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Beyer

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[54] **DEVICE FOR EXTRUDING PERMANENT MAGNET BODIES**

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Related U.S. Application Data

[60] Division of Ser. No. 243,842, April 13, 1972, abandoned, which is a continuation of Ser. No. 51,505, July 1, 1970, abandoned.

[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **425/174;** 425/461; 264/108; 264/DIG. 58; 425/DIG. 33

[51] **Int. Cl.**^{2} **B29B 3/04**

[58] **Field of Search** ...... 264/40, 108, 113, DIG. 58; 425/174, 174.8, 174.8 E, 461, DIG. 33

[56] **References Cited**

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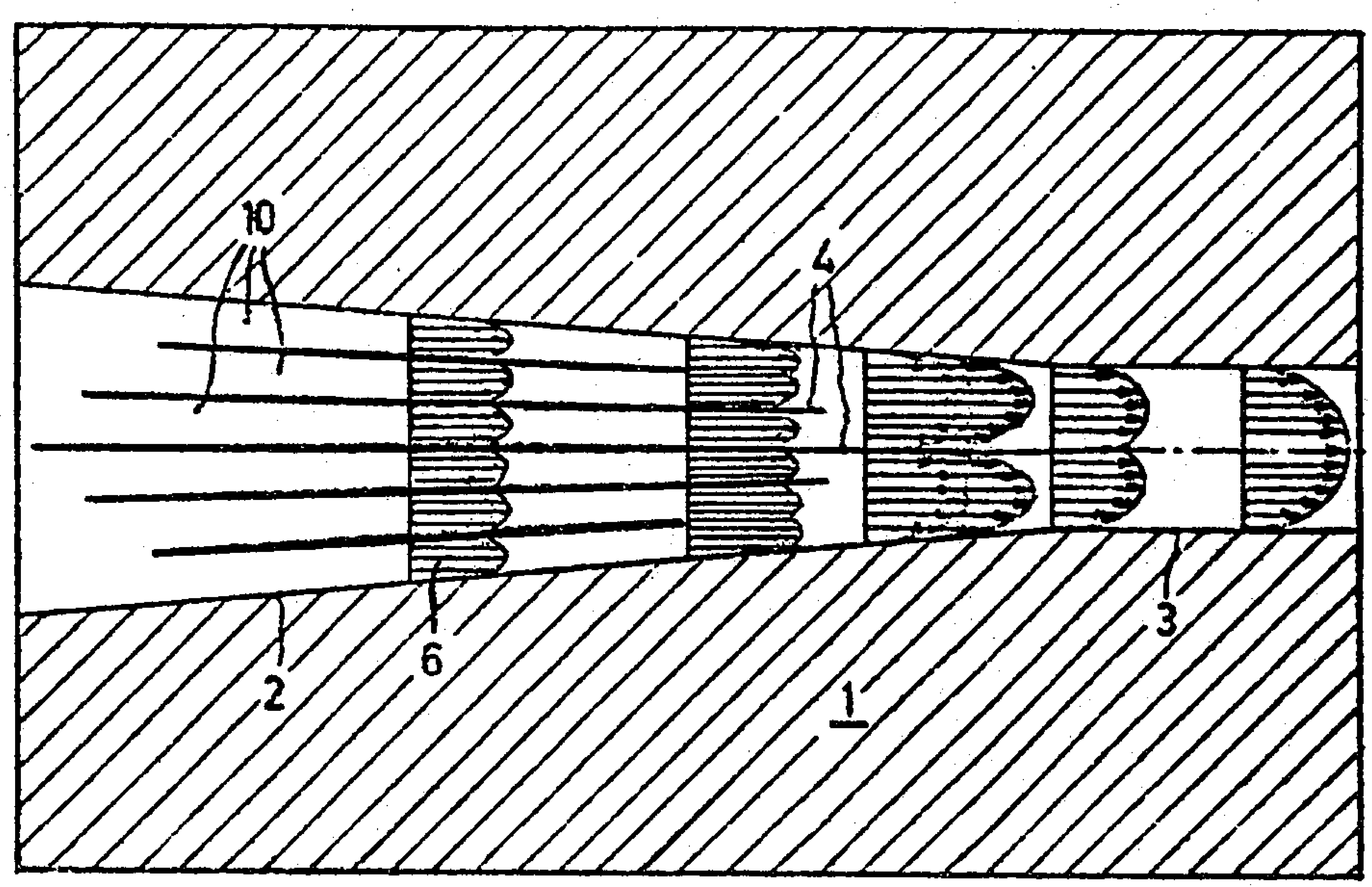
[57] **ABSTRACT**

A device for increasing the anisotropy of extruded bodies consisting of permanent magnetic material in which powdered material is mixed with a binder and extruded, in the presence of an orienting magnetic field, through a nozzle provided with partitions extending in the direction of extrusion so that the material is divided into several strips which are united again in the outlet of the nozzle to form a single unitary body.

