

TITLE OF INVENTION

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A resin bound type magnet and its production process

This invention relates to a resin bound type magnet which is used for a miniature motor, an encoder, a linear actuator, etc. which are applied for electronics-instruments, etc. and its production process, especially for a ^{cylindrical} clindrical or a thin plate resin bound type magnet, and its production process by using an extrusion moulding method.

The resin bound type magnet is generally produced by (1) an injection moulding method, (2) a press moulding method and (3) an extrusion moulding process.

Among these moulding methods, the injection moulding method is to mould a determined shape by packing a magnet composition comprising a magnetic powder and a thermoplastic resin into a die by heating it at a temperature at which a sufficient fluidity is attained.

The press moulding method is a moulding method by pressing after packing a magnet composition comprising a magnetic powder and a thermosetting resin into a die of a press machine.



extrusion moulding method is a moulding method by charging a magnetic composition in a fluidized state by heating a mixture of a magnetic powder and a resin to make it in a molten state by a screw, a ram or a plunger into a die, and by converging it there.

Among these moulding methods, the injection moulding and the press moulding can mould a magnet having an anisotropy by applying a magnetic field in the die at the moulding step. However as for the injection moulding method and a press moulding method for a moulding of a long sized magnet of which demand is recently being increased, in case of the injection moulding method because of an impossibility of packing of a magnet composition in a cavity and of taking out a moulded article, etc and in case of the press moulding method since a length of a moulded article is determined by a stroke of a moulding punch, they have a defect that the length of the moulded article is limited. Especially in case of a moulding of a cylindrical magnet having a radiated anisotropy, there is a limitation on the length of the moulded article, and a magnet, of which an outer diameter (hereinafter called as D), an inner diameter (hereinafter called as d) and a length (hereinafter called as L) satisfy a below-listed equation, can only be moulded.

$$2DL / d^2 < 1$$

(Reference literature: Masaaki Hamano, an abstract book on the 9th meeting of Injection Moulding Technology of High Performance Plastic Magnet and Its Application Development, Plastic Industry Technical Committee 1986)



Accordingly as to a cylindrical magnet which satisfies

$$2DL / d^2 \geq 1,$$

by 2 kinds were obtainable is one was a single moulded magnet with an isotropy or with a poor magnet performance and the other was a one which is prepared by sticking plural number of the magnets having a radiated anisotropy.

However the aforementioned cylindrical resin bound type magnet and its production process have problems listed below.

1) In order to get a high performance motor or an actuator by using an isotropic magnet or a magnet having a performance close to the isotropic magnet, the volume of the magnet to be used has to be large, and a miniaturization and a light weighing of these instruments can not be satisfied.

2) In case that plural number of the magnets having a radiated anisotropy is stuck, there are following problems.

[1] The sticking is weak against delamination and there is a danger of ^{DESTROY} destroying the bond by a repeated hot and cold cycle. It has an inferior reliability such as a variation of the sticking strength, etc.

[2] A production cost is raised because of a step of the sticking in a production process. Furthermore the stuck magnet has to be finished by a cutting fabrication, etc to ensure a dimensional



accuracy of the moulded article resulting a further increase of the production cost.

[3] In case of the finish by the cutting fabrication of the moulded article, there is a possibility of a deterioration of the magnet performance by the finish.

3) As for the injection moulding method and the press moulding method, it requires a fixed cycle of a packing, a moulding and a taking out of a magnet composition to/from a die in the moulding process, and the productivity is limited because it is basically a batch type production system. It is, therefore, difficult to achieve a reduction of the production cost.

4) As for the conventional extrusion moulding method, it is a major method not to apply a magnetic field at the moulding stage. However an isotropic magnet can only be attained by this moulding method.

Accordingly the extrusion moulding method, which has a very high productivity due to an ability of a continuous operation from a supply of a raw material to a receipt of a moulded article, and is able to easily mould a long sized magnet, becomes popular. Particularly there are many researches to improve the magnet performance, especially researches on an extrusion moulding method in a magnetic field in order to reform the magnetic property which has been considered to be poor.



Concerning a method to charge a magnetic field at the moulding step, as for a column type magnet, there is a report by R.E. Johnson ("Development The Production of Bonded Rare Earth-Cobalt Magnets." 5th International Workshop on Rare Earth-Cobalt Magnets and Their Applications, 1981), and for a cylindrical magnet, there are methods shown in Japan Patent Laid-Open Sho 58-219705 and Japan Patent Laid-Open Sho 61-121307.

Both of these methods were to form a magnet by orientating an axis of easy magnetization of a magnetic powder to a direction of a magnetic field by charging a magnetic field in a die of an extrusion machine while magnet composition was being passed through the die. However for example in a method described in Japan Patent Laid-Open Sho 61-121307, a cylindrical magnet magnetized and orientated in a die was cooled by a cooling unit outside the die, a direction of the anisotropy was only formed in one direction and a moulded article having a radiated anisotropy in a diameter direction could not be obtained. Moreover, when the moulded article was extruded from the die, its temperature was still high resulting a deterioration of a magnet performance by a disorder of an orientation of a magnetic powder. As a result it is not attainable to get a cylindrical magnet having a high magnet performance radiated anisotropy even if this method is applied.

Moreover there are below-listed problems in the aforementioned production method.

- (1) In the conventional extrusion moulding method in a magnetic field, a electromagnetic coil is merely installed on the die and no consideration

paid for a demagnetization of a moulded article produced. If there is residual magnetism in a moulded article, it is very difficult to handle the post process such as an adhesion at a cut stage to a cutter or other magnetic materials. Further when a predetermined magnetization is carried out for the magnet, the residual magnetism give an unfavorable influence to a balance of the magnetization.

(2) As an example of a moulding method in which the demagnetization of the extrusion moulded article is considered is disclosed in Japan Patent Mid-Open Sho 60-217617. However since the demagnetization coil is equipped at a front end of a die in this case, it results an extremely large die and a mouldability is poor. Especially since a passage of a raw material compound in the die is long, the moulding speed is slow and the moulding itself is also difficult.

(3) When a cylindrical magnet having a radiated anisotropy is moulded, a length of an orientation section on which a magnetic field is charged due to a constitution of a magnetic circuit is determined by an inner diameter of the moulded article. However since a considerably high magnetic field is generally required to orientate a rare earth magnet powder, the length of the orientation has to be relatively short in order to charge a sufficient magnetic field at the orientation section. Consequently it is essentially not able to mould a cylindrical magnet with a high magnet performance having a small inner diameter.

(4) When a column type or a sheet type magnet is moulded, the length of the orientation section can be made long in a certain degree. However a



between pole pieces can not be made too short due to a mechanical strength of the die, and thus it is not able to increase a magnetic field charged at the orientation too high. The magnet performance of the article therefore drops.

In case that a thermoplastic resin is used as a resin in the mentioned extrusion moulding method, the moulding is carried out by solidification with cooling of a molten mixture after orientating at front end of the die. When a thermosetting resin is used as a resin, there are methods to mould by a solidification with cooling after orientating at the front end of the die as same to the thermoplastic resin, and to mould by a curing with heating after the orientating.

In case of a method with the solidification with cooling by using the thermosetting resin, it is necessary to heat it to cure the resin after the moulding. Anyhow even if the moulding is done by either methods, a magnet moulded is extruded continuously, and it is ^{NECESSARY} necessary to cut the magnet moulded in a predetermined length. For the cut, mechanical cutting methods namely a guillotine cutter system or a rotary saw-tooth system were utilized in the conventional method.

However the conventional cutting methods had below-listed problems.

In case of a mechanical cutting method such as the guillotine cutter system or the rotary saw-tooth system, a force and a vibration are charged to a magnet to be cut. When an uncured resin bound type magnet moulded by a solidification with cooling by using a thermosetting resin

cut and a thin thickness magnet characterized by an extrusion moulding cut, a crack, a breakage and/or a deformation of the magnet are taken place during the cutting because of a brittleness and a weakness of the magnet to be cut.

Particularly when a volume ratio of the magnetic powder in a resin bound magnet is increased in order to improve a performance of the magnet, the volume ratio of the resin decreases and the aforementioned problems tends to happen further easily because of a reduction of bonding force of the resin with the magnetic powder. Moreover in case of the mechanical cutting method, a cut dust is unavoidably produced. In case of a rare earth magnet, especially a R-Co type magnet, a treatment of the cut dust is extremely important because cobalt has a bad effect to a human body, and it requires a recovery unit of the cut dust.

Further among the conventional moulding methods by using a thermosetting resin, a press moulding was a general, but an injection moulding and an extrusion moulding were not widely used and a thermoplastic resin was commonly used.

Accordingly only a few methods were available to cure an uncured magnet by heating moulded by the injection moulding and by the extrusion moulding, and the method was to secure a cylindrical shape of the magnet with a centrifugal force by rotating a jig after fixing its outer diameter to the jig.



problems of the aforescribed conventional technology are summarized below.

Firstly it is a use of a thermoplastic resin for moulding a magnet by an injection moulding and the extrusion moulding. In order to make a magnet moulded by a thermoplastic resin to be usable even at a temperature at around 150°C, its moulding temperature has to be at 200°C or more. Therefore a magnetic powder blended with the resin is exposed at such a temperature.

When a rare earth magnet, especially a R-Fe-B type magnet is used as a magnetic powder, a deterioration of a magnet performance of the magnet happens due to an oxidation of the magnetic powder at a high temperature above 200°C since the magnetic powder is easily to be oxidized. Moreover, the thermoplastic resin has problems on heat resistance and solvent resistance when compared with a thermosetting resin.

Next, methods of the curing by heating after moulding by using the thermosetting resin are pointed out. For a moulding by using the thermosetting resin, it requires that the resin possesses a thermoplastic property in a certain temperature region. Nevertheless this temperature region is lower or higher than the thermosetting temperature, it is necessary to secure the shape once moulded in order to cure it.

In order to achieve it, methods in the conventional technology are available. However in a conventional production process of a cylindrical resin bound type magnet, since the inner diameter is not fixed, a fixing

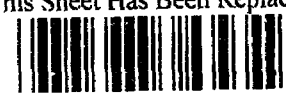


g of the outer diameter is rotated with a sample to secure the shape during the curing, and the jig for this purpose is thus required. Furthermore it is difficult to operate the curing treatment for lots of magnets by this method, and it has problems such as a curing treatment for a long sized magnet moulded by an extrusion moulding method is also difficult, etc.

Further in the past, as to a particle size of a magnetic powder in a resin bound type magnet, a concern of an oxidation when the magnetic powder was fining was considered, but no consideration of the particle size of the magnetic powder from a viewpoint of a thickness of a magnet moulded article was considered.

Further in order to mould a magnet with a thickness of 1mm, it was necessary to make the desired thickness by a cutting fabrication after moulding one with the thickness more than 1mm by a press moulding or an injection moulding in advance.

However the particle size of a magnetic powder gives a large influence to the thickness of a moulded article of an anisotropic resin bound type magnet. Namely if the average particle size of a magnetic powder does not change, an orientation of one magnetic particle affects more to a degree of the orientation of the magnet by thinning the thickness of the moulded article. For example, when an anisotropic magnet with a thickness of 0.5mm is moulded, if the average particle size of the magnetic powder is 50 μ m, the influence that one magnetic particle gives to the orientation is around 10%. Although the influence is reduced if



When the thickness of the moulded article becomes 0.5mm or more, the influence is enlarged if the thickness becomes thinner. Accordingly as to the average particle size of the magnet, a problem is generated that it should relate to the thickness of the magnet moulded article.

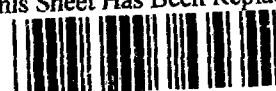
Further by a conventional method to mould a magnet with the thickness 1mm or less, it resulted a high production cost, etc because of the fabrication process required.

Further, a rare earth magnet, especially a rare earth-iron-boron type magnet was easily oxidized, and there was a problem of a formation of a rust during its service.

In order to solve the problem, a coating method of a resin on the magnet moulded, a metal plating and a coating of a ceramic or a resin on the magnetic powder were investigated in the past.

However following problems are enumerated in the aforementioned conventional rust resistance technology of a magnet.

