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Internal closed magnetic circuit anisotropic magnet and method.

An internal closed magnetic circuit anisotropic magnet magnetic particles orientation region serving as a working surface. Axes of easy magnetization are oriented to pass through the of the magnet from the edge portion to focus on the working surface.

The magnet is produced by supplying a fluid magnet raw material to a magnetic orientation molding machine, and molding the raw material while applying a magnetic field thereto. A pulsed strong magnetic field is applied by pulsatively passing a large current through an exciting coil a different magnetic field is applied for orienting the magnetic particles.

The present invention relates to an anisotropic magnet, and particularly to means for improvement of the surface magnetic field of a working surface of an anisotropic magnet after magnetization. It further relates to a novel method of making such a magnet.

The present invention can be effectively used for applications which require strong surface magnetic field and long lines of magnetic force. The application of the present invention is not limited, although it is preferably used for signal magnets, magnets for fixed displays such as paper, notes and the like, attractive display boards, health apparatus and the like.

Rare earth or ferrite sintered magnets and plastic magnets are generally used for attraction fixing. However, the magnetic particles in such magnets are oriented in the direction of the magnet thickness, and the magnetic characteristics depend upon the type of raw materials used and the content of the magnetic particles.

An anisotropic permanent magnet has been proposed as an improved magnet in Japanese Patent Publication No. 63-59243 in which consideration was given to the direction of orientation of the magnetic particles to improve magnetic characteristics. In this magnet, the directions of the axes of easy magnetization are focused on and oriented to a working surface from the non-working surfaces. The magnet permits an increase of magnetic flux density (or magnetic flux per unit segment), as compared with previous magnets.

Although the focusing orientation type anisotropic magnet has a greater surface magnetic field than that of an anisotropic magnet, the magnet cannot be satisfactorily used for some applications.

In addition, if an attempt is made to improve magnetic characteristics, expensive magnetic particles must be used, or an attempt must be made to increase the density of the magnetic particles of the magnet. This causes cost increase.

The present invention seeks to provide an anisotropic magnet having increased surface magnetic flux density, further to provide a superior magnet at lower cost and still further to provide a novel method of producing a magnet in accordance with the present invention. Other aims of the invention will be understood from the description the present invention below.

We have vigorously researched the reasons why the magnetic characteristics of the magnet disclosed in Japanese Patent Publication No. 63-59243 in which the orientation of magnetic particles is focused on and oriented to a working surface from non-working surfaces (referred to as "focusing orientation" hereinafter) are superior to those of a conventional magnet in which magnetic particles are oriented along the direction of the thickness of a plate (referred to as "axial orientation" hereinafter). As a result, we believe that the reason why the magnetic characteristics such as the attraction force and the like of the former magnet are superior to those of the latter magnet lies in the fact that the lines of magnetic force uselessly radiated from the non-working surfaces during attraction by the magnet, are decreased.

We have discovered that, when the lines of magnetic force uselessly radiated during attraction were removed, and when the radiation of a magnetic flux is limited to the working surface, the unexpected result of improving the surface magnetic field was obtained.

The present invention provides an internal closed magnetic circuit-type anisotropic magnet comprising a permanent magnet having at least one orientation region of magnetic particles on a working surface comprising a flat or curved surface, wherein the axes of easy magnetization of magnetic particles in the orientation region are passed through the magnet from the edge portion of the orientation region and focused on and oriented to the central portion of the orientation region.

The present invention also provides a method of effectively producing such a superior magnet.

For a better understanding of the invention and to show how the same may be carried into effect, reference will be made, by way of example only, to the following drawings, in which:

Fig. 1 is a drawing showing the state wherein lines of magnetic force are radiated from an internal closed magnetic circuit type anisotropic magnet in accordance with the present invention;

Fig. 2(a) is a drawing showing a pattern of a surface magnetic flux density on a working surface of the same magnet, Fig. 2(b) is a drawing showing the pattern of a surface magnetic flux density on a working surface of an axial type magnet; and Fig. 2(c) is a drawing showing a pattern of a surface magnetic flux density on a working surface of a focusing orientation the magnet;

Fig. 3(a) is a schematic drawing showing an example in which the present invention is applied to an annular magnet;

Fig. 3(b) is a sectional view showing a direction of orientation of the axes of easy magnetization of magnetic particles in a cross section taken along line A-A, of Fig. 3(a);

Fig. 3(b) is a sectional view showing a direction of orientation of the axes of easy magnetization of magnetic particles in a cross section taken along line B-B of Fig. 3(a);

Figs. 4(a) and 4(b) are drawings showing a cylindrical magnet having a working surface on the external periphery (4(a)) or the internal periphery (4(b)) thereof;

Figs. 5(a) and 5(b) are drawings showing a case wherein the present invention is applied to plate-like (5(b))

and disk-like (5(a)) magnets;

Fig. 6 is a schematic drawing showing a case wherein the present invention is applied to a spherical magnet;

