Patented Feb. 17, 1953

2,628,900

UNITED STATES PATENT OFFICE

2,628,900

NI-CR-MN ALLOYS

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No Drawing. Application November 29, 1949, Serial No. 130,066

6 Claims. (Cl. 75—171)

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This invention relates to electrical resistor alloys and more particularly to alloys wherein high electrical resistivity properties are combined with good physical properties.

It is, therefore, an object of this invention to provide an alloy for preparing electrical resistors, said alloy having special electrical properties such as high electrical resistivity, low thermal E. M. F. against copper, and a low temperature coefficient of electrical resistivity, together with good physical properties such as high tensile strength and good workability.

Further objects and advantages of the present invention will be apparent in view of the following detailed disclosure and description thereof.

In general, this invention relates to Ni-Cr-Mn alloys for electrical resistors and to methods of producing such alloys.

It has been found that alloys having compositions defined by the ranges 50% to 70% Ni, 8% to 28% Cr, and 15% to 36% Mn possess all the required and previously enumerated desirable properties of electrical resistor alloys. Preferred compositions in the range 55% to 65% Ni, 8% to 20% Cr, and 25% to 33% Mn possess these properties to a marked degree. An example of an alloy in this preferred range, and possessing the enumerated properties, is one containing 54.35% Ni, 18.1% Cr, and 27.2% Mn.

After the alloys of the present invention have been melted and poured into ingots they are usually hot-forged and then hot-rolled to a nominal size, and then wire-drawn. It has been found, as a part of this invention, that the electrical resistivity of wire so produced may be greatly improved by subjecting it to a heat treatment consisting of a solution treatment followed by an aging treatment at from about 600° F. to about 1200° F. for a period of from ¼ to 100 hours. Results of this treatment show that preferred aging temperatures are from about 850° F. to about 950° F. for a period of from 1 to 5 hours. The treatment above described produces an alloy of increased electrical resistivity with only a slight, acceptable embrittlement and a small, immaterial loss in ductility. In the aging treatment, the exact holding time will, of course, vary with the alloy composition, but preferred holding times can readily be determined experimentally for a particular alloy by preparing a plot of electrical resistivity as a function of time at holding temperature. When this is done, it will be found that as the holding time is increased the rate of increase in electrical resistivity becomes less, and the curve tends to flatten out.

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By selecting an aging time early in this flattening-off section one can obtain a ductile wire having an electrical resistivity only slightly lower than the maximum obtainable. Prolonged aging times would obviously produce slightly higher electrical resistivity values, but would also bring about undesirable embrittlement.

The solution treatment of the Ni-Cr-Mn alloys may be carried out at temperatures in the 1500° F. to 2100° F. range, with preferred temperatures in the 1700° F. to 2100° F. range. As the temperature of solution treatment is increased from 1500° F. to 2100° F' the time required is reduced from about 100 hours to about 2 seconds where the wire is small and where it has undergone some previous working and where annealing is used. Solution-treating time must be increased if material is treated in cast form, or if the material has been previously aged to cause excessive precipitation. It is necessary that the solution treatment be followed by reasonably rapid cooling. Air cooling is sufficient for fine wire although water quenching is preferred for wire of ⅛-inch diameter or larger. These times may be sharply reduced to a few seconds by solution-treating the wire before making a few final light wire-drawing passes and then repeating the solution-treatment.

A particular type of solution-treatment, designated as strand-annealing, is especially effective as a preliminary step in the treatment of resistor alloys to improve their resistivity properties. This strand-annealing step consists of passing the alloy through a long furnace after the alloy has been drawn to a fine wire size. This is done, preferably, by passing the wire through the furnace at such a rate that it is in the heating zone from 2 seconds to 4 minutes, while the furnace is maintained at a temperature of from about 1700° F. to about 2100° F. The rate and temperature depend on the wire size; the larger the wire diameter the slower the rate and the higher the temperature. After the strand-annealing step, the aging treatment must, of course, be carried out.

A composition in the preferred range and containing 60% Ni, 10% Cr, and 30% Mn has an electrical resistivity of about 876 ohms/mil foot as drawn and solution-treated at 1800° F. Upon aging for about 3 hours at 900° F., the electrical resistivity of this alloy has been increased to 1052 ohms/mil foot.

To further illustrate the alloys of this invention and the method of preparing them, the following detailed descriptions are presented by way of example, it being understood that the invention is not to be considered as limited thereby.

