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ALLOY

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1 Claim. (Cl. 75-171)

This invention relates to electrical resistance alloys particularly adapted for use at elevated temperatures.

One of the principal objects of the invention is to improve the capacity of such alloys for being hot and cold worked by such operations as forging, hot and cold rolling, drawing, pressing or other fabricating processes.

It is yet another object of the invention to reduce the wastage heretofore experienced in the fabricating of such alloys into wires, shapes, forms, etc.

As is well understood in the art, resistance alloys, consisting basically of nickel-chromium or nickel-chromium-iron, are conventionally employed where service conditions necessitate performance of the resistance material at elevated temperatures. These basic compositions of themselves are susceptible to mechanical failure in service which may be attributed to a large extent to the crystalline or grain structure of the material.

Because of the high affinity of chromium towards oxygen, nitrogen and carbon, and due to the high melting temperatures necessarily employed in the melting operation, the molten product is considerably contaminated during its manufacture. The resulting oxides, nitrides, carbides, etc., accumulate at the grain boundaries upon solidification, thereby producing an alloy which lacks uniformity in its thermo-expansive characteristics. As a result, the material tends to further oxidize along the grain boundaries when subjected to elevated temperatures.

By the addition of such elements as silicon, aluminum, calcium, magnesium, beryllium, zirconium, etc., the susceptibility of the produce to oxidation at elevated temperatures is appreciably lowered and, furthermore, these latter constituents function as cleansing agents to remove the non-metallic impurities introduced either during melting or which result from the use of relatively impure commercial chromium.

Such alloys are disclosed in the United States patents to Hunter, No. 2,005,423, and Lohr, Nos. 2,019,687, 2,019,688, 2,005,431, 2,051,562, 2,047,916, 2,047,917, 2,047,918, 2,005,430, 2,005,433 and 2,020,686.

Although the addition of such substances as silicon, aluminum, calcium, zirconium, etc., pro-

long the life of the product under service conditions, their presence in sufficient proportions to insure this result measurably detracts from the hot workability of the product during the fabricating operations.

I have found that the addition of a relatively small amount of boron to a nickel-chromium or to a nickel-chromium-iron alloy of the above character greatly improves the malleable characteristics of the product without adversely affecting other desirable properties.

Both slugs and ingots containing varying proportions of boron were cast and tested exhaustively to provide a wide range of data and corresponding accuracy of results. Furthermore, with a view to obtaining slugs which were truly representative of the composition of the ingots, the metal from which the slugs were formed was taken from the stream of liquid metal when the corresponding ingot mold was about half filled.

The test slug, like the ingot, is formed in a cast-iron slug mold and is approximately 2 inches square on the base, 4 inches in height and $1\frac{1}{4}$ inches square on the top surface so as to form, in effect, a truncated pyramid.

Both the ingot and slug were raised to temperatures of approximately 2200° Fahrenheit and forged under a steam hammer. The slug was subjected to a few hard blows of the hammer, as a result of which its height was reduced from 4 inches to $\frac{3}{4}$ inch, the mass of the metal being caused to define a flat cylindrical section. It will be apparent to those skilled in the art that the condition of the peripheral edge of this hammered cylindrical body will be dependent upon the hot workability or forgeability of the product. Thus, an alloy of poor forgeability will show cracks of varying depth and number in its circumferential edge, whereas an ideal product will be smooth and entirely free from cracks.

I have evaluated the results obtained in the above mentioned tests upon a number of nickel-chromium slugs containing manganese-boron by ascribing the letter "A" to those samples which produced perfect results; "B" to those which resulted in fair products; "C" for very poor products and "D" to indicate no forgeable characteristics. More particularly, only those samples, the circumference of which were completely smooth and free from cracks, were identified by

the mark "A" and only those having a few small cracks developed during the later stage of the upsetting were characterized by the letter "B." Those samples which showed a great number of cracks of medium depth were identified by the letter "C," and in those instances in which the entire circumference of the test piece was covered with very deep vertical cracks which started to form with the first blow of the hammer, the letter "D" is the index of the result.

Manganese-boron addition	Forgeability, sample slug
Grams	
No	C-
10	C
20	A
30	A
40	A
50	A
60	B
70	C

Now coming to the tests conducted upon the ingots: Whereas it is ordinary foundry practice to scrape or machine the surfaces of ingots whose corresponding sample slugs show forgeability corresponding with my "C" or "D" categories, all ingots of the boron-treated series herein described were not forged without resorting to scraping with a view to obtaining critical data concerning the effect of the varying additions of boron to the ingots.