Figs. 7(a) and 7(b) are schematic drawings showing a mold having a magnetic circuit formed therein and suitably used for producing a magnet of the present invention, in which Fig. 7(a) is a drawing showing a mold for a disk-like magnet, and Fig. 7(b) is a drawing showing a mold for a square magnet;

Fig. 8(a) is a comparative example showing a schematic drawing showing a mold for a conventional axial type magnet, and Fig. 8(b) is a schematic drawing showing another comparative mold for a conventional focusing orientation type magnet;

Fig. 9 is a drawing explaining an outline of calculation of the linear magnetic flux of a magnet;

Figs. 10(a) to 10(c) are schematic drawings respectively showing the orientation of ferrite magnetic particles when a magnetic field is applied thereto, and Figs. 10(d) to 10(f) are schematic drawings respectively showing the orientation of magnetic particles in a conventional case in which no pulsed strong magnetic field is applied;

Figs. 11(a) to 11(c) are schematic drawings showing the orientations of rare earth magnetic particles when a magnetic field is applied thereto, and Figs. 11(d) to 11(f) are schematic drawings showing the orientations of magnetic particles when no pulsed strong magnetic field is applied thereto; and

Fig. 12 is an explanatory drawing showing a disk-like magnet in which magnetic particles are oriented in accordance with the present invention.

The present invention described in detail below.

Fig. 1 shows the lines of magnetic force radiated when a magnet (internal closed magnetic circuit type anisotropic magnet) in accordance with the present invention is attached to a ferromagnetic substance.

As is seen from the drawing, substantially no line of magnetic force is radiated from any surface other than the working surface. A remarkably excellent magnetic flux density can thus be obtained, as compared with conventional axial type magnets or conventional focusing orientation type magnets.

The magnet of the present invention may have a flat or a curved working surface. This enables the magnet to attract any desired surface and allows the magnet to be applied to a rotor of a precision motor, for example.

In addition, an orientation region of magnetic particles is formed on the working surface, and the number of orientation regions may be one when the magnet is used simply for attraction. However, for example, when the magnet is used in a measuring machine, a plurality of orientation regions of magnetic particles may be arranged at constant intervals. The orientation regions may be appropriately physically arranged in accordance with the desired applications.

An important characteristic of the present invention is the arrangement of the axes of easy magnetization of the magnetic particles in the orientation region. According to the present invention the axes of easy magnetization of the magnetic particles in magnet 2 of Fig. 1 are oriented along lines which pass through the body of the magnet in direction extending substantially from the edge portion of the orientation region of the magnetic particles to a substantially central portion thereof. This is shown by the dotted lines 1 in Fig. 1. As result, in the orientation region, the axes of easy magnetization are arranged as substantially concentric rings as if they were arranged along "growth rings" as viewed in a cross section vertical to the working or attracting surface of the magnet.

Since the axes of easy magnetization are arranged in this way the distribution of the lines of magnetic force in the orientation region shows a pattern of substantially annular rings in correspondence with the axes of easy magnetization, and useless radiation of the lines of magnetic force to the outside is substantially completely prevented.

As shown in Fig. 2(a), the pattern of the surface magnetic flux density on the working surface of the magnet of the present invention thus has an angular form, which is sharper than that of a conventional axial magnet as shown in Fig. 2(b) and that of a conventional focusing orientation type magnet as shown in Fig. 2(c). A stronger surface magnetic flux density can thus be obtained, and the range of the lines of magnetic force is increased.

The present invention can be applied to a usual substantially disk-like magnet and to other magnets having various forms including the following:

(1) Application to a substantially annular magnet (Fig. 3)

Orientation regions 4 are regularly arranged on the working surface of a substantially annular magnet 2. The orientations of axes of easy magnetization in sections along line A-A and line B-B in the peripheral direction are as shown in Figs. 3(b) and 3(c), respectively.

This arrangement permits the magnet to be advantageously used for a signal.

(2) Application to substantially cylindrical magnet (Fig. 4)

Orientation regions 4 of magnetic particles are provided on the external peripheral surface (Fig. 4(a)) or the internal peripheral surface (Fig. 4(b)) of a substantially cylindrical magnet 2 at a constant pitch in accordance with one form of the present invention.

This arrangement permits the magnet to be used advantageously for a signal or a small precision motor, for example.

(3) Application to a plate magnet (Fig. 5)

Orientation regions of magnetic particles are provided at a constant pitch or in a geometrical pattern on the upper or lower surface of a plate magnet, which serves as a working surface. The present invention can be preferably applied to general types of plate magnets and to disk-like magnets. This magnet is used for fixing paper or sheet.

(4) Application to a substantially spherical magnet (Fig. 6)

Orientation regions of magnetic particles are provided on a substantially spherical surface serving as a working surface of a magnet along the longitude lines or parallels thereof, at a constant pitch. This type and arrangement of magnet is preferably used for health improving appliances, for example.

In this case, orientation regions of magnetic particles can be provided on the projections formed on the spherical surface.

(Production Method)

The present invention can be applied to either a plastic magnet or a sintered magnet, for example.

