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(71) Applicant: **The Arnold Engineering Company**
Marengo, Illinois 60152 (US)

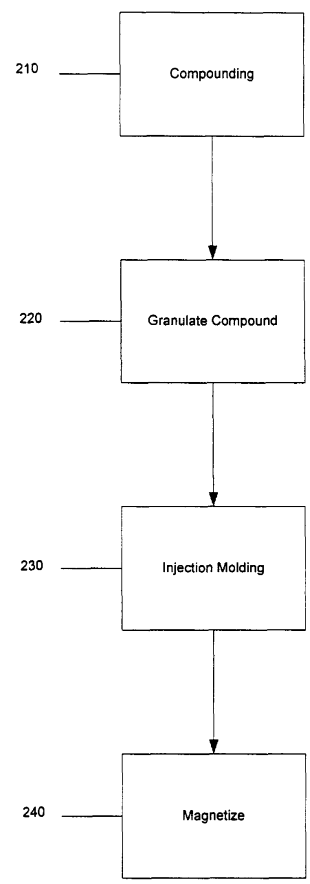
(72) Inventor: **Carlberg, James**
Norfolk, NE 68701 (US)

(74) Representative: **Boyce, Conor et al**
F. R. Kelly & Co.,
27 Clyde Road,
Ballsbridge
Dublin 4 (IE)

(54) **Flexible, moldable bonded magnet and process for producing same**

(57) Magnetic materials, such as ferrite, are produced. Mixing the magnetic powder with a thermoplastic elastomer material and a lubricant material using a twin screw compounding extruder forms the magnetic compound. After allowing for a mixing period, the mixed compound is granulated (i.e., reduced to small particles). Since the compound utilizes a thermoplastic elastomer rather than a thermoset elastomer material to achieve flexibility, the compound is amenable to further processing by injection molding. Thus the granulated compound is processed by an injection molding machine and the molded parts are afterwards pulse magnetized. Parts may be magnetized during injection molding. This results in a finished, flexible bonded magnet product formed according to complex shape specifications and magnetized in accordance with a variety of magnetization patterns.

FIGURE 2



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Description

Field of the Invention

[0001] The present invention relates to the field of magnetic parts and devices of the type used in a variety of industrial devices and other applications. More specifically, this invention relates to the field of flexible bonded magnetic compounds used in such devices and applications, and to the methods for producing such compounds.

Background of the Invention

[0002] In recent years, the use of permanent magnets has burgeoned in a wide range of applications in the computer peripheral, telecommunications and automotive industries. For example, the attractive or repelling force resulting from a magnetic field is often used to perform the work of many automotive applications, such as torque drives and bearing devices. In other applications, such as electric motors, loudspeakers and meters, magnetic fields are used to convert electrical current into mechanical force that performs work in the device. In still other more scientific applications, such as ion pumps, cyclotrons and traveling wave tubes, magnetic fields are used to direct and control electron or ion beams.

[0003] In many of these applications, it is preferable to use bonded magnets (i.e., magnets which are manufactured by mixing a plastic or rubber material with magnetic powder and either pouring the mixture into a mold or extruding it). Bonded magnets have several advantages over other types of magnets. They can be more cost effectively formed into a variety of shapes while allowing many magnetization patterns. Bonded magnets are also tougher and more chip resistant than other types of magnets.

[0004] Despite the wide ranging use of bonded magnets, their performance characteristics often suffer significant limitations. In particular, the choice of materials and processing for such magnets often require a tradeoff between flexibility and elasticity on the one hand, and the ability to form complex shapes, meet magnetic performance criteria and use various magnetization patterns on the other.

[0005] For example, a variety of automotive, fastening and other applications require flexible, elastic magnetic parts, which can withstand the force and impact of other moving parts or the tension caused by movement in the overall environment. In these instances, the bonded magnet is typically made from a mixture of thermoset rubber material and large amounts of magnetic material (e.g., ferrite material). Since the rubbery thermoset material is not amenable to processing by injection molding, the resulting compound must be either calendered or extruded into sheets from which magnetic parts are punched. Unfortunately, parts made this way can only be magnetized through their thickness, and cannot be made into complex shapes. Thus, such bonded magnets, though flexible, cannot be made to conform to a variety of magnetization patterns or complex shape specifications, characteristics that are desirable in many applications.

