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Description

This invention relates to a method and assembly for producing extruded permanent magnet articles from particle charges of permanent magnet alloys.

It is known to produce permanent magnet articles by powder metallurgy techniques, which include the consolidation of particles of the permanent magnet alloys. These practices are employed with permanent magnet alloys of at least one rare earth element and transition element. These conventional practices generally include the steps of aligning, pressing and sintering. With prior art practices of this type, high energy product (BH_{max}) and uniaxial anisotropic crystal alignment is achieved, and this combination finds utility in various permanent magnet applications.

Uniaxial anisotropic crystal alignment, however, is not always advantageous for magnet applications for rotating machinery, motor rotors, beam focussing devices and the like. For these applications a [100] fibre texture wherein the C crystallographic axis is perpendicular to the axis of the magnet may be desired. One of the primary applications for magnets of this construction is for use in DC motors. In this application, with conventional practice, multiple segments of uniaxial anistropic magnets are needed to form the armature for the motor, which segments are identified as 2 positioned around a motor shaft 4 in Fig. 1.

To obviate the need for the use of a plurality of magnet segments, as shown in Fig. 1, it is known to extrude a cylindrical magnet conforming to the required dimensions of the motor shaft. An extruded magnet 6 in association with a motor shaft 4 is shown in Fig.2.

Cylindrical, extruded magnets, as shown in Fig. 2, are conventionally produced by the use of a cylindrical extrusion container. Magnet alloy particles are introduced to the container, and the container is outgassed, evacuated and sealed. Thereafter, the container is heated to extrusion temperature and extruded to consolidate the particles to substantially full density. The hollow centre of the magnet is achieved by the use of a solid cylinder or mandrel of a diameter corresponding to the internal diameter of the magnet to be produced, which cylinder is attached to the extrusion ram. This solid cylinder moves with the extrusion ram during the extrusion operation and thereby maintains the desired inner diameter of the extruded magnet. It is difficult to maintain concentricity of the inner and outer peripheries of the extruded magnet because the mandrel tends to wander and thus is not maintained in axial alignment during the extrusion operation. In addition, at the high extrusion ratios breaking of the mandrel may occur. It may be seen, therefore, that in producing cylindrical magnets by conventional extrusion practices, a cylindrical magnet having the required concentric dimensions is difficult to achieve.

It is accordingly a primary object of the present invention to provide an extrusion method and assembly for use therewith that achieves improved concentricity in the production of extruded hollow cylindrical magnets.

Another object of the invention is a method and assembly for use therewith that enables the production of a complete assembly, including a permanent magnet and associated shaft in a single extrusion operation.

US 4640815 discloses a method and assembly for cladding an interior surface of a tubing with an alloy. A tubular insert is placed inside the tubing to be clad and the alloy particles are placed in the space between the tubular insert and the tubing. The assembly is then heated and extruded.

Broadly, in accordance with the method of invention for producing a compacted fully dense permanent magnet article, a particle charge is provided of a permanent magnet alloy composition from which the permanent magnet article is to be made. The particle charge is placed in a cylindrical container having a generally axially positioned core with the charge surrounding the core within the container. The container is evacuated and sealed against the atmosphere. The container and particle charge are heated to elevated temperature and the container and charge are then extruded to compact the charge to substantially full density to thereby produce a substantially fully dense permanent magnet article having substantially identical magnetic properties along two orthogonal directions perpendicular to the extrusion direction to achieve a [100] fibre texture.

To facilitate removal of the core to produce a cylindrical magnet article, a separating medium, such as magnesium oxide, may be provided on the core. The core may be of carbon steel, a soft magnet material or stainless steel. During the extrusion operation, the core may be bonded to the permanent magnet alloy. This is advantageous from the standpoint of producing a unitary magnet and shaft assembly during the extrusion operation.

Extrusion ratios within the range of 1.5:1 to 50:1 may be employed with extrusion temperatures within the range of 500 to 1200 °C.

The method of the invention finds particular use in producing rare earth element containing permanent magnets. More specifically, it may be used in the production of magnets of this type wherein at least one rare earth element, such as samarium, neodymium and dysprosium, may be used with a transition element, such as iron and cobalt, plus boron and/or carbon.