Known magnetic particles such as ferrite magnetic particles, Alnico magnetic particles, rare earth-type magnetic particles such as samarium-cobalt magnetic particles, neodymium-iron-boron magnetic particles and the like can be used as magnetic particles in a plastic magnet or a sintered magnet. The particle size of ferrite magnetic particles is preferably about 1.5 μm , as one example, and the particle size of other magnetic particles is preferably about 5 to 50 μm .

Generally known resins can be used. Typical examples of such resins include polyamide resins such as polyamide-6, polyamide-12 and the like; vinyl homopolymer or copolymer resins such as polyvinyl chloride, vinyl chloride-vinyl acetate copolymers, polyethyl methacrylate, polystyrene, polyethylene, polypropylene and the like; synthetic resins such as polyurethane, silicone, polycarbonate, PBT, PET, polyether ether ketone, PPS, chlorinated polyethylene, Hypalon and the like; synthetic rubbers such as propylene-ethylene rubber, Neoprene, styrene-butadiene rubber, acrylonitrile-butadiene rubber and the like; epoxy resins, and phenolic resins; natural resins such as natural rubber, rosin and coumarone-indene resin.

Although the mix ratio between the magnetic particles and the resin used as a binder is quite variable and depends upon application, the ratio of the magnetic particles is preferably about 40 to 70 vol%.

As a matter of course, other substances such as plasticizers, antioxidants, surface treatment agents and the like, which are generally used, can be added in appropriate amounts in accordance with the intended purpose.

In the present invention the surface magnetic field is improved by controlling in a novel arrangement the orientation of a magnetic particles in a magnet.

One outline of orientation of magnetic particles in accordance with the present invention is illustrated in Fig. 7 which shows a substantially disk-like or square magnet as an example. In the drawing, reference numeral 11 denotes a cavity provided on a magnetic orientation mold; reference numeral 12 is a main pole; reference numeral 14 is a counter pole; and reference numeral 15 is a yoke. In this example a the main pole 12 and the counter pole 13 are permanent magnets. However, electromagnets may be used instead.

A plastic magnet may be used consisting magnetic particles and a resin, mixed in a predetermined ratio. The mix is placed in the cavity 11, and the magnetic poles are then disposed at predetermined positions to orient the axes of easy magnetization of the magnetic particles along the lines of magnetic force 15, as shown by the arrows in Figs. 7(a) and 7(b).

(Embodiment)

Embodiment 1

- 5 A substantially disk-like magnet or a substantially square magnet having a diameter or side of 30 mm and a height of 10 mm was formed by magnetic orientation injection molding or magnetic orientation compression molding. A mold was used having each of the magnetic circuits shown in Figs. 7(a) and 7(b), and 8(a) and 8(b) (which are Comparative Examples).

10 Raw Material

Magnetic particle A: ferrite magnetic particle (magneto-plumbite type strontium ferrite with an average particle size of 1.5 μm)

Magnetic particle B: samarium-cobalt magnetic particle ($\text{Sm}_2\text{Co}_{17}$, average particle size 10 μm)

- 15 Synthetic resin: polyamide 12

Plasticizer: TTS (isopropyltriisostearoyl titanate)

Composition

20 Composition P (plastic magnet)

Magnetic particle: 64 vol%

Polyamide 12: 35 vol%

TTS: 1 vol%

25

Composition S (sintered magnet)

Magnetic particle: 50 wt%

Water: 50 wt%

30

Molding Conditions

Injection molding conditions (magnetic orientation injection molding machine containing coil)

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Pellet composition used: Composition A

Injection cylinder temperature: 280°C

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Mold temperature: 100°C

Injection pressure: 1500 kg/cm^2

Excitation time: 20 seconds

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Cooling time: 25 seconds

Injection cycle: 40 seconds

50 Compression molding conditions

Raw material used: Composition B

Drain method: Chamber method

Excitation method: Formation of vertical magnetic field

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Molding temperature: 25°C

Burning temperature: 1250°C

The disk-like magnet formed by the above method was examined with respect to its surface magnetic flux density (peak value) after magnetization and the linear magnetic flux when it was attached to an iron plate.

The results obtained are shown in Table 1.

The term "linear magnetic flux" corresponds to the integral of the magnetic flux distribution at a line on the working surface of a magnet, as illustrated in Fig. 9, and expressed by the following equation:

$$\text{Linear magnetic flux} = \sum P_m \cdot \Delta \ell$$

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Table 1

	Internal Closed Magnetic Circuit Anisotropic Magnet				Axial Type			Focusing Orientation Type	
	Example 1	Example 2	Example 4	Example 5	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Magnetic particle	A		B		A	A	B	A	B
Composition	P		S		P	S	S	P	S
Molding Method	Injection		Compression		Injection	Compression	Compression	Injection	Compression
Magnetic Circuit	Fig.7(a)	Fig.7(b)	Fig.7(a)	Fig.7(b)	Fig.8(a)				
Surface Magnetic Flux Density Peak Value (G)	1610	1490	4590	4200	470	610	1140	630	1500
Linear Magnetic Flux (T·mm)	3.62	3.45	9.00	8.60	1.15	1.51	2.85	1.31	3.25

As seen from Table 1, an all internal closed magnetic circuit type anisotropic magnets obtained in accor-

dance with the present invention, the surface magnetic flux density on the working surface and the linear magnetic flux on the attraction surface when the magnets are attached to an iron plate are significantly improved, as compared with axial type magnets and focusing orientation type magnets, which are obtained in accordance with conventional methods.

