very close to that of Sm-Co magnets, excepting that an anti-oxidation surface treatment is required in the last step of the process as they are very apt to oxidize.

The raw materials are melted in the furnace at around 1,600℃. As the magnets, if exposed to air, easily oxidize, anti-oxidation measures are required in all stages of the manufacturing process. Therefore, the melting mentioned above is done in a vacuum or argon atmosphere to prevent oxidation. The ingot is crushed and pulverized to 3～4 μm sized powder and put into a die and pressed into a desired form.

The powder needs to be mixed with binder and lubricant before being pressed, otherwise it will not hold its shape.

Application of a magnetic field immediately before and during pressing causes anisotropy (oriented c-axis) in the magnet, generating high magnetic performance.

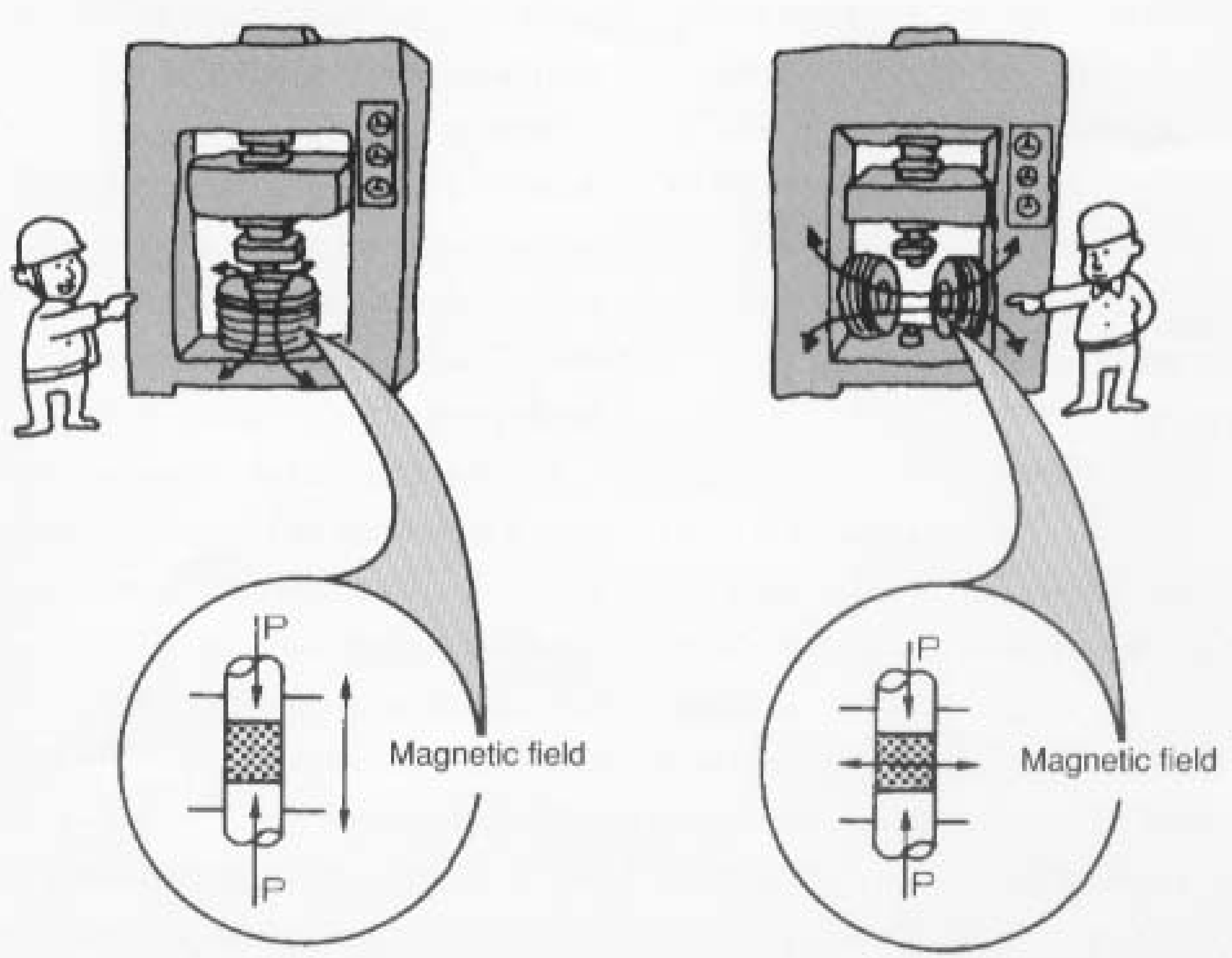
The pressed green is put into a sintering furnace to be sintered at 1,000～1,100℃. At this temperature, the Nd-rich phase having a relatively low melting point, changes into liquid phase, which penetrates into and fills up the interstice between the ferromagnetic particles, increasing the density of the magnet as a whole. This liquid phase generated during the sintering stage becomes non-magnetic grain boundary layers after cooling to a solid phase, which separate and enclose each ferromagnetic particle.

This microstructure, with its non-magnetic grain boundary layers enclosing each ferromagnetic particle, is very important for the magnet to exhibit high performance, on which the sintering process has a great influence. Following this, temper treatment is accomplished at around 600℃, which adds to the coercive force. Such coercive force increase is only a few percent, but this can have a big effect and merit depending on the magnet's application.

After finishing the treatment, the magnet is ground with a diamond wheel to the final shape.

As described earlier, surface treatments such as nickel electroplating and resin coating are then applied to prevent rusting in use, as this magnet is apt to oxidize.

An important point in the surface treatment is to make the thickness of the coating as thin as possible. Recent miniaturization of equipment demands thinner magnets, which further require thinner coatings.



Longitudinal Magnetic Field
(To apply the field parallel
to the pressing direction)

Transverse Magnetic Field
(To apply the field perpendicular
to the pressing direction)

Directions of Magnetic Field Applied During Pressing

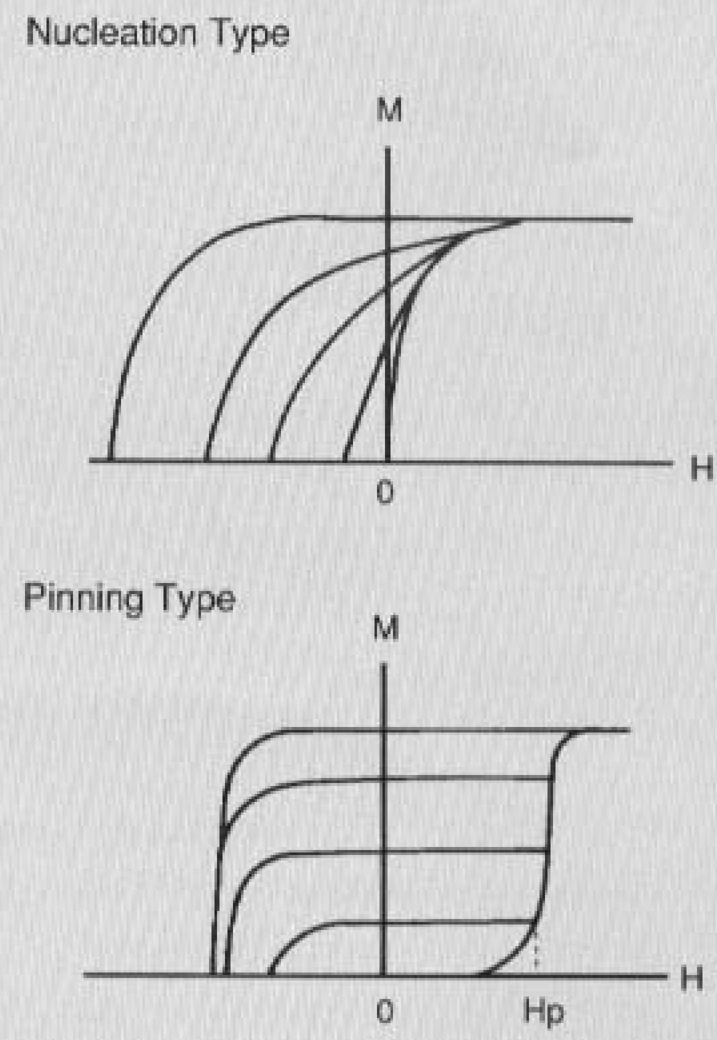
Manufacturing Process Enhancing Magnetic Properties

A permanent magnet is made of a material having some kind of large magnetic anisotropy. A powerful magnet can be obtained by orienting the directions of easy magnetization of all the crystal grains, taking advantage of this magnetic anisotropy. This is called an anisotropic magnet. To orient the directions of easy magnetization is to align the orientations of the magnet crystal grains.

While the samarium-cobalt magnet has a hexagonal or rhombohedral crystal lattice, the neodymium-iron-boron magnet has a tetragonal system, only one crystal axis of which is in the direction of easy magnetization. An externally applied magnetic field orients the directions of the particles, while being pressed, to yield a strong magnet.

There are two methods for applying the external magnetic field. One is to apply the field in the same direction as that of pressing (called longitudinal magnetic field). The other is to apply the field in the direction perpendicular to that of pressing (called transverse magnetic field).

The transverse field gives the magnet higher performance than the longitudinal field. However, since the magnet shape restricts the way of the field is applied, the direction of magnetic field application with respect to the shape should be confirmed prior to pressing.



Field Dependency of Initial Magnetization Curve of Rare Earth Magnets

Difference in Coercivity Mechanism

The higher the coercive force, the greater the resistance to demagnetizing, therefore, the more stable and better the magnet can be said to be. Although this is the general trend, in practice, a higher remanent magnetic flux density is preferred to a higher coercivity, and vice versa. There are two kinds of coercivity mechanisms in rare earth magnets, a nucleation type (the mechanism of the generation and growth of the nuclei) and a pinning type (the mechanism of pinning magnetic domain wall movements).