The invention also provides an assembly for use in producing a compacted, fully dense permanent magnet article by extrusion including a cylindrical container having a core generally axially positioned therein. The mandrel defines an annular chamber within the container. A particle charge of a permanent magnet alloy from which the article is to be made is provided within this annular chamber. Means are provided for sealing the annular chamber.

A separating medium may be provided on the core. This facilitates removal of the core from the compacted magnet after extrusion. The core may be constructed of carbon steel, a soft magnet material or stainless steel.

The invention will be more particularly described with reference to the accompanying drawings, in which:

Fig. 1 shows a conventional assembly of permanent magnet segments in association with a motor shaft;

Fig. 2 shows a conventional assembly of a motor shaft and an associated cylindrical permanent magnet;

Fig. 3 shows in vertical cross-section an embodiment of an assembly in accordance with the invention for use in the method thereof to produce an extruded magnet; and

Fig. 4 is a top view of the assembly of Fig.3.

In accordance with one embodiment of the invention, with reference to Figs. 3 and 4, there is shown a cylindrical container 8 having end plates 10 with axial openings 11 connected at opposite ends of the container, as by welding (not shown) to seal the container. A solid core 12 is connected at opposite ends thereof to the plates 10 and a portion extends through openings 11. The core is axially positioned within the container 8 to define therein an annular chamber 14 surrounding the core. Particles P of the magnet alloy composition from which the magnet is to be constructed are provided within the annular chamber 14 of the container 8.

The assembly of Figs.3 and 4 so constructed is then after outgassing heated to extrusion temperature and extruded in conventional extruding apparatus to compact the particles in the container to substantially full density. Thereafter, the core 12 may be removed from the compacted hollow cylindrical magnet. This may be facilitated by having the core provided with a separating medium, such as magnesium oxide, on the surface thereof. Alternately, the core may be bonded to the cylindrical magnet for use as an assembly in the production of a conventional motor rotor, as shown in Fig. 2.

Example 1

A carbon steel extrusion container was made with a solid low-carbon rod, 3/4" (19mm) in diameter, welded axially to the top and bottom plates of a mild carbon steel can. Atomized $(NdDy)_{15}Fe_{79}B_6$ powder was put into the 3-1/8" (79.38mm) diameter can and the can was heated to 150°C, evacuated and sealed. The container was then heated to 927°C and extruded with a ratio of 13.8:1. The final extrusion consisted of a 0.3" (7.62mm) diameter steel rod surrounded by a ring shaped magnet with a wall thickness of about 0.25" (6.35mm). The magnetic properties are listed in Table 1. The identical properties along two orthogonal directions perpendicular to the extrusion direction indicates that a [100] fibre texture is obtained. This is the same magnetic behaviour as is observed for magnets extruded by conventional methods.

These extruded magnets, with rods at their centres, can directly be magnetized into multiple poles and used for any type of rotating assembly.

TABLE I

Sample Designation	Test Direction	Br kG	Hc kOe	Hci kOe	BHmax MGOe
EX-267	Axial	3.8	3.3	15.3	3.1
	Transverse 1	7.3	6.4	15.8	12.3
	Transverse 2	7.2	6.3	15.7	11.6

Example 2

To compare the practice of Example 1 with a conventional practice, the identical powder used in Example 1, $(NdDy)_{15}FE_{79}B_6$, was placed into a 3-1/8" (79.38mm) diameter can and the can was heated to 150°C, evacuated and sealed. The can was then heated to 927°C and extruded with a ratio of 13.8:1. The magnetic properties of the resultant solid cylinder are presented in Table II. The magnetic properties are very similar to those obtained in Example 1. Thus, the extrusion technique of Example 1 in accordance with the invention will produce magnetic properties comparable to a conventional magnet extrusion method.