- 5 The internal closed magnetic circuit anisotropic magnet of the present invention has the advantage with of excellent attraction, as compared with conventional magnets.

(Improved Production Method)

- 10 As described above, the internal closed magnetic circuit anisotropic magnet of the present invention has the excellent advantage that substantially no line of magnetic force leaks to the outside and that the peak value of the surface magnetic flux density is extremely high. The magnet of the present invention can also easily be produced.

- 15 Although various magnet production methods may be used it is often preferable to employ the method about to be described for improving the uniformity of orientation of the axes of easy magnetization of the magnetic particles.

- The magnet raw material is provided with fluidity by dispersing magnetic particles therein and is supplied to a magnetic orientation molding machine, and is then molded while a magnetic field is being applied, so that the magnetic particles are oriented along the axes of easy magnetization. In this method, a pulsed strong magnetic field may be generated by pulsatively passing a large current through an exciting coil. It is applied to the magnet raw material before the orienting magnetic field is applied for orienting the magnetic particles.

- 20 The steps of this method are described below with reference to Figs. 10(a) to 10(c), in all of which the magnetic moment of each particle is shown by an arrow. In one step a strong magnetic field is applied to a magnet raw material for a short time so as to change only the magnetic direction of each of the magnetic particles with substantially no rotation of the magnetic particles (in the case of a ferrite magnet), or generate a magnetic moment (in the case of a rare earth magnet), thereby arranging the axes of easy magnetization of the magnetic particles within 90° from a direction desirable for the final product (Fig. 10(b)).

- 25 In a subsequent step, a different static magnetic field is applied which differs from the pulsed strong magnetic field of the previous step has an intensity that is effective for rotating and moving the magnetic particles. As a result, deviations of the axes of easy magnetization of the magnetic particles from various directions can be significantly decreased (Fig. 10(c)).

- This step-wise method thus enables the production of a magnet containing magnetic particles having small deviations from a desired direction with small required energy because rotation and movement of the magnetic particles in a plastic or in a slurry are very small.

- 35 The step-wise method is described in more detail below, wherein the orientations of the magnetic particles before a magnetic field are applied is shown in Fig. 10(a), is shown immediately after a pulsed strong magnetic field is applied in (Fig. 10(b)), and is shown after an orientation magnetic field is applied in Fig. 10(c). For comparison, Figs. 10(d) 10(f) schematically show the orientations of the magnetic particles before a magnetic field is applied (Figs. 10(d) and 10 (e)) and after an orientation magnetic field is applied (Fig. 10(f)) when no pulsed strong magnetic field is applied. There is some orientation, but it is not nearly as uniform as it is in Fig. 10(c).

- 40 Figs. 11(a) - 11(c) also schematically show orientations of magnetic particles before a magnetic field is applied (Fig. 10(a)), immediately after a pulsed strong magnetic field is applied (Fig. 10(b)), and after an orientation magnetic field is applied (Fig. 10(c)) when the production method of the present invention is applied to rare earth magnetic particles. For comparison, Figs. 10(a) - 10(c) schematically show orientations of magnetic particles before a magnetic field is applied (Figs. 10(d) and 10 (e)) and after an orientation magnetic field is applied (Fig. 10(f)) when no pulsed strong magnetic field is applied.

- 45 The ferrite magnetic particle 21a shown in Fig. 10(a) has a single magnetic domain structure and manifests the direction of a magnetic moment before the magnetic field is applied. The rare earth magnetic particle 21b shown in Fig. 11(a) displays no magnetic moment before the magnetic field is applied because equal magnetic moments in opposite directions are canceled in the particle. When a pulsed strong magnetic field is applied to the rare earth magnetic particles in accordance with the present invention, the magnetic moment is manifested. The magnetic moments of the magnetic particles are then easily arranged in the orientation direction by applying the orientation magnetic field is applied thereto. The present invention is thus useful for the case where rare earth magnetic particles having an intrinsic coercive force of at least 5000 oersted is used.

- 55 Generally known compositions may be used as the binder composition for a plastic magnet and the slurry composition for a sintered magnet in order to impart fluidity by dispersing the magnetic particles. Additives may be also appropriately added.

The pulsed strong magnetic field is preferably generated by pulsatively passing a large current through

an exciting coil. The optimum value of the large current supplied to the exciting coil depends upon the desired orientation direction and the number of turns of the exciting coil. However, the value of the large current is generally at least 100 A, preferably at least 1000 A, and more preferably, in the case of the exciting coil with a small number of turns, it is at least 10000 A. The standard of the magnetomotive force of the exciting coil is

5 5000 ampere-turn, preferably 15000 ampere-turn.