The former method in which a resin is coated on a magnet moulded does not have an effect to an oxidization of the magnetic powder during the moulding. In other words, when an injection moulding or an extrusion moulding is performed, the magnetic powder is exposed under a high temperature during kneading of the magnetic powder and the resin or moulding, and the magnetic powder can be oxidized at this stage resulting an impossibility of the moulding and a deterioration of a magnet



performance. Moreover if a slight pin hole is present in a coating film in the moulding, there is a problem that the magnet inside it is pulled from it.

considering these problems, the latter method in which a metal coating or a coating with a ceramic, a resin, etc on the magnetic powder may be a method to solve the aforementioned problems.

However the latter method still has a problem. The average particle size of magnetic powder is several ten microns, if a film is coated on it, the thickness has to be 1 micron or less, and therefore there is a problem that the film coated has to be extremely tough and strongly adhesive or it has to establish a production process not to remove the film coated.

Further in the past, a thin plate state resin bound type magnet was mainly produced by a calendar moulding method, an extrusion moulding method and an injection moulding method.

For each moulding method, a mixture kneaded of a magnetic powder and a thermoplastic resin is used and in case of the calendar moulding method, the aforescribed magnet raw material is made in a thin plate state by rolling with hot rollers.

However the production process of the aforementioned thin plate state resin bound type magnet has below-listed problems.



In case of the calendar moulding method, an isotropic moulded article can only be obtained when a rare earth magnetic powder is used since it is not possible to charge a magnetic field during the moulding, and thus magnet performance of the magnet is low.

Further because of a heating capacity of the rollers, it is not possible to use a resin having a very high melting point as a binder, and the heat resistance of the moulded article is inferior.

Furthermore it requires a certain flexibility in the moulded article for the moulding, and therefore an amount of a magnetic powder in a raw material can not be considerably large resulting a low magnet performance of the moulded article.

(2) In case of a moulding of a thin plate state magnet by an extrusion moulding method, an unevenness of the moulded article is likely to happen due to a difference of the extrusion rate between a central point and an outer point of the outlet of the die. Accordingly in order to produce an even moulded article, a complicated design of the passage in the die is required and the die becomes extremely expensive.

Further when the moulding is carried out in a magnetic field, the gap between pole pieces can not make very small because of a concern of mechanical strength of the die, and thus the magnetic field to be charged at the moulding can not be very high. Consequently a magnet performance of the moulded article is deteriorated.

In case of a moulding of a thin plate state magnet by an injection method, it is difficult to mould one having a thickness of 1mm or less. This is due to a generation of a poor moulding by an insufficient packing of the moulding raw material into the cavity of the die if the thickness is thin, since the moulding raw material has a poor fluidity containing a large amount of a magnetic powder.

Further when an anisotropic magnet is moulded and if the thickness is thin, a moulding with a substantially isotropy can only be obtained because of an effect of a skin layer (a section where the ratio of the resin is high) of the magnet surface.

Further a big moulding machine is required to mould a magnet having a large area, and it is disadvantageous from a moulding cost.

This invention, therefore, is to solve the above-discussed problems, and its objective is to provide a resin bound type magnet with a high magnet performance, especially a long sized cylindrical resin bound type magnet having a radiated anisotropy, and to provide a production process of the magnet with a good productivity.

Further the objective is to provide a production process of a magnet with a simple cutting method without a crack, a breakage and a deformation.

Furthermore this invention aims to provide a production process with simplifying the production process and with reducing a cost, by improving a magnet performance of a magnet moulded by means of establishing a



tion between a magnetic powder and a thickness of the magnet, and by adding a magnet by an extrusion with superior oxidation resistance and other resistance.

Moreover this invention aims to provide a production process with a good productivity for a high performance thin plate state resin bound type rare earth magnet.

BRIEF EXPLANATION OF FIGURES

Figure 1 is a sketch of an extrusion moulding machine used in Example of this invention.

Figure 2 is a sketch of a die structure for an extrusion moulding in a magnetic field of a cylindrical resin bound type magnet used in Example of this invention.

Figure 3 is a sketch of an extrusion moulding machine used in Example of this invention.

Figure 4 is a sketch of a pulse magnetization unit used in Example of this invention.

Figure 5 is a graph showing a relation between a magnetic field for the moulding and a residual magnetic flux density of the moulded article for cases with and without a magnetization of a magnetic powder prior to the moulding.



Figure 6 is a sketch of a die structure for an extrusion moulding in a magnetic field of a thin plate state resin bound type magnet used in Example of this invention.

Figure 7 is a graph showing a relation between a magnetic field for magnetization before the moulding and a residual magnetic flux density of the moulded article.

Figure 8 is a sketch of an extrusion moulding machine used in Example of this invention.

Figure 9 is a sketch of a die structure for an extrusion moulding in a magnetic field of a cylindrical resin bound type magnet used in Example of this invention.

Figure 10 is a sketch of an extrusion moulding machine used in Example 16 and 17 of this invention.

Figure 11 is a sketch of Example to cut and to make a thin plate state of cylindrical resin bound type magnet moulded by an extrusion in Example 16.

Figure 12 is a sketch of a press unit for moulding of a thin plate state magnet used in Example 17 of this invention.

This invention is a resin bound type magnet and its production process as described below.



A resin bound type magnet comprising a magnetic powder and an organic resin wherein it is moulded as a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$



among the outer diameter (D), the inner diameter (d) and the length (L) of the magnet, and it also has a radiated anisotropy in the diameter direction.

A composition of a resin bound type magnet of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

A production process of a resin bound type magnet wherein a raw material for the moulding comprising a magnetic powder and an organic resin is moulded by an extrusion by passing through a die in which a magnetic field is charged while it is being cured, is formed ~~by~~^{to} a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$



among the outer diameter (D), the inner diameter (d) and the length (L) of the ~~said cylindrical~~ magnet and it also has a radiated anisotropy in the diameter direction.

A composition of a resin bound type magnet in the production process of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder and an



an organic resin wherein a die structure for moulding is constituted that a front end of a mandrel section is projected in front of an edge of a die, a magnetic circuit is formed between the said mandrel section, ~~the die~~ ^{an electromagnetic coil} installed at an outer circumference of the ~~die and the~~ said die, it is moulded in a cylindrical form by charging a magnetic field in the die by the electromagnetic coil, and the moulded article extruded is demagnetized at the front end of the mandrel.

18) A Composition of the magnet of the aforementioned invention comprises magnetic powder, an organic resin and an additive.

19) A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder and an organic resin wherein an electromagnetic coil is installed at an outer circumference of a die, ^{by it} it is moulded in a cylindrical form by charging a magnetic field in the die, an electromagnetic coil with an air-core is also installed in front of the aforementioned electromagnetic coil to generate a magnetic field for demagnetization in the said electromagnetic coil, and the moulded article extruded is demagnetized.

20) A composition of the magnet of the aforementioned invention comprises magnetic powder, an organic resin and an additive.

21) A production process of a resin bound type magnet which is constituted by orientating a magnetic powder in a molten mixture of a magnetic powder and a resin in a section where a magnetic field is



charged at a front end of a die, moulding it in a cylindrical form, solidifying it with cooling and extruding it wherein when the magnet is cut, the resin is cut by ^{melting} ~~melting~~ by contacting the magnet with a heated re.

(10) A production process of a resin bound type magnet wherein a composition of the molten mixture of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

(11) A production process of a resin bound type magnet of the aforementioned (9) or (10) wherein the resin bound type magnet is an isotropic magnet moulded by an extrusion in a cylindrical form without an orientation.

(12) A production process of moulding a resin bound type magnet in a cylindrical form by an injection moulding or an extrusion moulding of a magnetic powder and a thermosetting resin wherein in order to cure the molten mixture of ^{the} ~~a~~ magnetic powder and ^{the} ~~a~~ resin by heating, it is cured by heating with fixing the outer circumference of the cylindrical magnet with a jig and the inner circumference by an elastic material expanded by a gas.

(13) A production process of a resin bound type magnet wherein a composition of the molten mixture of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.



A production process of a resin bound type magnet of the aforementioned (12) or (13) wherein the aforementioned elastic material is silicone rubber.

A production process of a resin bound type magnet comprising a magnetic powder and an organic resin wherein a mixture of ^{the} rare earth magnetic powder premagnetized in a magnetic field which is stronger than coercive force of the magnetic powder and ^{the} organic resin is kneaded, and the kneaded mixture is moulded by an extrusion in a magnetic field.

(16) A production process of a resin bound type rare earth magnet wherein composition of the magnet of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

(17) A production process of a resin bound type magnet by an extrusion moulding with a die in a magnetic field of a moulding raw material comprising a magnetic powder and an organic resin wherein it is moulded by an application of a slight vibration to the die at the moulding.

(18) A production process of a resin bound type rare earth magnet wherein a composition of the magnet of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

(19) A resin bound type magnet comprising a magnetic powder and a resin wherein an average particle size r of the aforementioned magnetic powder satisfies

$$r \leq 0.1 t \quad (t \leq 1\text{mm})$$



the thickness t of the moulded article of an anisotropic resin bound magnet comprising the said magnetic powder and the resin.

h) further (a production process of) a resin bound type rare earth magnet wherein a composition of the magnet of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

i) A production process of a resin bound type magnet comprising a magnetic powder and a resin wherein an average particle size r of the aforementioned magnetic powder satisfies

$$r \leq 0.1 t \quad (t \leq 1\text{mm})$$

with the thickness t of the moulded article of an anisotropic resin bound type magnet comprising the said magnetic powder and the resin, and the magnet is produced by an extrusion moulding with a die in a magnetic field.

j) A production process of a resin bound type rare earth magnet wherein a composition of the magnet of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

k) A production process of a resin bound type magnet comprising a moulding of a mixture of a magnetic powder and an organic resin by an injection moulding or an extrusion moulding wherein a compound is prepared by charging in a kneading machine after making a viscosity of the mixture of the aforementioned magnetic powder and organic resin in a state of

$$\eta \leq 8 \text{ [Kpoise]} \quad (\text{shear rate} = 10000 \text{ sec}^{-1})$$

by heating.



(23) A production process of a resin bound type magnet wherein a composition of the magnet of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

(24) A production process of a resin bound type magnet in the inventions of the aforementioned (23) and (24) wherein the surface of the magnetic powder is coated with a metal plating or ceramics.

(25) A production process of a thin plate state resin bound type rare earth magnet wherein a moulding raw material comprising a magnetic powder and an organic resin is moulded by an extrusion in a cylindrical magnet by passing it through a die, then one or plural points on the circumference of the said cylindrical magnet is/are cut in a direction parallel with the central axis of the moulded article and the moulded article cut is spread to make it in a thin plate state.

(26) A production process of a resin bound type magnet wherein a composition of the moulding raw material of the aforementioned invention comprises a magnetic powder, an organic resin and an additive.

(27) A production process of a resin bound type magnet in the inventions of the aforementioned (26) and (27) wherein the outer diameter (D) of the cylindrical magnet to be moulded by an extrusion and the inner diameter (d) satisfy a relation of

$$0.75 \leq d / D < 1.$$



29) A production process of a thin plate state resin bound type rare earth magnet wherein a moulding raw material comprising a magnetic powder and an organic resin is passed through a die where a magnetic field is applied to mould a cylindrical magnet having a radiated anisotropy in the diameter direction by an extrusion, then one or plural points on the circumference of the said cylindrical magnet is/are cut in a direction parallel with the central axis of the moulded article and the moulded article cut is spread to make it in a thin plate state.

30) Further a production process of a resin bound type magnet wherein a composition of the moulding raw material of the invention of the aforementioned (29) comprised a magnetic powder, an organic resin and an additive.

31) A production process of a resin bound type magnet in the inventions of the aforementioned (29) and (30) wherein the outer diameter (D) of the cylindrical magnet to be moulded by an extrusion and the inner diameter (d) satisfy a relation of

$$0.85 \leq d / D < 1$$

(32) - (41) are those in which the magnetic powder, the organic resin and the additive are limited for this invention.

