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ALUMINUM IRON ALLOY

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My invention relates to improved methods for the production of aluminum-iron alloy, and in particular for the production of such alloy in ductile strip form. This invention incorporates certain improvements and refinements over that disclosed and claimed in my copending patent application, Serial No. 344,003, filed March 23, 1953.

In the said copending patent application, I described at length methods and means whereby aluminum-rich material may be bonded to and taken up in a strip of iron-rich material, such as commercial steel strip, in order to form sheet or strip stock suitable for use in electromagnetic cores and having useful magnetostrictive properties. For production purposes, the described method required relatively elongated means, such as a muffle, for subjecting the strip to sufficient heat treatment to produce diffusion of the aluminum into the iron, but for some requirements I consider it a disadvantage that such elongated equipment be required. This is particularly true when it is desired to produce the alloy on a batch basis.

It is, accordingly, an object of the invention to provide an improved method for producing aluminum-iron alloy of the character indicated.

It is another object to provide a method for producing aluminum-iron alloy, whereby more compact equipment may be used.

It is also an object to provide an improved method for making aluminum-iron alloy on a batch basis, involving a maximum volume of product for minimum volume of furnace equipment.

Still another object is to provide an improved method for fabricating aluminum-iron alloy with greater homogeneity.

It is a specific object to provide, in methods of the character indicated, a reliable fixation of the aluminum in the iron, so that the tendency for aluminum droplets to form may be minimized, regardless of the subsequent heat treatment of the specimen.

Other objects and various further features of novelty and invention will be pointed out or will occur to those skilled in the art from a reading of the following specification.

Briefly stated, my invention contemplates the production of aluminum-iron alloy, without the tendency to form droplets and thus to produce surface inhomogeneities, by carefully fixing the aluminum in the iron prior to further heat treatment, as to produce homogeneity or a desired inhomogeneity of the alloy structure. I have discovered that fixation may be achieved by controlled, relatively slow traversal of the aluminum-coated iron up to and past the melting point of the aluminum, all in a non-oxidizing atmosphere. With care, this rate of traversal can be kept slow enough so that the aluminum is taken up in the iron sufficiently to prevent formation of liquid aluminum droplets.

Variously useful products, such as core materials having different electromagnetic effects, may be produced by

heat treatments after fixation. For example, a high-Q strip suitable for transformer and other cores may be produced merely upon cooling the fixed material, scaling off surface crystallites, and rolling to produce a uniform strip; such strip is characterized by an iron-rich center with some aluminum diffused therein, and an aluminum-rich covering with some iron diffused therein. Alternatively, to produce homogeneous alloy, as for magnetostrictive applications, the fixed material is subjected to a diffusing heat treatment, as by elevation to a temperature intermediate the melting points of the aluminum and of the iron, and preferably relatively near the melting point of the iron; the maximum temperature for diffusion will depend upon the proportions of the alloy constituents, and the time required for diffusion is found to vary inversely as the temperature, for temperatures under the maximum.

I have found that my method is particularly applicable to the preparation of aluminum-iron alloy on a batch basis, either in which aluminum-clad iron is rolled tightly into a helical compact, or in which the aluminum-clad iron strip is stamped to lamination shape and stacked, without spacers between laminations. By allowing the outer exposed aluminum surface to oxidize, sufficient refractory protection is provided to prevent sticking, even though the compact involves a stack or a tightly coiled winding. The fixed and further heat-treated compact may subsequently be separated or unwound, and even the unwound and thus flattened alloy strip may exhibit sufficient ductility to lend itself conveniently to the usual cutting, blanking, or other manufacturing steps required to produce a transducer core or core lamination.

Commencing with iron or iron-rich strip, a homogeneous alloy with aluminum is produced by first coating or cladding the iron-rich strip with an aluminum-rich material, all as described in greater detail in my said copending application. Upon coating, the exposed aluminum surface is caused or allowed to oxidize, and the strip is then subjected to fixing and diffusing heat treatments, both of which may be conducted in succession and in the same relatively non-oxidizing atmosphere. The non-oxidizing atmosphere may be provided by clean dry hydrogen, or by an evacuated vessel, or by subjecting the strip to a noble-gas atmosphere during heat treatment.

