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METHOD OF MAKING ELECTRICAL RESISTANCE IRON-ALUMINUM ALLOYS

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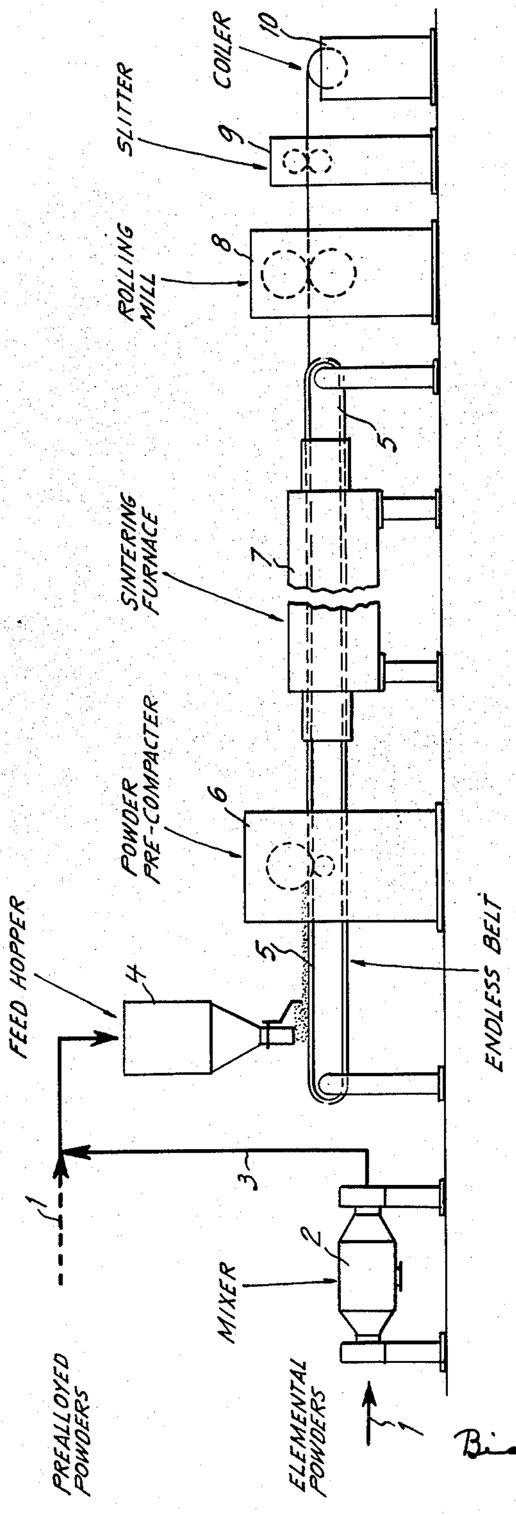

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METHOD OF MAKING ELECTRICAL RESISTANCE IRON-ALUMINUM ALLOYS

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The present invention is directed to the manufacture of electrical resistance alloys and more particularly to alloys containing aluminum and iron, with or without other alloying metals.

It is among the objects of the invention to produce alloys of the type described wherein powders of the metals used constitute the starting materials, which alloys have highly desirable properties for the described purpose.

It is also among the objects of the invention to devise a process which is simple in operation, does not require expensive or complicated equipment, and which may be conducted on a continuous or semi-continuous basis.

In the practice of the invention, high electric resistance alloys containing about 5 to 30 weight percent aluminum, about 0 to 40 weight percent manganese and balance iron, are fabricated from metal powders. Alloys so fabricated are useful for the manufacture of precision wire wound electrical resistors or furnace heating elements. The process used in fabricating these alloys consists basically of blending the constituents of the alloy in powder form, giving the powders a preliminary cold compaction, sintering at a temperature above the melting point of aluminum and manganese for a brief time, usually less than 15 minutes, and hot rolling the sintered compact into strip. The melting of the aluminum and manganese in the mixture results in a stronger compact than would be obtained if sintering occurred by virtue of solid state diffusion alone.

Strip so fabricated may be slit into the form of ribbon suitable for furnace heating elements or for futher processing to produce wire. Thus, ribbon may be prepared having a width approximately equal to its thickness and of rectangular cross-section. The rectangular ribbon may then be rolled to a circular cross-section and finally drawn into wire. The latter process is a continuous one but wire may also be fabricated by a batch type operation which has proven useful in the preparation of iron containing 15 weight percent aluminum. This process consists of loading the powders into steel tubes and hot rolling these in a rod mill so as to produce small diameter rod (say, about 0.050"). The rod is then drawn into wire utilizing conventional tungsten carbide dies.

