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MAGNETIC MATERIAL

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2 Claims. (Cl. 148—2)

This invention relates to permanent magnet alloys and to magnets produced therefrom which are caused to have more desirable properties as permanent magnets by a cold working treatment. The invention also relates to and includes methods of treating and producing such improved alloys and permanent magnets.

An object of the invention is the production of better and more efficient permanent magnet materials.

Among objects of the present invention are to provide better permanent magnets at little or no increase in cost; to produce useful permanent magnets from materials not hitherto known to possess permanent magnet properties to a useful extent; to improve the properties of compositions known to have useful permanent magnet properties; to produce useful permanent magnets from cheap or readily available raw materials; to increase either or both the product of "coercive force" and "residual induction" or the "maximum energy product" of magnetic materials; to provide elongated magnetic materials such as tapes and strips having useful "maximum energy products"; and to provide useful magnets from materials which may be worked with facility.

The present specification discloses and claims subject-matter divided from a copending application Serial No. 311,735, filed December 30, 1939.

A feature of the present invention resides in the fact that permanent magnet compositions, such as those described hereinafter, may be improved by reduction of the cross section thereof by a stage of cold working during their preparation and prior to the final heat treatment. Such working is preferably accomplished by methods which produce elongation and prevent lateral spreading. Methods that have been found beneficial include swaging, rolling with grooved rolls, and drawing. It appears that the resultant improved permanent magnet properties are manifested chiefly in the direction in which elongation occurs. Reduction of thickness by such rolling of a metal sheet as permits the material to spread laterally is only partially effective.

Materials of the compositions hereinafter defined when produced according to the present invention generally are anisotropic and their improved properties are manifested chiefly in the direction in which the elongation takes place.

In the said copending application it is pointed out that there are classes of materials including the materials claimed herein which, if maintained at a certain high temperature but below the melting point, assume a form known as the "gamma phase," and if the material is thereafter cooled to around room temperature, it tends to assume the "alpha" phase and thereafter if maintained at around 500° to 800° C. a finely dispersed small amount of the "gamma" phase forms in the "alpha" phase. This brief statement is to

be read in the light of the information, diagrams, and discussion of said copending application.

A suitable procedure for preparing permanent magnet material according to this invention is to melt the material and cool it to room temperature to produce formation of the "alpha" phase and thereafter elevate the material to a higher temperature between 500° C. to 800° C. for a length of time such as is necessary to allow a small amount of the "gamma" phase to precipitate in a highly dispersed form in the "alpha" phase. This produces dispersion hardening in the material and results in an effective permanent magnet material. This method of preparing permanent magnet materials is different and seemingly involves a different principle than that heretofore employed with respect to many others, such as alloys of iron, cobalt and molybdenum, in that, in the present instance the material is converted into a low temperature "alpha" phase and thereafter has a small amount of the high temperature "gamma" phase precipitated therein in a fine and dispersed state. In the usual case of permanent magnets hardened by precipitation the high temperature phase is preserved and a small amount of the low temperature phase is precipitated.

In some alloys of the type under discussion the "gamma" to "alpha" transformation may tend to occur at low temperatures at which the transformation becomes sluggish and non-equilibrium conditions exist.

Whether this is the case or not cold rolling these alloys in grooved rolls or working them mechanically by any equivalent method causes or expedites the formation at room temperature of the "alpha" phase and brings them into equilibrium. Some alloys of this type may not change completely to the "alpha" phase at room temperature unless given the above treatment. Others change to "alpha" phase only in part. This result whether complete or partial is one beneficial aspect of the present invention. However, there is a second beneficial aspect which is due to crystal orientation. X-ray measurements confirm this and magnetic tests show the best permanent magnet properties in the direction of elongation. Either or both of these beneficial aspects may be present in varying degrees.

After the alloys are brought completely or mainly into the "alpha" phase by the combination of cooling and cold working they are raised to a temperature in the range of temperatures which causes the precipitation in finely dispersed particles of some of the "gamma" phase. This results in the production of magnetic material having effective and desirable properties as permanent magnets in the direction of elongation. In every case care must be used not to raise the material to too high a temperature in order not to lose the effect of cold working.

A frequently used criterion of the desirability of permanent magnet materials is the product of "coercive force" and "residual induction." A more accurate figure of merit is that of "maximum energy product," which on the magnetization portion of the hysteresis loop, is the product of induction B and magnetizing force H at a point where this product is the greatest. See Wahl, "Applied Magnetism," pages 42 to 45, inclusive.

