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METHODS OF IMPROVING THE MAGNETIC QUALITY OF ANISOTROPIC PERMANENT MAGNETS CONTAINING IRON, NICKEL, COBALT, AND ALUMINUM

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2 Claims. (Cl. 148—10)

1

This invention relates to the production of permanent magnets, more especially of the types which consist principally of iron, nickel, cobalt, and aluminum, and specifically the types which are cooled in a magnetic field to give them increased values of magnetic energy.

In a patent to G. V. Jonas, 2,295,082, dated September 8, 1942, are described improved permanent magnets having a $(BH)_{max}$ value lying between 3,000,000 and 5,000,000 as compared to previously produced permanent magnets in which the $(BH)_{max}$ value generally did not exceed about 2,000,000 or at the most 3,000,000. Magnets prepared according to the Jonas method comprise various proportions of between 16 per cent to 30 per cent cobalt, 12 per cent to 20 per cent nickel, 6 per cent to 11 per cent aluminum, and the balance chiefly iron. The compositions may, however, include copper or titanium in amounts up to 7 per cent copper or 5 per cent titanium or both of these elements. The general subject-matter of the Jonas patent has been known for some time, having become available by the publication of British Patent 522,731, accepted June 26, 1940. During this time considerable efforts have been expended in producing magnets of various sizes and dimensions with high values of $(BH)_{max}$. In many cases where size or weight is an important consideration in a piece of apparatus or equipment, a correspondingly high value of $(BH)_{max}$ is likewise of importance. These attempts to produce products such as one would expect to produce did not achieve a uniform degree of success. It was found, for example, that there were unexpected variations in quality of magnets and that the expected high values of $(BH)_{max}$ were not always achieved.

Thus, for example, magnets having a nominal composition of 51½ per cent iron, 13½ per cent nickel, 24 per cent cobalt, 8 per cent aluminum and 3 per cent copper were found to vary in $(BH)_{max}$ value from $.25\times10^6$ to 4.6×10^6.

For these magnets, virgin commercial aluminum, electrolytic copper, electrolytic nickel, and cobalt in the form of rondelles refined from African ore were employed. The product was unexpectedly variable and much of it unsatisfactory in quality.

As part of a manufacturing process the magnets were cast, then maintained for from one to two hours at a temperature of from 1290° to 1320° C. and then cooled in a magnetic field of about 1,000 oersteds at a rate such that they reached a temperature of about 600° C. in nine months. In order to insure this rate of cooling, the specimens were covered with an asbestos shield or other suitable protective material while applied to the poles of an electromagnet. After being taken from the electromagnet at around 500° to 600° C. the specimens were cooled in air at room temperature and then treated by aging for eight hours at 595° C. It is not necessary, however, to cool the magnets to room temperature before aging at 595° C.

2

The non-uniformity of the product led to the supposition that the heat treatment at 1290° to 1320° C. had been unsatisfactorily or ineffectively performed and numerous unsatisfactory specimens were retreated one or more times with the result that in almost all instances the magnetic properties were greatly improved. In many instances, improvement was noted from each repetition of the heat treatment until the magnetic quality of the specimen became excellent. In the early stages of this development the reason for the improvement in quality was attributed to more effective heat treatment. However, it was found that this assumption was erroneous and the discovery upon which the present invention is based was made.

It was discovered that the improvement which was achieved by reheat-treating specimens resulted from the elimination of carbon which was contained as an impurity. It has been established by controlled experiments that harmful amounts of carbon in the alloys can be removed by suitable heat treatment. For instance, in the composition, 51½ per cent Fe, 13½ per cent Ni, 24 per cent Co, 8 per cent Al, and 3 per cent Cu, 0.1 per cent carbon reduces the $(BH)_{max}$ value from a normal of 5.0×10^6 (for nearly carbon free material) to approximately 1.0×10^6. Maintaining the specimens for about six hours at 1315° C., however, reduces the carbon content of the alloy to below .02 per cent and brings the $(BH)_{max}$ value back to normal. The mechanism by which carbon is removed from the alloy during heat treating is believed to be by oxidation to carbon monoxide and the effusion of carbon monoxide along grain boundaries. The oxygen supply is believed to be obtained from the oxides which form in the alloy during melting and casting. This heat treating operation may be carried out at temperatures between about 1,200° C. and about 1,350° C.

So far as is known at the present time the difference between 0.012 per cent carbon and the smallest amount which has been achieved, namely 0.005 per cent carbon, does not appear to be substantial as the difference in $(BH)_{max}$ at 0.012

per cent carbon and the smallest carbon content which could be achieved is no greater than about 5 per cent. As the carbon content increases, the magnetic quality decreases rapidly so that at about 0.084 per cent carbon the value of $(BH)_{max}$ is less than one-fourth of that achieved when the carbon content is kept low. As the carbon content increases, a further rapid reduction in the magnetic quality occurs.

Some typical experimental data are given in the following table.

Specimen No.	Per Cent Carbon	B_m Gausses	H_c Oersteds	B_r Gausses	$(BH)_{max}$ G-O$\times 10^6$	Fullness Factor
1	.005	16,210	620	12,990	5.09	.63
2	.008	16,320	607	13,220	5.13	.64
3	.012	16,310	604	12,700	4.83	.63
4	.084	16,050	355	10,670	1.13	.30
5	.168	15,720	209	8,560	.56	.31

In the above table:

B_m, measured in gausses, is maximum magnetization.

H_c, measured in oersteds, is coercive force.

B_r, measured in gausses, is residual magnetization.

$(BH)_{max}$, measured in millions of gausses-oerstads, is maximum energy product.

The fullness factor is the ratio

$$\frac{(BH)_{max}}{B_r H_c}$$

What is claimed is:

1. A method of improving the magnetic quality of a magnet formed of an alloy consisting essentially of about 51½ per cent iron, 13½ per cent nickel, 24 per cent cobalt, 8 per cent aluminum and 3 per cent copper and having initially a carbon content greater than .012 per cent, said magnet having been produced by subjecting a body of said alloy to a cycle comprising heating at a temperature between about 1290° C. and about 1320° C. for a period of time between about 1 hour and about 2 hours, cooling said body to about 600° C. in a magnetic field having a strength of about 1000 oersteds at a rate such that it reached 600° C. in about 9 minutes and aging at about 595° C. for about 8 hours, which method comprises again subjecting said magnet body to said cycle by reheating said magnet and again maintaining it at a temperature between about 1290° C. and about 1320° C. for between about 1 hour and about 2 hours, cooling said body to about 600° C. in a magnetic field having a field strength of about 1000 oersteds at a rate such that it reaches 600° C. in about 9 minutes and aging said body at about 595° C. for about 8 hours.

2. The method defined in claim 1 wherein the magnet is subjected to more than one repetition of the heat treating cycle set forth in said claim.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,358,810	Yensen	Nov. 16, 1920
1,542,233	Girin	June 16, 1925
1,621,523	Clement	Mar. 22, 1927
1,947,274	Ruder	Feb. 13, 1934
1,955,141	Meyer	Apr. 17, 1934
1,978,221	Otte	Oct. 23, 1934
2,002,689	Bozorth	May 28, 1935
2,048,166	Pilling	July 21, 1936
2,207,685	Russel et al.	July 9, 1940
2,293,240	Brauburger	Aug. 18, 1942
2,295,082	Jonas	Sept. 8, 1942

FOREIGN PATENTS

Number	Country	Date
522,731	Great Britain	June 26, 1940