Example I

A magnesia-lined induction furnace was used in melting down 4.2 pounds of nickel and 0.022 pound of NiO, the NiO being added to reduce the hydrogen content of the melt. When the nickel was molten, 2.1 pounds of electrolytic manganese was added. Before being added to the melt, the electrolytic manganese was treated to remove hydrogen, by being heated to about 1000° F. and then cooled slowly in a heat-treating furnace. 0.72 pound of chromium metal of the fused-chromium type containing less than 0.06% carbon and less than 1% iron was added. The heat was completely molten at 2610° F. at which time 0.042 pound of CaSi and 0.011 pound of Si metal were added. 0.01 pound of aluminum was then added and the heat was poured at 2810° F. into a 5-pound ingot mold and into a small bar mold which gave bars of 1/4'' and 1/2'' diameter. These small bars were cleaned up and swaged at 1800° F. to 0.125'' diameter without difficulty. The 5-pound ingot was forged at 1825° F. to 1 1/8'' square. The 1 1/8'' square stock was hot-rolled at 1800° F. to 1/4'' diameter. The swaged and the hot-rolled material was wire-drawn to 0.070'' diameter. In the 0.070'' diameter size as solution treated for 1 1/4 hours at 1800° F. the electrical resistivity was 869 ohms/mil foot. This was increased to 960 ohms/mil foot by aging for 48 hours at 700° F. A 72-hour aging at 700° F. produced an electrical resistivity of 990 ohms/mil foot and a 96-hour aging at 700° F. increased the resistivity value to 1007 ohms/mil foot. The electrical resistivity of this alloy wiredrawn, and in the solution-treated state, has been increased from 876 ohms/mil foot to as much as 1052 ohms/mil foot by aging at 900° F. for three hours. The alloy composition was about 60% Ni, 10% Cr, and 30% Mn.

Example 2

This alloy had an intended composition of 54.35% Ni, 18.1% Cr, 27.2% Mn, and 0.35% Si, and was prepared by first melting 4.2 pounds of electrolytic nickel and 0.022 pounds of NiO in a magnesia-lined induction furnace. As soon as this material was melted, 2.1 pounds of electrolytic manganese, previously annealed to remove hydrogen, was added. 1.4 pounds of fused-chromium metal was added, and, when the melt was completely fluid, 0.042 pound of CaSi and 0.011 pound of silicon metal were stirred into the melt. At this time the temperature of the melt was 2620° F. When the melt had been heated to 2710° F., 0.010 pound of aluminum wire was plunged into the melt, and the melt poured immediately. The processing of this heat was exactly the same as has been described in connection with Example I. The electrical resistivity after a solution-treatment at 1800° F. for 1 1/4 hours was 863 ohms/mil foot. This value was increased as follows by aging:

(*a*) After aging for 48 hours at 700° F.—885 ohms/mil foot.

(*b*) After aging for 72 hours at 700° F.—889 ohms/mil foot.

(*c*) After aging for 96 hours at 700° F.—893 ohms/mil foot.

The above examples illustrate the effect of the solution treatment followed by aging in improving the resistivity values of the alloys of this invention.

Temperature coefficients of resistivity for these Ni-Cr-Mn alloys have been measured and, in general, values in the range from −.000030 to +.000020 have been obtained. It seems reasonably certain that a value of +.00004 may be set as the maximum for the temperature coefficient of resistivity of these Ni-Cr-Mn alloys.

Small amounts of incidental elements will not prove detrimental to the beneficial results to be obtained in accordance with the present invention. For example, small amounts of iron or carbon may be present, while aluminum and silicon in contents up to 0.5% have been shown not to be detrimental.

In view of the above disclosure and description, it will now be apparent that new alloys for, and methods of preparing electrical resistor elements have been discovered, wherefore the novel features are hereinafter set forth in the attached claims.

What is claimed is:

1. An alloy for electrical resistor elements consisting of 50% to 70% Ni, 8% to 28% Cr, and the balance essentially all Mn, said Mn constituting 15% to 36% of the alloy, the resistivity properties of said alloy having been improved by solution treatment at 1500° F. to 2100° F. for from about 2 seconds to about 100 hours followed by an aging treatment at a temperature of from 600° F. to 1200° F. for a period of from 1/4 to 100 hours.

2. An alloy for electrical resistor elements consisting essentially of about 54.35% Ni, about 18.1% Cr, and about 27.2% Mn and which has been solution treated at 1700° F. to 2100° F. for from about 2 seconds to about 100 hours followed by an aging treatment at a temperature of from 850° F. to 950° F. for a period of from 1 to 5 hours.

3. An alloy for electrical resistor elements consisting of 50% to 70% Ni, 8% to 28% Cr, and the balance essentially all Mn, said Mn constituting 15% to 36% of the alloy, said alloy having been treated to improve its resistivity properties by a strand anneal at a temperature in the range 1700° F. to 2100° F. and at a rate such that the wire is in the heating zone for from 2 seconds to 4 minutes, followed by an aging treatment at about 850° F. to 950° F. for a period of from 1 to 5 hours.

4. An alloy for electrical resistor elements consisting essentially of about 54.35% Ni, about 18.1% Cr, and about 27.2% Mn and which has been treated to improve its resistivity properties by a strand anneal at a temperature in the range 1700° F. to 2100° F. and at a rate such that the wire is in the heating zone for from 2 seconds to 4 minutes, followed by an aging treatment at about 850° to 950° F. for a period of from 1 to 5 hours.

5. An electrical resistance alloy composed of 50% to 70% by weight nickel, 8% to 28% by weight chromium, and the balance essentially all manganese, said manganese constituting from 15% to 36% by weight of the alloy.

6. An electrical resistance alloy composed of 55% to 65% by weight nickel, 8% to 20% by weight chromium, and the balance essentially all manganese, said manganese constituting from 25% to 33% by weight of the alloy.

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