[0006] Where bonded magnets applications do require complex shaped magnets or magnets having particular magnetization patterns, the bonded magnet is typically made from a mixture of thermoplastic and magnetic materials. The mixture is then generally injection molded and magnetized to specification resulting in a customized magnetic part. Unfortunately, magnetic parts made using thermoplastics tend to be very stiff and brittle. Thus, such bonded magnets, though customized to specification, do not stand up well to tension or other forces impacting the magnetic parts.

[0007] Thus, given these limitations in the prior art, there is a need for a bonded magnet made of a material that is flexible, capable of being molded into complex shapes, and capable of being magnetized in accordance with a variety of magnetization patterns.

Summary of the Invention

[0008] The present invention addresses this need. In particular, the present invention provides a flexible, elastic magnet compound that can be molded into complex shapes and magnetized in a variety of patterns. To achieve this end, the preferred embodiments exploit the unique performance characteristics of thermoplastic elastomer materials, which provide a bonded magnet with the desired properties. More specifically, the magnetic compound of the preferred embodiments comprises: (1) 25% to 50% by volume of styrenic or polyamide based thermoplastic elastomer; (2) 50% to 70% by volume of magnetic material; and (3) 0% to 5% by volume of an internal lubricant.

[0009] The thermoplastic elastomer component of the compound provides the bonded magnet with flexibility and resistance to tension sufficient for most applications. At the same time, the thermoplastic elastomer component also makes the bonded magnet amenable to injection molding processing. Thus, in accordance with a preferred embodiment, the bonded magnet can be manufactured by: (1) blending magnetic materials; (2) granulating the magnetic material(s) with thermoplastic elastomer material(s) and a lubricant material; (3) injection molding the granulated compound; and (4) magnetizing the resulting molded part. The result is a flexible bonded magnet compound, which is also, injection molded and magnetized to detailed specification, if so desired.

Brief Description of the Drawings

[0010]

Figure 1 is a flow chart depicting a process for forming flexible bonded magnetic parts of the type known in the prior art.

Figure 2 is a flow chart depicting an injection molding process for forming a bonded magnet in accordance with an embodiment of the present invention.

Figure 3 depicts constituents of a bonded magnetic compound in accordance with an embodiment of the present invention.

Detailed Description of Preferred Embodiments

[0011] Various aspects of the present invention will now be described in greater detail with reference to the above referenced figures. Turning now to Figure 1, it is a flow chart depicting a process, existing in the prior art, for forming flexible bonded magnets of the type in conventional use.

[0012] As depicted, in Step 100 the manufacturer begins with raw materials used to form the flexible bonded magnet. Apart from the magnetic constituents, such as ferrites, the raw materials typically include thermoset elastomers, such as nitrile rubber, which give the magnet its elastic quality. Thermoset elastomers experience chemical change during processing and become permanently insoluble and infusible. Other examples of thermoset polymers include elastomers such as natural rubber or EPDM.

[0013] Next, in Step 110, the raw materials are mixed, typically using machinery designed expressly for the purpose. For example, in a typical application, the materials are fed through two roll components of an external compounder. As the material passes through the rollers, it is compacted, spread out and periodically sheared and folded to enhance the mixing. After allowing for a mixing period, the mixed material is cut and removed from the compounder.

[0014] After the compounding step, in Step 120, the mixed compound is granulated (i.e., reduced to small particles). The granulation ensures consistent material flow in later processing.

[0015] Since the compound includes thermoset elastomer material, it is not amenable to injection molding, and accordingly cannot be molded to precise, complex shape specifications. Instead, the granulated compound is next extruded or calendered. This also means the finished bonded magnet can only be magnetized through its thickness, rather than in accordance with any variety of magnetization patterns.

[0016] Thus in step 130a, the granulated compound is fed into an extruding machine. Typically, an extruder consists of a hollow heated barrel. The extruder also utilizes a screw, which forces the softened compound through a shaping orifice. As it exits the extruder, the shaped compound is cooled and hardened.

[0017] In the alternative, in Step 130b, the granulated compound is fed in between two rolls of a calendaring machine. The rolls squeeze the material into a continuous sheet that is wound onto a drum.

[0018] Finally, in Step 140, the sheet or parts consisting of the compound are further cut, shaped and otherwise undergo finishing operations required to produce the final bonded magnet product.

[0019] In contrast to the above described process for manufacturing bonded magnets, in one aspect of the present invention, an improved method for manufacturing bonded magnets is provided. In particular, turning now to Figure 2, it shows a flow chart depicting an improved process for forming a flexible bonded magnet in accordance with an embodiment of the present invention.