TABLE II

Sample Designation	Test Direction	Br kG	Hc kOe	Hci kOe	BHmax MGOe
EX-235	Axial	3.6	3.1	13.9	2.7
	Transverse 1	7.1	6.1	14.0	10.9
	Transverse 2	7.1	6.1	14.1	11.0

Example 3

The same powder as used in Examples 1 and 2 was placed in a carbon steel extrusion container. This extrusion container was in the shape of a hollow circular cylinder, 3-1/8" (79.38mm) OD and 3/4" (19mm) ID. The container was evacuated, sealed and heated to 927° C and extruded at a 10:1 extrusion ratio. The inner diameter was maintained during extrusion by affixing a solid mandrel to the ram of the extrusion press in accordance with conventional practice. The magnetic properties, Table III, are similar to the properties presented in Tables I and II. The concentricity defined as the ratio of minimum to maximum wall thickness, was calculated to be 0.90. This value is poorer than the concentricity, 0.95, measured on the sample extruded in Example 1 in accordance with the invention.

TABLE III

Sample Designation	Test Direction	Br kG	Hc kOe	Hci kOe	BHmax MGOe
EX-261	Axial	3.5	3.0	14.4	2.6
	Transverse	7.4	6.5	16.5	12.4

As may be seen from the above description and Examples, the invention provides for the production of a hollow permanent magnet by an extrusion practice wherein the desired dimensions of the magnet may be maintained while achieving permanent magnet properties comparable to conventional practices used for this purpose.

It is to be understood that the shape of the core may include symmetrical geometries other than cylindrical. The particles of magnetic material for compaction may be produced by atomization, rapidly solidified ribbon, cast and pulverized particles, direct cast ingots or particles made by a reduction-diffusion practice.

Since the core may be bonded to the compacted magnet during extrusion, an assembly may be produced having an outer shell of a permanent magnet alloy and a soft magnetic inner core, with the inner core acting to direct magnetic flux.

Claims

1. A method for producing a compacted fully dense permanent magnet article (6), said method comprising:

providing a particle (P) charge;

placing said charge in a cylindrical container; and

heating said container (8) and charge to an elevated temperature and extruding said container (8) and charge to compact said charge characterised in that the particle (P) charge is of a permanent magnet alloy composition from which said article (6) is to be made and the container (8) has a generally axially positioned core (12), with said charge surrounding said core (12) within said container (8) and the container (8) and charge are heated and extruded to form a substantially fully dense permanent magnet article (6) having substantially identical magnetic properties along two orthogonal directions perpendicular to the extrusion direction to achieve a [100] fiber texture.

2. A method according to Claim 1, wherein said core (12) is removed after compacting.

3. A method according to Claim 1 or 2, wherein a separating medium is provided on said core (12).

4. A method according to Claim 1, 2 or 3, wherein said core (12) is carbon steel.

5. A method according to Claim 1, 2 or 3, wherein said core (12) is a soft magnetic material.

6. A method according to Claim 1, 2 or 3, wherein said core (12) is stainless steel.

7. A method according to Claim 1 or any one of Claims 3 to 6, wherein said core (12) is bonded to said permanent magnet alloy during said extrusion.

8. A method according to any one of the preceding claims, wherein said extruding is performed with an extrusion ratio within the range of 1.5:1 to 50:1.

9. A method according to any one of the preceding claims, wherein said extruding is performed with said charge at a temperature within the range of 500 to 1200° C.

10. A method according to any one of the preceding claims, wherein said particle charge of a permanent magnet alloy comprises at least one rare earth element.

11. An assembly adapted for use in producing a compacted, fully dense permanent magnet article (6) by extrusion, said assembly comprising a cylindrical container (8) and a particle (P) charge, characterised in that said container (8) has a solid core (12) generally axially positioned within said container (8) defining an annular chamber (14) within said container (8), and the particle (P) charge is of a permanent magnet alloy from which said article (6) is to be made and is provided within said annular chamber (14).

12. An assembly according to Claim 11, wherein a separating medium is provided on said core (12).

13. An assembly according to Claim 11 or 12, wherein said core (12) is carbon steel.

14. An assembly according to Claim 11 or 12, wherein said core (12) is a soft magnet material.

15. An assembly according to Claim 12 wherein said core (12) is stainless steel.

16. An assembly according to any one of the preceding claims 11 to 15, wherein said particle charge of a permanent magnet alloy comprises at least one rare earth element.