The nucleation type include 1 samarium vs. 5 cobalt based magnets and sintered neodymium-iron-boron magnets in which their coercivity mechanism lies in the crystallite grain boundaries, allowing the domain walls to move freely inside the grains and making the initial magnetization curve rise steeply.

On the other hand, 2 samarium vs. 17 cobalt based magnets are known as the pinning type, in which their domain walls are pinned inside the grains and hard to move, requiring a high magnetizing field to saturate them. The neodymium-iron-boron magnet powder for bonded magnets is also said to be the pinning type.

A temperature change causes a magnet to demagnetize. While Alnico and samarium-cobalt magnets have a temperature coefficient of magnetic flux of −0.01 ~ −0.04 %/K, ferrite and neodymium-iron-boron magnets have one order of magnitude higher temperature coefficient of magnetic flux of − 0.1 ~ − 0.2 %/K.

Ferrite magnets have high, positive temperature dependency of magnetocrystalline anisotropy constants, causing the coercive force to increase as the temperature goes up, and on the contrary, to decrease as it goes down, which generates "irreversible loss at low temperature." The neodymium-iron-boron magnets have negative temperature coefficients, causing the coercive force to markedly decrease as the temperature goes up, which generates the problem of "irreversible loss at high temperature" in contrast to the ferrite type.

Since samarium-cobalt magnets have a high Curie temperature of 770℃ and low temperature coefficients of magnetic flux, similar to those of Alnico magnets, they are very stable in temperature change, while neodymium-iron-boron magnets have a low Curie temperature of 310℃, causing their magnetic properties to greatly deteriorate as the temperature goes up, which restricts their high temperature usage.

Merits and Demerits of Rare Earth Magnets

Rare earth magnets can store by far more energy than conventional magnets, enabling parts, devices or equipment to be miniaturized in response to recent market trends, which has prompted rare earth magnet production to soar. Their major merits and demerits are described below.

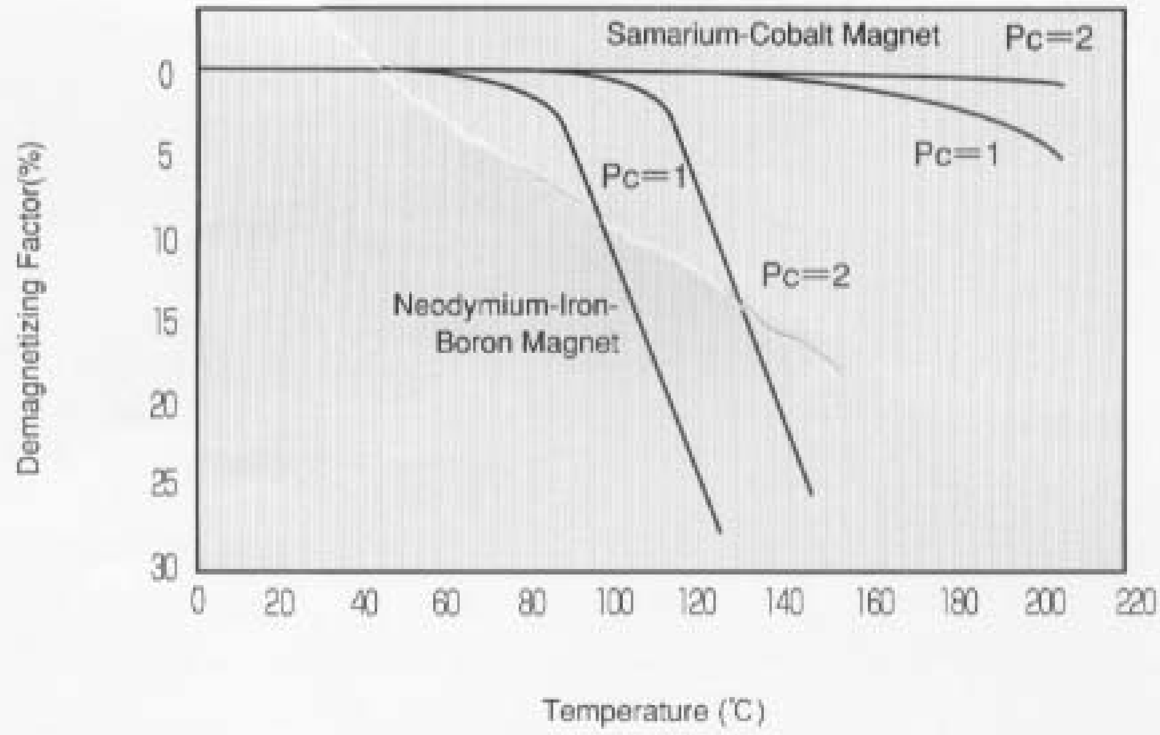
(1) Merits and Demerits of Samarium-Cobalt Magnets

Samarium-cobalt magnets, which were the strongest magnets in the world until the appearance of neodymium-iron-boron magnets, come in two major magnet types, 1 samarium vs. 5 cobalt based magnets having an excellent magnetic anisotropy and high coercive force, and 2 samarium vs. 17 cobalt based magnets having a high maximum energy product. Both of them have temperature coefficients of remanence and coercivity lower than those of neodymium-iron-boron magnets, giving them excellent thermal stability. Due to the fact that their corrosion resistance is better than that of neodymium-iron-boron magnets, surface treatment such as nickel plating that is required for neodymium-iron-boron magnets, can be dispensed with.

On the other hand, the supply of their raw materials, samarium and cobalt, is unstable and their prices high, resulting in the high cost of magnet manufacturing. In addition, they are mechanically weak and brittle, and hard to handle.

(2) Merits and Demerits of Neodymium-Iron-Boron Magnets

Neodymium-iron-boron magnets had performances higher than 278kJ/m^3 (35MGOe) at the start of their mass production, superseding the magnetic properties of samarium-cobalt magnets having the then typical high performance. Through the improvements and developments that followed, an ultra-high performance magnet was developed, possessing the highest magnetic properties of Br = 1.495T (14.95kG), HcJ = 845kA/m



Irreversible Loss at High Temperature of Rare Earth Magnets

(10.62kOe) and (BH)max = 431kJ/m^3(54.2MGOe) in 1993.

The neodymium-iron-boron magnets have a great advantage of such a high performance, stable supply for comparatively low cost owing to the main raw materials being relatively abundant neodymium and iron, unlike samarium-cobalt magnets which have future resource problems. In addition, their specific gravity is more than 10% smaller than that of Sm-Co magnets, which makes them suitable for use in smaller, lighter devices. As they have mechanical strength higher than that of Sm-Co magnets, there is less chipping and cracking in the manufacturing process, and grinding and handling after magnetizing is easier.

On the other hand, as the temperature coefficients of their remanence and coercive force are higher than those of Sm-Co magnets, attention must be paid to their working temperature, at the design stage.

Also, due to their low corrosion resistance, surface treatment is required to prevent the magnets from rusting in the event that they are used in an environment of high temperature and humidity. There are various kinds of surface treatments, depending on the application and shape.

Problems of Rare Earth Magnets Awaiting Solution

Samarium-cobalt magnets, besides having high thermal stability, exhibit superior magnetic properties to those of Alnico and ferrite magnets. Though inferior to neodymium-iron-boron magnets, their continued use is expected in such fields where high reliability is required. On the other hand, the supply of their raw materials is unstable and their prices high, resulting in a high manufacturing cost which has to be reduced.

While neodymium-iron-boron magnets, which have the highest maximum energy product among the various kinds of magnets and comparatively lower price, are enjoying soaring demand, the high temperature coefficient of their remanence and coercivity and low corrosion resistance present a bottle neck to further market expansion by restricting their applications. Efforts are being made to improve their temperature coefficient and corrosion resistance.

Methods of Surface Treatment of Nd-Fe-B Magnets

Method	Coating Thickness μm	Applied Magnet Weight g	Main Shape	Main Application
Al - Chromate	7 ~ 19	0.5 ~ 20	Ring, rectangular, segment and cylindrical	Motor and sensor
Epoxy - Resin Spray Coating	40 ~ 80	10 ~ 200	Rectangular, segment and others	VCM and MRI
Electrodeposition	20 ~ 30	5 ~ 100	Rectangular and large ring	VCM and rodless cylinder
Nickel Plating	10 ~ 20	0.5 ~ 200	Ring, rectangular, segment and cylindrical	VCM, motor and sensor
New Epoxy - Resin Spray Coating	10 ~ 20	10 ~ 100	Segment and others	VCM and motor

Magnetic, Physical & Mechanical Properties of Rare Earth Magnets (Typical Examples)

Upper line: unit in SI　Lower line: unit in C.G.S.