[0020] In Step 200, in a preferred embodiment of the present invention, a manufacturer receives and blends magnetic materials. The raw materials may include barium ferrite, strontium ferrite, neodymium-iron-boron and samarium cobalt powders.

[0021] Then, in Step 210, a magnetic compound is formed by mixing the magnetic powder with a thermoplastic elastomer material and a lubricant material using, for example, a twin screw compounding extruder. A thermoplastic elastomer is, generally speaking, a block copolymer. Thus, there are at least two types of monomers, or units, hooked together using an "ABAB" pattern. One segment is hard and crystalline. The other is soft and amorphous. When solid, the hard segments crystallize forming linkages allowing the soft parts to stretch while retaining shape. When molten, the hard segments become unordered allowing processing.

[0022] Thus, thermoplastic elastomers are flexible materials that can generally be elongated to more than double their original length at room temperature and yet re-assume their original length when tension is released. Equally importantly, they exhibit the advantageous processing characteristics of thermoplastic materials.

[0023] After allowing for a mixing period in Step 220, the mixed compound is granulated (i.e., reduced to small particles). The granulation ensures consistent material flow in later processing.

[0024] Since the compound utilizes a thermoplastic elastomer rather than a thermoset elastomer material to achieve flexibility, the compound is amenable to further processing by injection molding. Accordingly, the compound can be molded to precise, complex shape specifications and may also be magnetized in accordance with a variety of magnetization patterns.

[0025] Thus, in Step 230, the granulated compound is fed into an injection molding machine. Such machines may include a variety of vertical, horizontal and rotary molds depending upon the given application and the nature of the shape characteristics and magnetic field orientation desired.

[0026] Finally, after injection molding, in Step 240, the molded parts are placed in magnetizing fixtures specifically made for the part size and shape. The magnetizing fixtures function to pulse magnetize the parts, resulting in the finished, flexible bonded magnet product. This may also be done as in integral part of injection molding in Step 230.

[0027] An improved bonded magnetic product formed as described above addresses a variety of significant, currently existing commercial needs. For example, a magnetic closure might be used to replace Velcro® like latches in a variety of products. The magnetic closure might include a first magnet coupled to a flap, which in turn is coupled to the closure, and a second magnet also coupled to a bonding location on the closure. Either or both of the magnets could be comprised of a flexible bonded magnet compound made in accordance with the present invention.

[0028] Such a fastener, made in accordance with the present invention, is flexible enough to withstand tension, twisting and to conform to the shape of the particularized environment in which it may operate (e.g., the shape of a human hand in the case of a magnetic golf glove closure). It can also be molded to fit precisely in such an environment.

[0029] Similarly, a bonded magnet made in accordance with the present invention is particularly well suited to increasingly popular magnetic position sensor applications, such as magnetic sensor cylinders. A flexible bonded magnetic sensor made in accordance with the present invention can easily be made to the precise tolerances demanded by such applications. These designs tend to be thicker than can currently be achieved by punching from flexible sheet stock, but such dimensions are not a problem for injection molding. While standard injection molded magnets may also have favorable characteristics, they are not flexible enough to allow installation. When made with the present invention, parts have the desired magnetic performance level characteristics and can withstand the fluids and temperatures seen during operation of the sensors.

[0030] Having described a method for manufacturing an improved flexible bonded magnet, as well as generalized applications for such a magnet, the magnetic compound of the present invention is now described in greater detail. Turning now to Figure 3, it shows constituents of a bonded magnetic compound in accordance with an embodiment of the present invention. In particular, a preferred magnetic compound in accordance with the present invention comprises: 1) 25% to 50% by volume of styrenic or polyamide based thermoplastic elastomer or polymeric elastomer; (2) 50% to 70% by volume of magnetic material, such as, barium hexaferrite, strontium hexaferrite, neodymium-iron-boron powder, samarium cobalt powder, samarium iron nitride and aluminum nickel cobalt; and (3) 0% to 5% by volume of an internal lubricant.

