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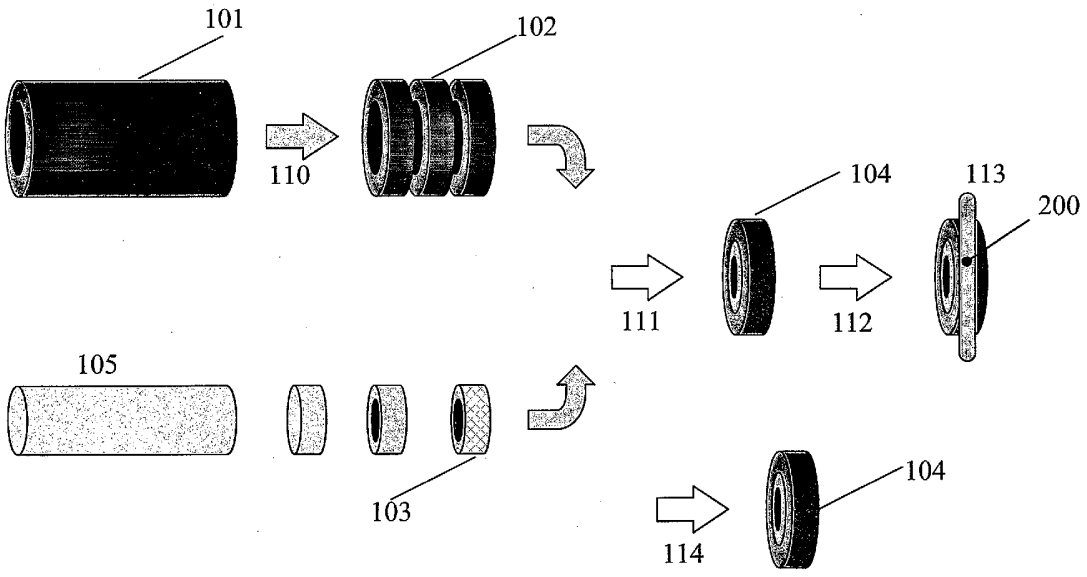
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(54) Title: ELECTRONIC POWER ASSIST STEERING WORM GEARS



(57) Abstract: Composite worm gears having little residual stress are prepared by forming a tube of synthetic resin by extrusion, compression molding, or centrifugal processing, and fixing the tube thus produced or rings cut therefrom onto a boss or core, preferably of metal. The process allows high performance high molecular weight thermoplastics to be employed.

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ELECTRONIC POWER ASSIST STEERING WORM GEARS

BACKGROUND OF THE INVENTION

1. Field of the invention

The invention is related to a process for making plastic hybrid worm gears and gear blanks using gear rims of synthetic materials, especially thermoplastic materials.

2. Background of the invention

In electronic power steering systems (EPS) many different types of worm/worm gear sets are used. For reasons of noise reduction, lower coefficient of friction and wear reduction, one of the components or the gear portion of that component is usually made of synthetic, thermoplastic material, preferably the worm gear.

Currently two technologies are used to produce worm gear sets. Such a worm gear may consist of a cast nylon ring of PA6 or a PA6/PA 12 blend, which is pressed on or cast over a mostly metallic hub (metal boss) and then fused together by induction heating.

The disadvantage of the above-mentioned process is that the nylon ring is only usable to a temperature up to about 80°C. However, if the product, for example a worm gear, is to be used in the motor compartment of a automobile or in another environment in which higher temperatures are possible, such a product should not be used.

Another type of worm gear is produced by injection molding a filled or non-filled synthetic material, generally based on polyamide (PA) 6, 6.6, 4.6, 12, PPA, or blends thereof; and also polyphenylenesulfide (PPS); polyamide-imide (PAI); and polyetheretherketone (PEEK); is directly fixed (by over-mold) to a hub, usually one having a metallic structure. In both cases one or more heat treatments are required to reduce the stresses in the products and/or to obtain required dimensional stability of the end product.

The disadvantage of the above-mentioned process is that the process of injection molding leads to a product, i.e. a worm gear, which is not stress resistant to the extent required by the application as mentioned above.

