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PERMANENT MAGNET ALLOY

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This invention relates to permanent-magnet alloys of the Alnico type (Fe-Ni-Al-Co-Cu) to which anisotropic characteristics have been imparted, and is a continuation-in-part of U. S. patent application Serial No. 591,183, filed November 9, 1948, now abandoned.

The method of producing anisotropic permanent magnets as now largely practised has its basis in work by D. A. Oliver and J. W. Shedden, who, as they set out in a letter published in the issue of "Nature" dated July 30, 1938 (p. 209), subjected a permanent magnet alloy of the Alnico type to the action of a magnetic field whilst cooling from a high temperature such as, for example, 1200° C. Since that date, such treatment has been applied on a large scale to magnet alloys capable of attaining anisotropic characteristics, and, although various additions—notably of titanium—to the basic Fe-Ni-Al-Co-Cu alloy have been proposed in endeavours to achieve still better magnetic properties, practice for some years past has been largely confined to this basic alloy, since it appeared that that alloy yielded the best results in the present state of knowledge.

Even prior to the publication of the work by Oliver and Shedden, numerous additions had been proposed to Alnico alloys to improve their properties (then, of course, isotropic) and/or to facilitate their manufacture; and, since the present invention is based on the discovery that very advantageous results may be achieved with anisotropic alloys of the type in question by the addition of columbium in conjunction with tantalum, it is relevant to mention that British patent specification No. 496,774 (dated November 5, 1937, and accepted December 6, 1938) described the addition of columbium to an isotropic Alnico permanent magnet alloy for the purpose of reducing the harmful effects of contamination by carbon to the magnetic properties of the alloy.

Since 1937, the general adoption of induction furnaces for melting magnet alloys has much reduced carbon contamination, so that 0.05% carbon would rank as a high amount of this impurity; 0.02% to 0.03% is the maximum now found in the best commercial alloys. It is, therefore, very doubtful if this smaller amount of carbon has any noticeable depressing effect on the magnetic properties, but British specification No. 496,774 shows that as little as 0.2% to 0.3% columbium would be ample to neutralise it.

As indicated above, the present invention makes use of columbium in conjunction with tantalum in anisotropic permanent magnet alloys of the Fe-Ni-Al-Co-Cu type, and the object of the invention is to obtain permanent magnets of this type having a high coercive force in the preferred direction, and particularly having a combination of high coercive force and high $(BH)_{max.}$ better than has hitherto been obtainable in magnets of such high coercivity, except by the use of columbium itself—as is described and claimed in co-pending U. S. patent application Serial No. 236,052 of even date herewith, itself a continuation-in-part of U. S. patent application Serial No. 59,183.

When a permanent magnet "alloy" is mentioned in the present specification, it is to be understood that this term applies alike to a casting produced by melting the constituent elements together and to a sintered mass produced by subjecting a powdered mixture of those elements to pressure in a mould and heating the compact, it having been found that such a sintered mass behaves very similarly to a casting of like composition when both

have been subjected to similar thermo-magnetic, thermal, and magnetic treatments required to achieve anisotropic characteristics.

According to the present invention, a magnetically anisotropic permanent magnet consists of an alloy of the Fe-Ni-Al-Co-Cu type containing about 12.5% to 14.5% nickel, 7.5% to 8.5% aluminium, 23.5% to 25.5% cobalt, 2.9% to 3.3% copper, less than 0.05% carbon, about 1½% columbium with about 1½% tantalum (all within the usual manufacturing tolerances), with the balance mainly iron, said magnet having in a preferred direction a coercivity of at least 800 oersted and a $(BH)_{max.}$ of at least 3.8×10^6 gauss-oersted, the product of coercivity and $(BH)_{max.}$ being at least 3.0×10^9. For practical purposes, the four first constituents may approximate to 13.5% nickel, 8% aluminium, 24.5% cobalt, and 3% copper.

