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METHOD OF CASTING AND HEAT TREATING NICKEL BASE ALLOYS

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This application is a continuation of application Serial No. 324,833, filed December 8, 1952.

This invention relates to treatments of certain cast nickel alloys so that they may be forged or otherwise worked by high temperature methods.

In particular, the invention is concerned with treating cast alloys having a composition, expressed in percent by weight, essentially as follows: carbon 0 to 0.35%, manganese 0 to 1%, silicon 0 to 1%, chromium 10 to 20%, molybdenum 2 to 24%, titanium 1 to 4%, aluminum 1 to 5%, iron 0.01 to 18%, boron 0.01 to 0.5%, and the balance nickel.

Alloys having compositions within the above described range heretofore have been readily cast but have exhibited poor forging characteristics, which, prior to my invention, have precluded forging or other hot working of these alloys in large scale operations. The poor forgeability of alloys of this type appears to be associated with the high-temperature strength of the alloy and a preferential melting of segregated complex intermetallic boride microconstituents, such as complex (Mo_2Cr, Ni) B, at a temperature considerably lower than the melting temperature in the predominant matrix phase. Such a preferential melting is conventionally referred to as "hot shortness." The specific influence which these complex intermetallic boride constituents play in forgeability is related to the necessary high forging temperature of 1900–2150° F. required for hot working alloys of very high hot strength. The heat generated by metal deformation during forging blows of the hammer can cause temperatures in the metal to instantaneously rise to or beyond the melting point of the complex intermetallic boride phase causing complete breakdown of the material. This breakdown is indicated by fractures in all directions while at the high temperature and during forging. Metal fragments have indicated selective or preferential melting as described above. The formation of these boride microconstituents is inherent to the complete solidification of the alloy from the molten state. This is indicated by the shape and distribution of the phases in the microstructure which indicate they are the last to freeze during solidification and are the first to melt when the alloy is reheated to a temperature above approximately 2300° F. A rapid cooling of such an alloy by quenching into water from the molten state will slightly reduce the amount of the intermetallic phase present within the general microstructure. On the other hand, a very slow rate of solidification produces a greater amount of the intermetallic phase. Slow cooling rates generally are properly representative of the solidification occurring in large cast ingots used in production forge shops. However, the cooling rate has but a negligible effect on the forgeability of the cast alloy, even in section thicknesses of one inch. Hence, a mere reduction in ingot size or the casting of ingots in the form of thin

slabs for use of the rolling of sheet stock will not produce practicably forgeable materials. Hence, up to the present time, alloys of the type contemplated herein have remained highly impracticable to forge or otherwise hot work.

Accordingly, it is the principal object of this invention to improve the forgeability of cast nickel base alloys of the type mentioned herein which contain boron as an essential alloying element. Other objects and advantages of the invention will appear more fully in the description which follows.

According to the present invention, the forgeability of cast nickel base alloys of the type described herein which contain boron as an essential alloying element may be greatly improved by a heat treatment which either completely diffuses the brittle microconstituents, existing in the alloy as cast, into the matrix or, in some cases, partially diffuses and breaks up the continuity of the intergranular network.

The practice of my invention involves soaking a cast nickel base alloy of the type mentioned herein at an elevated temperature for a period of time sufficient to render the alloy forgeable. Superior results are obtained if the soaking or heat treatment is conducted at a temperature within the range of approximately 1900° F. to 2300° F. If a temperature substantially above 2300° F. is employed initially, certain difficulties in forging are encountered because of the melting of the segregated microconstituents. However, in certain cases, after the diffusion of the microconstituents has begun, the soaking temperature may be increased without causing a melting of the microconstituents. If soaking temperatures substantially below 1900° F. are employed, an excessive length of time is required for the heat treatment.

Generally speaking, the cast nickel base alloy should be soaked at a temperature within the above-mentioned temperature range for a time equal to at least one hour per inch of cross section of the cast nickel base alloy. I have found that in most instances when the soaking time exceeds about 100 hours, no further improvement in the forgeability of the alloy is obtained. In practice, very beneficial results are obtained by soaking a cast nickel base alloy of the type described herein at an elevated temperature for a time within the range of 8 to 64 hours. At present the preferred heat treatment involves soaking the alloy for about 12 to 24 hours at a temperature within the range of approximately 1900° F. to 2300° F. In a typical heat treatment, the alloy is maintained at 2150° F. for 16 hours.

