Sept. 4, 1962 M. BAERMANN 3,051,988

MATERIAL WITH PERMANENT MAGNETIC PROPERTIES

Filed Oct. 31, 1957 2 Sheets-Sheet 1

FIG. 1

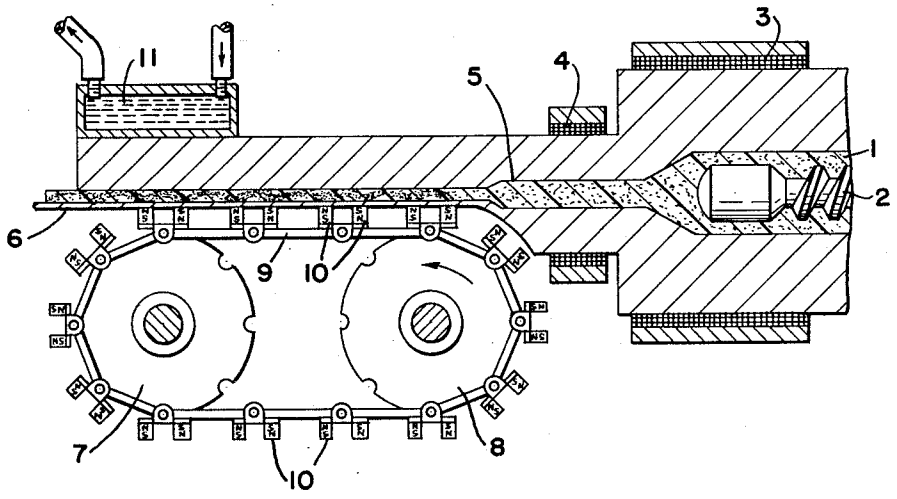
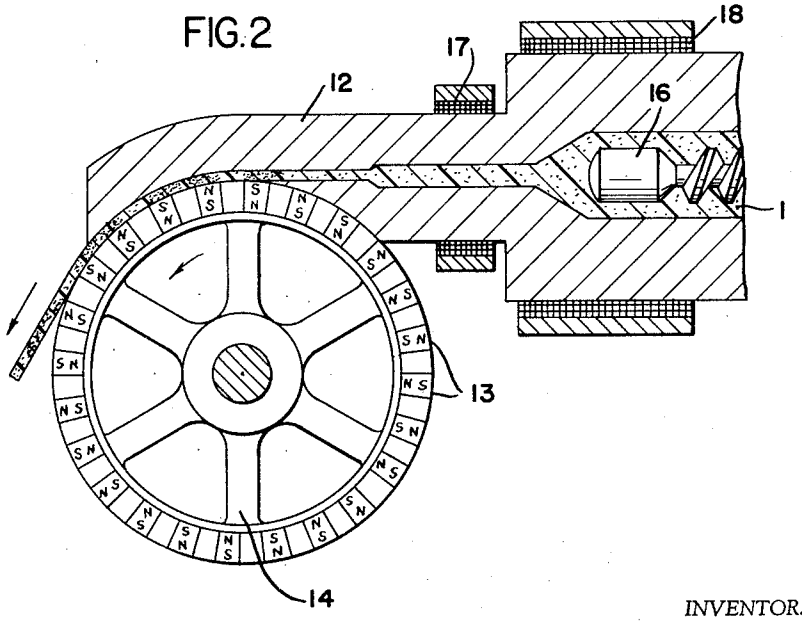


