(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 185 439
A1

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 85306148.9

(22) Date of filing: 30.08.85

(51) Int. Cl.[4]: H 01 F 1/14

(30) Priority: 10.12.84 US 679739

(43) Date of publication of application: 25.06.86 Bulletin 86/26

(84) Designated Contracting States: AT BE CH DE FR GB IT LI LU NL SE

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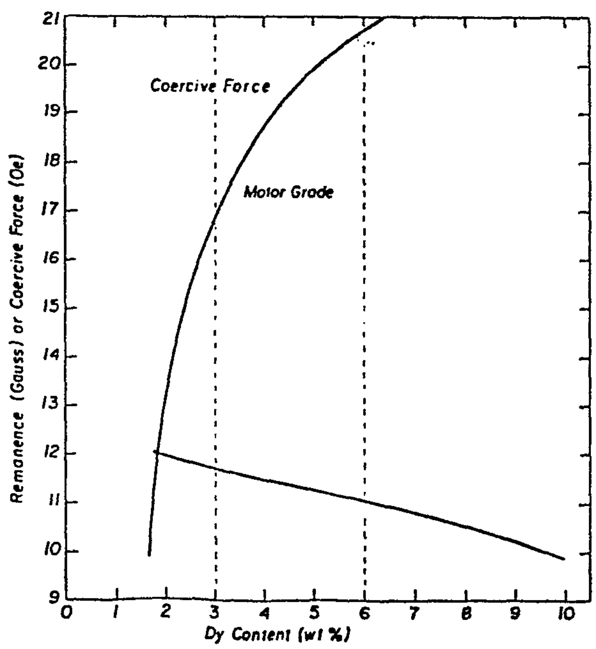
(54) **Permanent magnet alloy.**

(57) A permanent magnet alloy consisting of, in weight percent, 1 to 10 dysprosium, 20 to 37 neodymium, with the total dysprosium and neodymium content being within the range of 30 to 38, 0.8 to 1.33 boron and balance iron and impurities usual in metal alloys. This alloy is characterized by high resistance to demagnetization at elevated temperatures with the alloy content being of relatively low cost.



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PERMANENT MAGNET ALLOY

This invention relates to permanent magnet alloys.

Permanent magnet alloys used in the production of permanent magnets for use in electric motors, and particularly electric motors used in household appliances and the like, are required to have good resistance to demagnetization at elevated temperatures for efficient motor operation. The temperatures involved in these motor applications are typically within the range of 125 to 150°C. To achieve high resistance to demagnetization good remanence (B_r) and coercive force (H_{ci}) values are required within this temperature range. It is further desired in applications such as permanent magnets used in electric motors for household appliance applications that the alloy of the magnet be relatively low cost.

It is known that permanent magnet alloys of neodymium, iron, boron have remanence values sufficiently high for the purpose and these are relatively inexpensive alloys; however, at the typical service temperatures of 125 to 150°C magnets of these alloys are characterized by a loss of coercive force to below the level suitable for the purpose. Coercive force is known to be increased by increasing the crystal anisotropy or the anisotropy field (H_A).

It is accordingly a primary object of the present invention to provide a low-cost permanent magnet alloy that may be used in the manufacture of magnets having high resistance to demagnetization at elevated temperatures within the range of 125 to 150°C.

A more specific object of the invention is to provide a permanent magnet alloy of low cost having a good combination of both remanence and coercive force within the temperature range of 125 to 150°C which increase in coercive force is achieved by an improved crystal anisotropy without decreasing remanence to below acceptable levels.

The permanent magnet alloy of the invention consists of, in weight percent, 1 to 10 dysprosium, 20 to 37 neodymium, with the total dysprosium and neodymium content being within the range of 30 to 38, 0.8 to 1.33 boron and balance iron and impurities usual in metal alloys. Preferably the dysprosium content is from 2.5 to 6.5% and more preferred from 3 to 6%.

The invention will be more particularly described with reference to the accompanying drawing taken in conjunction with the following description and specific examples.

The single FIGURE of the drawing is a graph illustrating the effect of the dysprosium content of a magnet alloy on the coercive force.

