United States Patent Office 3,078,197
Patented Feb. 19, 1963

3,078,197

METHOD OF FORMING FERROUS ALLOYS

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No Drawing. Filed Oct. 24, 1960, Ser. No. 64,271
4 Claims. (Cl. 148—103)

This invention relates to methods of forming ferrous alloys and more particularly to hot deformation methods of forming ferrous alloys capable of developing high energy magnetic properties.

Ferrous alloys containing aluminum, nickel, cobalt and copper, adapted primarily for use in permanent magnets are known as "Alnico" alloys. Some of these alloys contain also titanium. Such alloys with high energy magnetic properties of four million gauss-oersteds and above are hard, brittle materials which are produced by casting and grinding. Neither hot nor cold deformation of these alloys has been feasible to date.

Alnico alloys with low energy magnetic properties under two million gauss-oersteds have been hot deformed by additions of titanium, zirconium and titanium, silicon, or zirconium, silicon and titanium. Previous published work disclosed that only zirconium additions would not produce a hot deformable alloy. High energy ferrous alloys of the above types have not been previously hot deformed although some of these alloys contain up to 5.2 weight percent titanium. Thus, it would be desirable to form ferrous alloys of predetermined shapes and sizes by hot deformation, which alloys have high energy magnetic properties or are capable of developing such properties.

It is an object of our invention to provide a method of forming ferrous alloys capable of developing high energy magnetic properties.

It is another object of our invention to provide a hot deformation method of forming ferrous alloys capable of developing high energy magnetic properties.

It is a further object of our invention to provide a hot deformation method of forming ferrous alloys which have high energy magnetic properties.

In carrying out our invention in one form, a ferrous alloy capable of developing high energy magnetic properties is formed by melting together 6 to 9.6 weight percent aluminum, 12 to 16 weight percent nickel, 22 to 34.5 weight percent cobalt, 0.70 to 3.5 weight percent copper, a metal selected from the group consisting of up to 0.41 weight percent zirconium, and up to 5.2 weight percent titanium, and the balance being iron; cooling the alloy, heating the alloy to a temperature in the range of 1050° C. to 1100° C. and deforming the alloy to a predetermined shape.

These and various objects, features, and advantages of the invention will be better understood from the following description.

Alnico alloys with high energy magnetic properties are not hot or cold worked because of their brittleness. We discovered unexpectedly that such alloys could be hot deformed in a narrow working temperature range of 1050° C. to 1100° C. We found further, unexpectedly, that the alloy could be cooled after deformation in a high energy magnetic field to impart high energy magnetic properties thereto.

In the practice of the present invention, 6 to 9.6 weight percent aluminum, 12 to 16 weight percent nickel, 22 to 34.5 weight percent cobalt, 0.70 to 3.5 weight percent copper, a metal selected from the group consisting of up to 0.41 weight percent zirconium, and up to 5.2 weight percent titanium, and the balance being iron is vacuum or air melted together and cooled subsequently to produce a ferrous alloy billet. If it is desired, commercially available cast alloys can be employed in the melting step. The billet is heated in a furnace to a temperature in the range of 1050° C. to 1100° C. and is then deformed to a predetermined shape by extruding, forging, swaging, or rolling. While we found that the alloy may initially be heated slowly to its working temperature range, the alloy can also be placed in a furnace already at the desired temperature. After deformation, the ferrous alloy is cooled to room temperature.

The initial deformation of the alloy provides greater strength in the material, eliminates voids, increases the ductility, and provides a more uniform grain structure. Subsequently, the alloy may be cut, or further worked by rolling or swaging to sheet or wire. After initial deformation or additional working, the alloy is treated in accordance with normal practices to provide it with high energy magnetic properties. The billet can be subjected after deformation to a magnetic field of 1700 oersteds during cooling to impart high energy magnetic properties thereto.

The subsequent magnetic properties of alloys produced in accordance with this invention are equivalent to the cast properties and the mechanical properties are improved due to finer grains and lower porosity. Thus, it is possible to make small diameter rod and thin sheets that could not be made by normal casting methods. Grinding of such fabricated alloys is much easier and better surface conditions are realized.