The intensity of the magnetic field generated in the mold by the above large current is preferably 5000 to 15000 oersted. Particularly, when magnetic particles of a rare earth magnet having an intrinsic magnetomotive force of at least 5000 oersted are oriented in a complicated manner, a magnetic field of at least 12000 oersted, preferably at least 15000 oersted, more preferably at least 18000 oersted, must be applied for a moment.

10 It is sufficient to apply the magnetic field for 5 milliseconds. If the application time is longer than this, since the quantity of heat generated from the coil is excessively large and is accumulated, there is the danger of burning wiring and insulating causing a short circuit.

In addition, with a ferrite magnet, an application time of 2 milliseconds is enough. A rare earth magnet requires an application time slightly longer than that for the ferrite magnet. Although it is useful for orienting the magnetic particles to apply a pulsed magnetic field once or twice for 5 milliseconds or less, consideration must be given to the removal of the heat generated in the exciting coil.

The direction of application of the pulsed strong magnetic field is preferably the same as that of the subsequent application of the magnetic field for orienting the magnetic particles. However, with rare earth magnetic particles, since it is sufficient to generate magnetic moment by the pulsed strong magnetic field, the application direction is not necessarily limited.

The magnetic field then applied for orienting the magnetic particles is also preferably generated by supplying a current to an exciting coil. The current value is about 30 A which is generally used. It is important to continue the application of the magnetic field until the magnetic particles are solidified in accordance with the shape of the product, the temperature of the heating cylinder of the molding machine used and the temperature of the mold. In a wet sintering method, it is also necessary to continue the application of the magnetic field until a predetermined amount of water has been discharged. The application time of the magnetic field is generally 30 seconds, and at longest 2 minutes, in accordance with the molding method.

The combination of a pulse power source and a constant current power source, both of which are separately disposed, is preferably used as the exciting power source because there are differences in the characteristics of the magnetic field applied. Known devices can be used as the power sources. The pulse generating section of the pulse power source may have a voltage up to 2000 V and an electric capacity of 2000 μ F.

Embodiment 2

35 The following two types of magnetic particles were used.

Magnetic particle A: ferrite magnetic particle

magneto-plumbite type strontium ferrite within average particle size of 1.5 μ m, intrinsic coercive force: 3000 oersted)

Magnetic particle B: samarium-cobalt magnetic particle

40 ($\text{Sm}_2\text{Co}_{17}$, average particle size 15 μ m, intrinsic coercive force: 8000 oersted)

The raw materials for a plastic magnet and a sintered magnet respectively had the following compositions:

Composition P (plastic magnet)

45 Magnetic particle: 63 vol%
Polyamide: 36 vol%
Aminosilane A1100: 1 vol%

Composition S (sintered magnet)

50 Magnetic particle: 50 wt%
Water: 50 wt%

The molding conditions for the plastic magnet and the sintered magnet were the following:

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Molding condition A (plastic magnet)

Pellet Composition used: Composition A

5 Molding machine: magnetic orientation
injection molding machine
10 containing coil

Injection cylinder temperature: 300°C

Mold temperature: 100°C

15 Injection pressure: 1500 kgf/cm²

Excitation time for orientation: 15 seconds

20 Cooling time: 20 seconds

Injection cycle: 40 seconds

Molding condition B (sintered magnet)

25 Slurry used: Composition B

Molding machine: Magnetic orientation compression molding machine containing coil

Drain method: Injection method

Molding temperature: 20°C

30 Burning temperature: 1250°C

An exciting power source of 2000 V and 1500 mF was used for applying a pulsed strong magnetic field, and a thick exciting coil of 2 turns was used, various values of currents being applied thereto. An exciting power source for then applying an orientation magnetic field was separately provided, and a current of 30 A was supplied to an exciting coil of 300 turns. A forced cooling jacket was provided on each of the exciting coils so as to cool it with cooling water at 10°C.

35 The surface magnetic flux density of each of the magnets obtained is shown in Table 2 together with the pulsed magnetic field application conditions.

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Table 2

	Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3
Magnetic Particle	A	B	B	A	B	B
Composition	P	S	S	P	P	S
Initial Applied Current Value (A)	8000	8000	8000	0	0	0
Initial Current Application Time	2 ms	5 ms	5 ms	0	0	0
Constant Current Value (A)	30	30	30	30	30	30
Constant Current Application Time (sec.)	20	20	20	20	20	20
Surface Magnetic Flux Density ($10^4 T$)	1550	3300	5300	1490	2250	4000

In the aforementioned production method, a magnet raw material which was provided with fluidity by dispersing magnetic particles therein was supplied to the magnetic orientation molding machine, and a pulsed strong magnetic field generated by pulsatively passing a large current through the exciting coil was applied to the magnet raw material before the magnetic particles were oriented along the axes of easy magnetization

thereof by molding the raw material while applying a magnetic field thereto. It was thus possible to easily orient the axes of easy magnetization of the magnetic particles in a predetermined direction and to improve the magnetic characteristics of the magnet produced.