Item		Unit	Samarium-Cobalt-Magnet				Neodymium-Iron-Boron Magnet	
Composition			$SmCo_5$		Sm_2Co_{17}		$Nd_2Fe_{14}B$	
Field Direction during Pressing			Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Remanent Flux Density Br		mT kG	800~900 8.0~9.0	850~960 8.5~9.6	940~1,040 9.4~10.4	960~1,100 9.6~11.0	1,000~1,330 10.0~13.3	1,050~1,350 10.5~13.5
Coercive Force H_{cB}		kA/m Oe	600~720 7,500~9,000	630~760 8,000~9,500	390~725 5,000~9,100	440~840 5,500~10,500	750~960 9,400~12,000	790~960 9,900~12,000
Coercive Force H_{cJ}		kA/m Oe	>1,190 >15,000	>1,190 >15,000	>420 >5,300	>420 >5,300	>880 >11,000	>880 >11,000
Maximum Energy Product (BH)max		kJ/m^3 MGOe	127~151 16~19	143~175 18~22	151~191 19~24	175~231 22~29	183~334 23~42	207~366 26~46
Temperature Coefficient	Br	%/K	-0.04	-0.04	-0.03~-0.04	-0.03~-0.04	-0.11	-0.11
	H_{cJ}	%/K	-0.3	-0.3	-0.2~-0.3	-0.2~-0.3	-0.51~-0.60	-0.51~-0.60
Curie Temperature Tc		K ℃	983 710	983 710	1,043~1,093 770~820	1,043~1,093 770~820	603~613 330~340	603~613 330~340
Recoil Relative Permeability μ_{rec}			1.02~1.05	1.02~1.05	1.02~1.05	1.02~1.05	1.05	1.05
Density		g/cm^3	8.2~8.3	8.2~8.3	8.4~8.5	8.4~8.5	7.5~7.6	7.5~7.6
Flexure Strength		MPa kgf/mm^2	98~118 10~12	98~118 10~12	98~118 10~12	98~118 10~12	245 25	245 25
Compression Strength		MPa kgf/mm^2	490~830 50~85	490~830 50~85	490~830 50~85	490~830 50~85		
Tensile Strength		MPa kgf/mm^2	39~49 4~5	39~49 4~5	39~49 4~5	39~49 4~5	44 4.5	44 4.5
Specific Heat		J/(kg・K) cal/g・℃	0.42×10^3 0.1	0.42×10^3 0.1	0.38×10^3 0.09	0.38×10^3 0.09	0.50×10^3 0.12	0.50×10^3 0.12
Thermal Expansion Coefficient	Parallel to easy magnetization axis	ppm/K	6~8	6~8	8	8	5.5~7.5	5.5~7.5
	Perpendicular to easy magnetization axis	ppm/K	11~13	11~13	11	11	-3~0.5	-3~0.5
Hardness Hv			550~600	550~600	550~600	550~600	560~650	560~650
Field Strength for Required Saturation Magnetizing		kA/m Oe	>1,600 >20,000	>1,600 >20,000	>1,600 >20,000	>1,600 >20,000	>2,000 >25,000	>2,000 >25,000

What are Bonded magnets?

The powder of ferrite or rare earth magnets, which has already been described, is mixed with a synthetic resin or rubber bonding material and formed into a desired shape, which is called a bonded magnet. With regard to bonded magnets, magnet powder is diluted with the synthetic resin or rubber bonding material, resulting in a weaker magnet, however, it has an excellent advantage in that it can easily be formed into a complicated, thin shape with narrow dimensional tolerances, which has allowed it to form a unique market.

Bonded magnets are classified according to the magnetic powder and bonding material used.

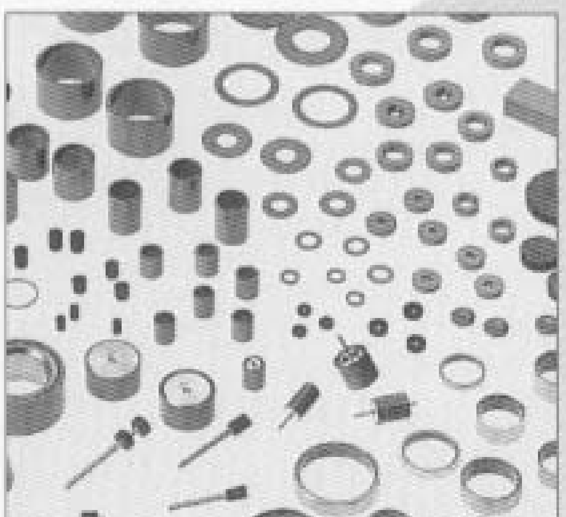
Both rigid and flexible bonded magnet can be formed in a number of ways corresponding to their applications. All these methods are basically similar to those for molding synthetic resins or rubbers.

Flexible bonded magnets began with their application in refrigerator doors. Today, flexible bonded ferrite magnet sheets printed with a beginner driver sign are stuck on cars.

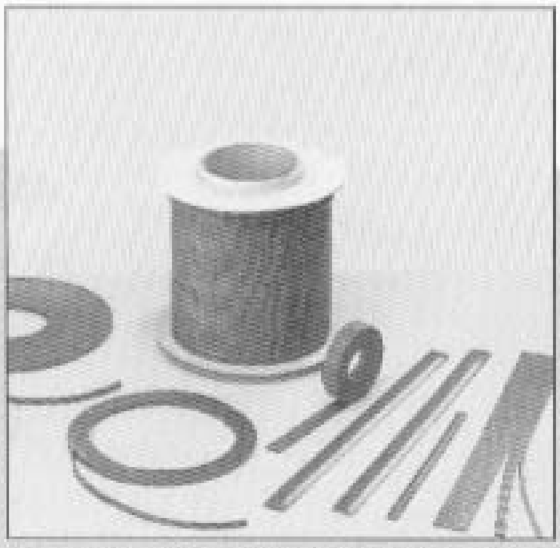
Rigid bonded magnets using rare earth magnet powder that boasts the highest magnetic energy, have recently come into wide use for micromotor applications. This resulted from a wide freedom to choose complicated and thin shapes, excellent reliability and comparatively low production cost, as well as high performance required to satisfy recent trends toward lightweight, thin and small devices.

Method of Molding	Rigid Bonded Magnet	Flexible Bonded Magnet
Compression	○	—
Injection	○	—
Calender Rolling	—	○
Extrusion	○	○

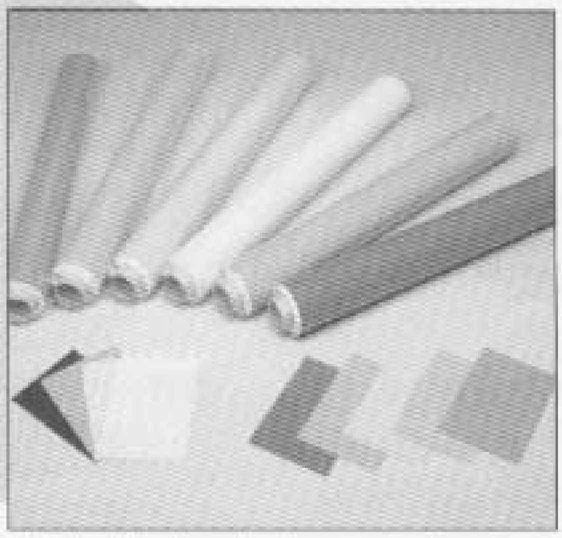
Magnet Powder \ Bonding Material		Synthetic Resin	Rubber
Ferrite Magnet		Rigid Bonded Ferrite Magnet	Flexible Bonded Ferrite Magnet
Rare Earth Magnet Powder	Sm-Co	Rigid Bonded Sm-Co Magnet	
	Nd-Fe-B	Rigid Bonded Nd-Fe-B Magnet	



▲ Rigid bonded magnets are widely used in micro motors.



▲ Flexible bonded magnets are possible easily to make bending.



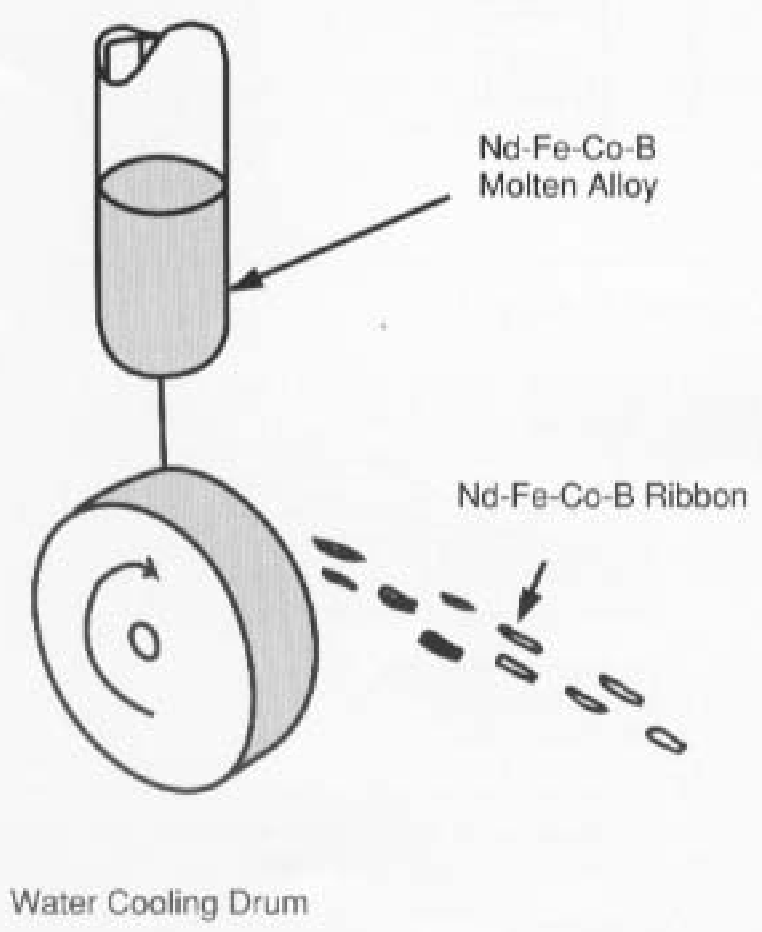
▲ Flexible bonded magnet sheets attached to a color film are available.