As for a magnetic powder which can be applied in this invention, a ferrite family magnetic powder and a so-called rare earth magnetic powder such as a magnetic powder composing of a rare earth metal and transition metals mainly constituting cobalt and iron as a basic composition, or a



basic powder composing of a rare earth metal, transition metals mainly constituting iron and boron as a basic composition, etc are enumerated.

for an organic resin which can be applied in this invention, it can be either a thermoplastic resin or a thermosetting resin, and as for the thermoplastic resin, for example, a plastic such as polyamide, polypropylene, polycarbonate, polyphenylenesulphide (PPS), etc, an elastomer such as chlorinated polyethylene, ethylene vinylacetate polymer (EVA), etc and synthetic rubber are enumerated.

as for the thermosetting resin, for example, ethylene family unsaturated polyester resin, epoxy resin, etc are enumerated.

Further as for the additive, a lubricant to reduce an extrusion resistance at the moulding such as a metal soap (zinc stearate, calcium stearate), wax, etc can be used, and as for the aforementioned crosslinkable thermosetting resin, an additive such as peroxides which accelerates the crosslinking reaction can also be used.

The magnetic powder is sufficiently mixed with the organic resin and the additive if it is necessary. Then the mixture is sufficiently kneaded in a kneading machine with heating above a temperature at which the organic resin is molten, and it is granulated. The magnetic composition granulated is charged in an extrusion machine, it is heated in a cylinder to make it in a fluidized state and is sent into a die by a screw or a plunger. The magnetic composition injected in the die is moulded by uniforming (orientating) an axis of easy magnetization of the magnetic

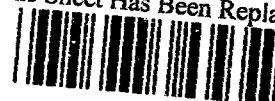


in the raw material to a direction of a magnetic field by passing through a die in which a magnetic field is charged. The magnetic position is solidified with cooling while it is in the magnetic field in the die, and it is extruded. The moulded article is then cut to a suitable length. When a crosslinkable organic resin is used as a binder, after a demagnetization of the moulded article cut, a crosslinking of the organic resin is achieved by heating or an irradiation (x ray, electron beam, etc). A resin bound type magnet is thus produced.

Further the moulded article extruded from the die is demagnetized by charging a magnetic field of a reverse direction to the magnetic field charged in the die at the moulding at a front end of the mandrel. The strength of the magnetic field is adjusted by a distance between the mandrel and a yoke of the electromagnetic coil. The moulded article extruded from the die is also demagnetized by charging a magnetic field for an attenuation by passing it through an electromagnetic coil for the demagnetization. A cylindrical resin bound magnet is thus produced.

Further this invention is useful to facilitate an orientation of a magnetic powder, to improve the magnetic property and to reduce an extrusion resistance at the moulding, and is also beneficial to increase the moulding rate by an application of a ultrasonic oscillator or a mechanical vibration such as a vibrator, etc.

According to this invention, by defining an average particle size of a magnetic powder with a thickness of an anisotropic resin bound type



...moulded article, and the magnet is moulded by an extrusion, it is able to mould a thin thickness anisotropic magnet without a fabrication, and further a high performance magnet is able to mould.

...ther according to this invention, it has effects to prevent a lamination of a coated film on the surface of a magnetic powder and to improve an oxidation resistance of the magnet moulded by kneading a mixture of the magnetic powder and a resin after heating it to make a viscosity of the mixture at 300 Kpoise or less prior to the kneading to absorb the molten state resin on the surface of the magnetic powder resulting a relief of a mechanical stress.

...ext, in order to make a thin plate state magnet, one or plural points on the circumference of the moulded article in a cylindrical form is cut in parallel with the central axis of the moulded article. Then the aforementioned moulded article cut is made in a thin plate state by using, for example, 2 rollers, etc. The moulded article is then solidified with cooling, and is cut into a suitable length.

...ther as an alternative method, after cutting a cylindrical moulded article extruded into a suitable length, one or plural points on the circumference of the moulded article is cut in parallel with the central axis of the moulded article. The moulded article cut is heated and it is spread when a viscosity of the moulding article drops to make a thin plate state.

described above, a magnet of this invention is superior to a conventional magnet, in which plural magnets are stucked, from a point of a reliability. Furthermore by an application of a production process of this invention,

A cylindrical resin bound type magnet with a high magnet performance can be produced with a high productivity and an economic cost.

Since no excess force or vibration is charged in the magnet at a cutting step by cutting an extruded resin bound type magnet with a wire heated by an electric resistance, it is possible to cut an uncured magnet which is very brittle and a thin thickness magnet without a crack and a breakage.

(3) A large amount of a thermosetting treatment can be operated with a low cost, the operation becomes easy, and further a dimension accuracy of a cylindrical resin bound type magnet can be improved.

(4) It has a significant effect for moulding a cylindrical magnet having a radiated anisotropy in a diameter direction though it is difficult to get a strong magnetic field at the moulding.

(5) It can be widely used for a magnetic sensor, an encoder, an actuator, a linear actuator which requires a miniturization, a precision and a high performance.



According to this invention by defining the average particle size of the magnetic powder by the thickness of the anisotropic resin bound magnet moulded article and by moulding the magnet by an extrusion, it is possible to mould a thin thickness anisotropic magnet without a fabrication, and it is also possible to mould a magnet with a high performance.

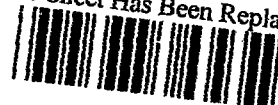
Furthermore according to this invention by kneading a mixture of a magnetic powder and a resin after heating it to make its viscosity at 300 °C or less prior to the kneading, the resin in a molten state is adsorbed on the surface of the magnetic powder, and thus it has effects to prevent the coated film on the surface of the magnetic powder by relieving a mechanical stress and to improve an oxidation resistance of the magnet moulded.

EXAMPLE

This invention is explained in details in accordance with examples shown below.

Example 1

Raw materials were molten to make a composition as Sm (Co 0.672 Cu 0.08 Fe 0.22 Zr 0.028) 8.35, after ^acasting, an ingot produced was magnetically cured by a heat treatment, and then a magnetic powder of its average particle size 10µm was prepared by crushing the said ingot.



magnetic powder, nylon 12 powder and zinc stearate powder were mixed in a ratio of 92 wt%, 7.9 wt% and 0.1 wt% respectively.

The mixture was kneaded by an 2 axes extrusion kneading machine at 260°C.

The kneaded material was granulated to make granules of an outer diameter of 10mm, they were used as a raw material compound 111, and a cylindrical magnet was produced by an extrusion machine.

The moulding method is explained in accordance with Figure 1. The moulding machine consists of a hopper 101, a raw material charging section 102, a cylinder 102, a screw 103, an adapter plate 104 to equip a die at the cylinder 102, a die 105 and a driving motor of the screw (which is not shown in Figure), and further an electromagnetic coil 109 to charge a magnetic field in the die is positioned at the outside of the die 105.

A yoke 110 comprising a magnetic material is installed around the electromagnetic coil 109.

The aforementioned granulated raw material compound was charged in the extrusion machine.

The raw material compound 111 was heated at 260°C in the cylinder 102 to make it in a fluidized state, and it was passed through the die 105. The die structure is shown in Figure 2.

is constituted by an outer die 201 and a mandrel 202. Although the outer die is made of a non-magnetic material, a ring shaped outer die of magnetic material 201a to induce a magnetic flux is installed at the front end. The mandrel 201 is also made of a non-magnetic material, further a mandrel section magnetic material 202a is installed at its front end.

When a current is passed through the electromagnetic coil 109 installed inside of the die, the magnetic flux generated flows alongside of a magnetic flux flow H shown in Figure by an arrow since it tends to pass through a magnetic material with a high magnetic permeability. Accordingly a radiated shape magnetic field is generated in a space hereinafter called as an orientation section) between the front end 202a of the mandrel 202 and the ring shaped outer die 201a of a magnetic material installed in the outer die 201. Therefore when a magnetic composition passes through the orientation section, it is moulded with a progress of the orientation of the magnetic powder.

In this Example, the magnetic field for moulding was 15 KOe, the temperature of the die at the moulding was 250°C and the cooling was performed by a forced air cooling at the outlet section of the die.

Accordingly, an orientated raw material compound was moulded by an extrusion with a solidification with cooling at the outlet of the die. The size of the moulded article was the outer diameter 32mm, the inner diameter 30mm, and the length was cut into 22mm. The magnetic property of the moulded article produced was



Br = 5.8 KG and
(BH) max = 7.3 MGOe.

Magnets thus produced were assembled in 25 units of DC motor, and a continuous operation test for 500 hours Test 1 was carried out.

For a comparative example for Test 2, the raw material having the same composition was moulded by an injection in a magnetic field and a cylindrical magnet of the outer diameter 32.5mm, the inner diameter 30mm and the length 6mm was moulded. The magnetic property of the moulded article produced was

Br = 5.7 KG and
(BH) max = 7.0 MGOe.

Pieces of the magnet were stuck by an epoxy type adhesive, and then the outer diameter and the length were made at 32mm and 22mm by a cutting fabrication.

The magnets were assembled in 25 units of DC motor and the 500 hour continuous operation was carried out as same as Test 1. The test results were shown in Table 1.

Table 1

DC Motor Tested
(units)

DC Motor Exhibited
a Deteriorated Property
(units)

(Example)	25	0
(comparative example)	25	2

Table 1, those of which the motor showed a deteriorated property cases that the rotation of the motor stopped or the torque was reduced due to an insufficient magnetic flux available by a delamination of adhesive area of the magnets stucked.

sequently by an application of the magnet of this invention, a ability of the motor can be improved.

ie 2

materials to make a composition $Nd_{13} Fe_{82.7} B_{4.3}$ were molten, were d and a quenched ribbon was prepared in an argon atmosphere by using anching and a ribbon rolling machine from the ingot obtained. The shed ribbon was coarsely crushed, was charged in a mould and a high erature press moulding was performed by applying a pressure of 20 mm^2 for a short time at 700 - 800°C in an argon atmosphere. A density he consolidated article was almost 100%.

consolidated article was again processed with a high temperature is moulding in a vertical direction to the first pressing direction a pressure of 10 Kg/mm^2 at 700 - 800°C in an argon atmosphere. mely it was treated with a die upset)



A bulk magnet obtained was crushed to make a magnetic powder of an average particle size of 20µm.

The magnetic powder was mixed with a resin~~ing~~ powder comprising bisphenol A type epoxy, novolak type epoxy and vinylbutyral-vinylalcohol copolymer, calcium stearate powder and silica powder as additives.

The ratio in the mixture was the magnetic powder 90.3 wt%, the resin powder 9.1 wt% and the additive 0.6 wt%.

The mixture was kneaded by a 2 roller type mill ^{at 90°C}. The kneaded mixture was granulated to an outer diameter of 1 - 10mm granules to make a raw material compound and was moulded in a cylindrical magnet by an extrusion machine as same as Example 1, and it was cut and was fired after a magnetization.

The size of the moulded article was the outer diameter 22mm and the inner diameter 21mm, and the magnetic field for the moulding was 14 KOe. The magnetic property of the moulded article obtained was

Br = 6.6 KG and

(BH) max = 9.8 MGOe.

Consequently as for the production process of this invention a high performance magnet can be obtained even a crosslinkable thermosetting resin is used.

Example 3



Magnetic powder of an average particle size of 10µm was prepared by the same composition and procedure as Example 1.

Coercive force H_c of this powder was 8 KOe. This is called as Powder

Further as for the other kind of powder, a magnetic powder of an average ~~particle~~ size of 20µm was prepared by the same composition and procedure as Example 2. A coercive force H_c of this powder was 12 KOe. This is called as Powder B.

Powder A, nylon 12 powder and zinc stearate powder were mixed to make a ratio of 92 wt%, 7.9 wt% and 0.1 wt% respectively.

Further Powder B was also mixed with the aforementioned resin powder and the additive to make a ratio of 91 wt%, 8.8 wt% and 0.2 wt%.

These mixtures were kneaded by a 2 axes extrusion kneading machine at 250°C. The kneaded mixture was granulated to granules of an outer diameter of 1 - 10mm to make a raw material compound 111, and a cylindrical magnet was moulded by a procedure explained in Example 1 by an extrusion moulding machine as shown in Figure 1.