Although preferred embodiments of the magnet producing method of the present invention are described above, as seen from the constitution of the method, the application of the method is not limited to the internal closed magnetic circuit type magnet to which the present invention relates. It is a matter of course that the method can be widely applied to production of various anisotropic magnets.

The present invention thus permits significant improvement in the surface magnetic flux density on the working surface of a magnet, the range of lines of magnetic force and the linear magnetic flux thereof. The present invention also permits the formation of an excellent surface magnetic field even in a ferrite synthetic magnet, as compared with that of a conventional sintered magnet.

Although this invention has been described with reference to several specific embodiments, many variations may be made as to the materials, temperatures, voltages, currents and the like, degree uniformity of axis orientation and sequence of method steps, all without departing from the spirit and scope of the invention, which is defined in the appended claims.

Claims

1. An internal closed magnetic circuit anisotropic magnet comprising a permanent magnet having at least one orientation region of magnetic particles on a working magnetic surface, said orientation region comprising magnetic particles having an edge portion and a substantially central portion and having axes of easy magnetization, said axes being substantially oriented in a direction to pass through the body of said magnet from said edge portion of said orientation region and to focus on said substantially central portion thereof.
2. An internal closed magnetic circuit anisotropic magnet according to Claim 1, wherein said magnet has substantially a disk shape and has only one orientation region of said magnetic particles.
3. An internal closed magnetic circuit anisotropic magnet according to Claim 1, having a plurality of orientation regions of said magnetic particles on said working magnetic surface.
4. An internal closed magnetic circuit anisotropic magnet according to Claim 1, wherein said magnet has a substantially annular shape.
5. An internal closed magnetic circuit anisotropic magnet according to Claim 4, wherein the upper or lower surface of said magnet serves as a working surface having a plurality of orientation regions of magnetic particles spaced at constant intervals thereon.
6. An internal closed magnetic circuit anisotropic magnet according to Claim 1, wherein said magnet is substantially cylindrical in shape, with an external or internal working surface, and wherein said external or internal surface is a working surface having a plurality of orientation regions of magnetic particles spaced at substantially constant intervals thereon.
7. An internal closed magnetic circuit anisotropic magnet according to Claim 1, wherein said magnet has a plate shape.
8. An internal closed magnetic circuit anisotropic magnet according to Claim 7, wherein said plate-like magnet has one or both sides constructed as a working surface having a plurality of orientation regions of magnetic particles, said orientation regions being spaced at substantially at constant intervals thereon.
9. An internal closed magnetic circuit anisotropic magnet according to Claim 1, wherein said magnet has a substantially spherical shape, and wherein the spherical surface of said sphere is constructed as a working surface.
10. A method of producing a magnet comprising:
 - supplying a fluid magnet raw material by dispersed magnetic particles,
 - introducing said raw material to a magnetic orientation molding machine, and molding said raw material while applying successive magnetic fields thereto, one such field comprising a pulsed strong mag-

netic field generated by pulsatively passing a large current through an exciting coil,
and another such field comprising an orienting field for orienting said magnetic particles.

- 5 11. A method according to Claim 10, wherein magnetic particles having an intrinsic coercive force of at least
5000 oersted comprise said magnet raw material.

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FIG. 1

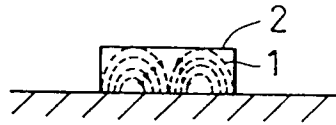


FIG. 2(a)



FIG. 2(b)



FIG. 2(c)



FIG. 3(a)

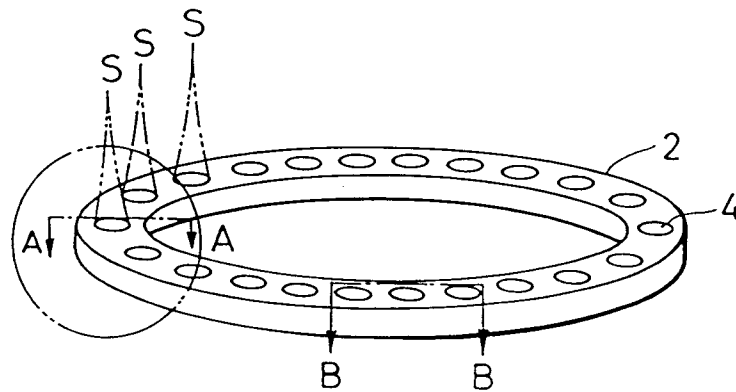


FIG. 3(b)

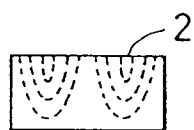


FIG. 3(c)

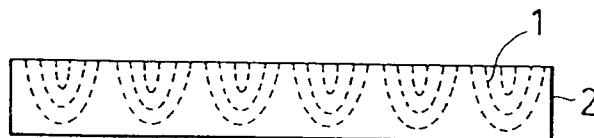


FIG. 4(a)