FIG. 2



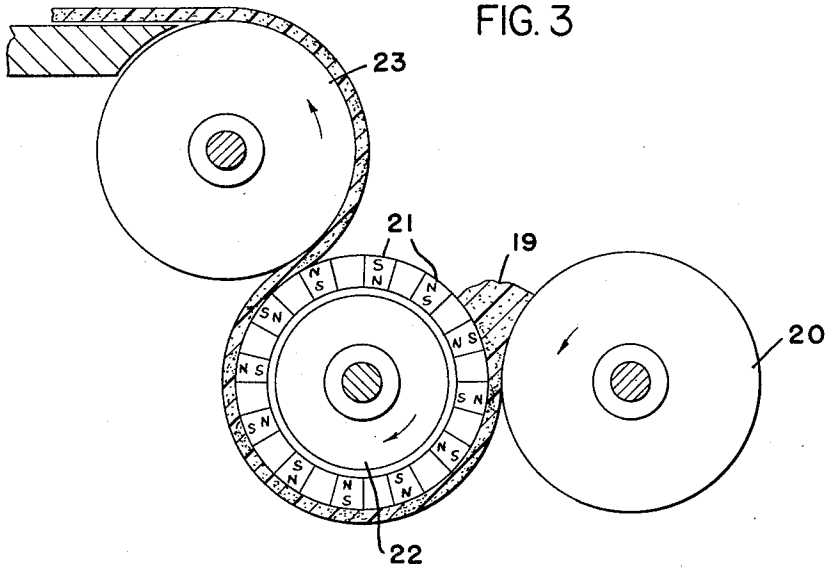
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MATERIAL WITH PERMANENT MAGNETIC PROPERTIES

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FIG. 3



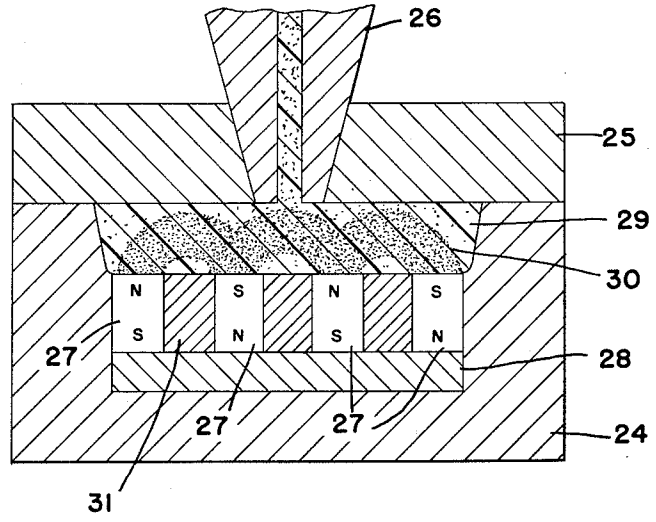


FIG. 4

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3,051,988

MATERIAL WITH PERMANENT MAGNETIC PROPERTIES

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17 Claims. (Cl. 18—12)

This invention pertains to the art of permanent magnets and more particularly to a material and method of manufacturing same having permanent magnetic properties.

The invention is particularly applicable to material for, and the manufacture of, soft elastic articles of manufacture which must adhere to similar articles or to magnetically permeable supports and will be described with particular reference thereto, although it will be appreciated that the invention is equally applicable to the manufacture of rigid articles of manufacture or where the magnetic field of the articles produced is used for purposes other than being attracted to other magnetic supports.

In accordance with the present invention, a thermoplastic material has incorporated therein as a filler material at some stage in the processing thereof to a final article of manufacture, permanent magnetic materials in either powdered or granular form in quantities of 20–80% by volume.

By thermoplastic is meant a material which will pass through a liquid or low viscosity phase during the heating thereof in the forming of articles of manufacture therefrom. As such, the permanent magnetic materials will in essence essentially float in the liquid plastic and when subjected to an external magnetizing force, may orient themselves in accordance with the present invention. Thus if the thermoplastic material with the permanent magnetic powder is injected into a mold as a liquid while subjecting the material to a magnetizing field, the permanent magnetic particles will become magnetized and tend to accumulate corresponding to the polarization of the magnetizing fields. When the thermoplastic material hardens or thickens, the permanent magnetic powders will be held in this position. When the permanent magnetic materials are anisotropic there is a further advantage that the particles will align themselves in their preferred position and will be held in such position resulting in a further increase of the ultimate magnetic field intensity.

Permanent magnetic materials usable with the invention are those, either isotropic or anisotropic, which can be mechanically crushed to a sufficiently small size or a combination of non-magnetic materials which when mixed in powdered or granular form result in either isotropic or anisotropic permanent magnetic materials and which would then be subjected to magnetizing forces during the process of forming the thermoplastic materials.