The moulding method was the same method as Example 1 and the die structure was also the same to Figure 2 as explained in Example 1.

current-flows in the electromagnetic coil equipped outside of the the magnetic flux generated flows in the arrow H in Figure since it is to pass through a magnetic material with a high magnetic permeability.

sequently a radiated magnetic field is generated in the orientation section which is a space between a magnetic material 202a of the mandrel and a magnetic material ring 20/a installed on the outer die. Therefore when a magnetic composition is passing through the orientation section, it is being moulded with a progress of an orientation of the magnetic powder.

Furthermore a magnetic field with a reverse direction to the magnetic field in the orientation section is generated in a space between the front end of the mandrel and the yoke 110 of the coil. Therefore a demagnetization of the moulded article can be achieved by making the magnetic field of this space at a suitable strength with an adjustment of distance between the mandrel and the yoke 110.

In this Example, the magnetic field for moulding was 14 KOe, the temperature of the die at the moulding was 250°C and the cooling was applied by a forced air cooling to the outlet section of the die.

By the above, the orientated raw material compound 111 was moulded by an extrusion with a solidification with cooling at the outlet of the die. A strength of the demagnetization magnetic field was adjusted to almost the



to the coercive force iH_c of the magnetic powder in the moulded
le.

size of the moulded article was the outer diameter 30mm and the inner
diameter 29mm. In Table 2, surface magnetic flux densities for cases
3 and 4 in which the demagnetization was performed, and for cases
5 and 6 without the demagnetization and shown.

Table 2

	<u>Powder</u>	<u>Surface Magnetic Flux Density (G)</u>
Test 3 Example	A	20
Test 4 Example	B	35
Test 5 Comparative example	A	150
Test 6 Comparative example	B	220

Example 4

A magnetic powder of an average particle size 10 μ m and iH_c 8 KOe was
prepared by the same composition and procedure as Example 1. This powder
is called as Powder A.

As for the other kind of powder, a magnetic powder of an average particle
size 20 μ m and a coercive force iH_c 12 KOe was prepared by the same

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position and procedure as Example 2. This powder is called as Powder

same to Example 3, the Powder A was mixed with nylon 12 powder and stearate powder to make a ratio of 92 wt%, 7.9 wt% and 0.1 wt% respectively.

der B was also mixed with the aforementioned resin powder and additive make a ratio of 91 wt%, 8.8 wt% and 0.2 wt% respectively.

These mixture were kneaded by a 2 axes extrusion kneading machine at 300°C. The kneaded mixture was granulated to granules of the outer diameter 1 - 10mm to make a raw material compound, and a cylindrical magnet was moulded by an extrusion moulding machine.

The moulding method is explained in accordance with Figure 3.

An extrusion moulding machine of Figure 3 is composed of a similar constitution to an extrusion moulding machine of Figure 1, and an electromagnetic coil 109 is positioned outside a die to charge a magnetic field in the die, but there is a difference ie an electromagnetic coil for demagnetization is installed in front of it.

The aforementioned granulated raw material compound 111 was charged in the extrusion moulding machine. The raw material compound 111 was heated at 260°C in the cylinder 102 to make it in a fluidized state, and it was passed through the die 105. The die structure was the same as explained



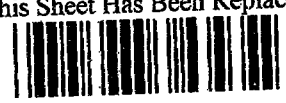
Example 1:- According to this invention, when the magnetic composition passed through the orientation section, it is moulded with a progress in orientation of the magnetic powder as same to Example 3.

In this Example, the magnetic field for moulding was also 14 KOe, the temperature of the die at the moulding was 250°C, and the cooling was given by a forced air cooling to the outlet section of the die. The demagnetized raw material compound 111 was moulded by an extrusion by a modification with cooling at the outlet of the die.

The demagnetization was carried out by generating a magnetic field for the demagnetization by turning on an attenuated pulse current in the electromagnetic coil 113. The strength of the magnetic field for the demagnetization was 30 KOe, and it was attenuated with 800m sec. The magnetic field was generated in the electromagnetic coil 113 in every 15 sec, and the demagnetization was carried out continuously. The size of the moulded article was the outer diameter 30mm and the inner diameter 29mm. Surface magnetic flux densities of the moulded articles for cases in which the demagnetization was performed (Test 7 and 8) and for cases without the demagnetization (Test 9 and 10) are shown in Table 3.

Table 3

	<u>Powder</u>	<u>Surface Magnetic Flux Density (G)</u>
Test 7 Example	A	10
Test 8 Example	B	15
Test 9 Comparative		



example	A	150
10 Comparative		
example	B	220

It is clear from Table, the surface magnetic flux density which
 gains in the moulded article could be dropped at 6 - 7% by an
 application of the process of this invention. Consequently the
 stability at the cutting step, etc was greatly improved.

Example 5

Magnetic Powder A or Powder B as the same compositions to Example 1 and
 and Resin a (a thermosetting epoxy resin) or Resin b (a thermoplastic
 resin ^Nnylon 12) were weighed to make a desired volume ratio, were mixed
 and a sheet state compound was prepared by kneading the mixture by
 passing it through a gap of a twin roller mill repeatedly after charging
 in the mill.

The kneading temperature of the mixture was at 90°C when Resin a was used
 at 250°C when Resin b was used.

Then the compound was crushed into particles and was moulded by an
 extrusion by passing through a cylindrical die by charging it in a screw
 type extrusion moulding machine.

Barrel temperature of the extrusion moulding machine was at 130°C for Resin a and at 250°C for Resin b and the die temperature was the moulding temperature for the each case.

Extrusion rate was 1 mm/sec.

Outlet temperature of the die was set at a solidification temperature for the composition moulded. This temperature differed by the processes.

Resin a was used for Process 1 and Process 2, Process 1 was a process to make the solidification with cooling at the outlet of the die, and Process 2 was a process to make the cure by heating at the front end of the die. Process 3 was a process to solidify with cooling at the outlet of the die using Resin b. The magnets thus produced were cut by method shown in Table 4.

Table 4

		<u>Cutting method</u>
Cutting Method 1		Cutting by melting with a heated wire
"	2	Cutting by a guillotine cutter system
"	3	Rotation saw tooth system

Among these, Cutting Method 1 was a cutting method of this invention wherein a current is turned on in a nickrome wire of a diameter of 0.2mm, it is contacted with a magnet when it is heated by the resistance and the magnet is cut by melting with heating.



Results of the cutting, when the magnets produced by these processes were shown in Table 5.

In this test, the magnet cut was a cylindrical magnet with the outer diameter 30mm and the inner diameter 29mm, and the volume ratio of the magnetic powder was 60 vol%.

Although the magnetic Powder A and B were used, both showed the same results.

Table 5

	<u>Process 1</u>	<u>Process 2</u>	<u>Process 3</u>
Cutting Method 1	excellent	good	excellent
" 2	bad	bad	bad
" 3	ordinary	excellent	excellent

The magnet of Process 1 was the most difficult sample to cut among the magnets of Process 1 - 3 because it was the most brittle. As it is clear from Table 5, the cutting method 1 and the cutting method 3 can be practiced for cutting these magnets, and it is not possible to cut it by the cutting method 2.

Example 6

Next, results of cutting when thickness of the magnet to be moulded was changed, were shown in Table 6.



magnets this time has an outer diameter of 30mm, was a cylindrical magnet and the magnet prepared by Process 1 was used. The results of whether the magnetic Powder A or B were the same.

Table 6

	<u>Thickness (mm)</u>				
	<u>1.0</u>	<u>0.7</u>	<u>0.5</u>	<u>0.1</u>	<u>0.05</u>
Cutting Method 1	good	excellent	excellent	excellent	excellent
Cutting Method 2	excellent	good	ordinary	bad	bad

As one of the features of the extrusion moulding method, it can be enumerated that a thin thickness magnet can be moulded. Therefore it is important to cut a thin thickness magnet.

In case of the Cutting Method 3, it was difficult to cut if the thickness of the magnet became 0.5mm or less, and it was not possible to cut when it was 0.1mm due to a formation of cracking.

On the other hand, in case of the Cutting Method 1, a thin thickness magnet can be cut since no excess stress is applied to the magnet at the cutting step.

Consequently it is clear that the cutting by melting with a heated wire is an advantageous method for the cutting.

Example 7

Results of the cutting when the volume ratio of the magnetic powder was changed were shown in Table 7.

The magnet cut this time had the outer diameter of 30mm and the inner diameter of 29mm, was a cylindrical magnet prepared by Process 1. The magnetic powder used was the magnetic Powder A.

Table 7

	<u>Volume Ratio of Magnetic Powder (vol^{space}%)</u>				
	<u>60</u>	<u>65</u>	<u>68</u>	<u>70</u>	<u>72</u>
Cutting Method 1	excellent	excellent	excellent	excellent	good
Cutting Method 2	ordinary	ordinary	bad	bad	bad

As the volume ratio of the magnetic powder increases, the volume ratio of the resin decreases accordingly, and the binding strength of the resin to the magnetic powder drops.

Therefore the magnet moulded becomes brittle as the magnetic powder increases. This trend is remarkable in a case of an uncured magnet produced by Process 1. As the volume ratio of the magnetic powder increases, the magnet performance of the magnet is improved, and therefore it is important that the cutting can be carried out even in a case of a large volume ratio of the magnetic powder.

In case of Cutting Method 3, the cutting could not be practiced when the volume ratio of the magnetic powder increased.



the other hand, in case of Cutting Method 1, the cutting can be carried out even the volume ratio of the magnetic powder is 72 vol %. Accordingly, it is clear from the results that Cutting Method 1 is a prior method for the cutting of a magnet of the extrusion.

Example 8

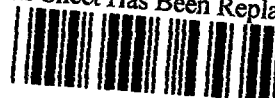
A cured cylindrical magnet was produced in accordance with followings use it for a curing unit of this invention.

First, 60 vol % of a magnetic powder of Sm - Co family magnet and 40 % of a thermosetting resin mainly comprising an epoxy resin were used and a compound was prepared by kneading it with a roller mill.

The epoxy resin used had a thermoplastic region of 100 - 150°C in which viscosity suddenly dropped, and it was cured at a temperature of 150°C.

The compound prepared was then coarsely crushed and it was charged in a moulding machine.

For the moulding machine, an injection moulding machine and an extrusion moulding machine could be used, but the extrusion moulding machine was used here. The charged compound was heated at 100 - 150°C in the moulding machine to make it in a molten state, the magnetic powder was orientated in a die, the molten mixture was solidified with cooling



As state and an uncured cylindrical magnet was prepared after a magnetization.

size of the magnet was the outer diameter 32.8mm and the inner diameter 31.8mm, and it was cut to make its length at 100mm.

Table 8, a comparison of various curing processes Test 11 - 13 for the mentioned uncured cylindrical magnet is shown.

Table 8

	<u>Shape</u>	<u>Operability</u>	<u>Cost</u>
Test 11	excellent	good	good
Test 12	excellent	ordinary	ordinary
Test 13	bad	excellent	excellent

Test 11 is the results of the curing process of this invention for a cylindrical magnet. Namely the outer circumference of the uncured cylindrical magnet is fixed by an elastic material, in this case it was a silicone rubber (hereinafter called as an inner body) expanded with a gas (in this case it was air), and it is cured by heating in an oven. *a jig, and the inner circumference is fixed by* ←

Test 12 is a conventional process in which the outer circumference is fixed with a jig, a rotation unit is attached to the jig, and it is cured by heating with a rotation in the circumferential direction. Test 13 is a process to cure the cylindrical magnet by heating by placing it in an oven as it is without the fixing.



thermocuring condition here was at 200°C for one hour in N₂ sphere. The shape in Table was the shape of the magnet after the

case of Test 13, the magnet after the cure is completely deformed and it is obvious that the fixing of the shape is necessary at the curing step. On the other hand, in cases that the shape is fixed, cylindrical form is nearly kept, and thus Test 11 and Test 12 are a good process from a viewpoint of the shape.

00

operability means an easiness of the operation of the unit and its capability for processing a large amount of the sample.

case of Test 12, it takes more time for an operation to connect the with the rotation unit than an operation of Test 11 to insert the ar body when compared with Test 11 of this invention. Furthermore in a viewpoint of cost, Test 12 is more costly because of the requirement of the rotation unit. Consequently the Test 11 process is a superior process to Test 12 and 13.

at the dimension accuracy after the cure when it is cured by heating by at 11 and Test 12 is shown in Table 9.