Raw Materials of Bonded Magnets

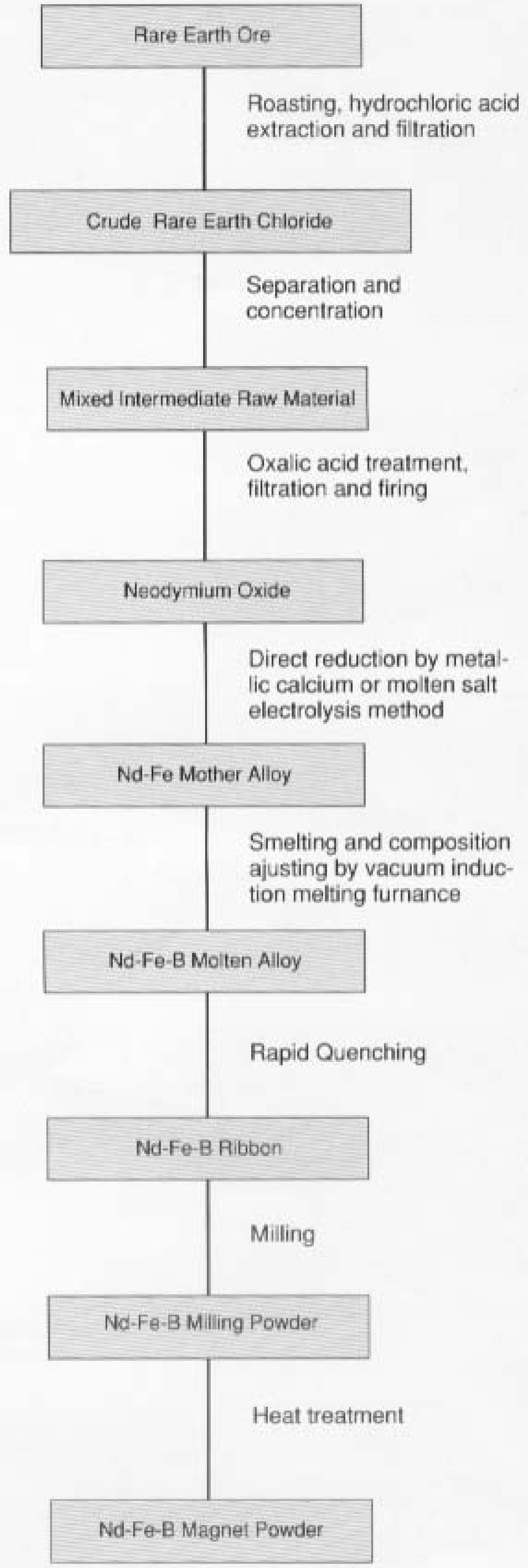
Various kinds of magnet powder are available as the raw material for bonded magnets, one of which is basically the same ferrite magnet powder that is used for the production of sintered ferrite magnets. Nd-Fe-B magnet powder is a typical example of rare earth magnet material, of which the representative composition is 27Nd-68Fe-4Co-1B developed by GM in the US.

The manufacturing process for this type of magnets is to first prepare a Nd-Fe-B alloy, then to obtain a 30μm or so thick crystallite ribbon by rapidly quenching the remolten alloy onto a water cooled drum rotating at high speed.

This ribbon is crushed into powder having the particle size of less than 200μm, and heat treated to develop its coercive force. By this heat treatment, the grain size is grown to tens to hundreds of nm.



Rapid Quenching Method of Nd-Fe-B Molter Alloy



Manufacturing Process of Nd-Fe-B Magnet Powder

Manufacturing Process of Bonded Magnets

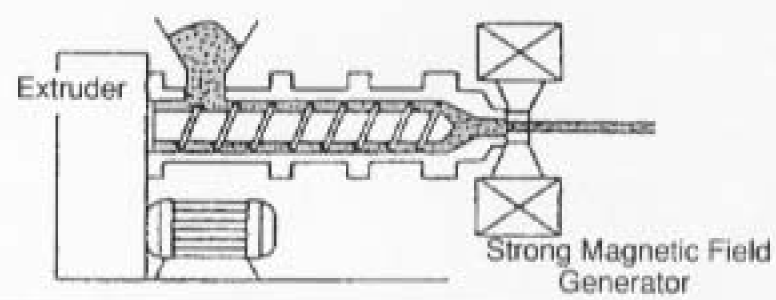
Typical processes taken from various production methods such as compression molding, injection molding, calender rolling and extrusion molding are introduced here.

Compression Molding

Magnet Powder / Epoxy Resin / Additives
→ Kneading
→ Compression Molding (In a magnetic field for anisotropic magnets)
→ Heat Curing
→ Cleaning
→ Coating (By electrodeposition or spraying)
→ Inspecting → Magnetizing → Finished Magnet

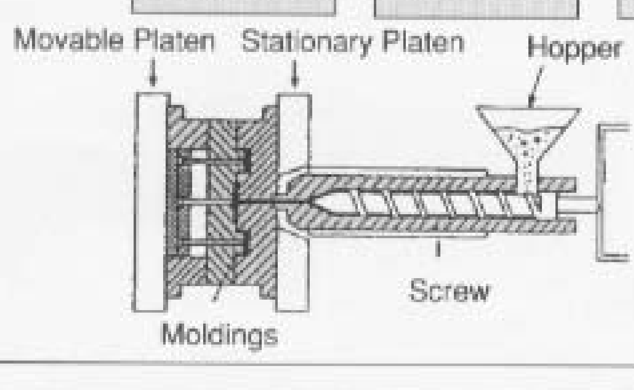
Extrusion Molding

Magnet Powder / Synthetic Resin / Additives
→ Kneading
→ Pelletizing
→ Extrusion Molding (In a magnetic field for anisotropic magnets)
→ Inspecting → Magnetizing → Finished Magnet



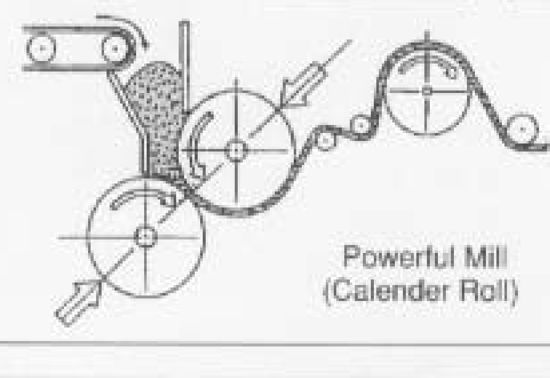
Injection Molding

Magnet Powder / Synthetic Resin / Additives
→ Kneading
→ Pelletizing
→ Injection Molding (In a magnetic field for anisotropic magnets)
→ Inspecting → Magnetizing → Finished Magnet



Calender Rolling

Magnet Powder / Rubber / Additives
→ Kneading
→ Pelletizing
→ Calender Rolling (For anisotropic magnets mechanical orientation suffices making no use of magnetic field .)
→ Inspecting → Magnetizing → Finished Magnet

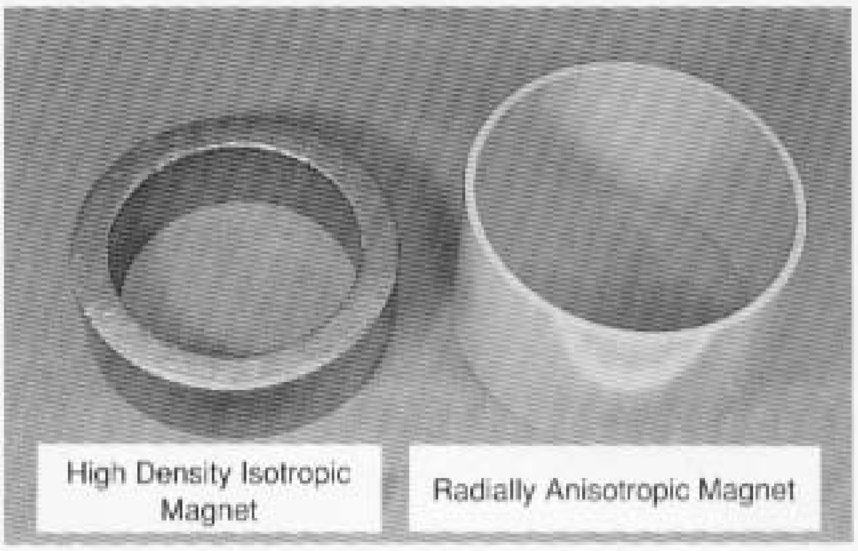


Magnetic, Physical & Mechanical Properties of Bonded Magnets (Typical Examples)

Upper line: unit in SI   Lower line: unit in C.G.S.

