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3,189,446

TERNARY NICKEL BASE ALLOYS

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No Drawing. Filed Dec. 31, 1956, Ser. No. 631,978
3 Claims. (Cl. 75-171)

This invention relates to new nickel base alloys and more particularly to ternary nickel, chromium, and rare earth metal alloys which contain from 5 to 25 weight percent of samarium, europium, or gadolinium, the remainder of the alloy consisting of 80 parts by weight of nickel and 20 parts by weight of chromium. These alloys are useful for the manufacture of control rods to be employed in neutronic reactors.

Previous to this invention control rods for neutronic reactors have been made from cadmium or from boron or boron compounds. Cadmium control rods cannot be used if the reactor is to be operated at a temperature above the relatively low melting point of cadmium. Boron control rods suffer from the disadvantage that when neutrons are captured by the boron, alpha particles are emitted, and these alpha particles because of their short relaxation length dissipate energy locally in the form of heat. This causes the boron control rods to become excessively hot.

This invention has as an object to provide oxidation resistant alloys that can be utilized in the manufacture of control rods for neutronic reactors. A further object is to provide alloys from which control rods can be fabricated which will not melt when the reactor is operated at moderately high temperatures. A still further object is to provide a material from which control rods can be made which will not become excessively hot due to the local generation of heat caused by neutron capture. Other objects will appear hereinafter.

These objects are accomplished by the following invention in accordance with which new oxidation resistant ternary nickel base alloys are prepared which consist of nickel, chromium, and a rare earth metal selected from the group consisting of samarium, europium, and gadolinium, the amount of nickel in said alloys being four times the weight of chromium and the amount of rare earth metal in said alloys constituting from 5 to 25 percent of the weight thereof.

The nickel-chromium-samarium alloys will be discussed first.

The use of samarium as a neutron absorber is desirable because in addition to having a very high thermal neutron cross-section, it produces little local heat upon neutron capture. The n -gamma reaction resulting from neutron capture by samarium does not result in the type of localized heating which characterizes the capture of neutrons by boron control elements. In addition, these Ni-Cr-Sm alloys are superior to cadmium because of their higher melting points.

The Ni-Cr-Sm alloys which were studied in detail contained 4 parts by weight of nickel, 1 part by weight of chromium, and enough added samarium to constitute 5, 10, and 15 weight percent of the alloy. Each of these alloys was arc melted in the form of a button. Each alloy was melted four times in a tungsten arc furnace using helium as a protective atmosphere. Each homogenized button was then cut up into small test specimens for metallurgical and analytical evaluations and cross-section analysis.

Each sample was given a 100 hour oxidation resistance test at 2200° F. The depth of oxide penetration was measured, and this penetration was found to be approximately 0.015 inch. In all cases the oxidation was found

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to be quite uniform, and variation in samarium content over the range studied did not appreciably affect the oxidation resistance of the alloys.

It was found that these alloys were workable at 2200° F., although in the case of alloys containing more than 10% of samarium special procedures had to be used. Room temperature hardness for the 5% samarium alloy was found to be 54-55 Rockwell A; for the 10% samarium alloy it was found to be 61-62 Rockwell A.

Substitution of europium for samarium in these alloys results in a series of alloys having similar metallurgical properties.

The Ni-Cr-Gd alloys will now be discussed.

Gadolinium as a neutron absorber is desirable because in addition to having a high thermal neutron cross section, little local heat is produced upon neutron capture. Gadolinium, which gives off gamma rays after capture of neutrons, dissipates the heat thereby generated in some other portion of the reactor beside the control element, which is in contrast to the behavior of boron control elements.

The Ni-Cr-Gd alloys which were studied in detail contained 4 parts by weight of nickel, 1 part by weight of chromium, and enough added gadolinium to constitute 5, 10, 15, 20, and 25 weight percent of the alloy. Each of these alloys was arc melted in the form of a button. Each alloy was melted several times in an arc furnace using helium as a protective atmosphere. Each homogenized button was then cut up into small test specimens for metallurgical and analytical evaluations and cross-section analysis.

These alloys were extensively scrutinized by metallographic examination and by X-ray diffraction studies. The diffraction results indicated that the alloys contained a primary Ni-Cr solid solution together with Ni₅Gd intermetallic compound. The microstructure of the 5% gadolinium alloy showed the primary grains of Ni-Cr to be surrounded by Ni₅Gd intermetallic phase. As the percentage of the gadolinium increased up to 15%, the primary grain structure decreased with a concomitant increase in the intermetallic Ni₅Gd phase. The microstructure of the 25% gadolinium alloy showed that it was practically all Ni₅Gd intermetallic phase. This alloy was so brittle that no accurate hardness could be determined with a Rockwell hardness tester.

Samples of the various gadolinium alloys were given a 100 hour static oxidation test at 2200° F., after which each sample was examined metallographically to determine the amount of oxidation. The average depth of heavy oxidation for the 10% gadolinium alloy was found to be only 0.007 inch. In all cases evaluations revealed that the oxidation was quite uniform. Measuring the depth of oxide penetration on all alloys showed that increase or decrease in the gadolinium content did not affect the oxidation resistance of the alloy.

It was found that the 5% gadolinium alloy was workable at 2050° F., and that the 10% gadolinium alloy could be worked at temperatures as low as 2000° F. without cracking. Workability studies indicated that alloys containing 15% or more of gadolinium could not be fabricated into form without developing surface cracks because of brittleness.

These newly developed Ni-Cr-Gd alloys have superior neutron absorption characteristics and are capable of operating at temperatures as high as 2200° F. without suffering adverse effects due to oxidation.

Because of fabrication difficulties in shaping control elements out of alloys containing 15% or more of samarium or gadolinium, the preferred alloys of this invention contain from 5% to 10% of samarium or gadolinium.

Resort may be had to such modifications and variations

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as fall within the spirit of the invention and the scope of the appended claims.

We claim:

1. An oxidation resistant ternary nickel base alloy which consists of nickel, chromium, and a rare earth metal selected from the group consisting of samarium, europium, and gadolinium, the weight ratio of nickel to chromium in said alloy being 4:1, and the amount of rare earth metal in said alloy constituting from 5 to 25 percent of the weight thereof.

2. A ternary nickel-chromium-samarium alloy in which the weight ratio of nickel to chromium is 4:1 and the amount of samarium in said alloy constitutes from 5 to 10 percent of the weight thereof.

3. An oxidation resistant ternary nickel-chromium-gadolinium alloy in which the weight ratio of nickel to chromium is 4:1 and the amount of gadolinium in said alloy constitutes from 5 to 10 percent of the weight thereof.

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