Table 9

	<u>Straightness</u>	<u>Roundness</u>
Test 11	0.005	0.01

Test 12	0.07	0.04
Before the cure	0.08	0.05

(Unit: mm)

rotation rate of Test 12 here was 500 rpm. This is the maximum rate
 can be practiced by taking the cost into consideration.

airpressure of the inner body of Test 11 was 1 atm.

magnet before the cure was prepared by somewhat decreasing its
 nsion accuracy in order to check a correction ability ^{on} ~~in~~ the ←
 nsion by the curing process by heating.

Table 9, it is understood that the dimension accuracy in corrected
 the curing process by heating such as Test 11 and Test 12.

is because that in case of Test 11 the air in the inner body is
 ended in the atmosphere of the thermocuring, it applies a force to the
 magnet resulting the correction of the dimension of the magnet while it
 is a thermoplastic state.

for Test 12, a centrifugal force generated by the rotation has a
 ilar action, but the dimension accuracy by the correction of Test 11
 further improved.

is because that the force by expansion of the air is stronger than
 centrifugal force resulting better correction of the dimension. From

correction ability of the dimension, it is also understood the
 ess of Test 11 of this invention is superior.

Example 9

materials to make the same composition of Powder A in Example 3, Sm
 0.672 Cu 0.08 Fe 0.22 Zr 0.028) 8.35 were molten, an ingot produced
 magnetically cured by a heat treatment after casting, and a magnetic
 powder having the average particle size of 10µm and the coercive force
 of 10 KOe was obtained by crushing the said ingot.

the powder was mixed with nylon 12 powder and zinc stearate powder to
 make a ratio of 92 wt%, 7.9 wt% and 0.1 wt% as same to Example 3.

The mixture was magnetized by a pulse magnetization unit shown in Figure
 with using a magnetic field of 25 KOe, and it was then kneaded by a two
 axes extrusion kneading machine at 260°C.

Figure 4, 301 is an electromagnetic coil, 322 is a pulse current
 generation power source, 303 is a table to adjust a height of a sample and
 305 is a raw material magnetic powder.

The kneaded mixture was granulated to particles of the outer diameter of
 1 - 10mm to make a raw material compound, and a cylindrical magnet was
 moulded by using the extrusion moulding machine shown in Figure 1 and the
 die shown in Figure 2 with a same procedure described above.



In this Example, the die temperature at the moulding was 250°C, and a cooling was carried out by a forced air cooling at the outlet of the die.

Accordingly, an orientated raw material compound was moulded by an extrusion by a solidification with cooling at the outlet of the die.

The size of the moulded article was the outer diameter 33mm and the inner diameter 32mm.

Figure 5, a comparison of changes of residual magnetic flux density (G) with magnetic fields for moulding for cases with and without magnetization of the raw material powder before the moulding is shown.

From Figure 5, it is understood that a magnet with a high Br is with a high degree of the orientation can be prepared by an adoption of the magnetization for the powder prior to the moulding even if the magnetic field for the moulding is low.

Furthermore as for the magnet performance at the high magnetic field (around 15 KOe) for the moulding, the cases with the magnetization showed higher values, and it was understood that the magnetization for the powder prior to the moulding had a bigger effect.

Example 10

Raw materials were molten to make a composition of Sm 0.5 Pr 0.5 (Co 0.672 Cu 0.08 Fe 0.22 Zr 0.028) 8.35, an ingot produced was magnetically

cured by a heat treatment after casting, and magnetic powders having an average particle size of 10 μ m were obtained by crushing the said ingot.

Two kinds of the magnetic powders having the coercive force 1Hc 7 KOe and 10 KOe respectively were prepared by changing a condition of the heat treatment.

These powders were mixed with nylon 12 powder and zinc stearate powder to make a ratio of 92 wt%, 7.9 wt% and 0.1 wt% respectively.

These magnetic powders were magnetized by using a direct current electromagnet unit, and then they were kneaded by a two axes extrusion kneading machine at 260°C.

The kneaded mixtures were granulated to particles of the outer diameter 1.0mm to make a raw material compound, and were moulded by an extrusion die to thin plate state magnets by using a die shown in Figure 6.

In the die 401, when a current is turned on in an electromagnetic coil, a magnetic field vertical to the passage of a compound in the die is generated between the upper and the lower pole pieces 404. Therefore a thin plate state magnet having an orientation of the magnetic powder to the thickness direction is moulded. By the way, 402 is a heater.

The size of the moulded article was the width of 60mm and the thickness 1mm, and the strength of the magnetic field at the moulding was 12 kOe.



In Figure 7, a relation between the strength of the magnetic field at the moulding was 12 KOe.

In Figure 7, a relation between the strength of the magnetic field for the magnetization prior to the moulding, and the residual magnetic flux density of the moulded article is shown.

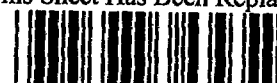
From the graph, it was understood that though there was no effect of the magnetization prior to the moulding if it was done in a magnetic field which was weaker than the coercive force of the magnetic powder, there was an effect to improve the magnetic performance if it was done in a magnetic field stronger than the coercive force.

Sample 11

Materials were molten to make a composition of Nd 13 Fe 82.7 B 4.3, then casted, and a quenched ribbon was prepared in argon atmosphere by using a quenching and ribbon rolling machine for the ingot produced.

The quenched ribbon was coarsely crushed, it was filled in a mould and a high temperature press moulding was carried out in argon atmosphere at 800°C with a pressure of 20 Kg/mm^2 for a short time.

The consolidated article obtained had a density almost 100%. The consolidated article obtained was moulded again by the high temperature press moulding in a vertical direction to the initial pressing direction ←



in argon atmosphere at 700 - 800°C with a 10 Kg/mm² pressure (Namely, a die upset was carried out).

A bulk state magnet obtained was crushed and a magnetic powder of an average particle size of 20µm was obtained. The coercive force of the magnetic powder was 12 KOe.

The magnetic powder was mixed with a resining powder comprising bisphenol A type epoxy, novolak type epoxy and vinylbutyral-vinylalcohol copolymer, ← calcium stearate powder and silica powder as additives to make a ratio of the magnetic powder 90.3 wt%, the resin powder 9.1 wt% and the additive 0.6 wt% respectively.

The mixture was magnetized with a 35 KOe magnetic field by using a pulse magnetization unit and it was kneaded by a 2 roller type mill at 90°C. The kneaded mixture was granulated to an outer diameter of 1 - 10mm granules to make a raw material compound and was moulded in a cylindrical magnet by an extrusion machine as same as Example 9.

In this Example, the die temperature at the moulding was 140°C, and the strength of the magnetic field for the moulding was 8 KOe.

The size of the moulded article was the outer diameter 8mm and the inner diameter 6mm. The moulded article was cut in a suitable length, was magnetized and was fired in conditions of 200°C x 45 minutes.



the magnetic property of the moulded articles obtained in Test 13 - 15 is shown in Table 10. Test 14 - 15, the comparative examples were a magnetic property of sample moulded with the magnetic field for the moulding at 8 KOe without the magnetization prior to the moulding (Test 14) and a sample magnetic property moulded with the magnetic field for the moulding at 15 KOe and a die of which the orientation section at the front end was shortened (Test 15).

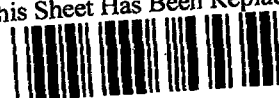
Test 10

		(BH) max
	<u>Br (KG)</u>	<u>(MGOe)</u>
Test 13	7.0	10.4
Test 14	4.3	3.5
Test 15	5.1	4.9

It is clear from Table 10, almost no orientation is observed in a comparative example Test 14, and the magnet obtained merely shows a performance close to an isotropic one.

On the contrary a high performance magnet with a sufficient orientation is obtained by this Example.

In the case of Test 15, the magnetic property is low in spite of its high magnetic field for the moulding, and it is considered that a sufficient orientation of the magnetic powder is not attained at the moulding since the length of the orientation section becomes extremely short such as 1mm



less in order to charge a 15 KOe magnetic field at the orientation
 tion due to its very fine cylindrical form having the inner diameter
 the moulded article 6mm.

efore a moulding process of this invention is a very effective
 ess for a case in which a high magnetic field for moulding is not
 ined because of a limitation of a moulded article or a structural
 lem of a die.

ple 12

his invention, Powder A and B were prepared by the same composition
 procedure to Example 4, they were kneaded with the resin, and
 adrical magnets were moulded by an extrusion moulding machine after
 ulating the kneaded mixture to particles having the outer diameter 1
 mm to make a raw material compound. The moulding process is briefed
 sing Figure 8.

xtrusion moulding machine of Figure 8 has a similar composition to
 extrusion moulding machine of Figure 1. However, at the front end of
 die, 4 pieces of ultrasonic oscillator (Langevin type) 114 are
 alled to generate a ~~slight~~ vibration.

slight

aforementioned granulated raw material compound 111 was charged to
 extrusion moulding machine of Figure 8. The raw material compound
 heated in the cylinder 102 at 260°C to make it in a fluidized state
 it was passed through the die 105.



The die structure was the same as Figure 2 explained in Example 1.

In this example, the magnetic powder is moulded while it is being orientated when the magnetic composition passes through the orientation section. The slight vibration from the ultrasonic oscillator was transmitted to the front end of the die.

In this example, the magnetic field for the moulding was 10 KOe, the die temperature at the moulding was 205°C and the cooling was applied by a forced air cooling to the outlet of the die. Thus the orientated raw material compound was solidified with cooling at the outlet of the die and was moulded by an extrusion. The size of the moulded article was the outer diameter of 25mm and the inner diameter of 23mm.

Differences of the magnet performance of the moulded article the moulding rate are shown in Table 11 for cases of an application of the slight vibration (Test 16, 17) and for cases of no application (Test 18, 19). Test 16 and 17 are the cases with the slight vibration and Test 18 and 19 are the cases without it.

Table 11

		(BH) max	Moulding Rate
	<u>Powder</u>	<u>(MGOe)</u>	<u>(mm/sec)</u>
Test 16	A	7.5	2.5
Test 17	B	10.2	2.0



Test 18	A	6.7	1.8
Test 19	B	8.5	1.5

As it is clear from Table 11, Examples shows an improvement on both of the magnetic property and the moulding rate. It is considered that it is due to an improved orientation by facilitating a rotation of the magnetic powder by the application of the slight vibration at the moulding.

Furthermore it can also be said that the moulding rate is improved by a reduction of the extrusion resistance by the slight vibration. The reason of the low magnetic powder did not sufficiently orientated because the magnetic field for the moulding which was able to charge was only 10 KOe. *property in comparative examples was that the magnetic*

Therefore the moulding process of this invention is a particularly effective process for the case in which a high magnetic field for the moulding can not be attained due to shapes of the die or the moulded article.

Example 13.

Table 12 shows how much degree of the thickness is mouldable without a post-fabrication in each moulding method of an extrusion moulding method, ← press moulding method and an injection moulding method.

Table 12

<u>Moulding Method</u>	<u>Thickness [mm]</u>				
	<u>1.0</u>	<u>0.9</u>	<u>0.7</u>	<u>0.1</u>	<u>0.01</u>
Extrusion Moulding	P	P	P	P	P
Press Moulding	P	P	I	I	I
Injection Moulding	P	P	I	I	I

P = possible

I = impossible

Magnets prepared here was ring shaped with the outer diameter of 30mm, and the mouldings were performed with the thickness shown in Table 12.

The magnetic powder used was Sm - Co family rare earth magnetic powder and as for the resin, nylon 12 was used for the extrusion moulding method and the injection moulding method, and an epoxy resin was used for the press moulding method.

The mixing ratio of the magnetic powder and the resin was 90 wt%: 10 wt% ←
for the extrusion moulding method and the injection moulding method, and
←
5 wt%: 2 wt% for the press moulding method.