It is known generally that coercive force (H_{ci})is increased by increases in the crystal anisotropy (H_A). It has been discovered, in accordance with the present invention, that generally with magnet alloys of iron and boron with a neodymium content of approximately 33% the H_A in kilo oersteds is 150; with similar alloys having dysprosium as the rare earth element the H_A values in kilo oersteds are approximately 314. It may be seen, therefore, that by the use of dysprosium in rare earth, iron, boron alloys the crystal anisotropy is improved to in turn increase the coercive force. In addition, however, it has been determined that the use of dysprosium in alloys of this type decreases remanence (B_r).

The following specific examples of the invention show with neodymium, iron, boron magnets the temperature effect on loss of coercive force. Also, the examples demonstrate that coercive force in magnet alloys of this type are increased by the addition of dysprosium as a rare earth element. They also show that increased dysprosium above the limits of the invention decreases remanence values to below acceptable levels.

Consequently, it is critical with regard to achieving a combination of good remanence and coercive force within the required temperature range of 125 to 150°C to have the rare earth element content of the alloy comprise a combination of dysprosium and neodymium.

An alloy of Nd (33%) B (1%) FE (66%) in weight percent was melted, crushed to about 1 to 10 micron particle size. The fine powder was oriented in a magnetic field and pressed. The pressed part was sintered over a temperature range of 1000°C - 1100°C and cooled. The sintered magnet had the intrinsic coercive force at the indicated temperatures in Table I.

TABLE I

INTRINSIC COERCIVE FORCE VARIATION WITH TEMPERATURE FOR AN ALLOY CONTAINING NO DY

Temperature (°C)	Intrinsic Coercive Force (Oe)
20	10,500
62	6,130
94	3,900
142	2,550

The remanence of the magnet varied from 12,100 Gauss to 10,738 Gauss from 20° to 145°C. The loss of intrinsic coercive force to below 6,000 Oersted at 94°C makes this magnet not applicable for motors.

Dysprosium was added to the NdFeB alloy while maintaining the total rare earth content as 35.6% and 37.1%. Tables II and III list the magnetic properties of the magnets.

TABLE II

INTRINSIC COERCIVE FORCE AND REMANENCE FOR ALLOYS OF NdDyFeB WITH A TOTAL Dy+Nd = 35.6% AT ROOM TEMPERATURE

Wt. % Dy	B_r (G)	H_{ci} (Oe)
1.86	11,200	9,600

2.97	11,650	15,830
4.10	11,700	18,800
5.21	11,560	>20,000
6.32	11,000	>20,000
6.88	11,000	>20,000
7.44	11,200	>20,000

TABLE III

Dy + Nd = 37.1%

Wt. % Dy	Br (G)	H_{ci} (Oe)
1.74	12,380	13,020
2.78	11,750	17,000
3.83	11,330	19,300
4.87	10,800	>20,000
5.92	11,300	>20,000
6.43	10,700	>20,000

As can be seen from Tables II and III and FIG.1 adding dysprosium increases the coercive force rapidly at room temperature. The temperature dependence of the coercive force of a 3% Dy containing alloy and 6% Dy containing alloy is given in Table IV.

TABLE IV

COERCIVE FORCE DEPENDENCE ON TEMPERATURE OF 3% AND 6% Dy CONTAINING MAGNET

3% Dy Containing Magnet

Temperature (^{o}C)	Intrinsic Coercive Force (Oe)
20	16,100
69	11,100
87	9,500
140	5,200

6% Dy Containing Magnet

Temperature (^{o}C)	Intrinsic Coercive Force (Oe)
20	20,000
78	15,900
106	12,750
147	8,400

As can be seen from Table IV, dysprosium addition in combination with neodymium permits utilization of these magnets at elevated temperatures. Increasing the dysprosium further results in a decrease in B_r which makes the magnets not have enough flux at the required temperature for the intended applications. Table V shows the magnetic properties of a 10% Dy containing magnet.