Rod and wire may also be made by shearing thick plate into rods having a rectangular cross-section. These may be further processed by rolling and drawing to produce rod and wire products, respectively.

The invention is more fully described in connection with the accompanying drawing constituting a part hereof, in which like reference characters indicate like parts, and in which the single FIGURE is a diagrammatic view of a plant for manufacturing electrical resistance alloys in ribbon form, in a continuous manner.

The process involves mixing of the elemental powders, giving them a cold precompaction at any where from zero to several thousand pounds per square inch, sintering the lightly compacted powders for a brief interval of about 2 to 15 minutes at 1300° C., consolidating the sintered powders in a rolling mill so as to produce a fully densified material and slitting the resultant strip to ribbon of the desired width. Note that the sintering operation is different from conventional sintering in that a liquid phase is present. The presence of a liquid phase produces a stronger and denser compact in a much shorter length of time than is possible when solid state diffusion is relied

upon alone, as in conventional powder metallurgical operations.

Referring to the drawing, elemental powders **1** blended in a rotary mixer **2** are fed at **3** to a feed hopper **4**. Powders from the feed hopper are deposited onto trays attached to a moving endless belt **5**. The trays have side walls but no front and back walls. The trays pass between a set of rolls **6** where they receive a light compaction, enough to cause a partial densification of the powders. The belt then moves through a sintering furnace **7** operating at about 1300° C. Here a continuous sinter cake is formed which is further hot rolled in the rolling mill **8**, slit at **9** to the desired ribbon widths and cooled at **10**. Although a precompaction operation is shown, this step can be eliminated through use of longer sintering times, higher sintering temperatures or both.

If desired, the powder **1** may be of the final alloy and it is fed into the system in the same manner as powder **1**. It is also feasible to feed in a partial alloy **1'** and mix it with the complementary metal powder **1** in proper proportions, and feed the mixture into the system.

A modified technique is used for the manufacture of small diameter electric resistance wire, in which the elemental or prealloyed powders are loaded into thin walled steel tubes preheated at about 1300° C. and rolled in a rod mill. When the rods are reduced to about 0.070 to 0.050" in diameter, they are drawn into fine wire using tungsten carbide dies. The rod rolling and drawing may be done hot or cold. If hot working is used the rod or wire need not be annealed after each reduction. If cold working is used, the material is annealed at 600 to 900° C. in air after a cold reduction of 25 or 30%.

Still another technique may be used for the manufacture of wire. This involves the fabrication of thick plate by the above described and illustrated method or by hot rolling the powders in a metal sheath at about 1300° C. The plate is then sheared into rods having a rectangular section and the rods are further rolled in a rod mill. The small diameter rods may then be drawn into wire as in the modified technique.

A variety of iron-aluminum base alloys containing varying percentages of manganese and other additives have been prepared and their electrical resistivities determined. It has been found possible to vary the reistance between wide limits; i.e., from a low of 445 ohms-circular mils per foot for an iron-aluminum alloy containing 5 w/o aluminum to a high of 2,010 ohm-circular mils per foot for an iron-aluminum alloy containing 20 w/o aluminum and 32 w/o manganese.

The resistivity of straight iron-aluminum alloys is a linear function of the aluminum content, varying from 445 ohm-circular per foot at 5 w/o aluminum to 1010 ohm-circular mils per foot at 20 w/o aluminum. Additions of manganese increase the resistivity of iron-aluminum alloys, the resistivity varying linearly with the weight percent of manganese. Thus for an iron-aluminum alloy containing 15 w/o aluminum, the resistivity varies from 838 ohm-circular mil per foot at 0 w/o manganese to 1765 ohm-circular mils per foot at 32 w/o manganese.

Numerous advantages are inherent in the process and the resulting product, among which is the fact that extremely high resistances can be obtained for powder fabricated alloys; in excess of 2000 ohm-circular mil per foot. This is due to the extreme crystal lattice distortions which occur when high concentrations of aluminum (up to 30 w/o) and manganese (up to 40 w/o) are added to iron.

The novel liquid phase sintering technique requires very short sintering times, usually less than 15 minutes, so that very high production rates can be achieved in relatively small sintering furnaces. Manufacturing costs are low because conventional melting, casting and numerous hot rolling operations as eliminated. One need not start with a large ingot and roll this down to final size. The powder product is reduced to final size in strip form by one or two passes through a rolling mill. This is particularly desirable in the manufacture of strip for the production of fine wire.