Many of these processes and products have been described in the prior art, for example JP-A-2002/172703 for a "resin molding having metal boss and its manufacturing method", JP-A-2002/079581 for a "manufacturing method for resin molded article having metal boss", JP-A-2002/370290 for a "method for fixing metal boss to thermoplastic resin molding", and JP-A-2003/118006 for a "resin molded article having metal boss and method manufacturing the same".

DE-A-101 27 224 discloses the production of a worm gear by a molding process of a thermoplastic to a metal core. This process, however, includes all the disadvantages of the prior art. A similar disclosure is included in JP-A-2002/248649. It would be desirable to provide a process for the manufacture of worm gears which does not share the deficiencies of previously disclosed processes.

SUMMARY OF THE INVENTION

An object of the invention is to provide a production process for worm gear parts comprising fewer steps and/or having higher quality. This and other objects are provided by a process in which tubes made by extrusion technology are employed. According to a first aspect of the invention,the object of the invention is solved by a process for forming an article comprising a boss, preferably a metal or metal-containing boss, and a synthetic resin outer part (102), preferably a thermoplastic resin outer part, the outer part surrounding a periphery of the metal boss, this process comprising the steps of: (a) extruding, compression molding, or centrifugal processing of tubes, optionally followed by machining, to the required dimensions, (b) cutting off rings from the tubes in an appropriate length, and (c) fixing a ring produced by step (b) onto the boss. As a principle result of the invention, the process leads to products with a lower internal stress level and better dimensional stability; higher wear resistance due to the higher molecular weights which can be used as compared to injection molding; and lower production expense.

According to another aspect of the invention an object of the invention is solved by a process for forming an article preferably comprising a metal boss or a metal-containing boss, and a synthetic resin outer part, preferably a thermoplastic resin outer part, the outer part circumscribing the metal boss, this embodiment comprising the steps of: (a) extruding, compression molding, or centrifugal processing of tubes in the required dimensions, optionally aided by machining steps, (b) fixing tubes produced by step (a) on a preformed core, and (c) cutting off rings from the

tubes fixed on a preformed core in an appropriate length.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates one embodiment of the invention wherein an extruded resin material is cut and then combined with metal rings, and

FIGURE 2 illustrates a further embodiment of the invention wherein the extruded resin material is directly combined with a metal rod and cut thereafter.

DETAILED DESCRIPRTION OF THE PREFERRED EMBODIMENT(S)

Both of the above-mentioned embodiments allow the production of tubes in a wide variety of materials and formulations thereof, including, for example but not by limitation, fillers, lubricants, copolymers, reinforcing fibers, etc. Preferred materials include the above mentioned PA based materials, POM, PPA, PPO, PPS, PEEK, PAEK and PEKK, PAI and LCP. Also, co-extrusion of more than one material or formulation is possible in order to obtain optimal properties in relation to the function of the particular layer, for example the gear layer and the layer which facilitates attachment to the hub. Extrusion and centrifugal molding make it possible to use materials with higher thermal capabilities to meet more demanding applications than those which can be achieved with monomer cast nylon 6 or nylon 12.

Further details, features and advantages of the objects of the invention are obtained from the description of the relevant drawings wherein, for example, two methods according to the present invention are explained.

One application of products produced by the inventive process pertains to worm gears for EPS-systems. Such worm gears are rated as a "safety part" in the automotive industry. Manufacturers of EPS-systems thus require materials and products without internal stress in order to assist in preventing breakage during use. The processes described herein for producing tubes from thermoplastic materials (extrusion, compression molding, and centrifugal processing) all provide products with a very low stress level, thus fulfilling the aforementioned needs of the automotive industry. Especially when compared with injection molded products, the inventive processes exhibit significant advantages by offering much higher safety levels.

There is a trend in the automotive industry to place EPS-systems "under the hood (bonnet)", close to the engine. Therefore all components of an EPS-system are exposed to higher temperatures, which are typically above 120°C. As a consequence, standard Polyamides are not usable in such applications due to their physical and thermal properties. For the same reason, casting of tubes made of Polyamide 6 is also no longer an option, so that injection molding of temperature-resistant thermoplastic materials would be the only alternative. The current invention offers another option with the significant advantages of lower stress level compared to injection molding. This includes the possibility to choose from a wide variety of temperature-resistant materials to respond to more specific technical requirements.