Item		Unit	Ferrite Magnet		Sm-Co Magnet		Nd-Fe-B Magnet	
Composition	Magnet Powder		$SrO \cdot 6Fe_2O_3$		$Sm_2(Co_{0.7}Fe_{0.3})_{17}$		$Nd_2Fe_{14}B$	
	Bonding Material		Synthetic Resin	Rubbr	Synthetic Resin	Synthetic Resin	Synthetic Resin	Synthetic Resin
Molding Method			Injection	Calender Rolling	Compression	Injection	Compression	Injection
Magnetic Direction			Anisotropic	Anisotropic	Anisotropic	Anisotropic	Isotropic	Isotropic
Remanent Flux Density Br		mT kG	230~300 2.3~3.0	220~260 2.2~2.6	620~890 6.2~8.9	540~680 5.4~6.8	570~760 5.7~7.6	410~620 4.1~6.2
Coercive Force HcB		kA/m Oe	160~200 2,000~2,500	150~180 1,900~2,300	430~540 5,400~6,800	370~490 4,600~6,200	370~470 4,700~5,900	250~400 3,100~4,900
Intrinsic Coercive Force HcJ		kA/m Oe	210~240 2,600~3,000	200~220 2,500~2,800	720~950 9,000~12,000	720~950 9,000~12,000	640~1,350 8,000~17,000	540~1,350 6,000~17,000
Maximum Energy Product (BH)max		kJ/m³ MGOe	10~17 1.5~2.3	9~12 1.1~1.5	88~135 11.0~17.0	48~84 6.0~10.5	60~96 7.5~12.0	28~60 3.5~7.5
Temperature Coefficient	Br	%/K	−0.18~−0.19	−0.18~−0.19	−0.032~−0.037	−0.032~−0.037	−0.1~−0.15	−0.1~−0.15
	HcJ	%/K	0.35~0.5	0.35~0.5				
Maximum Safe Temperature for Application		K ℃	393~413 120~140	353~393 80~120	393~423 120~150	393~413 120~140	393~453 120~180	393~413 120~140
Recoil Relative Permeability μ_{rec}			1.03~1.07	1.03~1.07	1.05	1.05	1.1~1.2	1.1~1.2
Density		g/cm³	3.2~3.8	3.2~3.8	6.8~7.2	5.2~6.1	5.6~6.2	4.2~5.5
Flexure Strength		MPa kgf/mm²	58.8~107.8 6.0~11.0		49.0~58.8 5.0~6.0		49.0~58.8 5.0~6.0	
Compression Strength		MPa kgf/mm²	1,265~1,853 29,000~189,000					
Tensile Strength		MPa kgf/mm²	30,000~60,000 3,061~6,122	3,000~5,600 306~510		30,000 3,061		30,000 3,061
Specific Heat		J/(kg·K) cal/g·℃	0.7~0.8×10³ 0.167~0.191	0.7~0.8×10³ 0.167~0.191				
Thermal Expansion Coefficient (In direction of easy magnetization axis)		ppm/K	40~60	100~150	13~15	50	13~15	50

Nd-Fe-B Ring Magnet by Hot Extrusion Molding



▲ A radial anisotropy is available by hot extruding .

Introduction

There are two representative methods for manufacturing Nd-Fe-B magnets, melt-spinning and sintering. The present magnets are formed into anisotropic magnets by hot extruding powder made by the melt-spinning method.

This method has made radially anisotropic ring magnets available, replacing some of the conventional segment magnets, which has reduced the production cost of motors and improved their performance.

Manufacturing Process

Examples of hot extruded radially anisotropic ring magnets are shown. The melt-spun magnetic powders made by MQI in the US are used as the raw material, which are cold pressed to be compacted and then hot pressed at 700～800℃ to be more densified. Thereafter, the densified material is hot extruded at the same temperature to obtain a radially anisotropic ring magnet.

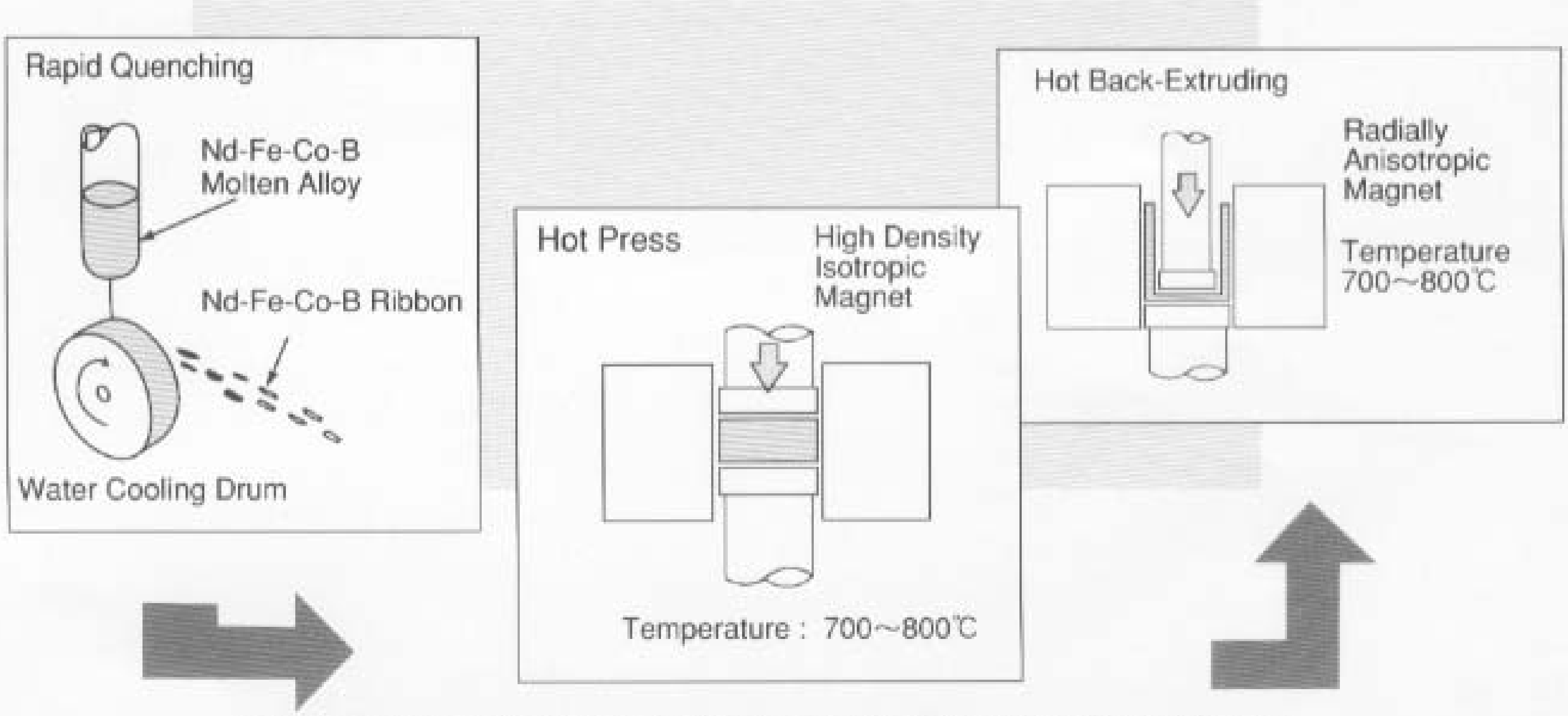
The raw materials of melt-spun magnetic powders consist of fine crystallites and an amorphous phase. The densified material as kept in fine crystallite grains is plastically hot worked to make anisotropy along the direction of compressive strain. This method is remarkably different from the sintering one in that it does not use any orienting magnetic field. Since this magnet is hot pressed to be densified at lower temperature than sintering one, it keeps the crystallite grains almost as fine as the raw material powders.

Merits

Magnetic properties in the radial direction are determined by the reduction ratio.

The maximum energy product of 240～280kJ/m^3 (30～35MGOe) can be obtained if a large enough reduction ratio is secured regardless of the magnetic diameter and thickness.

A long, cylindrical magnet with a maximum height 1.5 times its outer diameter and a minimum thickness of 1.5mm can be obtained by hot extrusion. The density of the magnet is close to its theoretical value, which means the almost no pores exist inside the magnet, allowing only an electrodeposited epoxy layer to secure enough corrosion resistance.



Manufacturing Process of Nd-Fe-B Hot Extrusion Ring Magnet

Manganese Aluminum Magnet

Introduction

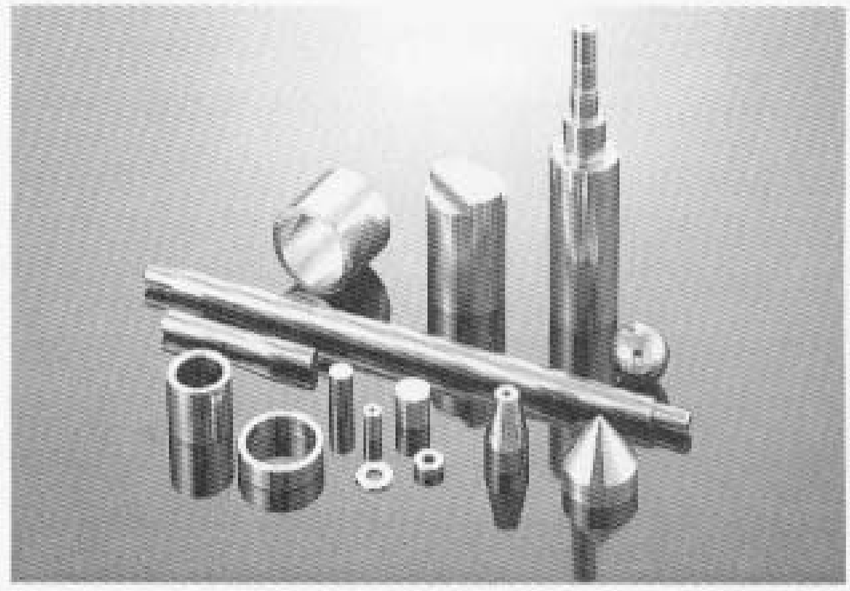
Manganese aluminum magnets are new high quality magnets having excellent productivity and applying atomized alloy powders. The magnets have no resource and supply problems, since their main raw materials are manganese, aluminum and carbon. They are unique magnets having excellent mechanical strength and machinability as well as enabling various magnetizing patterns to be produced. They are environment friendly magnets, contributing to the improvement and development of various sensors, motors and machine tools.