For most magnetic-core applications, it is desirable that the percentage by weight of aluminum-rich material in the alloy shall be from 3 to 16, and for magnetostrictive applications this percentage is preferably in the order of 13 to 14. In either event, fixation may be effected without formation of aluminum droplets by a relatively slow traversal of the coated strip past the melting point of aluminum, which is of the order of 1200° F.; slow traversal should preferably commence at a temperature not substantially exceeding 1100° F.

I have found, for example, that by allowing half an hour for traversal of the range from 1100 to 1300° F., one may be safely assured that no aluminum droplets will form, so that smoothness and longitudinal uniformity of the strip may result; however, results which might be considered acceptable for some applications have been achieved with traversal times in the order of one minute.

After fixing, the strip has a core of somewhat inhomogeneous aluminum-iron alloy, the central part being iron-rich with aluminum diffused therein and the outer part being aluminum-rich with iron diffused therein, and the crystalline outer surface will be observed to have thickness approximating that of the original coat of aluminum. This outer coat or surface is believed to contain substantially pure Al_3Fe; the coat is crystalline, brittle, and non-magnetic. However, the inhomogeneous interior of only slightly diffused material does have spe-

cific application for special-purpose magnetic effects; the fixed material may be reclaimed for such special use by scaling off the outer crust of predominantly Al_3Fe crystals, and by lightly rolling the slightly diffused alloy. To illustrate, I have found that such inhomogeneously diffused material, when used as a core for a suitable coil, may provide a relatively high-Q response for the strip thickness involved.

For magnetostrictive applications, and for most magnetic-core applications, relatively homogeneous material is needed and, as indicated generally above, further heat treatment involving diffusion of the iron in the aluminum and of the aluminum in the iron is required to produce homogeneity. For magnetostrictive core material, that is, for material in which the percentage by weight of aluminum is preferably in the order of 13 to 14, I have found that diffusion may be adequately produced by elevating the temperature (still within the non-oxidizing atmosphere) to a range approaching the melting point of the iron, as, for example, to at least substantially 2000° F. After fixing, the strip may be quickly elevated to this diffusing temperature, and in the process the Al_3Fe crystallites will be dispersed. At 2000° F., some two hours may be necessary to produce the desired homogeneity, and of course this will depend upon the depth or thickness of the material involved. By further elevating the temperature (as to 2250° F.) and still keeping this temperature below the melting point of the iron, diffusion may be accelerated; however, more care must be taken to avoid sudden temperature changes, if droplets are not to be formed. Once homogenized, the alloy is rendered suitable for use by thereafter slowly cooling in the protective atmosphere.

The resulting alloyed materials are found to have good physical properties for use in forming magnetic-core structures. The alloyed strip is ductile enough to permit re-rolling, cutting, blanking, etc., yet the material is brittle enough to cut easily without burring. The high electrical resistivity of the homogeneous alloy is attractive for minimal eddy-current loss.

From the point of view of economical manufacture of my alloy, in accordance with the methods discussed above, I have made the significant discovery that the fixing and, if necessary, diffusion steps may be carried out upon a helically developed roll or compact of the aluminum-clad iron-rich strip. Ordinarily, one might expect adjacent aluminum layers to stick to each other upon heating to fix the aluminum; however, after the aluminum-rich coating is applied to the iron-rich strip, the outer exposed surface of the aluminum may be simply oxidized by exposure to air or to some other oxidizing atmosphere, and the refractory properties of this oxidized layer will serve to isolate adjacent aluminum-rich layers in the helical compact sufficiently to prevent sticking between coils of the helix. Of course, further precautionary steps may be taken to assure against further sticking, and in this connection I prefer that, in commencing the heat treatment and prior to fixation, the aluminum-coated strip shall be deliberately exposed to air, as for example until a temperature of the order of 600 to 900° F. is attained; this will assure a good protective aluminum-oxide coating. Alternatively, and (if desired) in addition, a light layer of talc may be dusted upon one side of the coated strip prior to stacking or rolling into the helical compact; thereafter, the stack or compact with its protective refrectory layers may be subjected to the relatively slow traversal of the melting point of aluminum in order to produce fixation, and the other further heat-treatment steps may be taken, as indicated in greater detail above.