Another innovative aspect of the present invention is the fact that one can directly influence the properties of the thermoplastic tube by adjusting the process parameters. In particular, the need for increased toughness can be met by using resins with high molecular weight, which is often not possible in injection molding processes due to higher melt temperature and melt viscosity.

One first embodiment according to the present invention is described in more detail by means of Fig. 1.

The process of producing the worms/worm gear of the invention starts with the extrusion of tubes 101 in the required dimensions. From these tubes, rings 102 in appropriate length are cut off (process 110), if required machined to size, cleaned by a solvent if necessary, and pressed (process 111) onto a hub 103. These hubs are preferably metallic hubs made by a machining, sintering, forging, and/ or metal injection molding process, including blanking, and are cut into corresponding rings. According to a preferred embodiment of the invention, the process of pressing the ring onto the hub is facilitated by using the residual heat of the extrusion process. According to an alternative embodiment, however, further heat can be used for step 111. After pressing the ring 102 onto the hub 103 the device is cooled down (process 112). By secondary fusion (process 113) the product is fixed to the hub 103. This secondary fusion is preferably performed by means of induction coils 200 around the preformed rings. Depending on the material used and the required dimensions an annealing cycle (not shown in Fig. 1) may be used. In a final machining process 114 the product is separated into composite disks, if not already in this form, which then can be cut to a gear.

It is preferable that the inside diameter of the synthetic material ring be somewhat smaller than the outside diameter of the metal hub.

The process according to this embodiment can be used for all of the currently used materials as well as the ones mentioned above. Additional advantages occur in case of semi-crystalline/amorphous materials. By extruding at low temperatures and keeping the inside surface of the extruded tube below the Tg of the polymer in combination with quick cooling after extrusion, the material on the inside will stay amorphous (first layer). After cutting the rings and preheating to temperatures just above the Tg the amorphous layer will allow the ring to be pressed on the tube easily and with low stress buildup. During the fusion the material will be heated up to allow the crystallization of the former amorphous phase. Using this process leads to products with far lower stress levels and better wear properties than comparable products made through injection molding. In addition, the security of the application is increased, as in the injection molding process, the danger of void formation due to material shrinkage during cooling is a well known problem. However, void formation is totally absent in an extrusion process.

The hub may be made by any suitable process, and may be supplied in precut lengths, as billets of moderate length, or as a continuous or substantially continuous product. The surface is preferably "textured" to facilitate firm mating with the resin outer part. Various kinds of texturizing may be employed, such as the use of a sand blasted surface, a threaded or grooved surface, etc. A knurled surface, preferably one with a diamond pattern, is preferably used.

The hub is preferably of metal, all or in part. However, non-metallic hubs may also be useful in some applications. In general, the material of the hub will have higher strength properties than the "outer" which will be cut or machined into the gear. Examples of suitable thermoplastic materials include, without limitation, the polymers identified earlier, as well as thermoset polymers such as epoxy resins, bismaleimide resins, polyurethane resins, and the like. The hub material will in general have a different physical property profile than the gear outer, due to the different requirements of these respective portions of the hub, and in general will have higher hardness and temperature resistance, i.e. when a thermoplastic, will have a higher melt temperature than the gear layer. For improved strength requirements, such non-metallic hub materials may be fiber reinforced, e.g. with glass, carbon, or aramid fibers or the like.

The thermoplastic or thermoset hub materials may also contain metal particles so that induction heating can still be used for fusing a thermoplastic outer to the hub. In similar fashion, a hybrid hub can be prepared by filling a metal tube with the hub material. The tube, following pressing onto the gear outer, can be readily induction heated to fuse the tube and the outer together.

In the embodiment according to Fig. 2 the tubes 101 are continuously or semi-continuously extruded (process 120) or centrifugally molded onto a preformed core 105, resulting in an intermediate product 121. By fusion 113 the extrusion product is fixed to the core 105 according to the previous embodiment by means of induction coils 200 around the preformed product. In a final machining process 122 the product is finished by cutting and blanking.