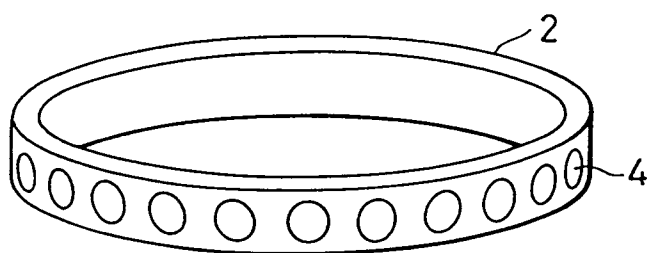


FIG. 4(b)

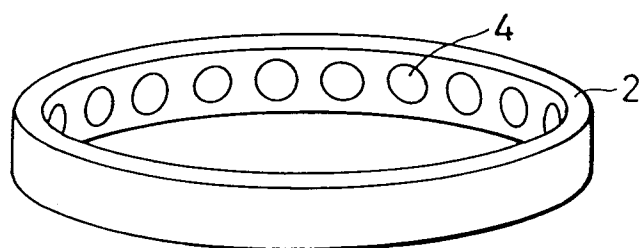


FIG. 5(a)

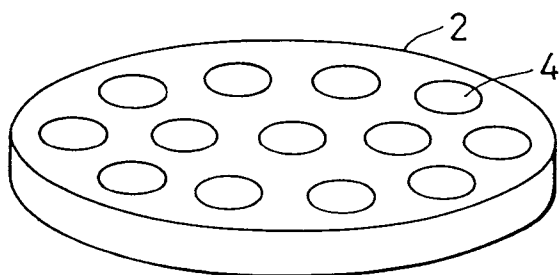


FIG. 5(b)

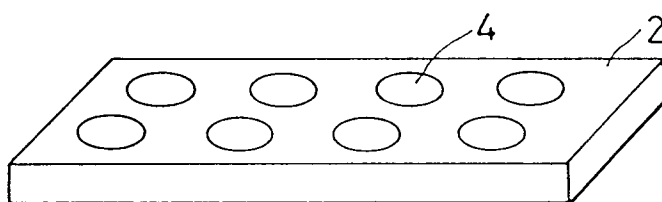


FIG. 6

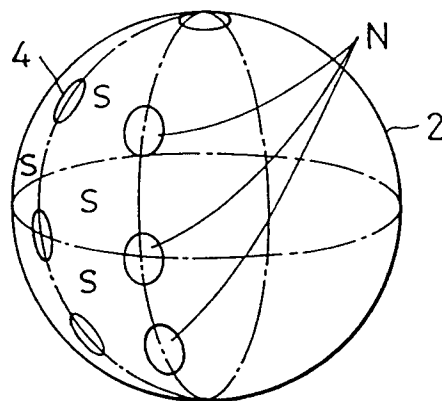


FIG. 7(a)

FIG. 7(b)

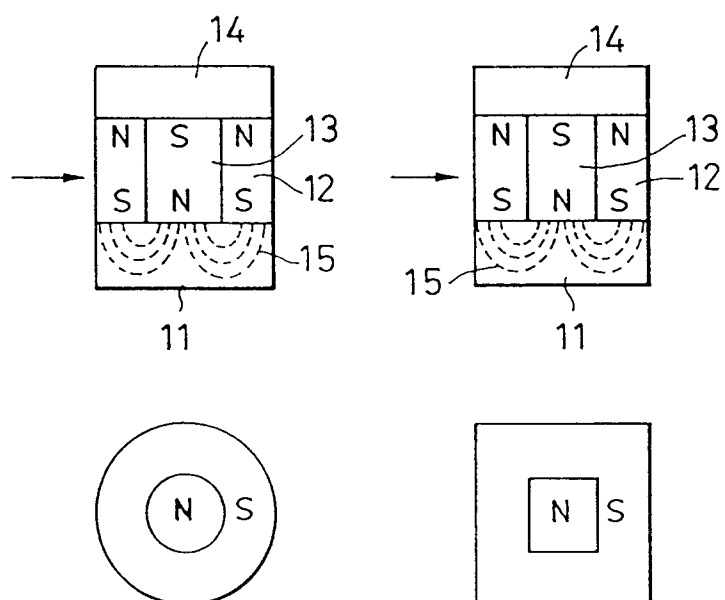


FIG. 8(a)

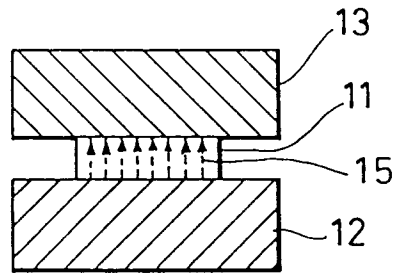


FIG. 8(b)

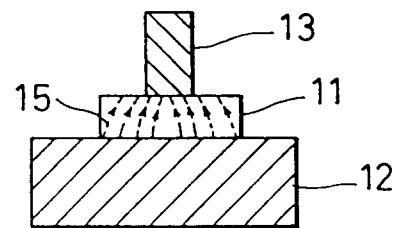
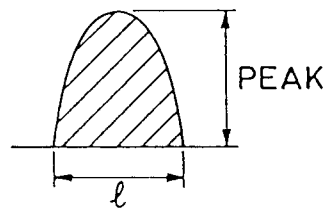