The heat treatment of the present invention preferably is employed to render forgeable a cast nickel base alloy having a composition, expressed in weight percent, within the following composition range:

Carbon	0.00– 0.25
Manganese	0.25– 1.00
Silicon	0.75– 1.00
Chromium	13.00–17.00
Molybdenum	4.00– 6.00
Titanium	1.50– 3.00
Aluminum	1.00– 4.00
Boron	0.01– 0.10
Iron	8.00–12.00
Nickel	Balance

Illustrative of specific cast nickel alloys which may be rendered forgeable by the present process are the following where the several ingredients are expressed in percent by weight:

Example I

Carbon	0.10
Manganese	0.10 max.
Silicon	0.52
Chromium	15.20
Molybdenum	4.95
Titanium	1.93
Aluminum	2.14
Boron	0.015
Iron	13.70
Nickel	Balance

Example II

Carbon	0.18
Manganese	0.07
Silicon	0.29
Chromium	15.20
Molybdenum	5.07
Iron	9.20
Aluminum	2.39
Titanium	1.86
Boron	0.046
Nickel	Balance

Example III

Carbon	0.10
Manganese	0.01 max.
Silicon	0.31
Chromium	15.20
Molybdenum	4.71
Iron	9.81
Aluminum	2.68
Titanium	2.47
Boron	0.036
Nickel	Balance

Example IV

Carbon	0.11
Manganese	0.03
Silicon	0.14
Chromium	15.50
Molybdenum	5.91
Iron	9.90
Aluminum	3.16
Titanium	2.28
Boron	0.017
Nickel	Balance

Cast nickel alloys having compositions as shown in the foregoing examples, when soaked at a temperature within the range of approximately 1900° F. to 2300° F. for varying times sufficient to cause diffusion of the brittle intergranular network into the matrix phase, were readily forged.

Nickel base alloys of the type contemplated herein generally are cast at temperatures within the range of approximately 2700° F. to 3200° F. In most instances, superior castings are obtained if the alloy is cast at a temperature within the range of approximately 2750° F. to 3000° F.

In carrying out the method of the present invention, the nickel base alloy is cast and the resulting ingots preferably are allowed to cool to permit inspection and scarfing.

The ingots are then heated to a temperature within the range of approximately 1900° F. to 2300° F. and are maintained at a temperature within this range for the desired length of time to cause diffusion of the brittle microconstituents.

The cast alloy ingots need not be allowed to completely cool before heat treatment; if desired, the ingots may be allowed to cool from the casting temperature to a temperature within the desired soaking temperature range and thereafter maintained at a temperature within this range to produce the forgeable structure.

Following the heat treatment, the cast nickel alloy may be allowed to cool before it is forged or, if desired, it may be forged or otherwise hot worked directly from the heat treatment with no intermediate cooling. The alloy may be forged or hot worked with any conventional forging equipment. In most cases, superior results are obtained if the cast nickel alloy is forged or hot worked at a temperature within the range of approximately 1900° F. to 2300° F.

The alloys employed in the practice of the present invention are singularly adaptable for use in applications which not only require a high corrosion and oxidation resistance but a high strength and dimensional stability as well.

Various changes and modifications of the embodiments of the invention described herein may be made by those skilled in the art without departing from the spirit and principles of the invention.

I claim:

1. A method which comprises the steps of casting an alloy consisting essentially of 0 to .35% carbon, 0 to 1.00% manganese, 0 to 1.00% silicon, 10 to 20% chromium, 2 to 24% molybdenum, 1 to 4% titanium, 1 to 5% aluminum, 0.01 to 18% iron, 0.01 to 0.50% boron, and the balance nickel and, after said cast nickel alloy has solidified, heating said cast nickel alloy to a temperature within the range of approximately 1900° F. to 2300° F. for a time of at least one hour per inch of cross-section of said cast nickel alloy to improve the hot working characteristics of said cast nickel alloy.

2. A method which comprises the steps of casting an alloy consisting essentially of 0 to 0.25% carbon, 0 to 1.00% manganese, 0 to 1.00% silicon, 13 to 17% chromium, 4 to 6% molybdenum, 1.50 to 3.00% titanium, 1 to 4% aluminum, 8 to 12% iron, 0.01 to 0.10% boron, and the balance nickel and, after said cast nickel alloy has solidified, heating said cast nickel alloy to a temperature within the range of approximately 1900° F. to 2300° F. for a time of at least one hour per inch of cross-section of said cast nickel alloy to improve the hot working characteristics of said cast nickel alloy.

References Cited in the file of this patent

UNITED STATES PATENTS

2,570,193	Bieber et al.	Oct. 9, 1951
2,688,536	Callaway et al.	Sept. 7, 1954
2,712,498	Gresham et al.	July 5, 1955

FOREIGN PATENTS

583,841	Great Britain	Jan. 1, 1947