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WORKABLE MAGNETIC COMPOSITIONS CONTAINING PRINCIPALLY IRON AND COBALT

No Drawing.

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Alloys of iron and cobalt are known to be suitable for magnetic structures requiring flux densities between 14,000 and 25,000 gauss. In particular, magnetic compositions having around 50% iron and 50% cobalt appear to be very suitable for use under such circumstances. Such iron-cobalt alloys are disclosed and claimed in U. S. patent to Elmen, 1,739,752, granted December 17, 1929, and also in British Patent 297,938, filed August 29, 1927. The superiority of iron-cobalt alloys having around 50% iron and 50% cobalt over iron is also apparent at flux densities below 1000 gauss for at these low flux densities the permeability is from two to three times that of a highly annealed grade of iron.

The field of most advantageous practical application of iron-cobalt magnetic structures is chiefly in devices where small magnetic parts are utilized. Examples of such small parts are pole pieces for light valves employed in sound recording and reproducing equipment, pole pieces for loud speakers and pole pieces for earphones for deaf sets. The iron-cobalt alloys especially those containing around 50% iron and 50% cobalt are brittle and cannot be worked as readily as is desirable into suitable small parts, nor can sheets composed of them be punched without cracking. In reducing the castings into rods or strips, they must be hot rolled and the temperature during the rolling process must be kept within close limits. The machining of small parts has proven to be somewhat difficult necessitating special precautions not convenient in commercial practice in order to achieve successful results. For example, in machining very small parts, pieces of the iron-cobalt alloy have been faced with brass in order to prevent them from crumbling.

In accordance with the present invention by selection of suitable compositions, a special casting and rolling operation and a special heat treatment material is produced which may be cold worked into any desirable shape and then given a heat treatment to develop the magnetic properties.

An object, therefore, of the present invention is to reduce the cost and difficulty of preparing highly magnetic iron-cobalt alloys

and to increase their ductility, workability and machinability with a minimum effect upon their magnetic properties.

In order to achieve the desired object an investigation was made in which various amounts of substantially all of the common metals of high melting point were added to iron-cobalt alloys, especially to those of around 50% iron-50% cobalt composition. As a result of this investigation it has been found that vanadium in amounts from a fraction of 1% up to 4%, and more especially 2% and over, reduces the brittleness of the iron-cobalt alloys to such a degree that by suitable heat treatment and rolling they may be reduced to any desired shape. From materials so made in the form of flat sheets .1 inch in thickness, rings have been successfully punched. Furthermore, such sheets can be bent 90° and 180° over a very short radius without signs of cracking. It also has been found possible to roll down thin strips 1 inch wide and 0.003 inch in thickness from which small receiver diaphragms have been stamped.

The compositions are preferably cast at as low a temperature as is consistent with fluidity. The casting is maintained at 1000° C. for three hours before hot rolling. After two passes through the rolls at 1000° C. in which the thickness is reduced .025 inch per pass the plate of material is kept at 1000° C. for five minutes in order to restore the temperature. This process is continued till the sheets are about 0.1 inch thick. The material at this stage is brittle and not workable. If the sheets are to be punched and bent a special heat treatment is necessary.

The sheets are put in a furnace at 900° C. $\pm 5^\circ$ C. for about five minutes or long enough for them to remain for one minute at 900° C. $\pm 5^\circ$ C. This can be ascertained by a thermocouple placed directly upon the sheets. They are then removed and quenched in brine and ice as quickly as possible. For best results the quenching is repeated three times. This method applies when 2% vanadium is employed. For higher vanadium content, i. e. 3% the treatment is not so critical and the temperature may be within the range of 850° C. to 950° C. and a single

quench used. For 1½% vanadium the temperature is very critical and three quenches must be performed. The heat treatment is believed to change the crystal structure from the hexagonal close-packed structure characteristic of alpha-cobalt to the face centered cubic.

A phenomenon noted is that thin tape rolled down to 0.006 inch or less in thickness may become quenched sufficiently rapidly in open air, especially with a higher vanadium content around 3%.

The sheets thus heat treated may be punched and bent into the form of plates with right angled lugs or other suitable shapes such as are often desirable for electromagnetic apparatus. However, it has at this stage poor magnetic properties and after forming must be heat treated as hereinafter described to develop the magnetic properties in the course of which it again becomes brittle and non-workable. This is of little consequence as the material is in the final form in which it will be employed.

The addition of the vanadium especially in quantities up to 2% has been found to have practically no effect upon the final magnetic properties of the material, reducing the permeability apparently only a small amount, if at all. Moreover, the addition of 2% vanadium increases the specific resistance of the iron-cobalt alloys quite considerably and quantities other than 2% cause proportional increases in the resistivity; thus for example, a composition having around 49% iron, 49% cobalt and 2% vanadium has a specific resistance of about 27 microhm centimeters, which is about three times that of the iron-cobalt alloy without vanadium. This increased resistivity is beneficial in reducing the eddy current loss wherever the magnetic material is subjected to an alternating flux.