[0031] With respect to the thermoplastic elastomer material, it may be either styrenic or polyamide based. Styrenic based materials work well in air and polar solvents, such as water. Polyamide based materials work well in non-polar solvents, such as oil. Other thermoplastic elastomer materials might include polyurethanes and polyesters. If the thermoplastic elastomer constituent is greater than the specified range, this comes at the cost of reducing the magnetic material amount and will lower the magnetic performance of the resulting compound to the point where it no longer is commercially viable product. If the thermoplastic elastomer constituent is lower than the specified range, the resulting compound will not exhibit physical properties unique to the present invention. In particular, the compound would not have elasticity exceeding current compounds and would become physically weaker. Also, if the compound is based on anisotropic materials such as ferrite, the level of magnetic material will become too high. In particular, anisotropic materials must orient or move during the molding process under the influence of a magnetic field. When the number of magnetic particles is too high, they interfere with each other's orientation reducing magnetic performance.

[0032] With respect to the internal lubricant material, it makes the compound more processable. It also improves magnetic performance through better orientation when anisotropic magnetic materials, such as barium ferrite, are used. Also, if too much internal lubricant is used, the resulting compound will be too weak physically to be marketable.

[0033] Finally, with respect to the magnetic material, both the amount (as mentioned above) and type of magnetic material used are important to both the physical and magnetic properties of the final compound. The effects of types of magnetic material are not detailed here as these effects of the various magnetic materials on magnetic performance are well known.

[0034] However in a preferred embodiment of the invention, the compound includes an optimum amount of 63% by volume barium hexaferrite magnetic material using a styrenic based thermoplastic elastomer. Further, in another preferred embodiment of the present invention, the compound includes an optimum amount of 61% by volume barium hexaferrite using a polyamide based thermoplastic elastomer.

[0035] In particular, experiments were conducted to optimize the amount of magnetic material used. Various recipes and settings were used with a twin screw compounding extruder and two loss-in-weight feeders. One of the feeders was used to meter the thermoplastic elastomer while the other was used for the ferrite. A side stuffer was used with the ferrite feeder. The material was granulated. Several ferrite volume loads were tried with the styrenic thermoplastic elastomer and 63% gave the highest Br and ultimate tensile elongation. For example, the sample with 61% by volume ferrite was less elastic and did not perform as well magnetically. With regards to the polyamide thermoplastic elastomer, several ferrite volume loads were also tried. With a polyamide thermoplastic elastomer, higher ferrite loads reduced ultimate tensile elongation substantially. Thus, for example, the sample with 59% by volume barium hexaferrite exhibited optimal characteristics.

Parameter	Setting 1	Setting 2
Thermoplastic Elastomer	37% by volume Styrenic	39% by volume Styrenic
Barium Hexaferrite	63% by volume	61% by volume
Extrusion Temperatures	170C	170C
Main Screw Speed	120 rpm	120rpm
Side Stuffer Screw Speed	100 rpm	100 rpm
Measured Torque	45%	40%
Melt Temperature	195C	188C
Die Pressure	40 psi	40 psi
Br (7 kOe Orienting Field)	2670 Gauss	2530 Gauss
Hc (7 kOe Orienting field)	2228 Oersteds	2141 Oersteds
Hci	3386 Oersteds	3386 Oersteds
BHmax (7 kOe Orienting Field)	1.70 mGOe	1.51 mGOe
Ultimate Tensile Strength	607 N/cm^2	594 n/CM^2
Ultimate Tensile Elongation	103%	97%

Parameter	Setting 1	Setting 2
Thermoplastic Elastomer	41% by volume Polyamide	39% by volume Polyamide
Barium Hexaferrite	59% by volume	61% by volume
Extrusion Temperatures	200C	200C
Main Screw Speed	120 rpm	120rpm
Side Stuffer Screw Speed	100 rpm	100 rpm
Measured Torque	63%	64%
Melt Temperature	205C	234C
Die Pressure	60 psi	80 psi
Br (7 kOe Orienting Field)	2420 Gauss	2440 Gauss
Hc (7 kOe Orienting field)	2100 Oersteds	2080 Oersteds
Hci	3160 Oersteds	3014 Oersteds
BHmax (7 kOe Orienting Field)	1.45 mGOe	1.51 mGOe
Ultimate Tensile Strength	2912 N/cm^2	3047 N/cm^2
Ultimate Tensile Elongation	6%	5%

Claims

1. A flexible bonded magnet compound comprising:

a. 25% to 50% by volume of a thermoplastic elastomer;

b. 50% to 70% by volume of a magnetic material; and
c. 0% to 5% of an internal lubricant.