3 Claims, 2 Drawing Figures



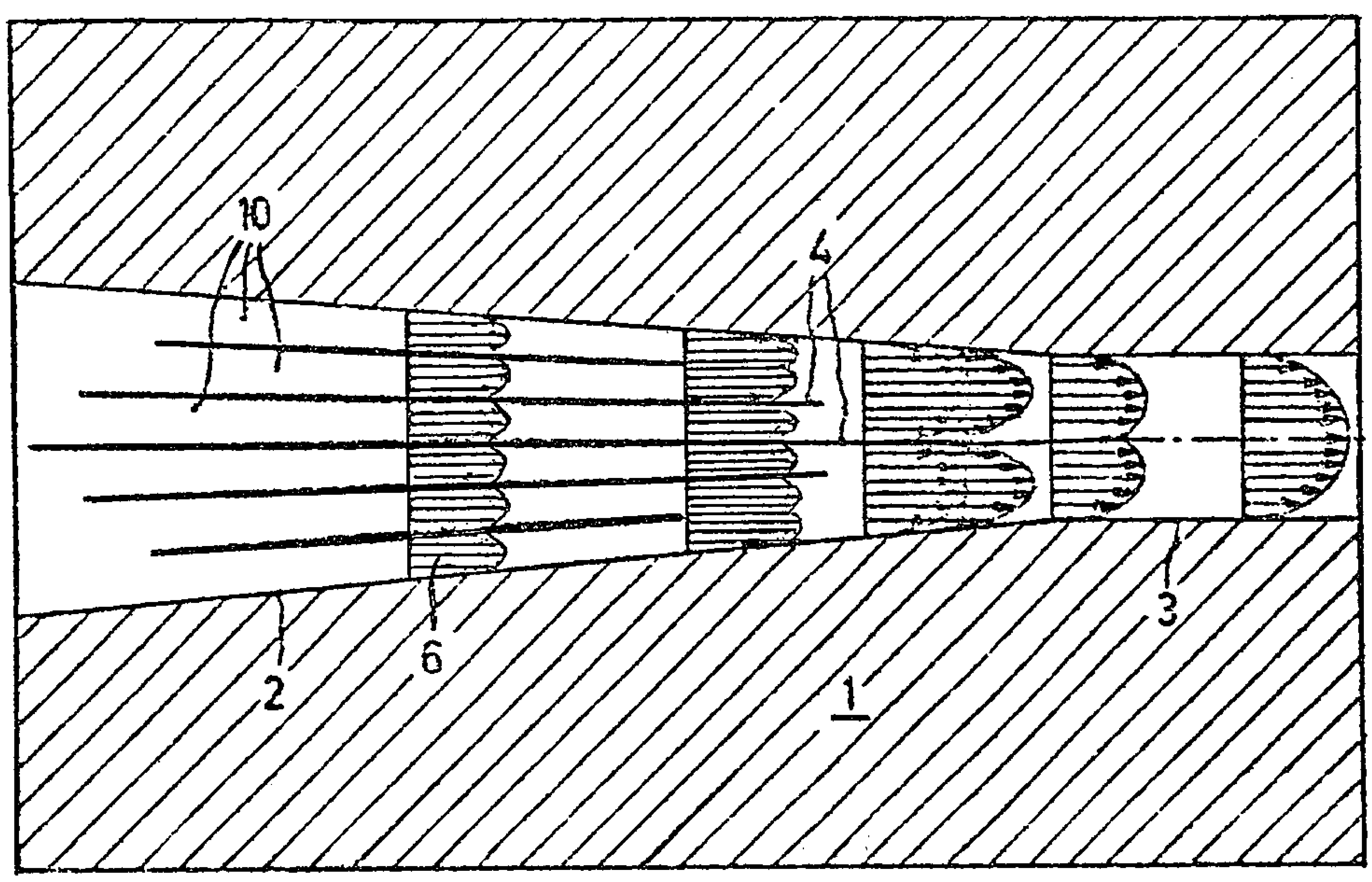


Fig.1

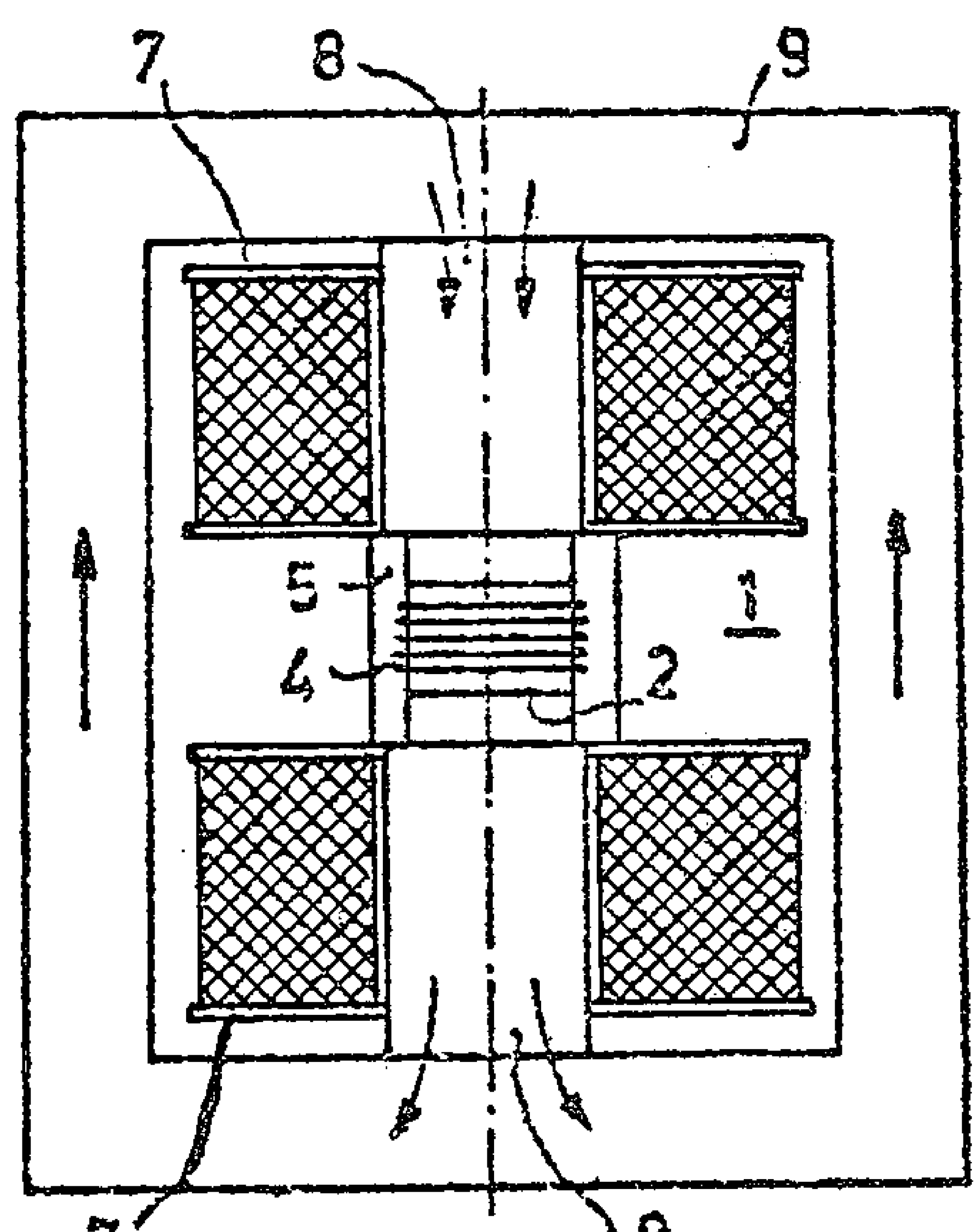


Fig.2

DEVICE FOR EXTRUDING PERMANENT MAGNET BODIES

This application is a division of application Ser. No. 243,842, filed Apr. 13, 1972, now abandoned which was a continuation of application Ser. No. 51,505, filed July 1, 1970 now abandoned.

The invention relates to a method of increasing the anisotropy of extruded bodies consisting of a permanent magnetic material, in which the powdered material mixed with a binder is extruded, under the influence of a magnetic orienting field, by the nozzle of an extruder and emerges from the outlet of the nozzle as an elongated body.

As a permanent magnetic material is to be considered for said purpose in particular a hexaferrite material of the formula $BaO.6Fe_2O_3$, in which the barium may be replaced in whole or in part by strontium, calcium or lead. The powder particles of these materials are plate-shaped. The largest dimension is approximately 5 μm. The thickness lies in the order of magnitude of 0.5 μm. The easy axis of magnetization of the said particles is at right angles to the plane of the particles, and lies in the direction of the thickness of the plates. Other permanent magnetic materials, for example, alloys or mixtures, for example, consisting of manganese- bitmuth, are also suitable for said method.