In an example according to the invention an alloy proved to have the following check analysis:

Ni	Al	Co	Cu	Cb	Ta	Balance
13.4%	7.75%	25.0%	3.0%	1.53%	1.99% (C less than 0.05%)	Fe etc.

was cast to form a test piece, $40\times35\times10$ mm., which, after being ground on all faces to obtain an accurate determination of magnetic properties, was cooled at 1.4° C./sec. from a solution temperature of 1250° C. to below the Curie point, aged at 590° C. for 48 hours followed by 560° C. for 48 hours, magnetised, and tested. The magnetic properties were:

$B_{rem.}$ gauss	H_c oersted	$(BH)_{max.}$ gauss-oersted
11,500	855	4.75×10^6

The product of H_c and $(BH)_{max.}$ of this test piece is 4.06×10^9—an exceptionally high figure, denoting an unusual combination of coercivity and energy values. The remanence of 11,500 gauss is also high, as is necessary to obtain a $(BH)_{max.}$ value of this order.

The columbium and tantalum are most conveniently introduced in the form of ferro-columbium-tantalum, with the columbium and tantalum contents approximately equal and with the iron content allowed for in the ultimate composition of the alloy.

The cooling rate is not critical. Thus, instead of the approximate 1.5° C./sec. of the above example, 1.0° C./sec. and 0.5° C./sec. may be used, or, in general, a cooling rate within the range 0.2° C./sec. to 5° C./sec.

Generally, the slower the cooling rate the higher the coercivity but the lower the remanence and $(BH)_{max.}$ whilst the faster the cooling the higher the remanence and $(BH)_{max.}$ but the lower the value of the coercivity. Consequently it is desirable to use the slower cooling rates for very short magnets and to increase the rate for longer magnets.

Further, it is generally advisable to reduce the cooling rate when the nickel content is reduced and to increase it when the aluminium content is reduced and vice versa.

For the purposes of the present invention, carbon, chromium, manganese, molybdenum, phosphorus, and silicon, silver, sulphur, titanium, tungsten, vanadium, or zirconium, are regarded as impurities (included, if present, with the balance of "Fe etc.") and should not be present in amounts exceeding a total of 1%. Carbon should be (and is, if induction heating is used) kept low—below 0.05%.

What I claim is:

1. A magnetically anisotropic permanent magnet, consisting of an alloy of the Fe-Ni-Al-Co-Cu type containing about 12.5% to 14.5% nickel, 7.5% to 8.5% aluminium, 23.5% to 25.5% cobalt, 2.9% to 3.3% copper, less than 0.05% carbon, 1½% columbium, and 1½% tantalum (all within the usual manufacturing limits), with

the balance mainly iron, said magnet having in a preferred direction a coercivity of at least 800 oersted, and a $(BH)_{max.}$ of at least 3.8×10^6 gauss-oersted, the product of the coercivity and the $(BH)_{max.}$ of the magnet being at least 3.0×10^9.

2. A magnetically anisotropic permanent magnet, consisting of an alloy of the Fe-Ni-Al-Co-Cu type containing about 13.5% nickel, 8% aluminium, 24.5% cobalt, 3% copper, less than 0.05% carbon, 1½% columbium, and 1½% tantalum (all within the usual manufacturing limits), with the balance mainly iron, said magnet having in a preferred direction a coercivity of at least 800 oersted, and a $(BH)_{max.}$ of at least 3.8×10^6 gauss-oersted, the product of the coercivity and the $(BH)_{max.}$ of the magnet being at least 3.0×10^9.

3. A magnetically anisotropic permanent magnet, consisting of an alloy of the Fe-Ni-Al-Co-Cu type containing about 13.4% nickel, 7.75% aluminium, 25.0% cobalt, 3.0% copper, less than 0.05% carbon, 1.53% columbium, and 1.99% tantalum (all within the usual manufacturing tolerances), with the balance mainly iron, said magnet having in a preferred direction a coercivity of about 855 oersted, and a $(BH)_{max.}$ of about 4.75×10^6 gauss-oersted.

4. A magnetically anisotropic permanent magnet consisting of an alloy of the Fe-Ni-Al-Co-Cu type containing about 13.5% nickel, 8% aluminium, 24.5% cobalt, 3% copper, less than 0.5% carbon, 1½% columbium, and 1½% tantalum, with the balance substantially all iron.

5. A magnetically anisotropic magnet consisting of an alloy of the Fe-Ni-Al-Co-Cu type containing about 13.5% nickel, 8% aluminum, 24.5% cobalt, 3% copper, 1½% columbium and 1½% tantalum, with the balance substantially all iron.

References Cited in the file of this patent

FOREIGN PATENTS

Number	Country	Date
496,774	Great Britain	Dec. 6, 1938
522,731	Great Britain	June 26, 1940