2. The flexible bonded magnet compound of claim 1 wherein said thermoplastic elastomer is one of a styrenic based thermoplastic elastomer or a polyamide based thermoplastic elastomer.

3. The flexible bonded magnet compound of claim 1 or 2 wherein the magnetic material is barium hexaferrite.

4. The flexible bonded magnet compound of claim 1 or 2 wherein the magnetic material is strontium hexaferrite.

5. The flexible bonded magnet compound of claim 1 or 2 wherein the magnetic material is neodymium-iron-boron powder.

6. The flexible bonded magnet compound of claim 1 or 2 wherein the magnetic material is samarium cobalt powder.

7. The flexible bonded magnet compound of claim 3 wherein the compound is 63% barium hexaferrite by volume.

8. The flexible bonded magnet compound of claim 1 or 2 wherein the magnetic material is aluminum nickel cobalt.

9. The flexible bonded magnet compound of claim 1 or 2 wherein the magnetic material is samarium iron nitride.

10. A magnetic closure comprising a first magnetic part coupled to a flap, and a second magnetic part coupled to a bonding location, said bonding location coupled to said flap, the first and second magnetic parts each comprising a flexible magnetic compound according to any previous claim.

11. A method for manufacturing a flexible bonded magnet, the method comprising:

a. forming a mixed compound by mixing the magnetic powder with a thermoplastic elastomer material and a lubricant material;
b. forming a granulated compound by granulating the mixed compound; and
c. injection molding the granulated compound into the flexible bonded magnet.

FIGURE 1
(PRIOR ART)