TABLE V

10% Dy CONTAINING MAGNET

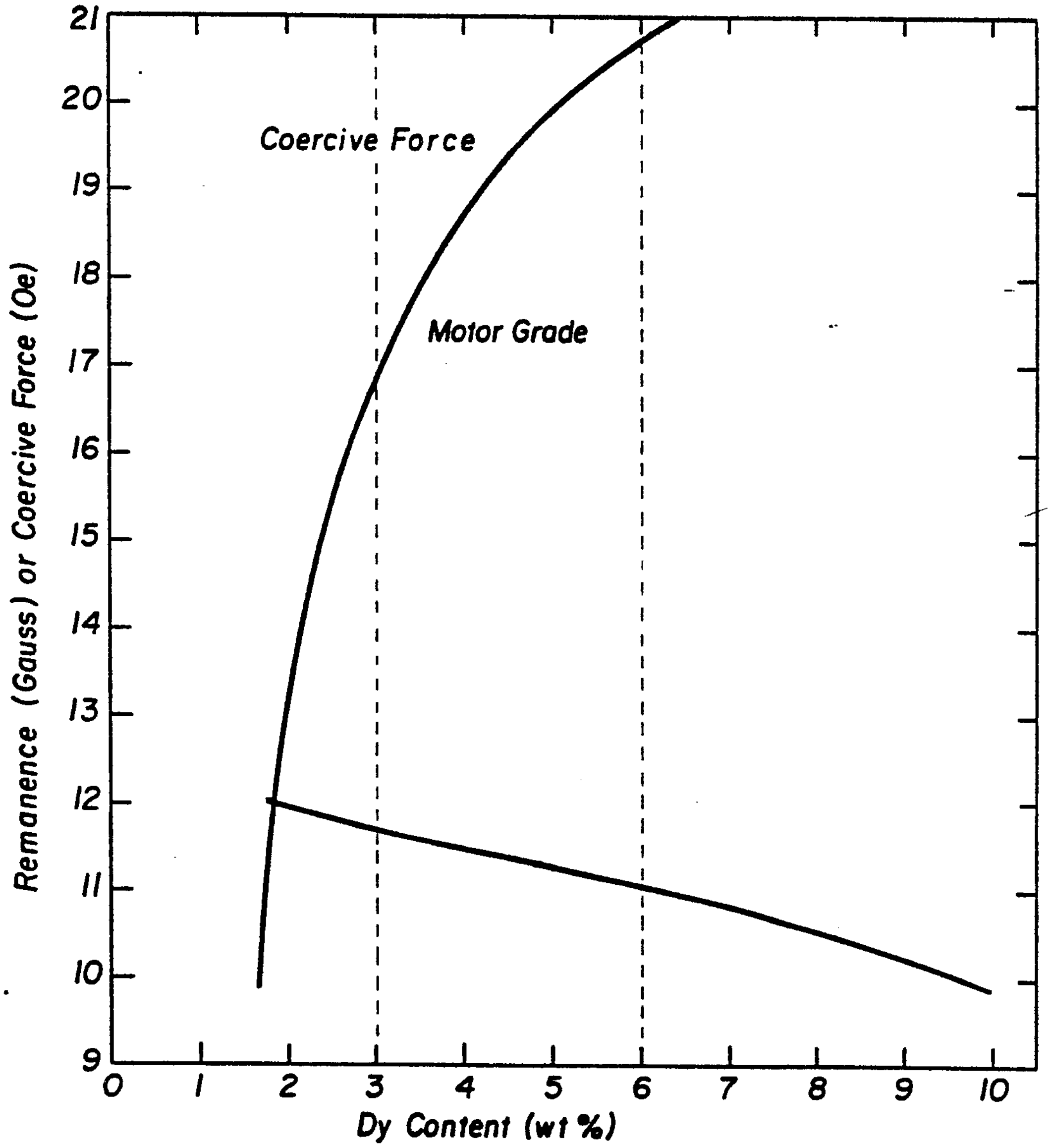
B_r (G)	H_{ci} (Oe)
9,900	>26,000

CLAIMS

1. A permanent magnet alloy characterised in consisting of, in weight percent, 1 to 10 dysprosium, 20 to 37 neodymium, with the total dysprosium and neodymium content being within the range of 30 to 38, 0.8 to 1.33 boron and balance iron and impurities usual in metal alloys.

2. An alloy according to claim 1, wherein dysprosium is present in an amount of from 2.5 to 6.5%.

3. An alloy according to claim 1 or 2, wherein dysprosium is present in an amount of from 3 to 6%.


Coercive Force
Motor Grade
Remanence (Gauss) or Coercive Force (Oe)
Dy Content (wt %)
21
20
19
18
17
16
15
14
13
12
11
10
9
0
1
2
3
4
5
6
7
8
9
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European Patent Office

0185439

Application number

EUROPEAN SEARCH REPORT

EP 85306148.0

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	ES - A3 - 8 504 404 (PROYECTOS MAGNETICOS) * Abstract; claims 1-5 * ----	1	H 01 F 1/14
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			H 01 F 1/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	14-03-1986	VAKIL

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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