As it is understood from Table 12, the moulding was not be able to perform if the thickness of the magnetic moulded article became thin for the press moulding method and the injection moulding method. This was due to a difficulty to fill the magnetic powder in a cavity if the thickness became thin for a case of the press moulding method, and is case of the injection moulding method, it could also not be moulded



because of a difficulty to inject a molten mixture of the magnetic powder and the resin in a cavity.

On the other hand, in case of the extrusion moulding method, a thin thickness magnet can be moulded because it is moulded by continuously flowing a molten mixture of the magnetic powder and the resin and by gradually converging the molten mixture. According it is clear that the extrusion moulding method is an effective method to mould a thin thickness magnet having the thickness of 1mm or less.

Example 14

Next effects on moulding radial magnet with a thin thickness by changing the magnetic powders are shown in Table 13.

The magnet ^{moulded} moulded was a ring shaped magnet of the outer diameter 32.8mm, the inner diameter 31.8mm and the thickness 0.5mm, and it was moulded by extrusion.

The compound used comprised 60 vol % of a magnetic powder and 40 vol % of resin and nylon 12 was used for the resin.

Further as for the magnetic powder, a rare earth magnet having a composition of Sm (Co 0.672 Cu 0.08 Fe 0.22 Zr 0.028) 8.35 was used, it was adjusted to make the average particle size $\bar{r}$ for each test of Test 20 and for comparative examples Test 25 - 27, and the results are shown in Table 13.



As shown in Table 13, there was a change of the magnet performance of the magnet moulded by changing the average particle size r of the magnetic powder. By making the average particle size r of the magnetic powder small, the magnet performance of the magnet is improved.

and a sufficient magnet performance was obtained when the average particle size r was not more than $1/10$ of the thickness of the magnet moulded article.

However in case when the average particle size is not less than $1/10$ of the thickness of the magnet, the magnet performance is low.

Table 13

Test No	r	BR	(BH) max
	[μm]	[KG]	[MGOe]
20	50	5.88	7.5
21	20	5.95	7.8
22	10	6.18	8.1
23	1	6.33	8.5
24	0.1	6.15	8.0
25	70	5.60	6.5
26	100	5.01	5.2
27	150	4.70	4.5

The reason why the above results was obtained was, in case of the extrusion moulding, the magnetic powder in the molten mixture of the



The reason why the above results were obtained was, in case of the extrusion moulding, the magnetic powder in the molten mixture of the magnetic powder and the resin was orientated at a section in which a magnetic field was charged by passing through the passage of a die, and the moulded article was extruded outside the die after solidifying it with cooling in the die by keeping the state as it is. Accordingly the molten mixture received a friction force at the contact section with the die. Thus the orientation of the magnetic powder at the contact surface of the molten mixture with the die might be disordered by the friction force while it was being solidified with cooling even though the magnetic powder was once orientated in the die.

When a thin plate state magnet is moulded, the effect of the layer where the said orientation is disordered becomes significant, the thickness of the layer is related with the particle size of the magnetic powder as well, and as the results the average particle size gives an influence to the magnet performance of the magnet.

As it is clear from Table 13, in order to reduce the influence, it is appropriate that the average particle size r of the magnetic powder is $1/10$ or less of the thickness of the magnetic moulded article.

Example 15

An alloy having a composition of Nd 14 Fe 81 B 5 was molten in a crucible, it was cooled rapidly by a meltspan method and a thin piece was prepared.



The thin piece was crushed till it had an average particle size of 35 μ m, and treatments shown in Table 14 were processed thereafter.

Table 14

<u>Treatment</u>	
Treatment 1	Cobalt-phosphorus-chromium plating
Treatment 2	SiO ₂ coating

Treatment 1 was that after crushing the magnetic powder, a cobalt-phosphorus plating was carried out in a sodium hypophosphite reduced ammonia, alkaline cobalt plating bath, then a chromate treatment was performed by putting the magnetic powder in a potassium dichromate solution and a cobalt plating layer was formed on the magnetic powder.

Treatment 2 was that pure water adjusted its pH with hydrochloric acid was mixed with tetramethoxysilane to make an approximate molar ratio of 4:1, and a hydrolysis was carried out by adding ethanol to it. After the decomposition and an addition of a surfactant, the magnetic powder was added and was stirred for a predetermined time.

Then the magnetic powder was separated from the solution, was dried and a heat treatment was performed to form SiO₂ film on the magnetic powder.

After the surface treatment, the magnetic powder and the resin to make a ratio of 60 vol % and 40 vol % were weighed and were mixed, and after the



mixing, it was charged in a kneading machine to knead it and a compound was prepared.

The kneading machine herewith used was a roller mill. Further as for the resin used, 2 kinds of resin were used. One was Resin a which was copolymer mainly comprising a thermosetting type epoxy resin, and the other Resin b was a thermoplastic polyamide resin (nylon 12).

After crushing the compound produced, it was moulded by an injection moulding machine or an extrusion moulding machine. In case that Resin a was used, the moulded article was heated to cure the resin after the moulding.

Firstly in order to check in which step the film tended to be removed, a coverage rate was determined by taking a sample before and after each step in the total process.

The magnetic powder used here was a plating-treated one with the plating thickness of 1 μ m, and the moulding was carried out by an extrusion moulding machine. The results are shown in Table 15.

The results were the same for either cases of Resin a and b. From Table 15, it is clear that the film coverage rate suddenly dropped between before and after the kneading. In other steps, the drop of the coverage ratio was small, and it was considered that it was due to a protection of the coated film by the mixed resin especially after the kneading.

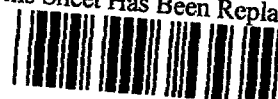


Table 15

<u>Step</u>	<u>Coverage Rate (%)</u>
Before mixing	100
After mixing (Before kneading)	95
After kneading (Before crushing)	50
After crushing (Before moulding)	48
After moulding	46

On the other hand, before kneading, the solid resin and magnetic powder were merely mixed, the resin does not give the protection for the coated film, and therefore the coated film is removed by a strong stress to the magnetic powder applied during the kneading.

Accordingly the mixture of the magnetic powder and the resin was heated before the kneading, and then the kneading was carried out. The coverage rates after the kneading which was carried out after heating at various temperatures were shown in Table 16.

The magnetic powders herewith used were that plating-treated of the plating thickness of 1 μ m for Test 28 - 33, and Test 34 thereafter were SiO₂ coated.

Resin a of a thermosetting resin was used for the resin. The coverage rate after the kneading was calculated setting the coverage rate before the kneading (after mixing) as 100, and the viscosity was a viscosity at



a shear rate 1000 sec^{-1} when the mixture was heated at the temperature indicated.

Table 16

	Temperature	Viscosity	Coverage Rate
	(°C)	[kpoise]	[%]
Test 28	Room Temperature	-	50
29	50	500	50
30	75	300	74
31	85	180	90
32	100	70	94
33	120	10	98

34	50	500	60
35	75	300	85
36	85	180	93
37	100	70	98
38	120	10	98

From Table 16, the mixture may have the viscosity by heating it. It is clear that the coverage rate is improved when the kneading is performed after heating the mixture to make it in a state in which it has the viscosity. Although the coverage rate of the plated one becomes worse than it of the SiO_2 coated one when compared in the same condition because of its weak adhesion of the film, an improvement is seen when the



viscosity reaches around 300 kpoise, and ^{below} above it, the coated film was sufficiently protected.

It is considered that the above results are obtained because as to the removal of the film during the kneading, it is largely influenced by a stress of the roller when it is applied to a state in which a sufficient heating is not given when the mixture is charged in the kneading machine, and the influence is relieved by giving the viscosity to the mixture.

Next an oxidation resistance of a magnet produced by the production process of this invention was investigated. The results of Test 39 and 40 as this Examples and Test 41 and 42 as comparative examples are shown in Table 17.

Table 17

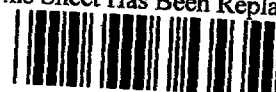
	<u>Surface Treatment</u>	<u>Oxidation Resistance</u>
Test 39	Treatment 1	A
40	" 2	A

41	" 1	C -
42	" 2	B -

A = Excellent

B = Good

C = Bad



Test 41 and 42 of the comparative examples were the cases in which the kneading was carried out without heating before the kneading, and Test 39 and 40 of Examples were carried out by heating at 100 kpoise.

The oxidation resistance was a result after storing the sample in a constant temperature and constant humidity oven at 80°C x 95% for 100 hours.

It is clear that the oxidation resistance is improved by the heat treatment before the kneading.

Example 16

Raw materials to make a composition of Sm (Co 0.672 Cu 0.08 Fe 0.22 Zr 0.028) 8.35 were molten, were casted, an ingot produced was magnetically cured by a heat treatment, and then a magnetic powder having an average particle size of 10µm was obtained by crushing it.

The powder was mixed with nylon 12 powder and zinc stearate powder to make a ratio of 92 wt%, 7.8 wt% and 0.1 wt%, respectively.

The mixture was then kneaded by a two axes extrusion kneading machine at 260°C. The kneaded mixture was granulated to particles of the outer diameter of 1 - 10mm to make a raw material compound, and a cylindrical magnet was moulded by an extrusion moulding machine.

The moulding method is explained in accordance with Figure 10.



shown in Figure 10, the extrusion moulding machine is constituted by a hopper 101 which is a section of charging material, a cylinder 102, a screw 103, an adaptor plate 104 to install a die to the cylinder section 102, a die 105 and a driving motor for the screw (which is not shown in figure).

The aforementioned granulated raw material compound 111 was charged in the extrusion moulding machine. The raw material compound 111 was heated in the cylinder 102 at 260°C to make it in a fluidized state, and it was passed through the die 105.

In this Example, the die temperature at the moulding was 250°C, and the cooling was carried out by a forced air cooling at the outlet section of the die. The size of the moulded article produced was the outer diameter of 33mm and the inner diameter of 32mm.

The moulded article was made in a thin plate state by a unit shown in Figure 11.

Figure 11 was a drawing viewed from upside, the cylindrical moulded article 112 extruded from the die 105 was split into two equal sections of the upside and the downside by the cutter 501 installed in front of the die 105, and the bisected moulded articles were moulded into thin plate state magnet by passing between 2 sets of 2 rollers 502 positioned in the rearward of the cutter 501.



Then the end surfaces of the thin plate state magnet 503 was cut to make it in a desired size. The size of the moulded article was the width of 50mm and the thickness of 1mm. The magnetic property of the moulded article obtained is shown in Table 18.

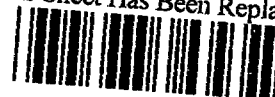
As a comparative example, a thin plate state moulded article was moulded by an extrusion by using a die which was generally used for an extrusion moulding of a thin plate state plastic, and its magnetic property is shown as Test 44.

For the raw material compound, the same magnetic powder, nylon 12 powder and zinc stearate powder as Test 43 of Example were mixed to make ratio of 91.5 wt%, 8.3 wt% and 0.2 wt% respectively, they were kneaded, re granulated, and were moulded for the determination of the magnetic property. The size of the moulded article was the same as Test 43.

Table 18, a mouldability of Example of this invention (Test 43) and a comparative example (Test 44) is also shown with the magnetic property.

Table 18

	(BH) max (MGO2)	<u>Mouldability</u>
Test 43 (Example)	2.5	G
Test 44 (Comparative example)	2.4	O



G = Good

O = Ordinary

As it is clear from Table 18, there is no significant difference on the magnetic property between Test 43 of Example and Test 44 of the comparative example, and a magnet, having its magnet performance equal to or above those obtained by the conventional moulding method, can be moulded.

On the other hand, from a viewpoint of the mouldability, it was difficult to achieve a stable moulding for Test 44 of the comparative example, and the rate of an rejected article was high. Furthermore the fabrication cost of the die used in Test 44 of the comparative example was approximately 3 times higher than the die of Test 43 of Example, and it was more expensive than a total cost of the die and the press unit of Example. Accordingly, a high performance thin plate state resin bound type rare earth magnet can be produced with a high productivity by using the moulding method of this invention.

Example 17

Materials to make a composition of Nd 14 (Fe 0.95 Co 0.05) 80.5 B 5.5 molten, were casted and a quenched ribbon was prepared in an argon atmosphere by using a quenching and ribbon rolling machine from the ingot melted.



