREATING NICKEL BASE ALLOYS

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Fig. 1.

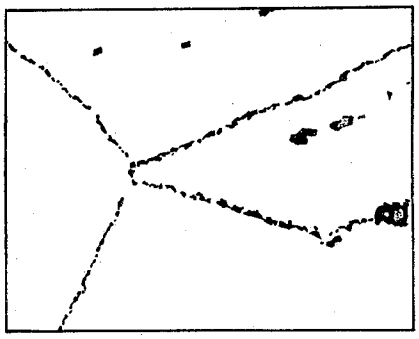
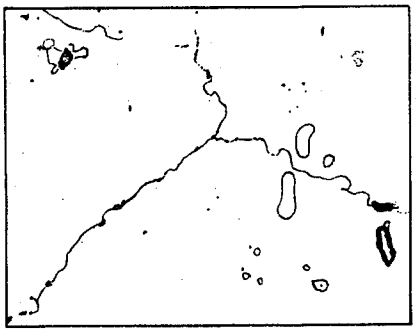


Fig. 2.



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3,146,136 METHOD OF HEAT TREATING NICKEL BASE ALLOYS

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This invention concerns a method of heat treating alloys which contain hardening elements, and, although it is not so restricted, is more particularly concerned with a method of heat treating highly alloyed nickel based alloys which are adapted for use under high stresses and at high temperatures.

Such alloys, which are employed, for example, in the manufacture of gas turbine engines, have previously been heat treated by a process comprising:

(*a*) Heating the alloy to a fixed high temperature for a given time. This part of the heat treatment is usually referred to as a "Solution Treatment," and its object is substantially or completely to dissolve and uniformly disperse the hardening elements in solid solution.

(*b*) Cooling the alloy to air temperature at a rate sufficiently rapid to retain the solid solution condition. A relatively fast rate of cooling is normally given, and this is effected by a water or oil quench or by air cooling from the solution treatment temperature. The alloy is metastable and soft when so cooled.

(*c*) Reheating the alloy to a temperature lower than the solution treatment temperature. This stage is generally known as "ageing" and effects hardening of the alloy by a precipitation process. The ageing may be effected at one or more fixed temperatures, dependent on the alloy, such temperatures being discoverable only by experiment and by physical and mechanical testing.

As the need for alloys which retain their strength at very high temperatures has increased, the percentage of hardening elements employed in the alloy to produce the required strength has also increased. While suitable high strength alloys have been found, the mechanical strength of the alloys has been obtained at the expense of ductility and particularly at the expense of their ability to withstand impact after long periods of operation at temperatures prevailing in service.

It has now been unexpectedly discovered that by giving such alloys a particular heat treatment, the strength required from the alloys can be maintained while ductility and reasonable impact properties can be substantially retained and stabilised so that operating conditions do not substantially lower these properties.

It was found that the brittleness of these alloys has mainly been due to the rejection, during ageing, of the excess precipitate or intermetallic compounds to the boundaries of the crystals of the alloy and the object of the present invention is to prevent or appreciably lessen this migration on ageing.

According to the present invention there is provided a method of heat treating an alloy which contains a substantial percentage by weight of hardening elements, said method comprising solution treating the alloy at a temperature and for a length of time such as to obtain a saturated solid solution, slowly cooling the alloy from the solution treatment temperature to a high temperature which is substantially less than that of the solution treatment temperature, cooling the alloy from the said high temperature to the temperature of the ambient air, and ageing the alloy by heating it to a temperature at which the alloy will be stabilised, the said slow cooling being effected at such a rate and to such a said high temperature that there is little or no migration of excess precipitate

or intermetallic compounds to the boundaries of the crystals of the alloy during the said ageing or stabilisation.

Preferably the solution treatment temperature is within the range 1150°–1220° C.

The said high temperature to which the alloy is slowly cooled may be within the range 800°–1110° C. and is preferably within the range 1090°–1100° C.

The alloy is preferably cooled from the solution treatment temperature to 1000° C. at the rate of substantially 0.5° C. to 5° C. per minute and preferably about 2° C. per minute. Preferably the alloy is swiftly cooled from the said high temperature but may be slowly cooled if desired.