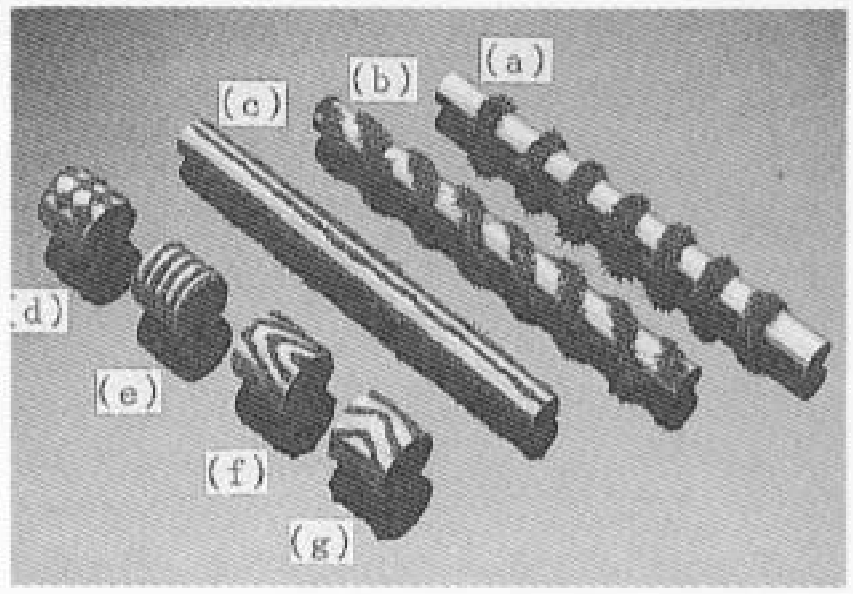
Manufacturing Process

They are manufactured by warm extruding gas atomized alloy powders into anisotropic magnets.

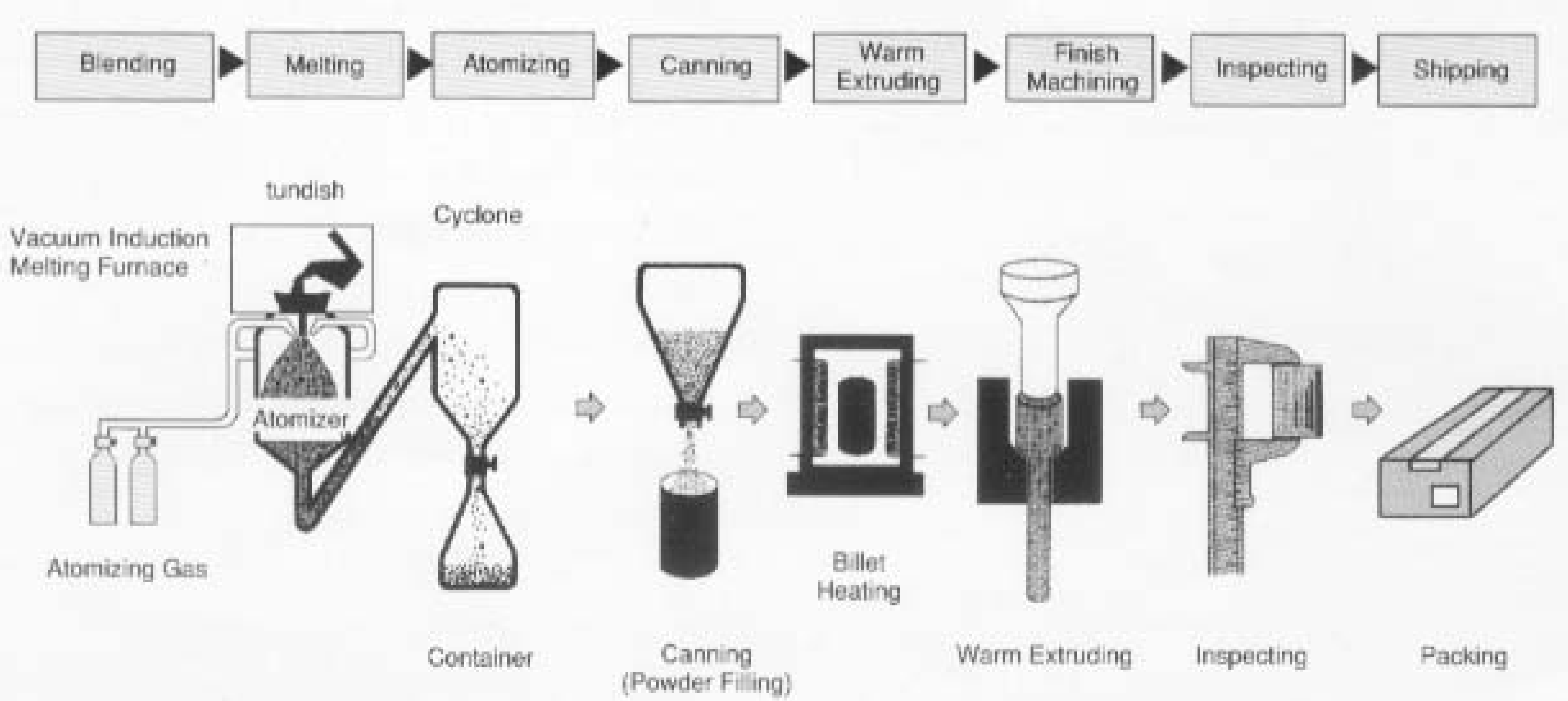
Merits

- Excellent in mechanical strength and available in a high speed rotation and high load environment.
- Excellent in machinability and able to correspond to avariety of shape requirements, including extremely thin.
- Possible to be magnetized in various precise patterns.





▲ Kinds of Magnetization Patterns
(a) Stepped Magnetization
(b) Spiraled Magnetization
(c) Striped Magnetization
(d) Meshed Magnetization
(e) Screwed Magnetization
(f) Wood-grained Magnetization
(g) Waved Magnetization



Manufacturing Process of Manganese Aluminum Magnet

Praseodymium Magnet
(Pr-Fe-B-based Cast and Rolled Magnet)

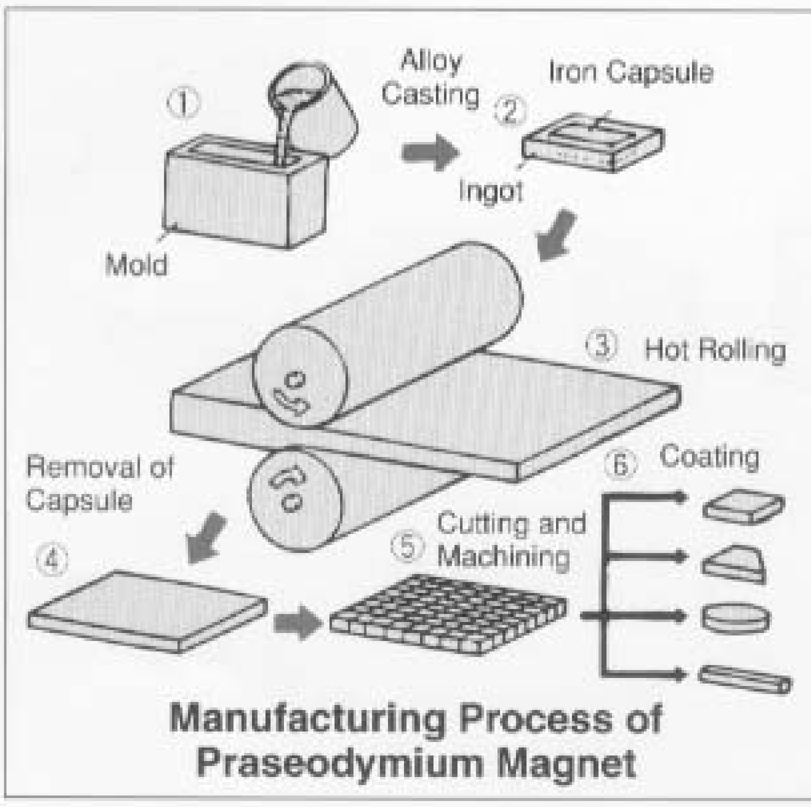
Introduction

Praseodymium magnet is high performance anisotropic magnet that is manufactured without passing through a powder metallurgical process. Columnar alloy is rolled in perpendicular direction to be supplied with anisotropy. Mechanical stress on rolling orients the crystal grains parallel to the rolling direction, when the alloy sealed in an iron capsule kept at 900～1,000℃ in a state of 15% liquid phase mixed with 85% solid one is rolled. The standard praseodymium magnet composition is a quaternary system of Pr-Fe-B-Cu, rare earth rich, boron poor in comparison with neodymium-iron-boron sintered magnets and copper added.

Manufacturing Process

Casting is done so that the crystal structure of the alloy results in columnar structure. Next, the alloy is sealed into an iron capsule and hot rolled, as rolling reduction is around 75%. After being rolled, the magnet becomes a large-sized anisotropic magnet, is cooled to room temperature and taken out of the capsule. It is heat treated to improve its performance and machined into a desired shape to become a final product.

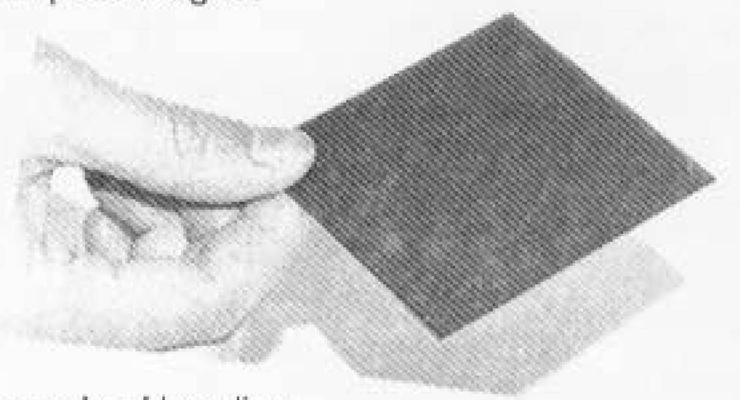
Item	Br	H_{cB}	H_{cJ}	(BH)max
Unit	T	kA/m	kA/m	kJ/m^3
Pr Magnet	1.1	770～830	1,200～1,500	216～240



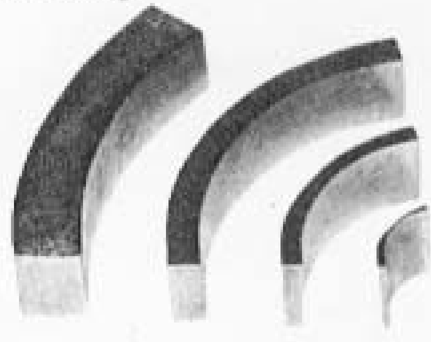
Manufacturing Process of Praseodymium Magnet

Example of thread cutting

Thin plate magnet



Example of bending



Merits

Hot rolling the alloy with a solid-liquid mixed phase and its peculiar compositions create a variety of unique practical merits.