Particularly suited for the present invention are the permanent magnetic materials which are manufactured and sold in the powdered form. As many of these materials oxidize readily, the further processing must be done by excluding oxygen, for example, by wetting the materials with appropriate liquids or using protective gases. Softeners may also be employed for this purpose.

Preferably the magnetic materials should offer a minimum of permeability. Typical of such materials are manganese-bismuth, so-called oxide magnets of the iron-barium, iron-strontium type.

Further in accordance with the present invention, a method of manufacturing permanent magnetic articles is provided comprising the steps of mixing a thermoplastic material as above defined with a powdered or granular non-magnetized permanent magnetic material, heating the mixture to a temperature such that the thermoplastic material has a low viscosity, forming the mixture to the desired shape and simultaneously subjecting it to a magnetizing force, and allowing the magnetized formed mixture to cool.

The method of forming may be those customary in the technique of plastic material in the production of plates, sheets, shaped rods or formed parts such as kneading, extrusion, rolling, molding, injection molding or blowing, the magnetizing in any desired polarization either on the surface or through the cross section taking place as the thermoplastic material changes from the liquid or low viscosity state to the congealed or hardened state.

Whenever the mixture is to be extruded or injection molded, it is often advantageous, in accordance with the invention, to form granules of the mixture which facilitates the manufacture of the material and enables a very homogeneous product to be obtained.

Plastics particularly usable with the present invention are the superpolyamids which have a melting temperature of about 220° C.

Further in accordance with the present invention, apparatus is provided for manufacturing articles from such material comprising means for forming the material through the desired shape at least in part of a non-magnetic material in combination with means having a fixed relationship relative to the material while being formed for exerting a magnetizing field on such material.

For an extrusion machine, in accordance with the invention, there is provided a forming nozzle of non-magnetic material preferably having a thin wall thickness at one surface in combination with magnetizing means movable longitudinally of the nozzle synchronously with the speed of movement of the plastic material through the nozzle. Where the nozzle is relatively straight, the magnetizing means can be in the form of an endless chain carrying the magnetizing poles longitudinally of the nozzle. Alternatively, the extrusion nozzle can extend in an arcuate manner and the magnetizing poles can be mounted on a rotating disc or wheel rotating at a speed such that the poles synchronously move with the speed of movement of the plastic material through the nozzle.

Where the plastic material is to be formed into flat sheets by means of calender rolls, in accordance with the invention, one or both of the calender rolls are formed of non-magnetic material and containing a plurality of circumferentially spaced axially extending magnetizing poles, either rotating with the roller or supported on a separate shaft, but in either event, moving synchronously with the speed of delivery of the material from the roller.

Further, where the material is to be injection molded, in accordance with the invention, at least one of the sections of the injection mold is formed of non-magnetic material having magnetizing poles inserted in recesses thereof, the base of which recess is relatively thin.

The principal object of the present invention is the provision of a new and improved permanent magnetic material which is easily manufactured to any desired shape which has a maximum field strength for a given weight of permanent magnetic ingredients and is simple and inexpensive.

Another object of the invention is the provision of a new and improved method of manufacturing permanent magnetic materials wherein the permanent magnetic materials may be concentrated in desired spots throughout the article.

Still another object of the invention is the provision of a new and improved method of manufacturing articles of manufacture made from thermoplastic materials containing powdered permanent magnetic materials wherein the permanent magnetic materials are bunched or grouped to provide maximum localized field strengths.

Still another object of the invention is the provision of a new and improved apparatus for molding or forming articles from a mixture of thermoplastic and permanent magnetic material comprising means for moving the mixture through a forming operation and other means for synchronously moving magnetizing fields with the mixture.

The invention may take physical form in certain parts and arrangements of parts and certain steps and combinations of steps preferred embodiments of which will be described in detail in this specification and illustrated in the accompanying drawings which are a part hereof and wherein,

FIGURE 1 is a side cross-sectional somewhat diagrammatical view of an extrusion press and nozzle having the magnetizing poles mounted on an endless chain all illustrating an embodiment of the invention.

FIGURE 2 is a view somewhat similar to FIGURE 1, but showing the magnetizing poles mounted on the periphery of a wheel.