The benefit of adding vanadium in the amounts indicated to iron-cobalt alloys is not limited to compositions in a range around 50% iron and 50% cobalt, but applies to a rather wide range of iron-cobalt alloys having between 30% and 70% iron and between 70% and 30% cobalt. However, the best results have been achieved in compositions in which the iron and cobalt were present in about equal quantities.

In addition to iron, cobalt and vanadium, commercial magnetic compositions in accordance with the invention contain minor quantities of impurities, for example, less than ½ of 1% manganese usually remains in the material from the manganese used to deoxidize the melt. Other impurities, for example, a fraction of 1% of nickel are often found in the commercially available materials.

Except for vanadium, the addition of other metals of high melting point appear to produce no material improvement in the work-

ability or to impair the magnetic properties of the material. Manganese is a possible exception to this. Quantities of manganese around 1% to somewhat above 2% appear to improve the workability somewhat with little detrimental effect upon the magnetic properties.

Magnetic materials of the composition set forth have been heat treated successfully in a variety of ways to develop their magnetic properties. A convenient method is to heat the material at around 900° to 1100° C. for one hour in an annealing pot in an electric furnace and let the material in the annealing pot cool down to room temperature in the furnace. This method has been varied by carrying out the heating in a vacuum in the same temperature range and also by doing the heating in an atmosphere of hydrogen. An additional treatment consisting of reheating the material to about 600° C. for 15 minutes and then placing it on a copper plate in the open air to cool down to room temperature has been observed to produce a slight improvement in the permeability. However, the advantage of this additional heat treating step does not appear to be noteworthy.

Among specific examples may be mentioned the following:

A composition analyzed as having 48.6% iron, 49.25% cobalt, 1.93% vanadium, .17% nickel and .33% manganese when vacuum heated at 1000° C. for one hour and cooled in the furnace had an initial permeability of 570, a maximum permeability 2170 at $H=6$, a hysteresis loss in ergs per cm^3 (for a loop of maximum flux density of 5250) of 1406, a flux density ranging from 21,900 to 22,400 gauss at $H=50$ and a specific resistance of 24.5 microhm centimeters.

Numerous other compositions having from ½ to 4% vanadium and about equal quantities of iron and cobalt were tested. Those having around 2% vanadium appear to be best.

Somewhat similar results were noted in the case of a composition having about 34% iron, 63% cobalt, 1.9% vanadium, .71% manganese and the balance impurities; as well as a composition having 62.3% iron, 34.1% cobalt, 2.1% vanadium, .7% manganese and the balance impurities; and others of the same general range of compositions. With a composition containing 49.10% iron, 48.88% cobalt, 1.53% vanadium, and .42% manganese a flux density of over 23,000 gauss at $H=50$ was measured. The initial permeability of these various compositions is commonly over 600 and frequently as high as 850.

What is claimed is:

1. A magnetic composition composed of between 30 and 70% iron, between 70 and 30% cobalt and capable of having induced therein a high flux density at high magnetiz-

ing forces when properly heat treated, characterized in this that the workability and ductility of the material is improved without appreciably impairing its magnetic properties by the inclusion therein of $\frac{1}{2}$ to 4% vanadium.

2. A magnetic composition comprising between 30 and 70% iron, between 70 and 30% cobalt and $\frac{1}{2}$ to 4% vanadium.

10 3. A magnetic composition comprising 45 to 55% each of iron and cobalt with $\frac{1}{2}$ to 4% vanadium.

4. A magnetic composition comprising between 30 and 70% iron, between 70 and 30%,
15 cobalt characterized by being machinable and workable when cold as a result of the inclusion therein of $\frac{1}{2}$ to 4% of metal selected from the group comprising vanadium and manganese and after a suitable heat treatment and further characterized by a flux
20 density of 20,000 gauss or over at a magnetizing force of 50 gauss after heat treatment at around 1000° C. followed by slow cooling.

5. A magnetic composition composed of
25 between 30 and 70% iron, between 70 and 30% cobalt and $\frac{1}{2}$ to 3% manganese, said composition being workable, machinable when cold; and when heat treated at 1000° C. and slowly cooled having a flux density of
30 20,000 gauss or over at $H=50$.

6. A cold-workable metallic composition comprising between 30 and 70% iron, between 70 and 30% cobalt and $\frac{1}{2}$ to 4% vanadium.

35 7. A method of producing a composition according to claim 6 which comprises maintaining the material at 900° C. $\pm 5^\circ$ for compositions of low vanadium content and with a greater latitude for higher vanadium content for at least a short time and then cooling
40 at the rapid rate characteristic of quenching in brine.

In witness whereof, we hereunto subscribe our names this 10th day of August, 1931.

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