1. This process can produce large solid magnets up to 1,500 x 200 x 50 mm * (* in the magnetizing direction).
2. Their mechanical strength is high, while their tensile strength boasts a high 250 MPa, more than three times that of Nd-Fe-B sintered magnets. Cracking or chipping does not occur.
3. Machining of the magnets, such as drilling, thread cutting and tapering, is very easy.
4. An extremely thin, high performance magnet having a wide area can be manufactured, for instance, a 0.1 mm thick magnet with (BH)max = 160kJ/m^3.
5. The high temperature bending makes the manufacture of roof tile magnet with an uniform thickness and radially oriented magnets possible.
6. The magnet has no pores, completely eliminating the possibility of degassing in a vacuum.
7. Low oxygen content in the alloy prevents easy rusting.

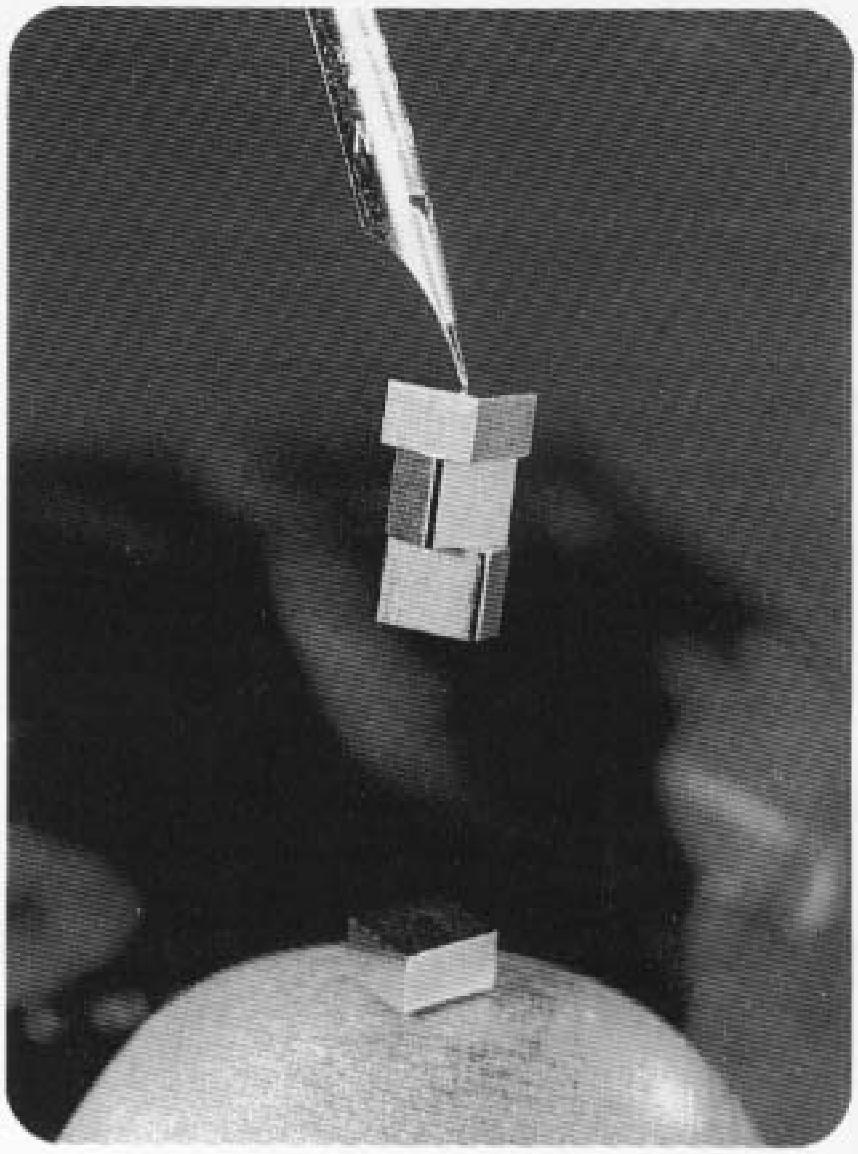
Platinum Magnet

Introduction

Platinum magnet is platinum-based cast magnet composing of Pt(70 wt%)-Fe-Nb. With the exception of rare earth magnets, it is the strongest of all the metal-based magnets. In addition, it is possible easily to make precision machining since it is cast magnet, having excellent corrosion resistance.

Not surprisingly, however, the price is ultra-high, making it difficult to develop applications.

One of the uses in the current market is in high-grade audio cartridges, which audiophiles refer to as a "platinum magnet." While on the other hand, medical researchers are interested in their potential application to medical tools and instruments.

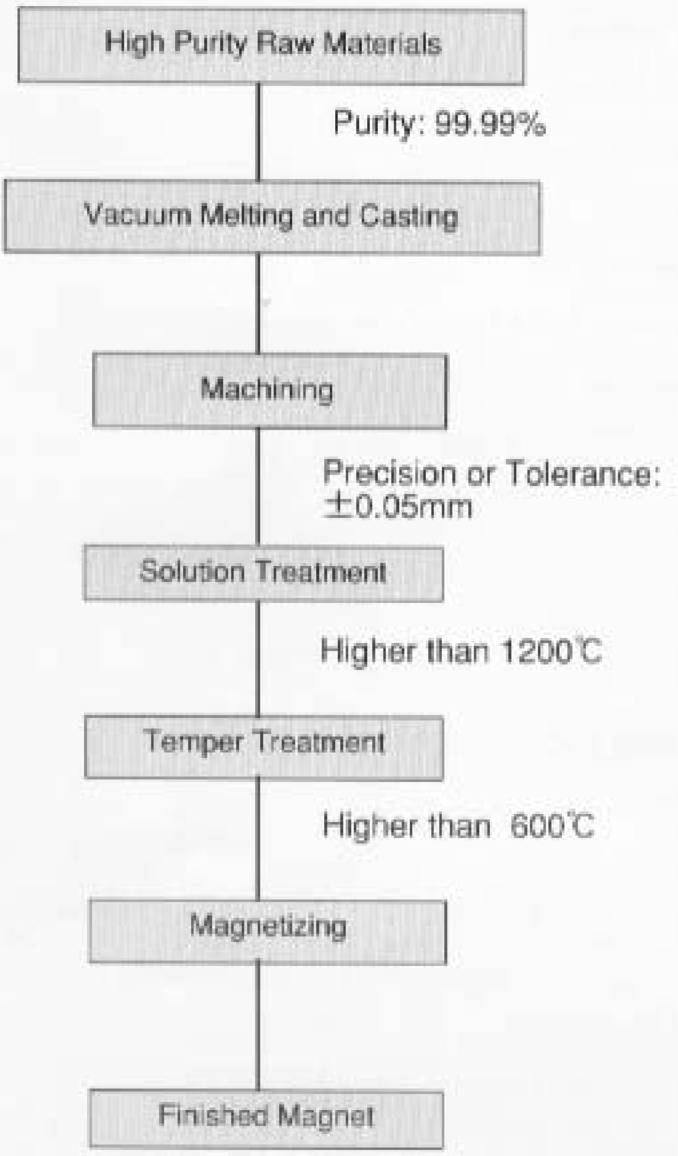


▲ Platinum magnets have excellent precision machinability and anti-corrosiveness.

Merits

1. Powerful performance next to that of rare earth magnets.
2. The magnet surface has a bright platinum color.
3. High dimensional accuracy by only machining.
4. The highest grade anti-corrosive magnet that does not suffer any rusting or staining in corrosive environments.
5. No chipping or cracking.

