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(73) Proprietor: **Hitachi Metals, Ltd.**
1-2, Marunouchi, 2-chome Chiyoda-ku
Tokyo 100 (JP)

(72) Inventor: **Ogata, Yasunobu**
450, Niibori-Shinden
Kumagaya (JP)
Inventor: **Sawada, Yoshizo**
641-44, Suganuma
Kawamoto Saitama (JP)
Inventor: **Yoshizawa, Yoshihito**
450, Niibori-Shinden
Kumagaya (JP)
Inventor: **Arai, Yasuo**
***Sunrise Mansion* 901**
Miyamae-cho Kumagaya (JP)
Inventor: **Arakawa, Shunsuke**
636-3, Niibori-Shinden
Kumagaya (JP)

(74) Representative: **Strehl, Peter, Dipl.-Ing. et al**
Strehl, Schübel-Hopf, Schulz Patentanwälte
Widenmayerstrasse 17 Postfach 22 03 45
D-8000 München 22 (DE)

Courier Press, Leamington Spa, England.

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Description

The present invention relates to a wound core having toroidal shape and being formed by winding a thin strip of a Co-base amorphous alloy and annealing the wound core in a magnetic field.

U.S. Patent 4 116 728 discloses a method for treating amorphous magnetic alloys to produce a wide range of magnetic properties. It reports that a $(Ni, Fe, Co)_{0,75}$ $(P, B, Al)_{0,25}$ alloy has a low coercive force and that annealing of a zero magnetostrictive composition reduces the coercive force to 1 A/m.

Wound iron cores made of, for example, anisotropic 50% Ni permalloy, supermalloy, directional silicon steel or the like material are finding use in magnetic phase shifters magnetic amplifiers, D.C. current detectors, magnetic modulators and nowadays in a switching power source carrying a magnetic amplifier. As is well known, these conventional wound iron cores have a large rectangle ratio Br/B_{10} in the B—H hysteresis curve. Recently, however, there is an increasing demand for a wound iron core which exhibits not only a large rectangle ratio Br/B_{10} but also a small coercive force Hc.

In a switching power source carrying a magnetic amplifier, the wound iron core is used at a high frequency of an order of several tens of kilohertz (KHz) or higher. The 50% Ni permalloy, which is one of the conventionally used materials, exhibits a coercive force Hc which is as large as 8 A/m to cause a large loss in the core resulting in a large heat generation. This gives a rise to a demand for a wound iron core having a rectangle ratio Br/B_{10} equivalent to that of the 50% Ni permalloy and a coercive force Hc smaller than that of the same.

Among the wound iron cores used hitherto, the core of permalloy system such as of 50% Ni permalloy, supermalloy and so forth has a high sensitivity to strain of the magnetic material, so that the magnetic property is deteriorated seriously due to mechanical strain incurred during handling, transportation and winding or coiling thereby making it impossible to attain the expected performance of the wound iron core and the electric balance. In addition, these conventional materials for forming the wound iron core are producible only through a careful and complicated process having the steps such as melting, ingot making, hot rolling, pickling, cold rolling and so forth, so that the production cost is raised uneconomically.

Summary of the invention

Accordingly, an object of the invention is to provide a less-expensive wound core having a rectangle ratio Br/B_{10} equivalent to that of ordinarily used 50% Ni permalloy and smaller coercive force than the same, while offering various advantages such as superior stability against strain and a high impact resistance, as well as easiness in heat treatment for attaining the rectangular hysteresis property, thereby to overcome the above-described problems of the prior art.

The invention is given according to claim 1.

Above and other objects, features and advantages of the invention will become clear from the following description of the preferred embodiment of the invention taken in conjunction with the attached drawing.

Brief description of the drawing

The attached sole Figure shows a D.C. hysteresis curve as obtained with a wound core of the invention formed from a Co-base amorphous alloy strip, in comparison with that exhibited by a wound iron core made from a conventional Fe-base material.

Description of the preferred embodiment

Generally, a Co-base amorphous alloy exhibits a magnetostriction of zero or substantially zero and, hence, a small magnetic anisotropy in the quenched state, which in turn facilitates the uniform and unidirectional magnetization by an external magnetic field during the annealing which is conducted under the influence of the magnetic field to attain a superior rectangular hysteresis property. It is, therefore, possible to attain a distinguished rectangular hysteresis property much more easily than in the case where an amorphous Fe-base alloy which tends to exhibit a large magnetostriction is used as the material. The small magnetostriction permits also a reduction in the coercive force down to a level below 1/10 of that presented by ordinarily used 50% Ni permalloy and below 1/2 of that presented by ordinarily used amorphous Fe-base alloy.