Patentansprüche

1. Verfahren zur Herstellung eines verdichteten, vollständig dichten Permanentmagnetgegenstandes (6), das folgende Schritte umfaßt:
Vorbereiten einer Teilchencharge (P),
Einbringen dieser Charge in einen zylindrischen Behälter, und
Erhitzen des Behälters (8) und der Charge auf eine erhöhte Temperatur und Extrudieren des Behälters (8) und der Charge, um die Charge zu verdichten,
dadurch **gekennzeichnet,** daß die Teilchencharge (P) aus einer Permanentmagnetlegierungs-Zusammensetzung besteht, aus der der Gegenstand (6) hergestellt werden soll, und daß der Behälter (8) einen im wesentlichen axial positionierten Kern (12) besitzt, wobei die Charge den Kern (12) im Behälter (8) umgibt, und daß der Behälter (8) und die Charge erhitzt und extrudiert werden, um einen im wesentlichen vollständig dichten Permanentmagnetgegenstand (6) zu bilden, der im wesentlichen identische magnetische Eigenschaften längs zweier orthogonaler Richtungen aufweist, die senkrecht zur Extrusionsrichtung stehen, um eine [100]-Fasertextur zu erzielen.

2. Verfahren nach Anspruch 1, bei dem der Kern (12) nach dem Verdichten entfernt wird.

3. Verfahren nach Anspruch 1 oder 2, bei dem auf dem Kern (12) ein Trennmedium vorgesehen ist.

4. Verfahren nach Anspruch 1, 2 oder 3, bei dem der Kern (12) aus Kohlenstoffstahl besteht.

5. Verfahren nach Anspruch 1, 2 oder 3, bei dem der Kern (12) aus einem weichmagnetischen Material besteht.

6. Verfahren nach Anspruch 1, 2 oder 3, bei dem der Kern (12) aus rostfreiem Stahl besteht.

7. Verfahren nach Anspruch 1 oder einem der Ansprüche 3 bis 6, bei dem der Kern (12) mit der Permanentmagnetlegierung während der Extrusion verbunden ist.

8. Verfahren nach einem der vorhergehenden Ansprüche, bei dem die Extrusion mit einem Extrusionsverhältnis im Bereich von 1,5:1 bis 50:1 durchgeführt wird.

9. Verfahren nach einem der vorhergehenden Ansprüche, bei dem die Extrusion mit der Charge bei einer Temperatur im Bereich von 500 ° C bis 1200 ° C durchgeführt wird.

10. Verfahren nach einem der vorhergehenden Ansprüche, bei dem die Teilchencharge einer Permanentmagnetlegierung wenigstens ein Element aus der Gruppe der seltenen Erden umfaßt.

11. Zusammenstellung, die für eine Verwendung bei der Herstellung eines verdichteten, vollständig dichten Permanentmagnetgegenstandes (6) durch Extrusion geeignet ist und einen zylindrischen Behälter (8) sowie eine Teilchencharge (P) umfaßt, dadurch **gekennzeichnet,** daß der Behälter (8) einen massiven Kern (12) aufweist, der im wesentlichen axial im Behälter (8) positioniert ist und mit dem Behälter (8) eine ringförmige Kammer (14) definiert, und daß die Teilchencharge (P) aus einer Permanentmagnetlegierung, aus der der Gegenstand (6) hergestellt werden soll, besteht und in der ringförmigen Kammer (14) angeordnet ist.

12. Zusammenstellung nach Anspruch 11, bei der auf dem Kern (12) ein Trennmedium vorgesehen ist.

13. Zusammenstellung nach Anspruch 11 oder 12, bei der der Kern (12) aus Kohlenstoffstahl besteht.

14. Zusammenstellung nach Anspruch 11 oder 12, bei der der Kern (12) aus einem weichmagnetischen Material besteht.

15. Zusammenstellung nach Anspruch 12, bei der der Kern (12) aus rostfreiem Stahl besteht.

16. Zusammenstellung nach einem der vorhergehenden Ansprüche 11 bis 15, bei der die Teilchencharge aus einer Permanentmagnetlegierung wenigstens ein Element aus der Gruppe der seltenen Erden umfaßt.