One may fabricate by the present invention alloys which are impossible to fabricate by conventional casting and rolling techniques, such as iron-aluminum alloys containing 20 to 30 weight percent aluminum. In the as-cast condition, the grain structure of such alloys is extremely coarse. Thus, the tendency is for the cast material to break up during rolling. In the present product, fine grains are obtained, grain growth being limited by oxide films surrounding individual powder particles and by the low processing temperatures and short processing times used. Thus, the iron-aluminum alloys are processed at 1100 to 1300° C. or a few hundred degrees below the melting point of the alloy and for short periods of time; less than ¼ hour.

The alloy may be processed in the form of an elemental powder mixture or a prealloyed powder or a combination of both. Processing of elemental powder mixtures is sometimes desirable because the final alloyed product may be brittle and normally difficult to process. By postponing complete alloying of the mixture, as is possible by the technique described, it is possible to work the material more easily and to a point where considerable fibering of the grain structure has been achieved. By this time complete alloying has occurred but the structure is fibered so that it can be worked more easily.

Excellent mechanical properties are obtained for alloys which are ordinarily very brittle such as iron-aluminum base alloys containing 15 or more weight percent aluminum. The higher ductility of powder fabricated iron-aluminum base alloys is attributed to the high purity of the starting materials and to their fine grain structure. Powder fabricated iron-aluminum alloys, for example, may be cold sheared to narrow widths less than ½ inch, whereas the conventional cast-wrought product breaks up readily when subjected to the same treatment.

Corrosion resistance of the iron-aluminum base alloys is very good owing to the presence of adherent impervious protective films of aluminum oxide at the surfaces of these alloys. The corrosion of these alloys in common tap water is reduced to a negligible value by preoxidizing them at 500° to 900° C. for about an hour in air. This treatment hardly discolors the alloy yet creates a highly corrosion resistant surface film which prevents exposure and corrosion of the base metal.

The naturally occurring aluminum oxide films on iron-aluminum alloys may be utilized as an electrical insulating material in lieu of the enamels or fabric braids normally used for this purpose. This considerably reduces the cost of the finished wire.

Iron-aluminum base alloys have excellent high temperature oxidation resistance so that such alloys have long life in furnace heating element service. Oxidation resistance is obtained by virtue of the adherent aluminum oxide film which forms on the surface of these alloys at elevated temperature. The surface film is also self-healing, reforming immediately at points where it may spall off. Such alloys have a lower density than iron base

alloys because of the relatively large percentages of aluminum which they contain. Thus, such alloys find application in services where light weight is an important factor; for example, in electrical components for ballistic missiles, space satellites and portable electronic measuring devices.

I claim:

1. A method of making electrical resistance alloys, comprising the steps of providing a powder consisting essentially of 5% to 30% by weight of aluminum, up to 40% by weight of manganese, and the remainder of iron, subjecting the powder to a temperature above the melting point of aluminum but below that of iron to effect sintering in the liquid phase thereby to form a sinter cake, and hot-working the sinter cake to form a coherent resistance body.

2. A method according to claim 1 characterized in that the temperature of said sintering is about 1100° to 1300° C.

3. A method of making electrical resistance alloys which comprises providing a powder blend consisting essentially of about 5% to 30% by weight of aluminum, 1 to 40% of manganese and the remainder being iron, pre-compacting said powder to form a green compact, subjecting said compact to a temperature above the melting point of aluminum and manganese but below the melting point of iron to effect sintering in the liquid phase thereby to form sinter cake, and hot rolling said sinter cake to form a coherent body.

4. A method according to claim 3 characterized in that the temperature of hot rolling is below the melting point of the iron.

5. A method according to claim 3 characterized in that the temperature of said sintering is about 1100° to 1300° C.

6. A method according to claim 1 characterized in that the metals of said powder are prealloyed.

7. A method according to claim 1 characterized in that the metals of said powder are in physical mixture.

8. A method according to claim 1 characterized in that a protective oxide film is formed on said body by oxidizing it after said hot-working.

9. A method according to claim 1 characterized in that a protective oxide film is formed on said body by oxidation thereof after said hot-working at about 500° to 900° C.

10. A method of fabricating an alloy having a highly electrical resistance comprising the steps of providing a blend consisting essentially of aluminum, manganese and iron powders to form a mixture having a ratio of about 5 to 30 percent aluminum by weight, manganese not in excess of 40 percent by weight and the balance of iron, pre-compacting said mixture to form a green compact, sintering the compact in the liquid phase above the melting point of aluminum and manganese but below that of iron to form a sinter cake, and hot rolling the sinter cake into strip.

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