The alloy may be aged by heating it to a temperature within the range 980° C.–1060° C. but preferably after the alloy has been heated to the solution temperature and has been cooled to about 1000° C. it is reheated to a temperature within the range 750°–930° C., preferably about 870° C.–900° C. Alternatively, the ageing may be omitted.

Preferably the alloy is a nickel based alloy, e.g. one falling within the following percentage composition by weight:

	Percent
Aluminium	0.1–9.0
Titanium	0.1–0.5
Cobalt	0–30
Chromium	5–30
Molybdenum	0–15
Tungsten	0–15
Niobium	0–7
Hafnium	0–8
Tantalum	0–5
Vanadium	0–6
Boron	0–0.3
Zirconium	0–1.2
Carbon	0.01–0.3
Manganese	0–1.0
Silicon	0–1.5
Iron	0–5.0
Beryllium	0–0.5
Nitrogen	0–0.15
Copper	0–0.9
Rare earths	0–0.2
Sulphur	0.01 max.
Phosphorus	0.02 max.
Calcium	0.08 max.
Magnesium	0.15 max.

the balance being nickel and impurities, but such that the nickel is at least 35%, the combined aluminium and titanium is at least 5%, and there is present over 1% molybdenum and/or other combined hardeners within the given limits.

Example I

An alloy, hereinafter called Alloy A, was prepared having the following percentage composition by weight:

	Percent
Chromium	15.0
Titanium	4.0
Aluminium	5.0
Cobalt	15.0
Manganese	0.06
Silicon	0.60
Molybdenum	4.0
Iron	0.65
Zirconium	0.20
Carbon	0.18
Boron	0.015
Sulphur	0.003

Nickel, remainder (including de-oxidizers and impurities).

This alloy was solution treated for 1½ hours at 1190° C. after which it was slowly cooled, at the rate of 2° C. per minute, from the said 1190° C. to 1000° C.

The alloy was then rapidly cooled in air, at the average rate of 50° C. per minute, to the temperature of the ambient air.

The alloy was then reheated to 890° C. and maintained at this temperature for 10 hours after which it was air cooled.

The most important period of the slow cooling is from the solution treatment to 1090° C. below which the rate of cooling may be increased if desired.

Example II

In order to illustrate the effect of the heat treatment according to the present invention, the same Alloy A was subjected to the normal heat treatment in which the alloy was rapidly air cooled right from the solution treatment temperature of 1190° C. down to ambient air temperature and given 10 hours ageing at 1050° C. and air cooled.

The results of the two heat treatments are indicated in the following table:

Heat treatment	As in Example I	As in Example II
Ultimate tensile strength, tons/sq. in. (at 20° C.)	78–80	69–70
Elongation percent	17–33	8–10
Impact, ft./lbs.[1]	80–130	10
Angle of bend (degrees) of standard bar after 4 hours at 980° C.	[2] 90	5
Creep life (hours) under 7 tons at 980° C.	100–170	100–180

[1] Employing Charpy un-notched round bar 0.283 inch diameter.
[2] Unbroken.

In the accompanying drawings, FIGURES 1 and 2 represent microphotographs of the Alloy A when prepared in accordance with Example II and Example I respectively.

As will be seen from FIGURE 1, the boundaries of the crystals are very clearly marked because excess precipitate and intermetallic compounds migrate to the boundaries. When the slow cooling step is included, however, it will be noted from FIGURE 2 that those boundaries are scarcely visible since there is little or no such migration of excess precipitate and intermetallic compounds to the boundaries.