FIGURE 3 is an end elevational view of calendering rolls with one of the rolls having magnetizing poles mounted thereon illustrating an alternative embodiment of the invention, and

FIGURE 4 is a side cross-sectional view of an injection mold showing somewhat diagrammatically built-in magnetizing magnets.

Referring now to the drawings wherein the showings are for the purposes of illustrating preferred embodiments of the invention only and not for the purposes of limiting same, FIGURE 1 shows a plastic material **1** being extruded under the effect of a worm **2** through an extrusion nozzle **5** heated as is conventional by heating coils **3** and **4**. The material **1**, in accordance with the invention, is formed of a mixture of:

(*a*) Any of the known thermoplastic materials capable upon heating to elevated temperatures of liquifying or having a low viscosity preferably a superpolyamid, and,

(*b*) Any of the known permanent magnetic materials capable of being crushed or ground to granular or powdered form and preferably having a minimum permeability such as the manganese bismuth compounds or the various known oxide magnets, e.g., without limitation, iron-barium or iron-strontium.

The permanent magnetic materials preferably have a volume of 60–70% of the total of the material **1** although the volume may range from 20–80%.

The heating coils **3**, **4** heat the material **1** above the plastic or liquifying temperature of the thermoplastic portions thereof.

This material **1** in a plastic state is advanced longitudinally through the nozzle **5** which has a relatively thin wall **6** of non-magnetic material. A plurality of permanent magnets **10** are arranged in close relationship to this wall **6** for the purpose of imposing a plurality of longitudinally spaced magnetizing fields on the material **1** in the nozzle **5**. These magnets **10** are mounted on an endless chain **9** in turn supported on a pair of sprocket wheels **7**, **8**. The sprocket wheels **7**, **8** are rotated by external power means not shown at a speed such as to move the magnets **10** longitudinally of the nozzle **5** at a speed synchronous with the speed of movement of the material **1** through the nozzle **5**. As the arrangements for maintaining this synchronous speed are well known to those skilled in the art, this apparatus is not more specifically shown.

The far end of the nozzle **5** is cooled by a cooling device **11** through which water flows.

Thus it will be seen that the material **1** comprised of a mixture of thermoplastic material and nonmagnetized permanent magnetic ingredients is first heated to the plastic temperature of the thermoplastic material and then advanced longitudinally of the nozzle **5** in such heated state. In effect the nonmagnetized permanent magnetic particles are floating in this liquid. However, as the mixture comes opposite to the magnets **10**, the magnetic

particles are free to float and orient themselves in bunches or concentrations corresponding to the positions of the magnets **10**. The effect is to concentrate the magnetic material at the pole points.

It is believed that I am the first to ever have mixed nonmagnetized permanent magnetic material with a thermoplastic material, heated the thermoplastic material to the liquid or plastic state and then subjected it to magnetizing forces which are stationary relative to the mixture whereby the magnetic particles can group or concentrate themselves in accordance with the magnetizing forces.

FIGURE 2 shows an alternative embodiment of the invention comprised of a nozzle **12** through which the material **1** is forced by means of the worm screw **16**, the nozzle **12** being heated by the heating coils **17**, **18** as is conventional. The outer end of the nozzle **12** is arcuate and is milled away so that a portion of the passage of the nozzle **12** is exposed. A wheel **14** having a plurality of magnetizing magnets **13** arranged around its periphery rotates in the milled end of the nozzle **12** at a speed such that the peripheral velocity of the wheel **14** is the same as the speed of movement of the material **1** through the passage.

Cooling means are not shown but may be employed. However, the wheel **14** may exert a cooling effect on the material **1** as the material comes into contact therewith.

FIGURE 3 shows the invention as applied to roller calenders. In FIGURE 3 the material **19** similar to the material **1** above described is advanced between rollers **20**, **22** rotating on parallel axes, then continues around the roller **22** and thence between roller **23** and roller **22**. The roller **22** as shown has a plurality of permanent magnets **21** extending axially along its surface and circumferentially spaced. Adjacent magnets as shown have opposite magnetic polarity.

No means are shown for heating the material **19** but it will be understood that the material **19** is in a heated state. Alternatively, the wheel **22** can be heated to an amount sufficient to heat the material **19**.