Two groups of anisotropic magnets which can be manufactured by extrusion are to be distinguished:

1. sintered magnets:
the extruded body, after compression, is sintered which is associated with shrinkage and variation in shape. For maintaining small tolerances it is required to grind the sintered magnets afterwards.

2. plastomagnets:
the powdered magnetic material is mixed with a synthetic resin or rubber which hardens after shaping. Usually, plastomagnets, after their design, in this case after the extrusion, are therefore ready and further machining is not necessary. The drawback of plastomagnets as compared with sintered magnets, however, is a lower density and an associated lower magnetic flux density.

In order to obtain the magnetic anisotropy the same methods are to be considered both for the sintered magnets and for the plastomagnets. It is known, for example, from German Auslegeschrift No. 1,286,230, to manufacture bodies consisting of barium ferrite powder by means of an extruder, in which the nozzle of the extruder is surrounded by a device for producing an orienting magnetic field. As a result of the size of the outlet of the nozzle, the powder particles are not noteworthily oriented mechanically. The extruded bodies are then sintered and have the following properties in the easy axis of magnetisation:

B_r = = **2800** gauss.

B^Hc = = **22000** oersted.

$(BH)_{max}$ = **1.7.10**^{6} gauss-oersted.

On the other hand it is known to orient plate-shaped anisotropic magnetic powder particles by shear stresses which are produced by the method of designing. British Pat. specification No. 860,220 describes a method in which a plastoferrite material is rolled between two rollers to a foil having a thickness of approximately 0.75 mm. On the basis of the strong shear stresses prevailing in a narrow rolling slit, said foils have a pronounced easy axis of magnetization since the plate-shaped magnetic particles have been oriented mechanically during

rolling. In practice, such thin foils are hardly used. Therefore, several such foils would have to be rolled one on the other for manufacturing anisotropic permanenet magnets of the desirable thicknesses, which is cumbersome and expensive.

It is the object of the present invention to provide a method of increasing the anisotropy of extruded bodies having substantially any thickness, in which the magnetic powder particles are oriented not only by an external magnetic field but also by shear stresses produced in the nozzle.

In the above-mentioned method according to the invention this is achieved in that the material to be extruded is conducted in the nozzle along partitions provided in the direction of extrusion and is divided into several strips which are united again to form a compact elongated body in the outlet of the nozzle.

The elongated body is divided into a number of thin strips by the partitions, in which strips, due to the presence of the slit-shaped space between two partitions, shear stresses are produced which result in a high degree of orientation of the permanent magnetic particles at the surface of the strips, so that the particles are oriented mechanically and hence anisotropy occurs. For stimulating the mechanical orientation, a d.c. magnetic field of from 3 to 10 kilo-oersted is applied throughout the length of the nozzle of the extruder. As a result of this, first of all a de-orientation of the particles is avoided when the material leaves the ends of the partitions, at the transition of two strips to one single elongated body. After passing the partitions, the anisotropic strips are again united to form one single elongated body in the outlet of the nozzle, which body emerges as such from the nozzle.

The invention will be described with reference to the accompanying drawing, in which

FIG. **1** is a longitudinal cross-sectional view on an enlarged scale of a nozzle of a device for carrying out the method according to the invention,

FIG. **2** is the cross-sectional view of a device shown in FIG. **1.**

As a preferred embodiment of manufacturing extruded bodies, the manufacture will now be described of a ferrite material of the formula $BaO.6Fe_2O_3$ having a hexagonal crystal lattice structure.

The starting materials, for example, barium carbonate and iron oxide and, if desirable, other additions, are mixed in a corresponding ratio and sintered at temperatures between approximately 1000° and 1300°C. The sintered product is then ground to powder having a particle size of approximately 5 to 10 μm and mixed with a binder. The resulting plastic mass is then extruded in a device according to the invention to form a body having the desirable diameter.