We claim:

1. A method of heat treating an alloy having the following percentage composition by weight:

	Percent
Aluminium	0.1–9.0
Titanium	0.1–6.5
Cobalt	0–30
Chromium	5–30
Molybdenum	0–15
Tungsten	0–15
Niobium	0–7
Hafnium	0–8
Tantalum	0–5
Vanadium	0–6
Boron	0–0.3
Zirconium	0–1.2
Carbon	0.01–0.3
Manganese	0–1.0
Silicon	0–1.5
Iron	0–5.0
Beryllium	0–0.5
Nitrogen	0–0.15
Copper	0–0.9
Rare earths	0–0.2
Sulphur	0.01 max.
Phosphorus	0.02 max.
Calcium	0.08 max.
Magnesium	0.15 max.

the balance being nickel and impurities, but such that the nickel is at least 35%, the combined aluminium and titanium is at least 5%, and there is present over 1% of at least one member of the group consisting of molybdenum and other hardeners within the given limits, said method comprising solution heating the alloy at a temperature within the range 1150°–1220° C. and for a length of time such as to obtain a saturated solid solution, cooling the alloy at the rate of substantially 0.5° to 5° C. per minute from the solution treatment temperature to a high temperature within the range 800°–1110° C., and cooling the alloy from the said high temperature to the temperature of the ambient air.

2. A method of heat treating an alloy having the following percentage composition by weight:

	Percent
Aluminium	0.1–9.0
Titanium	0.1–6.5
Cobalt	0–30
Chromium	5–30
Molybdenum	0–15
Tungsten	0–15
Niobium	0–7
Hafnium	0–8
Tantalum	0–5
Vanadium	0–6
Boron	0–0.3
Zirconium	0–1.2
Carbon	0.01–0.3
Manganese	0–1.0
Silicon	0–1.5
Iron	0–5.0
Beryllium	0–0.5
Nitrogen	0–0.15
Copper	0–0.9
Rare earths	0–0.2
Sulphur	0.01 max.
Phosphorus	0.02 max.
Calcium	0.08 max.
Magnesium	0.15 max.

the balance being nickel and impurities, but such that the nickel is at least 35%, the combined aluminium and titanium is at least 5%, and there is present over 1% of at least one member of the group consisting of molybdenum and other hardeners within the given limits, said method comprising solution heating the alloy at a temperature within the range 1150°–1220° C. and for a length of time such as to obtain a saturated solid solution, cooling the alloy at the rate of substantially 0.5° C. to 5° C. per minute from the solution treatment temperature to a high temperature within the range 1090°C.–1100° C., and cooling the alloy from the said high temperature to the temperature of the ambient air.

3. A method as claimed in claim 1 in which said rate of cooling is substantially 2° C. per minute.

4. A method of heat treating an alloy having the following percentage composition by weight:

	Percent
Aluminium	0.1–9.0
Titanium	0.1–6.5
Cobalt	0–30
Chromium	5–30
Molybdenum	0–15
Tungsten	0–15
Niobium	0–7
Hafnium	0–8
Tantalum	0–5
Vanadium	0–6
Boron	0–0.3
Zirconium	0–1.2
Carbon	0.01–0.3
Manganese	0–1.0
Silicon	0–1.5
Iron	0–5.0
Beryllium	0–0.5
Nitrogen	0–0.15

	Percent
Copper	0–0.9
Rare earths	0–0.2
Sulphur	0.01 max.
Phosphorus	0.02 max.
Calcium	0.08 max.
Magnesium	0.15 max.

the balance being nickel and impurities, but such that the nickel is at least 35%, the combined aluminium and titanium is at least 5%, and there is present over 1% of at least one member of the group consisting of molybdenum and other hardeners within the given limits, said method comprising solution heating the alloy at a temperature within the range 1150°–1220° C. and for a length of time such as to obtain a saturated solid solution, cooling the alloy at the rate of substantially 0.5° C. to 5° C. per minute from the solution treatment temperature to a high temperature within the range 800°–1110° C., cooling the alloy from the said high temperature to the temperature of the ambient air, and ageing the alloy by heating it to a temperature within the range 750° C. to 930° C. at which the alloy will be stabilised, the said rate of cooling and the said high temperature being such that there is little migration of excess precipitate and intermetallic compounds to the boundaries of the crystals of the alloy during the said ageing and stabilisation.

5. A method as claimed in claim 4 in which the ageing temperature is within the range 870° C. to 900° C.

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