The process of the invention includes several alternatives which can be described as follows:

"cable extrusion"
In this process the material is continuously or semi-continuously extruded on a preformed core. The core is either formed in billets (Fig. 1) or "endless" (Fig. 2).

"online"
The extrusion heat is used to press the rings on the hubs "on line".

"Offline"
The tube and rings are cooled down and assembled "off line"

The skilled artisan can choose a process largely depending upon the form of the hub and the required tolerances and performance criteria as ordered by the customer and thus will select the most appropriate process in accordance with these constraints.

Examples

The following are provided as examples of the subject EPS invention being put to practice:

Example 1

UHWM (Ultra high molecular weight polyethylene) rod stock was fused to a carbon steel (SAE 1117) core using a 1 KHz induction unit. The procedure was as follows:

1. The extruded UHMW rod was machined into a tubular geometry with the ID being machined to a dimension

that was 2% smaller than the outside diameter of the steel (core) insert. The approximate dimensions were 3"OD x 2" ID x 6" length (7.6 cm x 5.1 cm x 15.2 cm).

2. The UHMW tube was heated to 65°C in an oven for 30 minutes in order to help it stretch over the steel insert.
3. The steel insert which had a knurled outside diameter (12 pitch diamond knurl) was pressed into the heated UHMW tube using a small pneumatic press.
4. The assembly was cooled to room temperature.
5. The assembly was placed inside an induction coil and induction heated so that the steel surface reached a temperature above the melting point of the UHMW. The exact time and surface temperature was selected by observation of a melt bead that forms at the steel-polymer interface. In this case, the power level and time chosen resulted in a cycle time of 30 seconds and a surface temperature of the steel of 135°C.
6. The assembly was cooled to room temperature
7. The 6-inch (15.2 cm) lengths were saw cut to shorter length pieces.

Example 2

UHWM rod stock was fused to an aluminum core using a 1 KHz induction unit. The procedure was as follows:

1. The extruded UHMW rod was machined into a tubular geometry with the ID being machined to a dimension that was 2% smaller than the outside diameter of the aluminum (core) insert. The approximate dimensions were 3"OD x 2" ID x 6" length (7.6 cm x 5.1 cm x 15.2 cm).
2. The UHMW tube was heated to 65°C in an oven for 30 minutes in order to help it stretch over the aluminum insert.

3. The aluminum insert which had a knurled outside diameter (12 pitch diamond knurl) was pressed into the heated UHMW tube using a small pneumatic press.
4. The assembly was cooled to room temperature.
5. The assembly was placed inside an induction coil and induction heated so that the aluminum surface reached a temperature above the melting point of the UHMW. The exact time and surface temperature was selected by observation of a melt bead that forms at the aluminum-polymer interface. In this case, the power level and time chosen resulted in a cycle time of 2 minutes and a surface temperature of the aluminum of 135°C.
6. The assembly was cooled to room temperature
7. The 6 (15.2 cm)inch lengths were saw cut to shorter length pieces

Example 3

Torlon PAI tube stock was fused to a carbon steel (SAE 1117) core using a 1 KHz induction unit. The procedure was as follows:

1. The extruded Torlon PAI rod was machined into a tubular geometry with the ID being machined to a dimension that was 1% smaller than the outside diameter of the steel insert. The approximate dimensions were 2.5"OD x 2" ID x 6" length (6.4 cm x 5.1 cm x 15.2 cm).
2. The Torlon PAI tube was heated to 200°C in an oven for 45 minutes in order to help it stretch over the steel insert.
3. The steel insert which had a knurled outside diameter (12 pitch diamond knurl) was pressed into the heated Torlon PAI tube using a small pneumatic press.
4. The assembly was cooled to room temperature.

5. The assembly was placed inside an induction coil and induction heated so that the steel surface reached a temperature above the glass transition temperature of the Torlon PAI (285°C). The exact time and surface temperature was selected by observation of a melt bead that formed at the steel-polymer interface. In this case, the power level and time chosen resulted in a cycle time of 40 seconds and a surface temperature of the steel of 315°C.
6. The assembly was cooled to room temperature.
7. The 6-inch (15.2 cm)lengths were saw cut to shorter length pieces.