An extruder for carrying out the method according to the invention comprises a nozzle **1** consisting of a non-magnetic material, for example, brass. The rectangular nozzle channel is denoted by **2** and its cross-section decreases towards the end of the nozzle, at which end the channel changes into an outlet **3** having a constant cross-section. In the channel **2** of the nozzle, a number of partitions **4** are provided which extend in the direction of extrusion and at least mainly parallel to the upper and lower walls of the channel as well as relative to each other. The partitions **4** are mortised in the sidewalls **5** of the nozzle **1.** They may consist of a magnetic or a non-magnetic material, for example, bronze or brass, and have a thickness of approximately 0.8 mm in the centre. At the beginning and if desirable at the end, the partitions are shaped in the form of knife-edges. Viewed in the direction of extrusion, the length of the partitions **4** decreases from the centre of the nozzle radially towards the outside. The mutual distance between the partitions **4** decreases in the direction of the outlet of the nozzle **3**; on the side of the extruder it is approximately 2 mm and decreases in the direction towards the outlet **3** of the nozzle to approximately 1 mm.

In this manner the partitions **4** divide the nozzle channel **2** into slit-shaped spaces **10** through which the above-described material **6**, i.e. a ferrite material of the formula $BaO.6Fe_2O_3$is forced so that an approximately parabolic velocity distribution over the height of the strips formed by the partitions **4** is obtained. The formation of a parabolic velocity distribution over the height of the slit is characteristic in itself of a laminar flow in a space having a slit-shaped cross-section. However, in the case of plastic masses this law experiences a variation which is caused by the dependence, difficult to understand, of the properties of the substance on the condition of movement prevailing at any instant, or on the influencing shear stresses; such masses are denoted by "structure viscous." In these masses the influence of the properties of the substance on the local flow rates is complicated. With an increasing deviation from the Newton fluid laws, a stronger smoothing of the original parabolic velocity distribution across the slit-shaped space between two partitions **4** is formed, that is to say, the central zone, in which the effective shear stress is small or equal to zero, increases with increasing deviation of the mass from Newton fluid laws.

Therefore, a strip extruded, for example, from the above-mentioned ferrite mass has at its surface a high degree of orientation of the magnetic particles, the central layers on the contrary being highly unoriented. From this it follows that the thickness of the elongated body and the height of the spaces **10** formed between two partitions **4**, respectively, is decisive of an anisotropy averaged over the thickness of the body. On the basis of the steeper velocity profile in an elongated plane space **10**, a thin strip has a higher degree of orientation than rather thick strips. In FIG. **1**, the decrease of veloctiy of the elongated bodies of material dependent upon the slit height is denoted by arrows.

The material to be extruded is first divided by the partitions **4** into several, in the present case six, strips which, as a result of their small thickness, show a steep velocity profile so that a strong mechanical orienting effect is exerted on the powder particles. The plate-shaped anisotropic powder particles orient themselves with their longitudinal plane parallel to the partitions **4**.

FIG. **1** shows how the velocity profiles of the strips in the individual spaces **10** between the partitions **4**, successively pass into a common profile, that is to say into one single elongated body in the outlet **3** of the nozzle. This single elongated body then emerges from the outlet **3**.

In order to stimulate the mechanical orientation, a d.c. magnetic field of from 3 to 10 kilo-oersted is applied throughout the length of the nozzle **1**. FIG. **2** shows the device for producing said magnetic field. This device comprises two coils **7**, soft-magnetic poleshoes **8**, and a soft-magnetic frame **9** for closing the magnetic circuit. The magnetic field produced passes at right angles through the partitions **4**. Since the anisotropic magnetic plates extend substantially in parallel relative to the partitions **4**, the magnetic field hence also extends at right angles to the plane through the plate, so in the easy axis of magnetisation thereof.

Instead of an electromagnetic device for producing an orienting magnetic field, permanent magnetic devices may also be used.

In accordance with the type of added binder, the body extruded in this manner can be used as a plasto-magnet or be subjected to a subsequent sintering treatment at temperatures between approximately 1200° and 1300°C. The finished bodies are magnetized. Anisotropic sintered magnets consisting of $BaO.6Fe_2O_3$ manufactured by a method according to the invention had the following properties in the easy axis of magnetisation.

$B_r = 3400$ gauss.

$B^Hc = 2400$ oersted.

$(BH)_{max} = 2.6.10^6$ gauss-oersted.

What is claimed is:

1. A device for extruding permanent magnetic bodies consisting of magnetic particles mixed with a binder comprising a nozzle having a tubular member and a plurality of thin juxtaposed partitions each provided with a knife-edge extending longitudinally within said tubular member in the direction of extrusion, the length of each of the partitions decreasing radially from the center of the tubular member towards the wall, and means surrounding said tubular member for producing an orienting magnetic field within said tubular member.

2. A device as claimed in claim **1** in which the free cross-section of the tubular member is constant and the partitions extend parallel to one another.

3. A device as claimed in claim **1** in which the free cross-section of the nozzle decreases in the direction of the outlet and the distance between adjacent partitions decreases in the direction of extrustion.

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