Hitherto, the Co-base amorphous alloy has been used mainly as the material of magnetic heads. No proposal nor attempt has been made up to now as to the use of the Co-base amorphous alloy in place of the 50% Ni permalloy as the magnetic core for the wound iron core, by realizing a rectangular hysteresis property through an annealing of the core in a magnetic field the direction of which is substantially coincident with the direction of the magnetic path in the core.

The present inventors have found that a wound iron core simultaneously exhibiting a large value of the rectangle ratio Br/B_{10} and a low coercive force Hc is obtainable by a process which has the steps of preparing a strip of an amorphous alloy having a composition expressed by $Co_{100-a-b-c}X_aSi_bB_c$, where X represents one, two or more elements selected from the group consisting of Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, and satisfying the conditions of $0 \leqq a \leqq 15$ (atomic %) $10 \leqq b \leqq 20$ (atomic %) and $7 \leqq c \leqq 10$ (atomic %), winding the strip into the form of a core and annealing the

core in a magnetic field having a direction substantially coincident with the direction of the magnetic path in the core.

Metalloid or semimetal elements such as C, Si, B, P, Ge and Al are known as elements for forming amorphous structure. However, for attaining a high thermal stability and toughness, it is preferred to use a combination of Si and B. Although the effect of the invention is not affected seriously by the presence of C, P, Ge or Al, the content of such elements is preferably not greater than 5 atom %. When a specifically high resistance to environmental condition, e.g. a specifically high moisture proof or anti-alkali property is required, the B content should be selected to be not greater than 10 atom % but the B content should not be reduced down below 7 atom % for otherwise the amorphous structure will not be obtained. Any Si content less than 10 atom % and not smaller than 20 atom % is not preferred because such an Si content will seriously deteriorate the thermal stability and increase the coercive force undesirably.

The content of the element X which serves as the transition metal element should be selected to be not greater than 15 atom %, because X content above 15% undesirably increases the magnetostriction λs to a level of 10×10^{-6} or greater. Elements other than Fe, Ni and Mn, when added by an amount smaller than 15 atom %, reduces the magnetostriction nearly to zero and improves the ability for forming the amorphous structure advantageously. The elements X, particularly Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, improves the hardness and, in addition, provides a higher thermal stability through raising the crystallization temperature.

The expected rectangular hysteresis property can be obtained also when the Co-base amorphous alloy strip of above-specified composition is annealed in a magnetic field the direction of which usually coincides with the longitudinal direction of the strip.

Although direct electric current has been used hitherto for forming the external magnetic field during the annealing, an effect almost equivalent to that produced by the direct electric current is obtainable when an electric current obtained by a half-wave rectification or even alternating current (commercial frequency) is used for the formation of the magnetic field.

The advantage of the invention will be fully realized from the following description of example.

Example 1

A Co-base amorphous alloy strip of 55 mm wide was prepared to have a composition expressed by $(Co_{0.94}Fe_{0.06})_{76.5}Si_{14}B_{9.5}$. The strip was wound in a substantially toroidal form into a wound iron core having an outside diameter of 35 mm and an inside diameter of 25 mm. The wound iron core was subjected to an annealing which was conducted at 320°C for 1 hour in a circumferentially directed magnetic field of 4000 A/m. The properties of the thus produced wound iron core are shown in Table 1 and Fig. 1 in comparison with those of wound iron cores produced from conventionally used 50% Ni permalloy and supermalloy. The wound iron core of Fe-base amorphous alloy appearing in Table 1 and Fig. 1 was made from an alloy having a composition expressed by $Fe_{71}Ni_{10}Si_{10}B_9$ and had been subjected to an optimum annealing conducted in a magnetic field of 4000 A/m as in the case of the iron core of the invention.