The quenched ribbon was crushed and a magnetic powder of an average particle size of 20 μ m was obtained.

This magnetic powder was mixed with a resin powder comprising bisphenol A type epoxy, novolak type epoxy and vinylbutyral-vinylalcohol copolymer, calcium stearate powder and silica powder as additives to make a ratio of 10.3 wt%, 9.1 wt%, 0.4 wt% and 0.2 wt% respectively.

The mixture was kneaded by a 2 roller type mill at 90°C. The kneaded mixture was granulated to outer diameter of 1 - 10mm particles to make a material compound and was moulded in a cylindrical magnet by using an extrusion moulding machine shown in Figure 10 of the aforementioned sample 16.

After the moulded article was cut into an appropriate length, one point on the circumference of the moulded article was also cut in parallel with the central axis.

The moulded article was fired at 200°C for 45 minutes while it was being pressed to make a thin plate state by a press unit shown in Figure 12.

The press unit shown in Figure 12 is to press a moulded article by moving a press plate 601 located in upper position downward as shown by an arrow. The thickness of the moulded article 603 is adjusted by a spacer



The press unit was placed in a firing furnace, was heated and the aforementioned moulded article was set on the press plate 601.

A press was carried out to make a thin plate state when the viscosity of the moulded article dropped, and it was further heated to crosslink the organic resin in the moulded article.

Lastly the edges of the moulded article were cut and a thin plate state magnet with the desired size was prepared. The magnetic property and the surface condition of the thin plate state moulded articles of Test 49 - in which the sizes of the moulded article extruded by an extrusion are altered, were shown in Table 19.

Table 19

	Outer Diameter	Inner Diameter		(BH) max	Surface
<u>Test No</u>	<u>(mm)</u>	<u>(mm)</u>	<u>d/D</u>	<u>(MGOe)</u>	<u>Condition</u>
9	22	22	0.91	5.0	Good
0	22	18	0.82	4.9	Good
1	22	16	0.73	-	Bad
2	33	25	0.76	4.9	Good
3	33	23	0.70	-	Bad

Table 19, the "Bad" mark in the surface condition means that it is not use as a magnet because of a formation of cracks on the surface.



As it is clear from Table 19, if the ratio d/D between the outer diameter (D) and the inner diameter (d) is below 0.75, it can not be used as a magnet. It is considered that this is due to a formation of cracks on the surface by a stress when it is treated to make a thin plate state since the thickness of the cylindrical moulded article is thick relative to the outer diameter.

Concerning the magnetic property, there is no problem if d/D is 0.75 or more.

Accordingly in the moulding method of this invention when d/D is limited

$$0.75 \leq d/D < 1,$$

magnet having a high magnetic property without defects such as the crack, etc can be produced.

Example 18

Materials to make a composition of 8m (Co 0.672 Cu 0.08 Fe 0.22 Zr 28) 8.35 were molten, were casted, an ingot produced was magnetically ad by a heat treatment, and then a magnetic powder having the average particle size of 10 μ m was prepared by crushing the ingot. —

powder was mixed with nylon 12 powder and zinc stearate powder to a ratio of 92 wt%, 7.8 wt% and 0.2 wt% respectively.



then the mixture was kneaded by a two axes extrusion kneading machine at 260°C. The kneaded mixture was granulated to particles having the outer diameter of 1 - 10mm to make a raw material compound, and a cylindrical magnet was moulded by an extrusion moulding machine shown in Figure 1.

The moulding method was the same method to Example 1.

As same to Figure 1, the extrusion moulding machine consists of a hopper 101, a raw material charging section, a cylinder 102, a screw 103, an adaptor plate 104 to equip a die at the cylinder, the die 105 and a driving motor for the screw (which is not shown in Figure), and further an electromagnetic coil 109 to charge a magnetic field in the die 105 is positioned at the outside of the die 105. 106, 107 and 108 are heaters.

The aforementioned granulated raw material compound 111 was charged in the extrusion moulding machine. The raw material compound was heated in the cylinder 102 at 260°C to make it in a fluidized state, and was passed through the die 105 of which structure was shown in Figure 2.

The die is constituted by an outer die 201 and a mandrel 202. The outer die is made of a non-magnetic material, but a ring shaped magnetic material 201a is installed at the front end to induce a magnetic flux. The mandrel 202 is also made of a non-magnetic material, and at its front end a magnetic material 202a is installed as well.

When a current is turned on in the electromagnetic coil 109 installed outside the die, the magnetic flux generated flows in a direction of the



arrow H in Figure since it tends to pass in a magnetic material with a high magnetic permeability. Therefore a radiated magnetic field is generated in a space (hereinafter called as an orientation section) between the front end 202a of the mandrel and magnetic material ring 201a installed in the outer die. Thus while a magnetic composition passes through the orientation section, it is moulded with a progress of an orientation of the magnetic powder.

In this Example, the magnetic field for the moulding was 15 kOe, the die temperature at the moulding was 250°C, and the cooling was carried out by forced air cooling at the outlet section of the die. Thus the orientated raw material compound 111 was moulded by an extrusion by a solidification with cooling at the outlet of the die. The size of the cylindrical moulded article was the outer diameter of 33mm and the inner diameter of 32mm.

The moulded article was cut into a suitable length, was demagnetized, and then it was divided into two equal sections in parallel with the central axis of the moulded article. The moulded article was then made a thin plate state by heating at 180°C with a press unit shown in Figure 12.

The press unit is to press a moulded article 603 by moving the press plate 601 located in upper position downward as shown by an arrow. The thickness of the moulded article is adjusted by a spacer 602. The press unit was placed in a firing furnace as same as Example 17, was heated and the moulded article was set on the press plate.



press was carried out to make a thin plate state when the viscosity of the moulded article dropped, the edges were cut, and finally a thin plate state magnet with the desired size was obtained. The size of the moulded article was the width of 50mm and the thickness of 1mm. The magnetic property of the moulded article obtained in Test 54 is shown in Table 20.

as a comparative example, Test 55 was carried out by an extrusion moulding by using a die shown in Figure 6, and the magnetic property of the moulded article in a thin plate state is also shown.

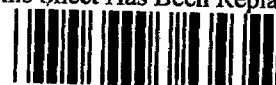
for the raw material compound, the same one to Test 54 was used.

the die, when a current is turned on in the electromagnetic coil 403, magnetic field vertical to the passage of the compound in the die is formed between upper and lower pole pieces 404. Therefore a thin plate state magnet of which the magnetic powder is orientated in the thickness direction can be moulded. The magnetic field at the moulding was 11 kOe, the size of the moulded article was the same to Example of Test 54.

Mouldability is also shown in Table 20 with the magnetic property.

Table 20

	(BH) max	
	(MGOe)	<u>Mouldability</u>
Test 54 (Example)	7.5	Good
Test 55 (Comparative		



example)

2.4

Ordinary

As it is clear from Table 20, though the same moulding raw material was used, the comparative example Test 55 showed lower magnetic property. It was considered that it was due to an impossibility to enlarge the magnetic field for the moulding because of the structural problem of the die in case of the comparative example Test 55 resulting an insufficient orientation of the magnetic powder.

Furthermore it was very difficult to achieve a stable moulding in case of Test 55 of the comparative example, and it had a high rejection rate. Moreover the fabrication cost of the die used in the comparative example Test 55 was approximately 3 times more expensive than the die used in Test 54 of Example, and it was more costly than the total cost of the die and the press unit in Example of Test 54.

Consequently, by using the moulding method of this invention, a high performance thin plate state resin bound type rare earth magnet can be produced with a good productivity.

Example 19.

Materials to make a composition of Nd 13 Fe 82.7 B 4.3 were molten as similar to Example 17, were casted and a quenched ribbon was prepared in argon atmosphere by using a quenching and ribbon rolling machine from ingot obtained.



The quenched ribbon was coarsely crushed, it was transferred to a mould, and a high pressure press moulding was carried out in an argon atmosphere at 700 - 800°C with a 20 Kg/mm² pressure for a short time.

The consolidated article obtained had a density almost 100%. The consolidated article obtained was moulded again by the high temperature press moulding in a vertical direction to the first pressing direction in an argon atmosphere at 700 - 800°C with a 10 Kg/mm² pressure (Namely a die upset was carried out).

The bulk state magnet was crushed and a magnetic powder of an average particle size of 20µm was obtained.

The magnetic powder was mixed with a resin powder comprising a mixture of phenol A type epoxy, novolak type epoxy and vinylbutyral-vinylalcohol polymer, calcium stearate powder and silica powder as additives to make ratio of 90.3 wt%, 9.1 wt% and 0.4 wt% and 0.2 wt% respectively.

The mixture was kneaded by a 2 roller type mill at 90°C. The kneaded mixture was granulated to particles of the outer diameter of 1 - 2 mm to make a raw material compound, and a cylindrical magnet was formed by using an extrusion moulding machine shown in Figure 1 and a die shown in Figure 2 as similar to Example 18.

The moulded article was cut into a suitable length, were demagnetized, further one point on the circumference parallel to the central axis of the moulded article was cut. The moulded article was fired at 200°C



or 45 minutes while it was being made in a thin plate state by a press similar to Example 18 to crosslink the organic resin in the moulded article.

The magnetic properties of the thin plate state moulded articles when test 56 - 61 were carried out by changing the size of the moulded articles of the extrusion moulding are shown in Table 21.

Table 21

Test No	Outer Diameter	Inner Diameter	(BH) max	
	(mm)	(mm)	d/D	(MGOe)
6	22	20	0.91	10.2
7	22	19	0.86	10.0
8	22	18	0.82	8.2
9	33	32	0.97	10.4
10	33	28	0.85	10.1
	33	25	0.76	7.5

It is clear from Table 21, if the ratio d/D between the outer diameter and the inner diameter (d) is below 0.85, the magnetic property is deteriorated. It is considered that this is due to a formation of disorder on the orientation of the magnetic powder while it is being made in thin plate state because the thickness of the cylindrical moulded article is thick in comparison with the outer diameter. Consequently in the moulding process of this invention when the d/D is limited as

$$0.85 \leq d/D < 1,$$



magnet with a high magnet performance can be produced.

AIMS

A resin bound type magnet comprising a magnetic powder and an organic resin wherein it is moulded as a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$

where D is the outer diameter (D), the inner diameter (d) and the length (L) of the magnet, and it also has a radiated anisotropy in the diameter direction.

A resin bound type magnet comprising a magnetic powder, an organic resin and an additive wherein it is moulded as a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$

where D is the outer diameter (D), the inner diameter (d) and the length (L) of the magnet, and it also has a radiated anisotropy in the diameter direction.

A production process of a resin bound type magnet wherein a raw material for the moulding comprising a magnetic powder and an organic resin is moulded by an extrusion by passing through a die in which a magnetic field is charged while it is being cured, is formed to a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$





5

magnet with a high magnet performance can be produced.

AIMS

A resin bound type magnet comprising a magnetic powder and an organic resin wherein it is moulded as a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$

where D is the outer diameter (D), the inner diameter (d) and the length (L) of the magnet, and it also has a radiated anisotropy in the diameter section.

A resin bound type magnet comprising a magnetic powder, an organic resin and an additive wherein it is moulded as a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$

where D is the outer diameter (D), the inner diameter (d) and the length (L) of the magnet, and it also has a radiated anisotropy in the diameter section.

A production process of a resin bound type magnet wherein a raw material for the moulding comprising a magnetic powder and an organic resin is moulded by an extrusion by passing through a die in which a magnetic field is charged while it is being cured, is formed to a single body in a cylindrical form satisfying a relation of

$$2DL / d^2 \geq 1$$





among the outer diameter (D), the inner diameter (d) and the length (L) of the magnet and it also has a radiated anisotropy in the diameter direction.

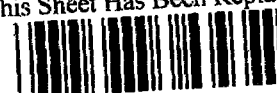
4) A production process of a resin bound type magnet wherein a raw material for the moulding comprising a magnetic powder, an organic resin and an additive is moulded by an extrusion by passing through a die in which magnetic field is charged while it is being cured, is formed to a single body in a cylindrical form satisfying a relation of

$$2DL < d^2 \geq 1$$

among the outer diameter (D), the inner diameter (d) and the length (L) of the magnet and it also has a radiated anisotropy in the diameter direction.

