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SINTERED ANISOTROPIC PERMANENT MAGNET

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The present invention relates to sintered anisotropic permanent magnet alloys. It is particularly concerned with sintered Alnico magnets prepared by powder metallurgy techniques and having BH max. values corresponding to or approaching those of the best cast Alnico magnets.

Essentially isotropic permanent magnets of the type known as Alnico magnets contain iron, nickel and aluminum as basic or essential ingredients. It is well known or has been proposed to include other elements such as cobalt, copper, titanium, silicon, chromium, molybdenum, tungsten, manganese, sulphur, and others either for the purpose of modifying or enhancing the physical and/or magnetic properties of the alloys. Many of these magnetic alloys have been produced in both cast and sintered form, and provided the proper procedures are followed in the manufacture of the sintered products to prevent oxidation of the aluminum and any other highly oxidizable elements, it has been found that for most of the alloys the sintered products exhibited the same or approximately the same magnetic properties as the cast products of the same composition.

Another known development in the Alnico magnet field was the discovery described more fully in Jonas Patent 2,295,082 that certain cast Ni-Al-Fe alloys having a cobalt content of 16 to 30%, a nickel content of 12 to 20%, and an aluminum content of 6 to 11% when heat treated in a magnetic field would exhibit BH max. values in one direction (anisotrope) which was at least 50%, and generally over 100%, higher than that for the same alloy whose magnetic properties were substantially equal in all directions (isotrope). As a result of this development there is now commercially available cast Alnico magnets having approximately the following minimum magnetic properties:

Peak H	oersteds	2,000
Peak B	gauss	15,700
Coercive force H_c	oersteds	575
Residual B_r	gauss	12,000
BH max	gauss-oersteds	4.5×10^6

A cast magnet possessing these excellent magnetic values consists of an alloy of about 8% aluminum, 14% nickel, 24% cobalt, 3% copper, balance substantially iron, the exceptional magnetic properties being obtained by heat treatment or cooling of the alloy in a magnetic field as described in the above-mentioned Jonas patent. Because of the exceptional magnetic qualities of this cast alloy and the known advantages of the powder metallurgy techniques numerous attempts have been made to duplicate its magnetic properties in a sintered magnet alloy.

Unlike the isotropic type of Alnico alloys, it was found that simple duplication of the chemical composition of the anisotropic type of alloy, as described in the Jonas patent, in a sintered product, did not result in a very satisfactory permanent magnet. There appears to be many other factors which influence the effectiveness of the magnetic field treatment in imparting superior available energy products to the alloy.

The present invention is based on the discovery that an anisotropic sintered magnet can be prepared by including additions of titanium in the compositions now employed in making cast magnets having directional properties. It has been found that the titanium is an essential element of the sintered magnets of the present invention in order to obtain a high available energy product. In accordance with prior teachings concerning the effect of titanium in the cast magnets this element has been considered non-essential and when employed, its effect was that of a lattice stress raiser with a tendency to increase the coercive force of the cast alloy at some sacrifice of available energy. In the sintered products of the present invention the titanium addition does not produce as marked an increase in coercive force as noted with the cast alloys. The titanium addition in the sintered product appears to make the magnetic field treatment more effective in obtaining a high available energy product, which product is an accepted criterion for comparing permanent magnet alloys. Hence, the effect of the titanium on the magnetic properties seems to be quite different in the sintered and cast alloy fields.

The sintered magnets of the present invention are characterized by a titanium content of at least 0.25% and not over 1.5%, generally from 0.6 to 1.25%. While the invention is broadly applicable to the various known anisotropic magnet alloys characterized by a cobalt content of 16 to 30%, a nickel content of 11 to 20%, and an aluminum content of 6 to 11%, the preferred sintered magnets are those containing 7.5 to 9% aluminum, 0.6 to 1.25% titanium, 22 to 26% cobalt, 2 to 4% copper, 13 to 15% nickel, remainder iron except for incidental impurities.