Examples of ferrous alloys capable of developing high energy magnetic properties formed in accordance with the methods of the present invention are as follows:

A series of ferrous alloy billets were produced by vacuum melting as set forth in Table I. The billet dimensions, container dimensions, and die diameters are shown in Table II. After each billet was heated in a hydrogen furnace to a temperature in the range of 1050° C. to 1100° C. as set forth in Table III, it was extruded with a 500 ton press from a container through a die as set forth in Table II. The billet was lubricated prior to each extrusion. The deformed billets had resulting diameters as set forth in Table III.

Table I

No.	Chemical Analysis (Balance is Iron)				
	Al	Ni	Co	Cu	Zr
1	8.0	13.8	24.0	3.3	0.38
2	7.6	14.3	23.6	2.3	0.20
3	7.7	13.8	24.1	3.0	0.28
4	8.0	13.7	23.9	3.2	0.27

Table II

No.	Billet Dimensions, inches		Container Diameter, inches	Die Diameter, inches
	Length	Diameter		
1	5.75	2.441	2.470	1.096
2	5.75	2.338	2.470	0.947
3	5.75	2.338	2.470	1.150
4	5.75	2.338	2.470	1.150

Table III

No.	Temperature, degrees Centigrade	Dedormed Pillet Diameter, Inches
1	1,095	1.075
2	1,080	0.929
3	1,065	1.134
4	1,070	1.144

While other modifications of this invention and variations of method which may be employed within the scope of the invention have not been described, the invention is intended to include such that may be embraced within the following claims.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A method of forming a ferrous alloy capable of developing high energy magnetic properties which comprises melting together 6 to 9.6 weight percent aluminum, 12 to 16 weight percent nickel, 22 to 34.5 weight percent cobalt, 0.70 to 3.5 weight percent copper, a metal selected from the group consisting of up to 0.41 weight percent zirconium and up to 5.2 weight percent titanium, and the balance being iron; cooling said alloy, heating said alloy to a temperature in the range of 1050° C. to 1100° C., and deforming said alloy at a temperature in the range of 1050° C. to 1100° C. to a predetermined shape.

2. A method of forming a ferrous alloy capable of developing high energy magnetic properties which comprises melting together 6 to 9.6 weight percent aluminum, 12 to 16 weight percent nickel, 22 to 34.5 weight percent cobalt, 0.70 to 3.5 weight percent copper, a metal selected from the group consisting of up to 0.41 weight percent zirconium and up to 5.2 weight percent titanium, and the balance being iron; cooling said alloy, heating said alloy to a temperature in the range of 1050° C. to 1100° C., and extruding said alloy at a temperature in the range of 1050° C. to 1100° C. to a predetermined shape.

3. A method of forming a ferrous alloy with high energy magnetic properties which comprises melting together 6 to 9.6 weight percent aluminum, 12 to 16 weight percent nickel, 22 to 34.5 weight percent cobalt, 0.70 to 3.5 weight percent copper, a metal selected from the group consisting of up to 0.41 weight percent zirconium and up to 5.2 weight percent titanium, and the balance being iron; cooling said alloy, heating said alloy to a temperature in the range of 1050° C. to 1100° C., deforming said alloy at a temperature in the range of 1050° C. to 1100° C. to a predetermined shape, and cooling said alloy in a high energy magnetic field to impart high energy magnetic properties thereto.

4. A method of forming a ferrous alloy with high energy magnetic properties which comprises melting together 6 to 9.6 weight percent aluminum, 12 to 16 weight percent nickel, 22 to 34.5 weight percent cobalt, 0.70 to 3.5 weight percent copper, a metal selected from the group consisting of up to 0.41 weight percent zirconium and up to 5.2 weight percent titanium, and the balance being iron; cooling said alloy, heating said alloy to a temperature in the range of 1050° C. to 1100° C., deforming said alloy at a temperature in the range of 1050° C. to 1100° C. to a predetermined shape, and subjecting said alloy to a high energy magnetic field to impart high energy magnetic properties thereto.

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