FIGURE 4 shows a still further alternative embodiment of the invention particularly applied to an injection mold comprised of two sections **24**, **25** of nonmagnetic material and defining a mold cavity. A plurality of magnetizing magnets **27** are built into the mold cavity in spaced side by side relationship, adjacent magnets having opposite magnetic polarity. A plate of magnetic material is positioned behind these magnets so as to provide a magnetic connection of high permeability. Plates **31** of nonmagnetic material space the magnets **27**.

The thermoplastic mixture **29** as above described with reference to material **1** of FIGURE 1 is injected in a heated state into the mold cavity through the nozzle **26** and fills up this mold cavity. The magnetic particles floating in the thermoplastic material migrate in the material to arrange themselves in concentrated areas corresponding to the lines of magnetic force between the magnets **27**. Such concentrations are indicated by the dotted lines **30**.

It will thus be appreciated that embodiments of the invention have been described which accomplish all of the objects heretofore set forth and others and provide a permanent magnetic material which may be readily molded, has high field strengths for a given weight of permanent magnetic material together with improved apparatus for producing such materials.

The invention has been described with reference to preferred embodiments. Obviously modifications and alterations will occur to others upon a reading and understanding of this specification and it is my intention to include all such modifications and alterations insofar as they come within the scope of the appended claims.

Having thus described my invention, I claim:

1. Apparatus for forming plastically molded permanent

magnetic articles of manufacture comprising in combination an extrusion nozzle at least in part of nonmagnetic material, means for forcing a thermoplastic material containing powdered nonmagnetized permanent magnetic materials through said nozzle and means for magnetizing the mixture as it goes through the extrusion nozzle comprising a plurality of magnetic poles and means for moving such poles along said nozzle synchronously with the movement of the mixture therethrough.

2. Apparatus for forming continuous lengths of permanent magnetic material comprising an elongated forming nozzle at least in part of a nonmagnetic material and means for advancing a mixture of a thermoplastic material and nonmagnetized particles capable of being permanently magnetized through such nozzle and means comprised of at least a pair of close spaced opposite polarity magnetic poles having axes perpendicular to the length of such nozzle and adjacent such nozzle for subjecting such mixture to a magnetizing force.

3. The combination of claim 2 wherein such means are movable longitudinally of the nozzle and means are provided for maintaining the speed of movement synchronous with the speed of movement of the mixture through the nozzle.

4. Apparatus for forming continuous lengths of permanent magnetic material comprising in combination an extrusion nozzle, means for forcing a mixture of thermoplastic material and nonmagnetized particles capable of being permanently magnetized through such nozzle, one side of said nozzle being open and means closing said side comprising a magnetizing device including a pair of magnetic poles having an axis of magnetization perpendicular to the length of said nozzle.

5. Apparatus for forming continuous sheets of a permanent magnetic material comprising in combination a plurality of calender rolls in spaced relationship and rotatable on parallel axes, at least one of said rolls having a plurality of axially extending circumferentially spaced opposite magnetic poles.

6. A method of forming a permanent magnet body which comprises the steps of providing a mass of plastic material having finely divided permanent magnet particles therein, providing a plurality of spaced magnetizing magnets which present pole faces of opposite magnetic polarity, and, while said mass of material is in a flowable condition, moving it along a predetermined path and forming it into an elongated body of indefinite length and simultaneously bringing one longitudinal face of said elongated mass of material and said opposite polarity pole faces of the magnetizing magnets into proximity to each other so that said magnetizing magnets magnetize said permanent magnet particles in said mass and produce continuous spaced apart permanent magnet poles of alternate polarity at said one longitudinal face of the finished body.

7. A method of forming a permanent magnet body which comprises the steps of providing a mass of plastic material having finely divided permanent magnet particles therein, providing a plurality of spaced magnetizing magnets, and, while said mass of material is in a flowing condition, causing the mass to flow at a predetermined speed along a predetermined path of movement and moving said magnetizing magnets along said path of movement at the same speed in proximity to said flowing mass to magnetize said permanent magnet particles in said mass.