It will be appreciated that I have described a relatively simple method for selectively producing homogeneous or inhomogeneous magnetic-core materials of aluminum-iron alloy. My method is particularly attractive in that it lends itself either to continuous strip or to batch production of the alloy, and in the production of batch quantities maximum yield is obtained from minimum oven dimensions.

Throughout the foregoing specification, I have referred to the alloy as being aluminum-iron alloy or as comprising aluminum-rich material in conjunction with iron-rich material; either use of language will be understood to be merely descriptive of the principal components of the alloy, in that there may, of course, be minor constituents, as is the case when the iron-rich material is one of a variety of steels.

While I have described the invention in detail for certain preferred methods, it will be understood that modifications may be made within the scope of the invention, as defined in the claims which follow.

I claim:

1. The method of producing an elongated strip of substantially homogeneous alloy composed of an iron-rich material and an aluminum-rich material, which comprises coating a strip of iron-rich material with the aluminum rich material in substantially the desired alloy proportions, oxidizing the exposed aluminum-rich surface, whereby a protective refractory layer is formed, rolling the coated strip into a helical compact, whereby aluminum-rich coatings of different parts of said strip will be in immediate adjacency, subjecting said compact to a non-oxidizing atmosphere, and in said non-oxidizing atmosphere fixing the aluminum in the iron by a relatively slow traverse of the melting point of aluminum and thereafter diffusing the aluminum into the iron by holding said compact in said atmosphere at an elevated temperature in the range 2000° F. to 2400° F., and continuing such diffusion until substantially homogeneously alloyed strip results.

2. The method according to claim 1, and including the further step of applying talc to one surface of said strip prior to rolling the coated strip to a helical compact, whereby the talc may provide further assurance against sticking upon fixation.

3. The method of processing a composite strip of iron-rich material with aluminum-rich material, which comprises heating said strip in a non-oxidizing atmosphere to an elevated temperature in the range 2000° F. to 2400° F., said heating being characterized by a relatively slow traverse of the melting point of the aluminum-rich material, whereby the aluminum may be sufficiently taken up in the iron so that no liquid phase appears which can cause drops of unevenness of the strip, maintaining the strip at said elevated temperature for a sufficient length of time to allow substantially full diffusion of the aluminum into the iron to produce a substantially homogeneous alloy strip, cooling said heat treated strip, scaling off surface crystallites formed during the treatment and then rolling the scaled off strip.

4. The method according to claim 6, in which the time for traversal of said range is of the order of half an hour.

5. The method according to claim 3, in which the percentage by weight of aluminum to iron is of the order of 13 to 14.

6. The method according to claim 3, in which said relatively slow traverse extends over the temperature range substantially between 1100° F. and 1300° F.

7. The method of producing aluminum alloy laminations in quantity which comprises aluminum coating an iron rich sheet, oxidizing said aluminum-coated surface to form an aluminum oxide layer, producing from said treated sheets a plurality of laminations, stacking each of said laminations one upon the other with the oxide surface of one contacting the oxide surface of the other to provide protection against sticking during heating, subjecting said stacked laminations to a diffusion heat treatment in a non-oxidizing atmosphere wherein the aluminum is first fixed in the iron by a relatively slow traverse of the aluminum melting point, thereafter diffusing the aluminum into the iron by holding said stack in

said non-oxidizing atmosphere at an elevated temperature in the range of about 2,000° F. to 2,400° F., and continuing such diffusion heating until the laminations are substantially homogeneously alloyed.

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