Item Unit	Br T	HcB kA/m	(BH)max kJ/m³	Curie Temp. ℃
Pt Magnet	~1.1	~438	~175	460



Manufacturing Process of Platinum Magnet

Applications in Many Fields

First of all, let's see how so-called permanent magnets are being utilized and applied in practice. Methods of utilization and application can be classified as follows:

1. Electrical to Mechanical Energy Conversion

(1) To Vibrational Force :

Loudspeakers and headphones

(2) To Rotational Force or Displacement* : *(In the case of linear motors)

Various kinds of motors and linear motors

(3) Utilization for Measurement and Control :

Various kinds of industrial motors and electrocardiograph actuators

2. Mechanical to Electrical Energy Conversion

(1) Vibrational Force to Electric Signals :

Microphones and pickups

(2) Rotational Force to Electric Power :

Dynamo righting set for bicycles and generators for motorcycles

3. Mechanical to Mechanical Energy Conversion

(1) Application of Attracting Force to Ferromagnetic Material :

Separation: Magnetic ore separators and magnetic filters

Holding: Magnet chucks, magnet holders and magnet stands

Conveyance: Magnet rollers and lifting magnets

Attraction: Door catches, button magnets and cowmagnets

(2) Application of Attracting and Repulsing Force between Each Other's Magnets :

Repulsion: Magnetic levitation and magnetic bearings

Attraction: Magnetic couplings, dentures and magnetic earrings

(3) Application of Eddy Current :

Brake: Hysteresis brakes and watt-hour meters

4. Other Applications

(1) Magnetron tubes, TWTs (Traveling Wave Tubes) and microwave ovens

(2) MRIs (Magnetic Resonance Tomographic Imagers)

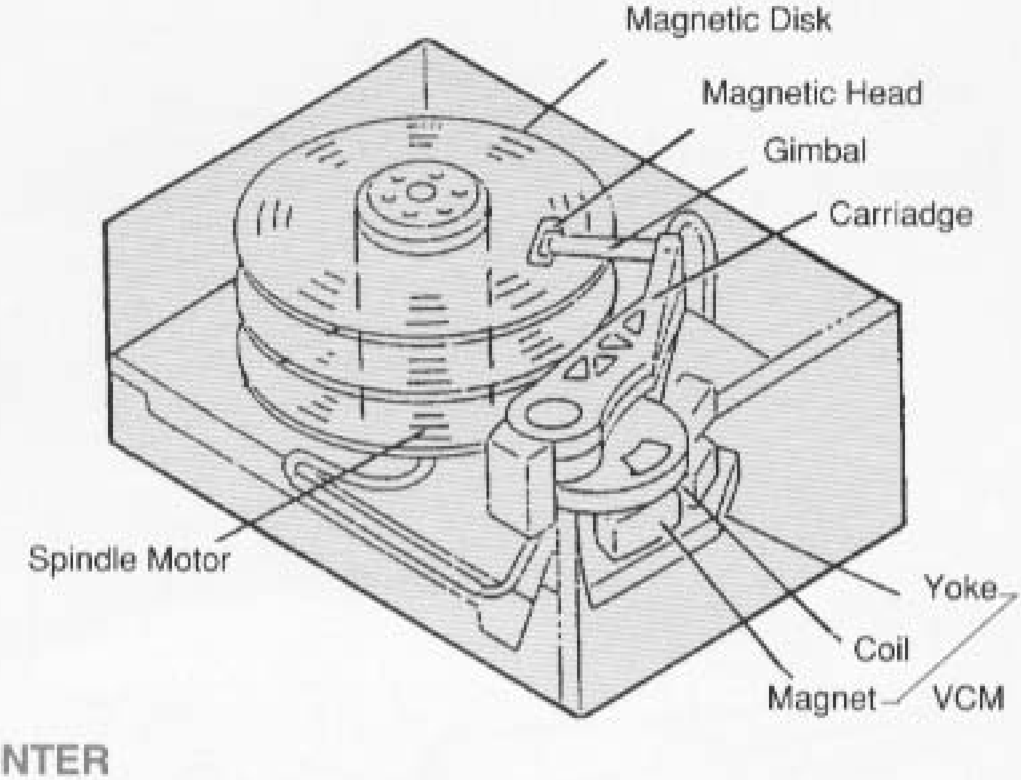
(3) Electron beam compensators (CTV)

(4) Automotive ABS sensors

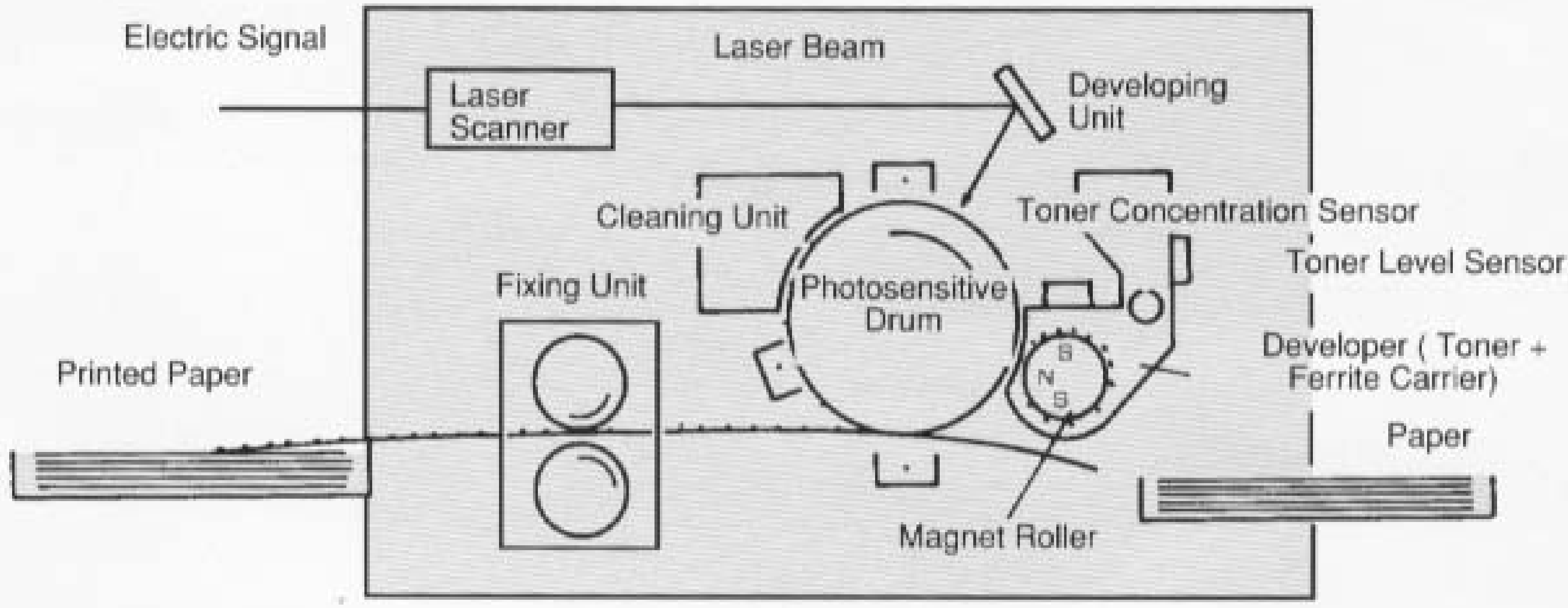
(5) Bio-magnetic health care devices : Bracelets, necklaces, sticking magnets and magnetic stomach Bands

From among the many applications, let's look at some of them using drawings and photographs.

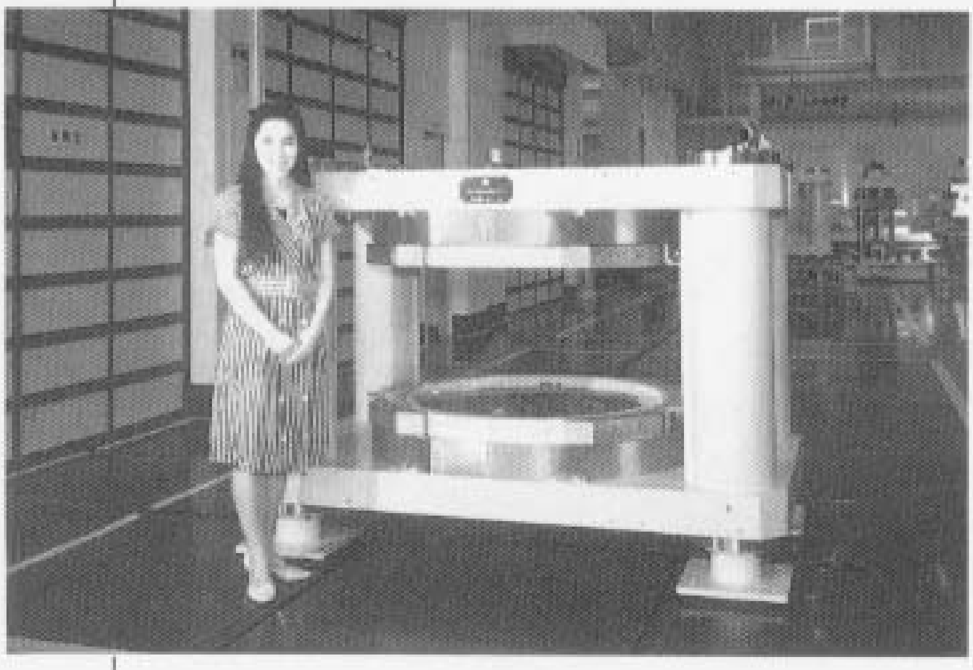
HDD

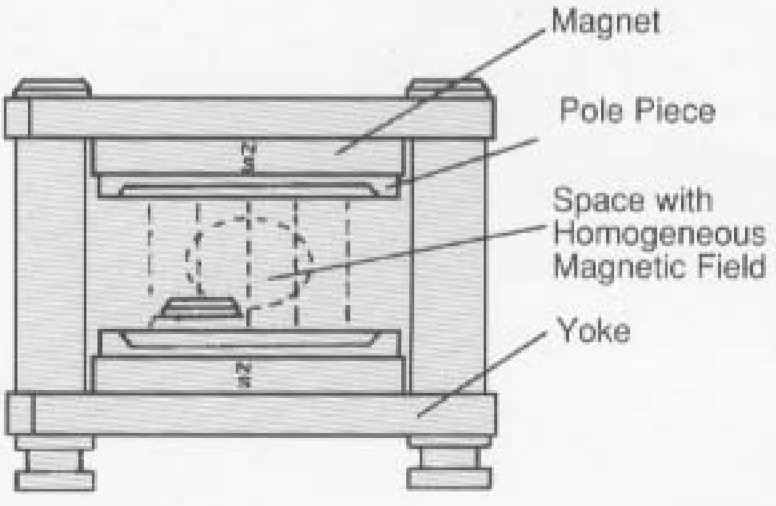


LASER PRINTER



MRI (Magnetic Resonance Imaging)





Applications of Magnets

Nearly 100 magnets are used as sensors and actuators in various kinds of automotive components.