FIG. 9



LINEAR MAGNETIC FLUX
 $= \sum P_m * \Delta l$

FIG. 10 (a)

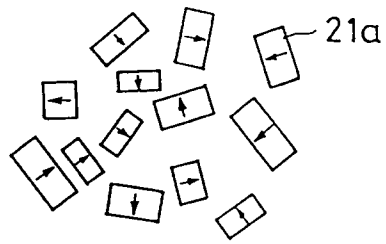


FIG. 10 (d)

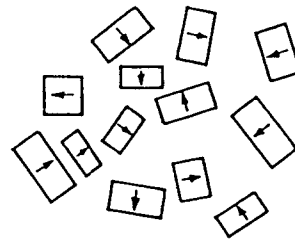


FIG. 10 (b)

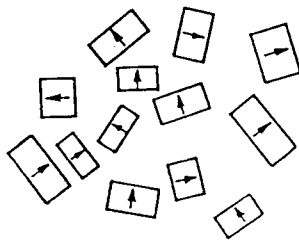


FIG. 10 (e)

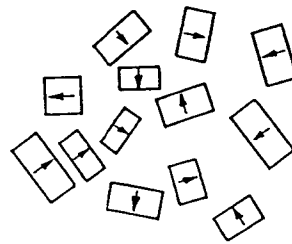


FIG. 10 (c)

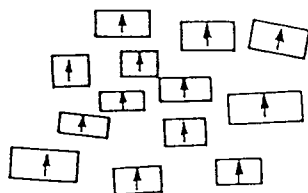
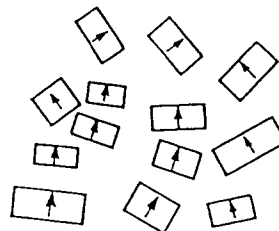


FIG. 10 (f)



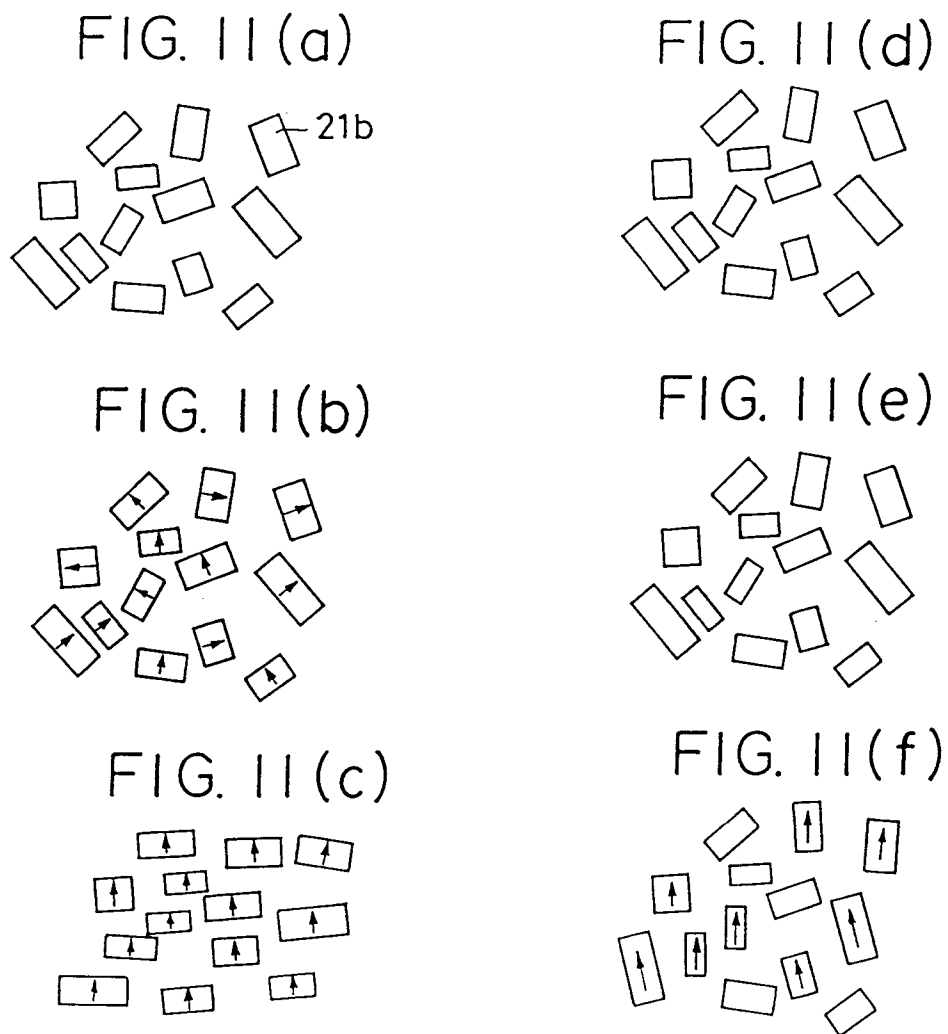


FIG. 12

