

UNITED STATES PATENT OFFICE

2,546,047

SINTERED ANISOTROPIC ALNICO MAGNET

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The present invention relates to sintered anisotropic Alnico magnet alloys. It is particularly concerned with sintered Alnico magnets containing zirconium, which magnets are prepared by powder metallurgy techniques and have BH_{max} values corresponding to those, 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 2,295,982 that certain cast nickel-aluminum-iron alloys having a cobalt content of 16 to 30 per cent, a nickel content of 12 to 20 per cent, and an aluminum content of 6 to 11 per cent when heat treated in a magnetic field would exhibit BH_{max} values in one direction (anisotrope) which was at least 50 per cent, and generally over 100 per cent, 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	-----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 per cent aluminum, 14 per cent nickel, 24 per cent cobalt, 3 per cent 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-

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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.

In my copending application, Serial No. 9,013, filed February 17, 1948, and assigned to the same assignee as the present invention, there are described anisotropic sintered magnets possessing high BH_{max} values, the sintered magnets containing titanium as an essential ingredient.

The present invention is based on the discovery that an anisotropic sintered magnet can also be obtained by including additions of zirconium in the compositions employed in making cast anisotropic magnets. The zirconium appears to perform the same function in the sintered alloys as does the titanium although, in general, only about half as much by weight of zirconium is required to obtain the same magnetic properties in the finished sintered alloy.

The presence of zirconium in the sintered products 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. In addition, by using the zirconium in smaller amounts by weight than titanium to obtain a product having equivalent magnetic characteristics, it has been found that there is less tendency toward surface oxidation and distortion of the sintered material.

The sintered magnets of the present invention are generally characterized by a zirconium content of at least .15 to about 1.25 per cent, generally from 0.3 to 1.0 per cent. While the invention is broadly applicable to the various known anisotropic magnet alloys characterized by a cobalt content of 16 to 30 per cent, a nickel content of 11 to 20 per cent, and an aluminum content of 6 to 11 per cent, the preferred sintered magnets are those containing 7.5 to 9 per cent aluminum, 0.3 to 0.8 per cent zirconium, 22 to 26 per cent cobalt, 2 to 4 per cent copper, 13 to 15 per cent nickel, remainder substantially all iron except

for incidental impurities. Small amounts of titanium may also be present in the sintered alloy in amounts not exceeding about 1.25 per cent, and when titanium is present it may function as a substitute for a part of the zirconium in the proportions of about 2 parts titanium for each part zirconium.

Particularly good results have been obtained by employing 8.5 per cent aluminum, 0.5 per cent zirconium, 25 per cent cobalt, 3.25 per cent copper, 14 per cent 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. The source of zirconium may suitably be a foundation alloy of nickel-zirconium such as 50-50 nickel-zirconium alloy powder, while the foundation alloy of iron-aluminum, cobalt-aluminum, or nickel-aluminum can be used as a source of aluminum. 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 usually exhibit a BH_{max} at least equal to 3.5×10^6 gauss-oersteds, a B_r of at least 10,000 and H_c of at least 600. Typical magnetic properties of a sintered magnet having the preferred composition set forth hereinbefore include a B_r of 10,600 gauss an H_c of 600 oersteds, and a BH_{max} of 4×10^6 . These BH_{max} values are to be compared with values of 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. The effect of the zirconium on the magnetic properties of the sintered material becomes clearly evident from

a comparison of the magnetic characteristics of a heat-treated, sintered mixture of from 8 to 8.5 per cent aluminium, 24 per cent cobalt, 14 to 14.5 per cent nickel, 3.25 per cent copper, balance iron with the magnetic characteristics of a similarly prepared and heat treated sintered material of the same composition but containing in addition .5 per cent zirconium. The sintered alloy free of zirconium is characterized by a B_r of 11,000 to 12,000 and H_c of 450 to 550 and BH_{max} of 2.0 to 3.0×10^6 , whereas the sintered alloy containing an addition of .5 per cent zirconium has a slightly lower B_r of 10,600, a somewhat higher H_c of 600, and a much higher BH_{max} of 4×10^6 .

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 per cent aluminum, 13 to 15 per cent nickel, 22 to 26 per cent cobalt, 2 to 4 per cent copper, 0.3 to 1.0 per cent zirconium, 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 per cent aluminum, 14 per cent nickel, 25 per cent cobalt, 3 per cent copper, 0.3 to 0.8 per cent zirconium, 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 per cent aluminum, 14 per cent nickel, 25 per cent cobalt, 3 per cent copper, 0.5 per cent zirconium, balance substantially all iron, said magnet having a BH_{max} of at least 3.5×10^6 .

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REFERENCES CITED

The following references are of record in the file of this patent:

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