TABLE 1

No.		material	B_{10} (10^{-4} T)	Br/B_{10} (%)	Hc(A/m)
1	*	supermalloy (5Mo-79Ni-Fe)	8,000	85	1,2
2		50% Ni permalloy (50Ni-Fe)	15,500	93	9,6
3	Amorphous Material	$(Co_{0.92}Mn_{0.06}Fe_{0.02})_{76}Si_{15}B_9$	9,200	94	0,4
4		$(Co_{0.92}Mn_{0.07}Fe_{0.01})_{76}Cr_1Si_{14}B_9$	8,900	95	1,12
5		$(Co_{0.90}Fe_{0.05}Ni_{0.05})_{77}Si_{14}B_9$	9,400	96	0,32
6		$(Co_{0.80}Fe_{0.05}Ni_{0.15})_{78}Si_{12.5}B_{9.5}$	8,000	97	0,4
7		$(Co_{0.92}Fe_{0.05}Zr_{0.03})_{76}Si_{12}B_{12}$	8,100	92	1,28
8		$(Co_{0.90}Fe_{0.04}Ti_{0.01}Nb_{0.05})_{76}Si_{10}B_{14}$	7,800	91	1,6
9		$(Co_{0.92}Fe_{0.05}Mo_{0.02}Ti_{0.01})_{76}Si_{10}C_2B_{12}$	7,900	93	3,2
10		$(Co_{0.90}Fe_{0.04}Ru_{0.06})_{75}Cr_2Si_{14}B_9$	7,800	95	1,6
11		$(Co_{0.91}Fe_{0.04}W_{0.03}Y_{0.01}Ce_{0.01})_{76}Si_{15}B_9$	8,200	96	2,4
12		$(Co_{0.94}Fe_{0.06})_{75}V_1Y_{0.5}Nb_{0.5}Si_{14}B_9$	8,700	97	1,6
13		$(Co_{0.94}Fe_{0.06})_{75}Cr_2Hf_{0.5}Dy_{0.5}Si_{13}B_9$	8,800	96	2,0
14		$(Co_{0.94}Fe_{0.06})_{74}Cr_2Pr_{0.5}Sm_{0.5}Si_{13}B_{10}$	8,600	95	1,76
15		$(Co_{0.94}Fe_{0.06})_{75}Mo_1Eu_{0.2}Gd_{0.3}Tb_{0.5}Si_{12}B_{11}$	8,500	96	2,0
16		$(Co_{0.94}Fe_{0.06})_{79}Zr_1Ta_2B_{18}$	9,900	97	3,6
17		$(Co_{0.94}Mn_{0.05}Cr_{0.01})_{72}Al_2Si_{14}B_{12}$	9,600	95	3,76
18		$(Co_{0.94}Fe_{0.06})_{75}P_2Ge_3Si_8B_{12}$	9,400	97	3,84

* conventionally used crystalline material

From Table 1, it will be seen that the wound iron core of the invention formed from Co-base amorphous alloy exhibits a superior rectangle ratio Br/B_{10} of 96%, and a coercive force which is as small as less than 1/10 of that exhibited by the iron core formed from conventionally used 50% Ni permalloy.

The wound core made from the strip of Co-base amorphous metal alloy is quite superior to the known wound iron core made from an Fe-base amorphous alloy.

As has been described, according to the invention it is possible to produce easily a wound core having a distinguished performance over known wound iron cores, thereby to offer a great advantage in the field of industry concerned.

Claims

1. A wound core having toroidal shape and being formed by winding a thin strip of a Co-base amorphous magnetic alloy and annealing the wound strip in a magnetic field coincident with the magnetic path in the core, characterized in that said strip has a composition which is expressed by $Co_{100-a-b-c}X_aSi_bB_c$, wherein X represents at least one element selected from the group consisting of Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb and Dy, and wherein a, b and c are numbers satisfying the following relations: $0 \leqq a \leqq 15$ (atomic %), $10 \leqq b \leqq 20$ (atomic %), and $7 \leqq c \leqq 10$ (atomic %).

2. The wound core of claim 1, characterized in that the core has a rectangular ratio Br/B_{10} of 85% or higher in D.C. hysteresis curve.