The above criterion is independent of the matter of cost, ease or difficulty of preparation rolling or drawing, brittleness, availability of raw materials and other factors which must receive consideration for many practical purposes and applications. Thus a permanent magnet composition which has an absolute "maximum energy product" less than some other which is less available or suitable from some one or more of the above aspects may be a valuable contribution to the art, if, for example, it may be made to possess a considerably greater "maximum energy product" than the same material possessed heretofore.

The subject-matter of the invention or discovery therefore comprises a group of magnetic alloys which by appropriate combined heat treatment and cold rolling or elongating treatment will have one or the other or both of the above-named magnetic products or the coercive force or the residual induction increased in the direction of elongation by from one hundred to several hundred per cent as compared to the material in the cast or unsuitably heat treated or unsuitably worked condition.

A feature of the invention or discovery is the lack of any necessity for quenching the material at any time in order to improve its properties; however, rapid cooling after casting may be practiced. One of the beneficial aspects of the discovery is that the cooling rates may vary widely as convenience or necessity demands.

The alloys may be prepared in the form of rods, bars, wire or tapes. A suitable treatment for any previously prepared material is first to give it the desired amount of cold working plus a low temperature bake. No other heat treatment is necessary. Satisfactory results have been obtained with reductions in area of 75 per cent, although this exact amount is by no means critical.

In greater detail, the material is cast, which gives it the necessary high temperature treatment; it may be given a further or special heat treatment at around 800° to 1300° C. The cooled material, which may be cooled to room temperature slowly or rapidly, and must be cooled substantially below about 600° C., is forcibly elongated by rolling with grooved rolls, swaging, drawing through dies or by combinations of these methods or by any similar method or methods so as to reduce the cross section in one or several steps over a range from a small amount to a small fraction of the original cross section. The material is then heated to a temperature generally in the range 500° to 800° C. and maintained for a sufficient time such as a matter of seconds or minutes at the higher temperature to one to several hours at a lower temperature, and somewhat more as the temperature approaches the bottom of the range. Too high a temperature destroys the effect of the cold rolling, and too low a temperature or too short a time is only partially effective. A quenching treatment is unnecessary.

Compositions within the scope of this invention which respond to this type of treatment and a specific example are:

Iron	Cobalt	Chromium
Percent 30 to 52 36	Percent 36 to 62 56	Percent 6 to 16, specifically 8

Small amounts of such impurities as are usually present in commercial materials (except substantial amounts of carbon) may be present. Some of the chromium may be replaced by vanadium without change in the other constituents and the claims are to be interpreted as including and defining this replacement.

Carbon above about 0.1 per cent is not an essential constituent and in fact is absent from these materials.

Thus there are described certain permanent magnet materials, an improvement in them by a heat treatment, a further and often considerable improvement by a cold working treatment, and avoidance of necessity for quenching. These compositions possess or may be made to possess substantial permanent magnet properties and are notably improved in properties by a treatment of the kind described. They may be prepared from raw materials which are ordinarily cheap and readily available. They respond to the described treatment and may be made to acquire magnetic properties increased as a result of the treatment described as compared with identical compositions as cast. In some cases the increase in energy product due to cold rolling may be 100 per cent as compared to the same material heat treated but not cold rolled.

The type of rolls illustrated in the above-noted parent application or any other suitable rolls or apparatus may be used to perform the cold rolling or elongating process.

The finished magnets may be magnetized by any of the usually employed methods or employed in any usual manner as recording or reproducing tape or wire.

What is claimed is:

1. A tough non-brittle magnetic article of high permanent magnet properties composed of an alloy comprising as essential constituents 30 to 52 per cent iron, 36 to 62 per cent cobalt, and 6 to 16 per cent chromium produced by heating the alloy to from 800° to 1300° C., cooling substantially below 600° C., forcibly elongating the material in the cold condition, thereafter maintaining it at around 500° C. to 800° C. for a period of time from several hours at the lower range to a much shorter time at the higher range and thereafter magnetizing it.

2. The method of preparing material for permanent magnet use which comprises melting an alloy composed of 30 to 52 per cent iron, 36 to 62 per cent cobalt and 6 to 16 per cent chromium, thereafter cooling the material to substantially in the neighborhood of room temperature, thereafter forcibly elongating the material in the cold condition and thereafter maintaining it at that higher temperature above room temperature at which the finely dispersed "gamma" phase of the material is formed but without raising it to the temperature at which the entire body of the material is converted to "gamma" phase.

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