Particularly good results have been obtained by employing 8.5% aluminum, 1% titanium, 25% cobalt, 3% copper, 14% nickel, balance iron. The sintered products are prepared in the manner usually employed in making sintered Alnico magnets as described for example in Howe Patents 2,192,743 and 2,192,744. A foundation alloy of iron-aluminum, cobalt-aluminum or nickel-aluminum is used as the source of aluminum, while a titanium alloy such as a 70–30 titanium-nickel alloy can be used to supply the desired titanium content of the product. The finely-divided materials are mixed in the desired proportions, and pressed to the desired form or shape. The pressed products are sintered in a hydrogen atmosphere at temperatures of from 1000 to 1400° C. preferably at a temperature below but close to the melting point of the alloy. The time required for the sintering action will, of course, depend upon the furnace load and size of the pieces to be sintered. The sintered material can then be normalized by heating to an elevated temperature after which the sintered product is subjected to a further heat treatment in a magnetic field as described in the Jonas Patent 2,295,082 to make the sintered alloy magnetically anisotropic. The heat treatment in the magnetic field is preferably carried out by withdrawing the sintered alloy compacts from the sintering zone of the furnace at a temperature of about 1250° C. and controlling their cooling cycle in a magnetic field of proper field strength. Further low temperature treatments may be applied as described by Jonas.

The resultant magnets are characterized by a BH max. at least equal to 3.5×10^6 gauss-oersteds and in some cases energy products as high as 4.5×10^6 have been obtained. In general, the magnetic properties of the sintered magnets of the specific formula given hereinbefore include a peak B of at least 15,000, a B_r of at least 10,000, an H_c of at least 600 and a BH max. of about 4 to 4.25×10^6. These BH max. values are to be compared with values of from 1.4 to 1.6×10^6 for the best commercially available sintered Alnico magnets and 4.5 to 6×10^6 for the best anisotropic cast Alnicos.

As indicated hereinbefore, the effect of titanium on the sintered products differs from that in the cast alloys. For instance, whereas the addition of one per cent titanium to the best anisotropic cast Alnico, i. e., an Alnico containing 8% aluminum, 14% nickel, 24% cobalt, 3% copper, balance iron lowers the BH max. value of the alloy, the addition of the same amount of titanium to a sintered Alnico composition of the same composition increases the BH max. value.

This effect of titanium on the magnetic properties of cast and sintered Alnico products is apparent from the following table setting forth the representative magnetic

values of cast and sintered products all of which contained from 8 to 8.5% aluminum, 24% cobalt, 14 to 14.5% nickel, to 3.25% copper, balance iron except in those cases where 1% titanium has been substituted for a corresponding amount of iron:

Titanium	Alloy	B_r	H_c	BH max.
None	Cast	12,500–13,000	540–600	4.5 to 5.5×10⁶
None	Sintered	11,000–12,000	450–550	2.0 to 3.0×10⁶
1%	Cast	10,000–10,500	750–800	2.8 to 3.5×10⁶
1%	Sintered	10,000–10,500	600–650	3.5 to 4.5×10⁶

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

1. An anisotropic sintered permanent magnet containing 7.5 to 9% aluminum, 13 to 15% nickel, 22 to 26% cobalt, 2 to 4% copper, 0.6 to 1.50% titanium, balance iron except for incidental impurities, said magnet having a BH max. in the principal direction at least equal to 3.5×10^6.

2. An anisotropic sintered permanent magnet consisting of 8.5% aluminum, 14% nickel, 25% cobalt, 3% copper, 0.6–1.25% titanium, balance iron except for incidental impurities, said sintered magnet having a BH max. of at least 3.5×10^6.

3. An anisotropic sintered permanent magnet consisting of 8.5% aluminum, 14% nickel, 25% cobalt, 3% copper, 1% titanium, balance substantially all iron, said magnet having a BH max. of at least 3.5×10^6.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,167,240	Hensel	July 25, 1939
2,245,477	Jonas	June 10, 1941
2,285,406	Bieber	June 9, 1942
2,295,082	Jonas	Sept. 8, 1942
2,384,450	Bieber	Sept. 11, 1945

FOREIGN PATENTS

Number	Country	Date
102,215	Great Britain	Oct. 6, 1937
462,248	Great Britain	Mar. 4, 1937
522,731	Great Britain	June 26, 1940