A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder and an organic resin wherein a die structure for moulding is constituted that a front end of a mandrel section is projected in front of an edge of a outer die, a magnetic circuit is formed among the said mandrel section, the outer die and an electromagnetic coil installed at an outer circumference of the said die, it is moulded in a cylindrical form by applying a magnetic field in the die by the electromagnetic coil, and the moulded article extruded is demagnetized at the front end of the mandrel.

A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder, an organic resin and an additive wherein a die structure for moulding is





constituted that a front end of a mandrel section is projected in front of an edge of a outer die, a magnetic circuit is formed among the said mandrel section, the outer die and an electromagnetic coil installed at an outer circumference of the said die, it is moulded in a cylindrical form by charging a magnetic field in the die by the electromagnetic coil, and the moulded article extruded is demagnetized at the front end of the mandrel.

1) A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder and an organic resin wherein an electromagnetic coil is installed at an outer circumference of a die, it is moulded in a cylindrical form by charging a magnetic field in the die by it, an electromagnetic coil with an air-core also installed in front of the aforementioned electromagnetic coil to generate a magnetic field for demagnetization in the said electromagnetic coil, and the moulded article extruded is demagnetized.

A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder, an organic resin and an additive wherein an electromagnetic coil is installed at an outer circumference of a die, it is moulded in a cylindrical form by charging a magnetic field in the die by it, an electromagnetic coil with an air-core is also installed in front of the aforementioned electromagnetic coil to generate a magnetic field for demagnetization in the said electromagnetic coil, and the moulded article extruded is demagnetized.





(9) A production process of a resin bound type magnet which is constituted by orientating a magnetic powder in a molten mixture of a magnetic powder and an organic resin in a section where a magnetic field is charged at a front end of a die, moulding it in a cylindrical form, solidifying it with cooling and extruding it wherein when the magnet is cut, the resin is cut by melting by contacting the magnet with a heated wire.

10) A production process of a resin bound type magnet which is constituted by orientating a magnetic powder in a molten mixture of a magnetic powder, an organic resin and an additive in a section where a magnetic field is charged at a front end of a die, moulding it in a cylindrical form, solidifying it with cooling and extruding it wherein when the magnet is cut, the resin is cut by melting by contacting the magnet with a heated wire.

11) A production process of a resin bound type magnet of Claim (9) or Claim (10) wherein the resin bound type magnet is an isotropic magnet moulded by an extrusion in a cylindrical form without an orientation.

12) A production process of moulding a cylindrical resin bound type magnet by an injection moulding or an extrusion moulding of a magnetic powder and a thermosetting resin wherein in order to cure the molten mixture of the magnetic powder and the thermosetting resin by heating, it is cured with fixing the outer circumference of the cylindrical magnet by





jig and the inner circumference by an elastic material expanded by a gas.

3) A production process of moulding a cylindrical resin bound type magnet by an injection moulding or an extrusion moulding of a magnetic powder, a thermosetting resin and an additive wherein in order to cure the molten mixture of the magnetic powder, the thermosetting resin and the additive by heating, it is cured with fixing the outer circumference of the cylindrical magnet by a jig and the inner circumference by an elastic material expanded by a gas.

4) A production process of a resin bound type magnet of Claim (12) or Claim (13) wherein the aforementioned elastic material is a silicone rubber.

5) A production process of a resin bound type magnet comprising a magnetic powder and an organic resin wherein a mixture of the rare earth magnetic powder premagnetized in a magnetic field which is stronger than the coercive force of the magnetic powder and the organic resin are kneaded, and the kneaded mixture is moulded by an extrusion in a magnetic field.

6) A production process of a resin bound type magnet comprising a magnetic resin, an organic resin and an additive wherein a mixture of the rare earth magnetic powder premagnetized in a magnetic field which is stronger than a coercive force of the magnetic powder, the organic resin





and the additive are kneaded, and the kneaded mixture is moulded by an extrusion in a magnetic field.

17) A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder and an organic resin with a die in a magnetic field wherein it is moulded by an application of a slight vibration to the die at the moulding.

8) A production process of a resin bound type magnet by an extrusion moulding of a moulding raw material comprising a magnetic powder, an organic resin and an additive with a die in a magnetic field wherein it is moulded by an application of a slight vibration to the die at the moulding.

1) A resin bound type magnet comprising a magnetic powder and an organic resin wherein an average particle size r of the aforementioned magnetic powder satisfies

$$r \leq 0.1 t \quad (t \leq 1\text{mm})$$

where t is the thickness of the moulded article of an anisotropic resin bound magnet comprising the said magnetic powder and the resin.

2) A resin bound type magnet comprising a magnetic powder, an organic resin and an additive wherein an average particle size r of the aforementioned magnetic powder satisfies

$$r \leq 0.1 t \quad (t \leq 1\text{mm})$$

where t is the thickness of the moulded article of an anisotropic resin bound magnet comprising the said magnetic powder, resin and additive.





21) A production process of a resin bound type magnet comprising a magnetic powder and an organic resin wherein an average particle size r of the aforementioned magnetic powder satisfies

$$r \leq 0.1 t \quad (t \leq 1\text{mm})$$

with the thickness t of the moulded article of an anisotropic resin bound type magnet comprising the said magnetic powder and the resin, and the magnet is produced by an extrusion moulding with a die in a magnetic field.

2) A production process of a resin bound type magnet comprising a magnetic powder, an organic resin and an additive wherein an average particle size r of the aforementioned magnetic powder satisfies

$$r \leq 0.1 t \quad (t \leq 1\text{mm})$$

with the thickness t of the moulded article of an anisotropic resin bound type magnet comprising the said magnetic powder, the resin and the additive, and the magnet is by an extrusion moulding with a die in a magnetic field.

3) A production process of a resin bound type magnet comprising a moulding of a mixture of a magnetic powder and an organic resin by an injection moulding or an extrusion moulding wherein a γ -compound is prepared by charging in a kneading machine after making a viscosity η of mixture of the aforementioned magnetic powder and organic resin in a state of

$$\eta \leq 300 \text{ [kpoise]} \quad (\text{shear rate} = 1000 \text{ sec}^{-1})$$

kneading.





24) A production process of a resin bound type magnet comprising a moulding of a mixture of a magnetic powder, an organic resin and an additive by an injection moulding or an extrusion moulding wherein a compound is prepared by charging in a kneading machine after making a viscosity η of the mixture of the aforementioned magnetic powder, organic resin and additive in a state of

$$\eta \leq 300 \text{ [kpoise]} \text{ (shear rate} = 1000 \text{ sec}^{-1}\text{)}$$

by heating.

25) A production process of a resin bound type magnet described in Claim (3) or Claim (24) wherein the surface of the aforementioned magnetic powder is coated with a metal plating or ceramics.

26) A production process of a resin bound type magnet wherein a moulding material comprising a magnetic powder and an organic resin is moulded by an extrusion in a cylindrical magnet by passing it through a die, then one or plural points on the circumference of the said cylindrical magnet are cut in a direction parallel with the central axis of the moulded article and the moulded article cut is spread to make it in a thin plate etc.

27) A production process of a resin bound type magnet wherein a moulding material comprising a magnetic powder, an organic resin and an additive is moulded by an extrusion in a cylindrical magnet by passing it through a die, then one or plural points on the circumference of the said cylindrical magnet is/are cut in a direction parallel with the central





axis of the moulded article and the moulded article cut is spread to make it in a thin plate state.

(28) A production process of a resin bound type magnet described in Claim (26) or Claim (27) wherein the outer diameter (D) and the inner diameter (d) of the aforementioned cylindrical magnet to be moulded by an extrusion satisfy a relation of

$$0.75 \leq d / D < 1.$$

(29) A production process of a resin bound type magnet wherein a moulding raw material comprising a magnetic powder and an organic resin is passed through a die where a magnetic field is charged to mould a cylindrical magnet having a radiated anisotropy in the diameter direction by an extrusion moulding, then one or plural points on the circumference of the said cylindrical magnet is/are cut in a direction parallel with the central axis of the moulded article and the moulded article cut is spread to make it in a thin plate state.

(30) A production process of a resin bound type magnet wherein a moulding raw material comprising a magnetic powder, an organic resin and an additive is passed through a die where a magnetic field is charged to mould a cylindrical magnet having a radiated anisotropy in the diameter direction by an extrusion moulding, then one or plural points on the circumference of the said cylindrical magnet is/are cut in a direction parallel with the central axis of the moulded article and the moulded article cut is spread to make it in a thin plate state.





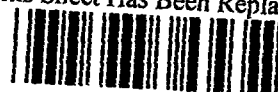
31) A production process of a resin bound type magnet described in Claim 29) or Claim (30) wherein the outer diameter (D) and the inner diameter d) of the aforementioned cylindrical magnet to be moulded by an extrusion satisfy a relation of

$$0.85 \leq d / D < 1.$$

32) A resin bound type magnetic described in Claim 1, Claim 2, Claim 19 and Claim 20 wherein the aforementioned magnetic powder is selected from magnetic powders of a ferrite family magnet, a magnet having a composition comprising rare earth metal and transition metals mainly constituting cobalt and iron or a magnet having a composition comprising rare earth metal, transition metal mainly constituting iron and boron.

3) A production process of a resin bound type magnet described in Claim - Claim 10, Claim 12, Claim 13, Claim 15 - Claim 18, Claim 21 - Claim , Claim 26, Claim 27, Claim 29 and Claim 30 wherein the aforementioned magnetic powder is selected from magnetic powders of a ferrite family magnet, a magnet having a composition comprising rare earth metal, transition metals mainly constituting cobalt and iron or a magnet having composition comprising rare earth metal, transition metal mainly constituting iron and boron.

4) A resin bound type magnet described in Claim 1, Claim 2, Claim 19 Claim 20 wherein the aforementioned organic resin is a thermoplastic resin or a thermosetting resin.





5) A production process of a resin bound type magnet described in Claim 10, Claim 12, Claim 13, Claim 15 - 18, Claim 21 - 24, Claim 26, Claim 29 and Claim 30 wherein the aforementioned organic resin is a thermoplastic resin or a thermosetting resin.

6) A resin bound type magnet described in Claim 34 wherein the aforementioned thermoplastic resin is selected from one or more of polyamide, polypropylene, polycarbonate, polyphenylenesulphide, chlorinated polyethylene, an elastomer of vinyl ethylene acetate copolymer and a synthetic rubber.

7) A production process of a resin bound type magnet described in Claim 34 wherein the aforementioned thermoplastic resin is selected from one or more of polyamide, polypropylene, polyphenylenesulphide, chlorinated polyethylene, an elastomer of vinyl ethylene acetate copolymer and a synthetic rubber.

8) A resin bound type magnet described in Claim 34 wherein the aforementioned thermosetting resin is an ethylene family unsaturated polyester resin or an epoxy resin.

9) A production process of a resin bound type magnet described in Claim 34 wherein the aforementioned thermosetting resin is an ethylene family unsaturated polyester resin or an epoxy resin.





) A resin bound type magnet described in Claim 2 or Claim 20 wherein the aforementioned additive is selected from one or more of zinc stearate, calcium stearate, wax and peroxides.

) A production process of a resin bound type magnet described in Claim 6, Claim 8, Claim 10, Claim 13, Claim 16, Claim 18, Claim 22, Claim 24, Claim 27 and Claim 30 wherein the said additive is selected from one or more of zinc stearate, calcium stearate, wax and peroxides.

ABSTRACT

This invention relates to a resin bound type magnet and its production process, especially a cylindrical or a thin plate state magnet and its production process.

A resin bound type magnet comprising a magnetic powder and an organic resin or further with an additive and its production process wherein it is moulded as a single body in a cylindrical form satisfying a relation

$$2DL / d^2 \geq 1$$

where D is the outer diameter (D), the inner diameter (d) and the length (L) of the said magnet, and it also has a radiated anisotropy in the diameter direction.

Whether this invention is a resin bound type magnet and a production process of a resin bound type magnet by an extrusion moulding of the said