Example 4

Stanyl PA4.6 plate stock was fused to a powder-metal formed insert using a 1 KHz induction unit. The procedure was as follows:

1. The extruded Stanyl PA4.6 plate was machined into a ring-shaped geometry with the ID being machined to a dimension that was 2% smaller than the outside diameter of the p/m steel inserts. The approximate dimensions were 4.625"OD x 2.75" ID x 1" length (11.8 cm x 7.0 cm x 2.5 cm).
2. The Stanyl 4.6 rings were heated to 150°C in an oven for 30 minutes in order to help them stretch over the p/m steel inserts.
3. The steel inserts which had a knurled outside diameter (12 pitch diamond knurl) were pressed into the heated Stanyl PA 4.6 rings using a small pneumatic press. The outer knurled surface was treated with a silane mixture to promote adhesion of the plastic phase to the steel insert.
4. The assemblies were cooled to room temperature.
5. The assemblies were placed inside an induction coil and induction heated so that the steel surface reached a temperature above the melting point of the

Stanyl PA 4.6 (290°C). The exact time and surface temperature was selected by observation of a melt bead that forms at the steel-polymer interface. In this case, the power level (50 kW) and time chosen resulted in a cycle time of 15 seconds and a surface temperature of the steel of 329°C.

6. The assemblies were cooled to room temperature.

It is expected that in a full production process, the resin outer part will be extruded into a tube having the desired inside and outside diameters so as to avoid or minimize machining processes. However, the use of rod stock and sheet stock as in the Examples illustrate the flexibility of the process, particularly in "one-off" products or short production runs which render separate extrusion of unique outer profiles less economical.

Claims

1. A process for forming a composite gear blank (104), comprising a boss, preferably a metal or metal-containing boss (103), and a synthetic resin outer part (102), preferably a thermoplastic resin outer part, said outer part enclosing said boss (103) in a circumferentially adjacent manner, said process comprising the steps of:

   (a) extruding, compression molding or centrifugally processing a tube (101) in the required dimensions,
   (b) cutting off rings (102) from said tubes in an appropriate length
   (c) fixing said ring (102) produced by step (b) around said boss (103).

2. The process according to claim 1, wherein the residual heat of the extrusion process is used for step (c).

3. The process according to claim 1 or 2, wherein additionally added heat is used for step (c).

4. The process according to any of claims 1 to 3, wherein an annealing cycle (d) is added.

5. The process according to any of claims 1 to 3 wherein said boss is a metal or metal-containing boss.

6. A process for forming a composite gear blank comprising a boss, preferably a metal or metal-containing boss, and a synthetic resin outer part, preferably a thermoplastic resin outer part, said outer part enclosing said boss in a

circumferentially adjacent manner, said process comprising the steps of:

(a) extruding, compression molding or centrifugally processing of a tube (101) in the required dimensions,
(b) fixing said tube produced by step (a) onto a preformed core (105), and
(c) cutting off rings (104) comprising a length of said tubes (101) and a length of said preformed core (105).

7. The process according to any of claims 1 to 6, wherein said material (101) is continuously or semi-continuously extruded.

8. The process according to claim 6 or 7, wherein said core (105) is endless.

9. The process according to any of claims 6 - 8 wherein said core is a metal core or a metal-containing core.

10. The process of any of claims 1 - 5 wherein said boss has a textured surface.

11. The process of claim 10 wherein said textured surface is a knurled surface.

12. The process of any of claims 6 to 9 wherein said core has a textured surface.

13. The process of claim 12 wherein said textured surface is a knurled surface.

14. The process of any of claims 1 to 13, wherein said tube is produced by coextruding at least two thermoplastics in concentric layers.

15. The process of any of claims 1 to 14, further comprising induction heating the gear blank following fixing in step c) to a temperature above the melt temperature of the thermoplastic.

16. The process of any of claims 1 - 15 wherein the tube is of semi-crystalline or crystallizable amorphous thermoplastic and extruded such that an inside diameter of the tube remains amorphous, further comprising heating the tube prior to the step of fixing (c) to just above the Tg of the thermoplastic, followed by further heating after fixing to crystallize the thermoplastic.