8. A method of forming a permanent magnet body which comprises the steps of providing a mass of plastic material having finely divided permanent magnet particles therein, heating said mass of material to a flowing condition and causing the heated mass to flow at a predetermined speed along a predetermined path of movement, and moving a plurality of magnetizing magnets having successive pole faces of alternate polarity along said path of movement at the same speed with said alternate polarity pole faces of the magnetizing magnets in proximity to one face of said flowing mass, to magnetize said permanent magnet particles in said mass and produce successive spaced permanent magnet poles of alternate polarity at said one face of the body.

9. The method of claim 8 wherein said mass is extruded through a nozzle and the permanent magnet particles therein are magnetized by said magnetizing magnets during such extrusion.

10. The method of claim 8 wherein said mass is extruded through a nozzle and the permanent magnet particles therein are magnetized by said magnetizing magnets immediately following such extrusion.

11. The method of claim 8 wherein said mass is passed around calendering rolls and the permanent magnet particles therein are magnetized by said magnetizing magnets during such passage.

12. A method of forming a flexible elongated permanent magnet strip which comprises providing a mass of thermoplastic material, mixing in with said mass finely divided permanent magnet particles, moving a plurality of movable spaced magnetizing magnets having adjacent pole faces of alternate polarity along a predetermined path heating said mass of material to a flowing condition and forming it into a strip which flows at a predetermined speed along a path of travel which is in proximity to a portion of said path of movement of said magnetizing magnets, and moving said magnetizing magnets at the same speed as said flowing strip to magnetize said permanent magnet particles in the latter and produce spaced permanent magnet poles of successively alternate polarity at the adjacent face of the strip.

13. A method of making a permanent magnet body which comprises the steps of providing a mass of plastic material having finely divided permanent magnet particles therein, forming said mass into an elongated body, providing spaced magnetizing magnets which present respectively spaced opposite polarity pole faces, and while said mass of material in the body is in a moving condition bringing one face of the body and said opposite polarity pole faces of the magnetizing magnets into proximity to each other so that said magnetizing magnets magnetize said permanent magnet particles in said mass and produce spaced apart permanent magnet poles of opposite polarity at said one face of the body.

14. A method of making an elongated flexible permanent magnet strip which comprises the steps of providing a mass of thermoplastic material having finely divided permanent magnet particles therein, forming said mass into a continuous elongated strip, providing spaced magnetizing magnets which present respectively opposite polarity pole faces, and moving said strip lengthwise past said magnetizing magnets with one face of the strip in proximity to said opposite polarity pole faces of the magnetizing magnets so that said magnetizing magnets magnetize said permanent magnet particles in said mass and produce along the length of the strip spaced apart permanent magnet poles of opposite polarity at said one face of the strip.

15. Apparatus for magnetizing elongated lengths of a mixture of nonmagnetized particles capable of being permanently magnetized and a plastic nonmagnetic binder so as to have on one elongated surface, at least a pair of oppositely polarized permanent magnet poles comprising in combination: means for moving said mixture along a predetermined path, means on said path for continuously forming said mixture into an elongated body of predetermined transverse dimensions, and means for magnetizing said particles as said elongated body moves along said path including at least a pair of close spaced opposite polarity magnetic poles disposed on one side of said path with the axes of magnetization perpendicular to said path.

16. Apparatus for magnetizing elongated lengths of a mixture of nonmagnetized particles capable of being permanently magnetized and a plastic nonmagnetic binder so as to have on one elongated surface at least a pair of oppositely polarized permanent magnet poles comprising in combination: means for moving said mixture along a predetermined path, means for changing the transverse dimensions of said mixture and means for simultaneously magnetizing said particles as said mixture moves along said path including at least a pair of close spaced oppositely polarized magnetic poles disposed on one side of said path with the axes of magnetization perpendicular to said path.

17. Apparatus for magnetizing elongated lengths of a mixture of non-magnetized particles capable of being permanently magnetized and a plastic non-magnetic binder so as to have on one elongated surface a plurality of permanent magnetic poles comprising in combination: means for moving said mixture along a predetermined path, forming means for changing the transverse dimensions of said mixture, means for magnetizing said particles including a plurality of close spaced magnetic poles disposed on one side of said path with the axis of magnetization perpendicular to said path.

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