Revendications

1. Procédé pour produire un aimant permanent compacté à densité totale (6), ce procédé comprenant les stades suivants :
procurer une charge de particules (P) ;
placer cette charge dans un récipient cylindrique ; et
chauffer ce récipient (8) et la charge à une température élevée et extruder le récipient (8) et la charge pour compacter cette charge, caractérisé en ce que la charge de particules (P) est d'une composition d'alliage magnétique permanent dont l'aimant (6) doit être fait, en ce que le récipient (8) comporte un noyau (12) positionné sensiblement axialement, la charge entourant le noyau (12) à l'intérieur du récipient (8), et en ce que le récipient (8) et la charge sont chauffés et extrudés pour former un aimant permanent pratiquement totalement dense (6) ayant des propriétés magnétiques pratiquement identiques selon deux directions orthogonales perpendiculaires à la direction d'extrusion pour obtenir une texture de fibres [100].

2. Procédé selon la revendication 1, dans lequel le noyau (12) est retiré après compactage.

3. Procédé selon la revendication 1 ou la revendication 2, dans lequel un agent de séparation est appliqué sur le noyau (12).

4. Procédé selon l'une des revendications 1 à 3, dans lequel le noyau (12) est en acier au carbone.

5. procédé selon l'une des revendications 1 à 3, dans lequel le noyau (12) est en un matériau magnétique doux.

6. Procédé selon l'une des revendications 1 à 3, dans lequel le noyau (12) est en acier inoxydable.

7. Procédé selon la revendication 1 ou l'une quelconque des revendications 3 à 6, dans lequel le noyau (12) est lié à l'alliage magnétique permanent pendant l'extrusion.

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'extrusion est effectuée avec un taux d'extrusion compris entre 1,5:1 et 50:1.

9. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'extrusion est effectuée avec la charge à une température comprise entre 500 et 1200 ° C.

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel la charge de particules d'alliage magnétique permanent comprend au moins un élément de terre rare.

11. Dispositif adapté pour être utilisé pour produire par extrusion un aimant permanent compacté totalement dense (6), ce dispositif comprenant un récipient cylindrique (8) et une charge de particules (P), caractérisé en ce qu'un noyau massif (12) est positionné sensiblement axialement à l'intérieur du récipient (8) et définit avec celui-ci une chambre annulaire (14), et en ce que la charge de particules (P) est en un alliage magnétique permanent dont l'aimant (6) doit être fait et est prévue à l'intérieur de cette chambre annulaire (14).

12. Dispositif selon la revendication 1,, dans lequel un agent de séparation est appliqué sur le noyau (12).

13. Dispositif selon la revendication 11 ou la revendication 12, dans lequel le noyau (12) est en acier au carbone.

14. Dispositif selon la revendication 11 ou la revendication 12, dans lequel le noyau (12) est en un matériau magnétique doux.

15. Dispositif selon la revendication 12, dans lequel le noyau (12) est en acier inoxydable.

16. Dispositif selon l'une quelconque des revendications 11 à 15, dans lequel la charge de particules d'un alliage magnétique permanent comprend au moins un élément de terre rare.