17. The process of any of claims 1 - 16 wherein said tube has an inner diameter which is smaller than the outer diameter of the boss or core prior to said step of fixing (c).

18. A worm gear or worm/worm gear combination, characterized in that a worm gear blank is produced according to any of claims 1 to 17, and the synthetic resin outer part is machined into a worm gear.

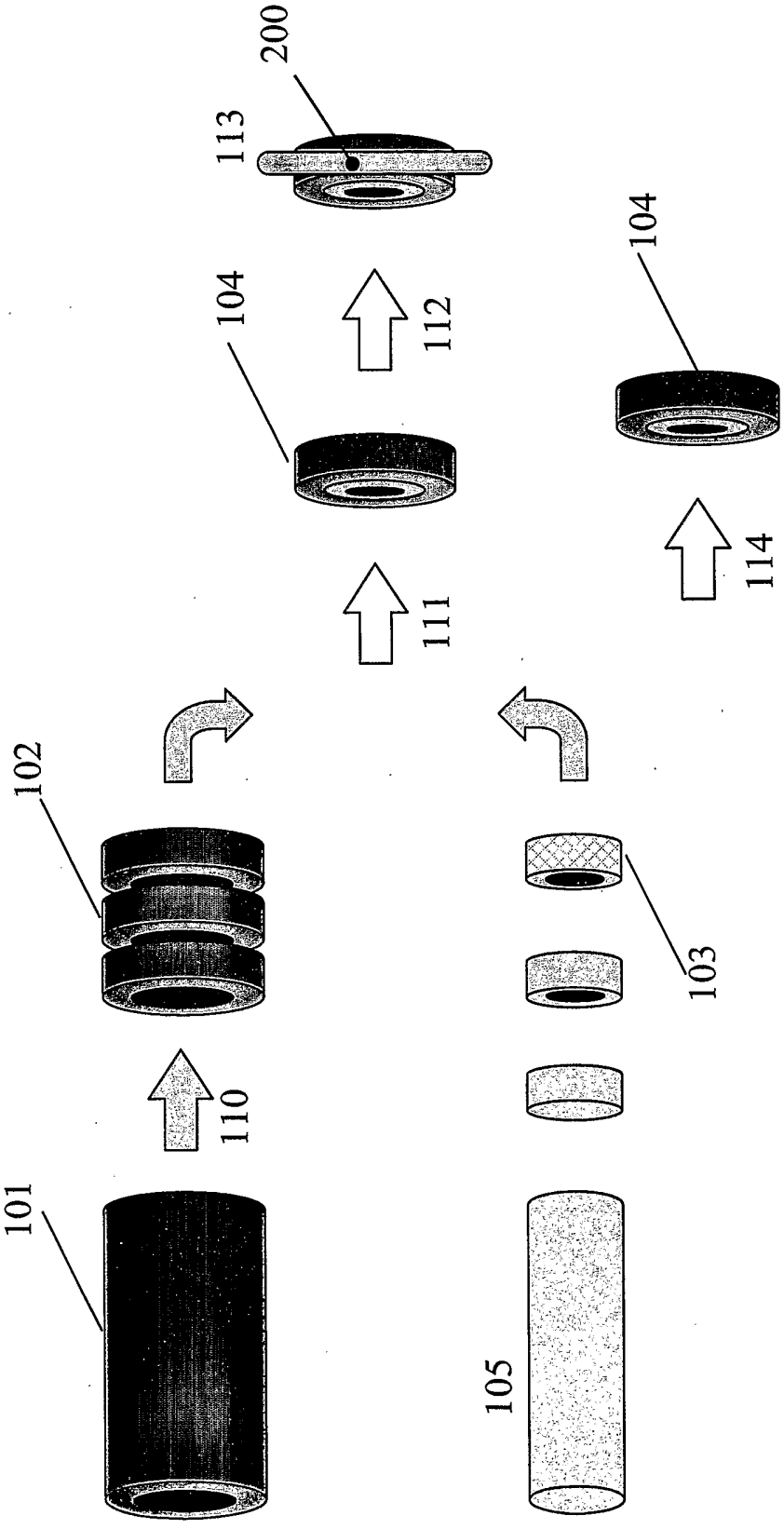


Fig. 1

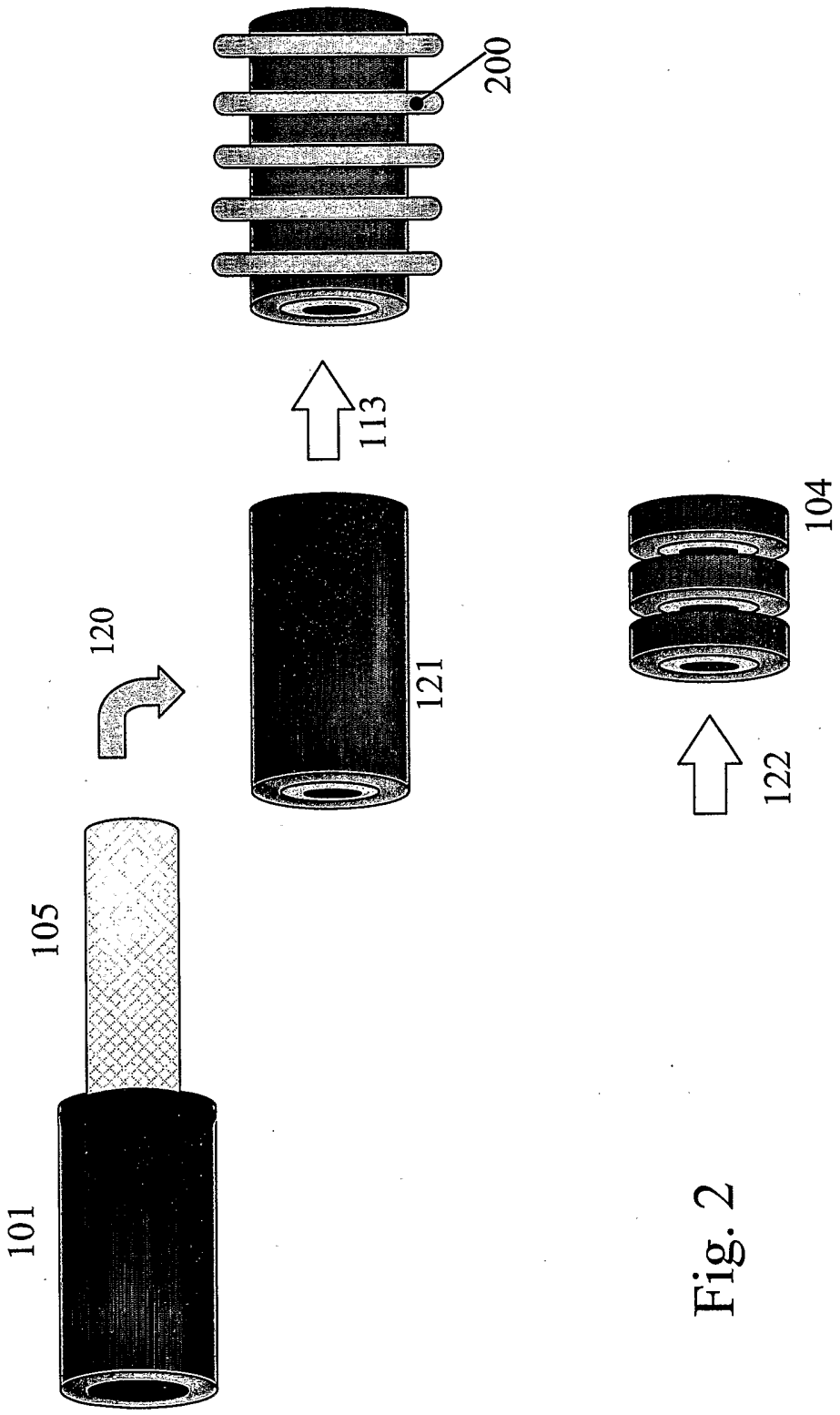


Fig. 2