Patentansprüche

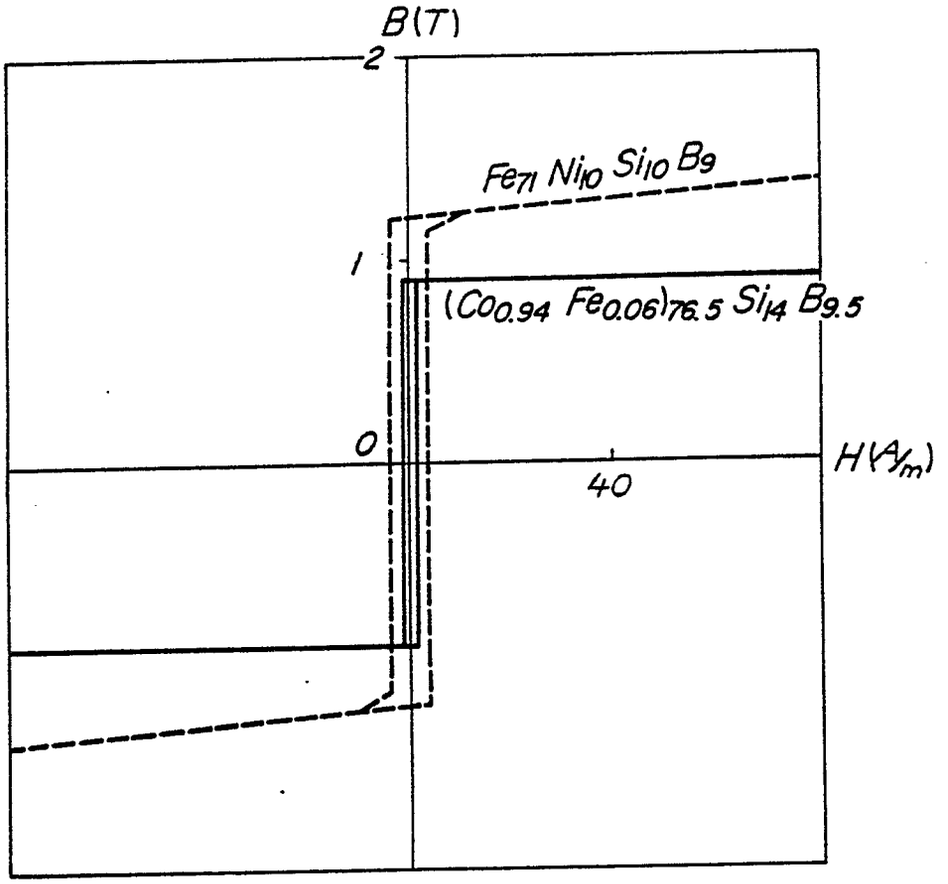
1. Gewickelter Eisenkern mit einer toroidförmigen Gestalt, der durch Aufwickeln eines dünnen Streifens einer amorphen magnetischen Legierung auf Co-Basis und durch Tempern des aufgewickelten Streifens in einem Magnetfeld, das mit dem magnetischen Weg in dem Kern zusammenfällt, hergestellt worden ist, dadurch gekennzeichnet, daß der Streifen eine durch $Co_{100-a-b-c}X_aSi_bB_c$ ausgedrückte Zusammensetzung besitzt, wobei X wenigstens ein Element darstellt, das aus der Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb und Dy umfassenden Gruppe ausgewählt ist und wobei a, b und c Zahlen sind, die die folgenden Beziehungen erfüllen: $0 \leqq a \leqq 15$ (Atom-%), $10 \leqq b \leqq 20$ (Atom-%), und $7 \leqq c \leqq 10$ (Atom-%).

2. Gewickelter Eisenkern nach Anspruch 1, dadurch gekennzeichnet, daß das Rechteckverhältnis Br/B_{10} in der Gleichstrom-Hysteresekurve des Kerns 85% oder mehr beträgt.

Revendications

1. Noyau bobiné de forme toroïdale et formé par enroulement d'une bande mince d'un alliage magnétique amorphe à base de Co et recuit de la bande enroulée dans un champ magnétique coïncidant avec le trajet magnétique dans le noyau, caractérisé en ce que ladite bande a une composition exprimée par $Co_{100-a-b-c}X_aSi_bB_c$, où X représente au moins un élément choisi dans le groupe consistant en Ti, V, Cr, Mn, Fe, Ni, Zr, Nb, Mo, Ru, Hf, Ta, W, Y, Ce, Pr, Nd, Sm, Eu, Gd, Tb et Dy, et en ce que a, b et c sont des nombres satisfaisant les relations suivantes: $0 \leqq a \leqq 15$ (% atomique) $10 \leqq b \leqq 20$ (% atomique), et $7 \leqq c \leqq 10$ (% atomique).

2. Noyau bobiné selon la revendication 1, caractérisé en ce que le noyau présente un rapport rectangulaire Br/B_{10} de 85% ou plus dans la courbe d'hystérésis en courant continu.


B(T)
2
1
0
40
H(A/m)
Fe71 Ni10 Si10 B9
(Co0.94 Fe0.06)76.5 Si14 B9.5