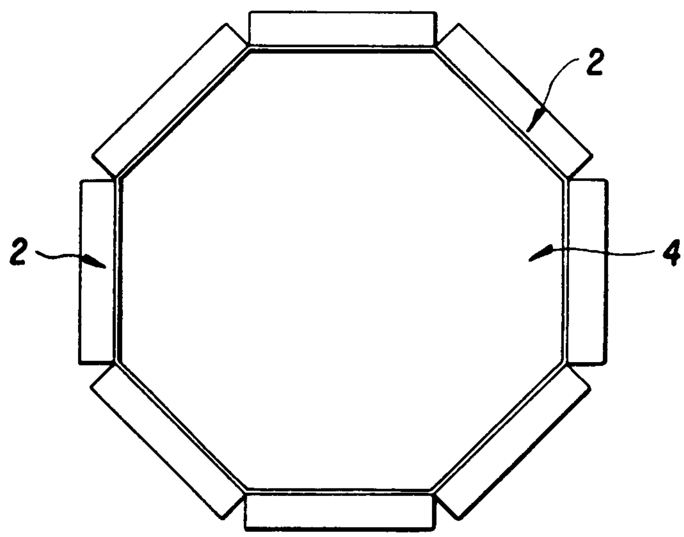

FIG. 1
PRIOR ART

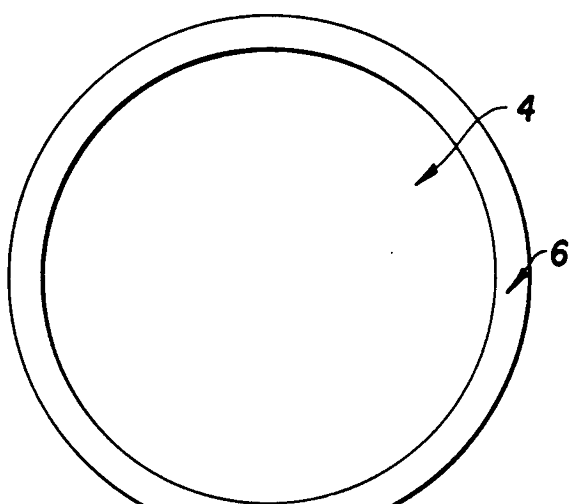

FIG. 2

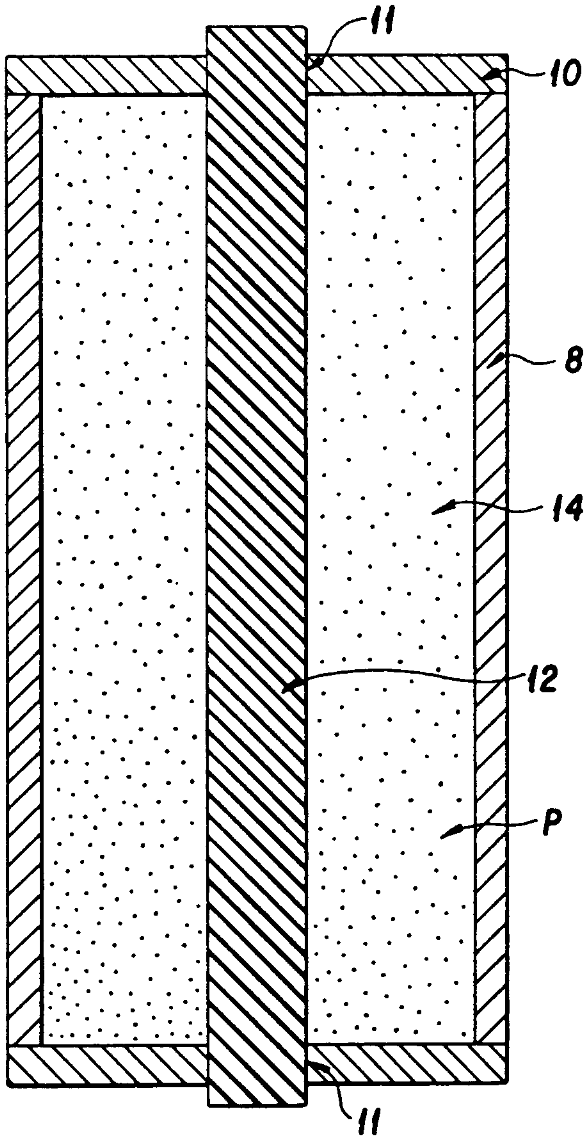

FIG. 3

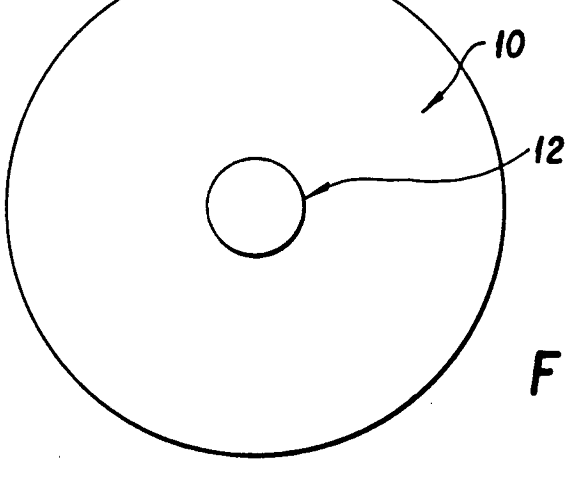

FIG. 4