After raising the temperature of the ingots to 2200° Fahrenheit, they were placed under a steam hammer to billets of 1½ x 1½ cross sectional area. Predicated upon the number, size and character of cracks appearing in the billets, the scale of forgeability indices which were used to characterize the workability of the slugs were again applied.

The result of these tests was as follows:

Manganese-boron addition	Forgeability, ingot
Grams	
No	C-
10	C
20	B
30	A
40	A
50	A
60	A
70	D

Now by collating the test results of both slugs and ingots, it will be seen that the degree of forgeability of the two corresponds very closely with the percentage of boron employed.

It will be observed that the above series of tests are in substantial qualitative agreement and such deviations as occurred may doubtless be ascribed to the faster rate of forging of the slugs as compared with the ingots.

Manganese-boron addition	Forgeability	
	Sample slug	Ingot
Grams		
No	C-	C-
10	C	C
20	A	B
30	A	A
40	A	A
50	A	A
60	B	A
70	C-	D

In addition to its property of improving the hot working characteristics of the alloy, the boron constituent serves additionally to materially increase the yield of usable material. The "yield" of usable material is predicated upon the percentage or weight of good stock obtained, to the original weight of the ingots as cast or produced in the foundry. In ordinary practice the ingot is poured with a so-called "hot-top," which refers to a ceramic, or metal form, inserted in the top of the ingot through which the hot metal is poured and which functions as a reservoir of hot metal to allow the production of a full ingot when shrinkage occurs during the solidifying action. After cooling, the "hot-top," which is a necessary and unavoidable loss, is removed, and the surface of the ingot is machined to remove scale and impurities and to provide a clear surface, free of cracks. The decapitated and machined ingot is then reheated and partially converted or formed into a billet which, in turn, is allowed to cool before imperfections, such as seams, cracks or imbedded material are either chipped or ground out of its surface. After this second operation to remove waste material, the billets are reheated and then fabricated into rods and the "yields," above referred to, is the ratio of the weight of good stock in the rods to the original weight of all of the ingots in their first form as cast in the foundry.

While the losses entailed in the skimming of the ingot, removing of "hot-tops" and surfacing of billets are considered to be necessary and unavoidable in their nature, their relative amount is decidedly reduced by the addition of boron.

Furthermore, the minute temperature control formerly necessary to prevent cracking or fracturing in the surfaces of the ingot or billet during the rolling operation to effect change of shape, is eliminated by the presence of boron. Not only does the boron constituent permit of the employment of greater latitude of rolling temperatures, but a relatively higher yield of good stock is obtained at the same time.

To indicate the effect of boron upon "yield," 100 ingots of 100 pounds each were made under identical conditions and from the same nickel-chromium base constituents. To one group of these ingots, 40 grams of manganese-boron was added in the manner above described. To another, 50 grams of manganese-boron was added, and to the third, 60 grams of manganese-boron.

All of the ingots were then carefully scraped or machined until crack and scale-free surfaces were reached and the ingots were then forged to billets, which, after surface preparation, were hot rolled to ¼ inch rod. Evaluating the per cent of yield of the finished ¼ inch rod in terms of the total weight of the three groups of ingots, as identified by the 40, 50 and 60 gram additions of boron, the following results were obtained:

Manganese-boron addition	Percent yield/cast weight
Grams	Percent
40	71.2
50	75.0
60	61.8

Hence, the addition of boron to the basic nickel-chromium alloy exercises a salutary influence upon the yield of usable material.

Furthermore, it will be evident that the boron content does not function as do the conventional deoxidizers, such as are described in some of their

aspects in the United States patent to Hunter No. 2,005,423, because it produces a cleaner metal, as is demonstrated by the reduction of wastage.

In carrying out the method of my invention, I utilize boron in the forms in which it is readily obtainable commercially; that is, as manganese-boron, nickel-boron, boron metal and other alloys of boron. Furthermore, the boron constituent representing the most reactive addition to the basic alloy is introduced only after the basic materials are in molten condition and just prior to pouring. It will be apparent likewise that this practice insures a residual quantity of boron in the finished product.

Although I have enumerated the constituents of a typical nickel-chromium alloy, experimentation has shown that boron is equally beneficial when added to a nickel-chromium-iron alloy containing substantially 60 per cent of nickel, 15 per cent chromium, with the balance iron, or 30 per cent nickel, 20 per cent chromium and the balance iron.

I claim as my invention:

An electrical resistance alloy containing approximately 60% of nickel, approximately 15% of chromium, an appreciable amount of boron, up to 2%, and the balance, iron.

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