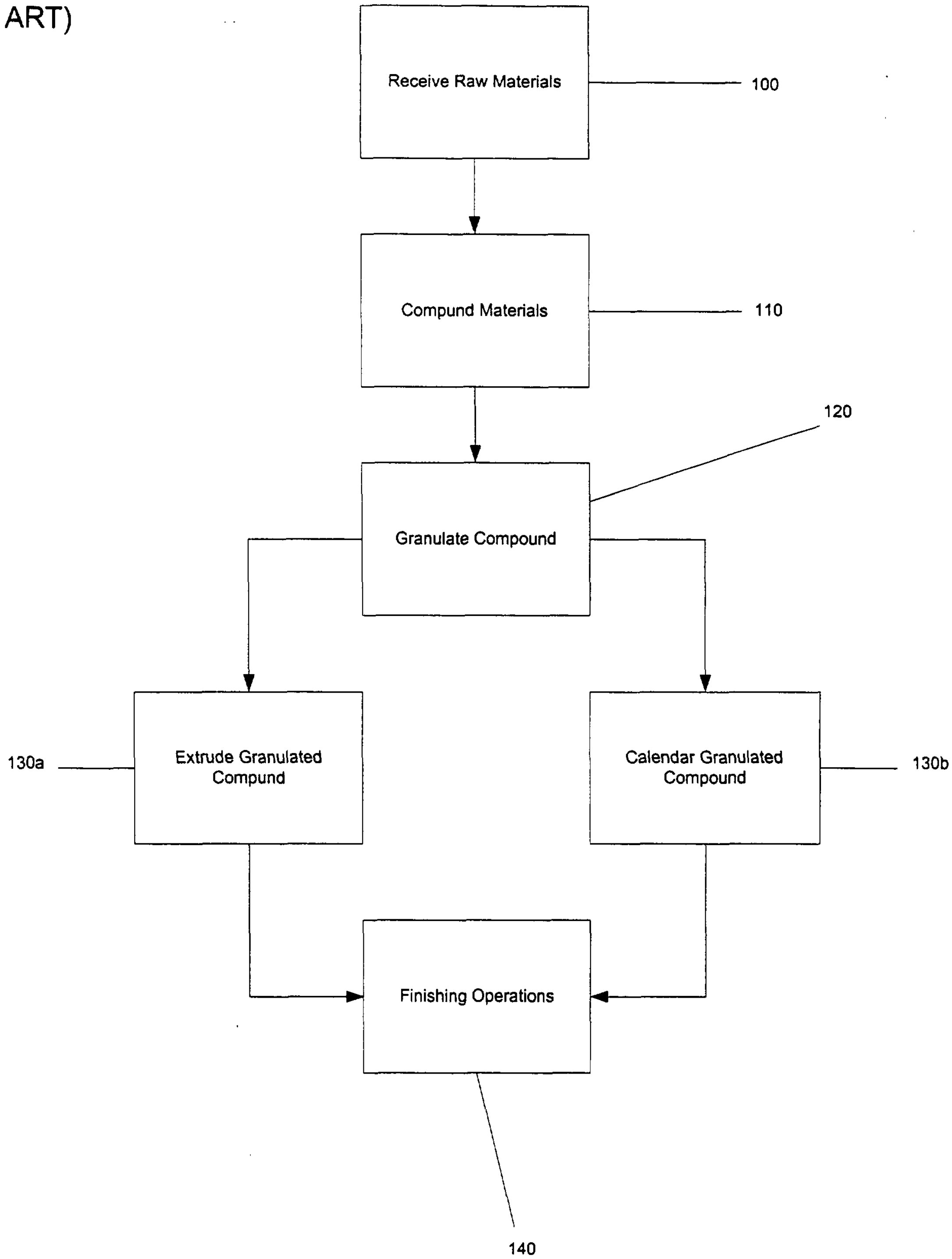


FIGURE 2

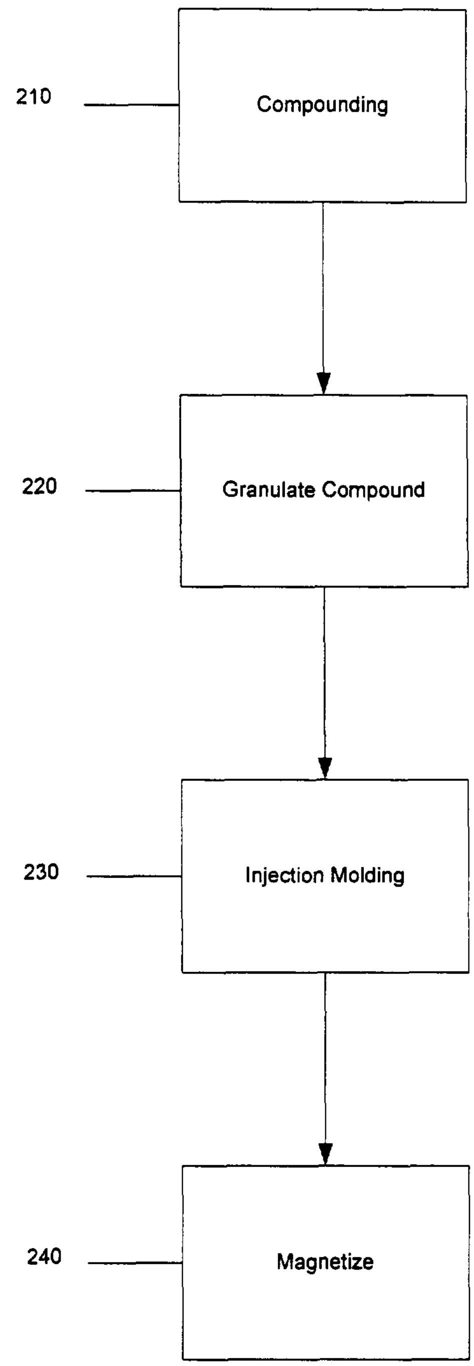
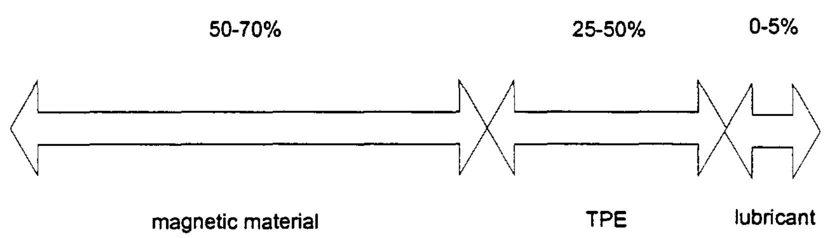

210
Compounding
220
Granulate Compound
230
Injection Molding
240
Magnetize

FIGURE 3



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EUROPEAN SEARCH REPORT

Application Number
EP 01 65 0115

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X	* column 8, line 36 - line 43 * * column 5, line 20 - line 25 *	11	
A	US 5 958 283 A (AEPLI ETIENNE ET AL) 28 September 1999 (1999-09-28) * claims 14,22 * * column 1, line 5 - line 9 * * column 4, line 3 - line 41 * * column 5, line 8 - line 25 *	1,3-7,11	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 January 2002	Stichauer, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 65 0115

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