INJECTION MOLDING USING A COMPOSITE STRUCTURE INSERT WITHIN THE MOLDING CAVITY

An injection molded reinforced structure (20) is prepared by providing an injection mold (40) having an injection molding cavity (42), and preparing a freestanding injection-mold insert (60) conforming to at least a portion of the shape of the injection molding cavity (42). The insert (60) preferably is formed of reinforcing fibers embedded in an insert thermoplastic resin matrix. The insert (60) is placed into the injection molding cavity (42), and an injection thermoplastic resin is injected into the injection molding cavity (42) and thence around the insert (60), thereby forming the injection molded reinforced composite structure (20).
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INJECTION MOLDING USING A COMPOSITE STRUCTURE INSERT  
WITHIN THE MOLDING CAVITY

BACKGROUND OF THE INVENTION

This invention relates to the production of nonmetallic articles, and, more particularly, to improving the strength properties of injection molded articles.

In injection molding, an organic resin is heated to a temperature at which it is flowable, and then injected into a mold cavity by an injection apparatus. The resin quickly cools and hardens into the shape defined by the interior of the mold cavity, or is cured within the mold cavity. The article is ejected from the mold, cleaned, and trimmed. Multi-station machines have been developed to manufacture injection molded articles rapidly and inexpensively.

Articles made by injection molding are widely used in commerce. For many such articles, there is no requirement of more than a minimal strength and no requirement for achieving good mechanical properties at elevated temperatures. For these articles, ordinary resin materials may be rapidly formed to shape by injection molding and are fully serviceable.

Other articles require higher strengths in service, at room temperature and also at elevated temperatures in some cases. High-temperature resins have been developed responsive to the need for strength at elevated temperatures. Fillings such as hard particles and/or short fibers may be mixed and co-injected with the thermoplastic resin, resulting in a composite structure for the article that achieves higher strength without significantly higher weight.

The fillings are limited to generally equiaxed particles and relatively short fibers, because longer fibers increase the viscosity of the thermoplastic resin in the injection molding apparatus so that it is difficult or impossible to force the resin mixture into the mold. The positioning and orientation of the injected short fibers is determined by the patterns of fluid flow during the resin injection, so that it is normally difficult or impossible to ensure that the short fibers would be oriented as needed to optimize the properties of the final article. Additionally, the hard
particles and fibers are highly erosive to the injection molding equipment. The barrel of the injection molding apparatus used to inject thermoplastic resins with hard particles and/or fibers embedded therein must be of specially selected and made of expensive alloys, and even then the erosion rate is usually quite high.

The inventors have recognized a need for an improved approach to the injection molding of articles which require good room-temperature and elevated-temperature mechanical properties. The present invention fulfills this need, and further provides related advantages.

SUMMARY OF THE INVENTION

The present invention provides an approach to the fabrication of articles by injection molding, which allows the articles to have improved mechanical properties, at both room and elevated temperatures. The improvement in mechanical properties is controllable as to direction and magnitude. The improvement may be achieved with little added weight or little added cost.

In accordance with the invention, a method for fabricating an injection molded reinforced structure comprises the steps of providing an injection mold having an injection molding cavity, and preparing an injection-mold insert made of a nonmetallic composite material. The method further includes placing the insert into the injection molding cavity, and injecting an injection thermoplastic resin into the injection molding cavity and hence around the insert, thereby forming the injection molded reinforced composite structure.

The final injection molded article thus comprises an injection molded body having an insert embedded therein. The body is an injection thermoplastic resin and the insert comprises elongated fibers embedded in an organic matrix.

Most preferably, the injection molding insert is a reinforced composite element formed of long reinforcing fibers embedded in an insert thermoplastic organic matrix. Any operable reinforcing fibers and any operable thermoplastic organic material may be used in the insert, but preferably the insert thermoplastic organic material is the same as the injection thermoplastic organic material.

The insert may be formed in any operable manner. In a preferred approach, the insert is made by providing a piece of a composite material of
reinforcing fibers embedded in an insert thermoplastic resin matrix, heating the piece of composite material to a forming temperature at which the resin matrix becomes plastically formable, and press forming the piece of the composite material to a shape of about that of a portion of the interior of the mold cavity, while the piece is at the forming temperature. In another approach, the insert is made by providing a piece of a composite material of reinforcing fibers embedded in an insert thermoplastic resin matrix, and cutting the insert from the piece. In yet another approach, the insert is prepared by a layup (collation) approach on a form. In each case, the insert is a freestanding article prepared prior to the injection molding operation and inserted into the mold prior to the injection molding operation.

This approach allows the strength of the article to be increased significantly. The directional nature of the strength increase is controllable, because the insert may be prepared to have an anisotropy which yields the desired directional properties, and also because the location and geometry of the insert may be selected to achieve the desired final properties of the article. In a typical example, it is estimated that the use of an insert of elongated fibers in an insert thermoplastic resin with 10 percent of the volume of the final article results in a 50 percent increase in strength and/or stiffness. The insert may be made of a combination of materials and with a size, shape, and orientation that produces the required mechanical properties, with little or no increase in weight of the article and no change in its size, shape, or functionality.

Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. The scope of the invention is not, however, limited to this preferred embodiment.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1A is a perspective view of a typical article made by the approach of the invention;

Figure 1B is a sectional view of the article of Figure 1A, taken generally
along lines 1B-1B;

Figure 2 is a block flow diagram of a preferred approach for practicing the invention;

Figure 3 is a schematic view of an injection mold and injection molding apparatus;

Figure 4 is a schematic view of an injection-mold insert used with the article of Figure 1;

Figure 5 is a perspective view of another, more complex injection-mold insert made according to the approach of the invention; and

Figure 6 is a perspective view of the insert of Figure 5 in relation to the final article, which is injection molded using the insert.

**DETAILED DESCRIPTION OF THE INVENTION**

The invention is most readily described in relation to a specific article made by its approach, but the use of the invention is not limited to this article. For illustrative purposes, Figures 1A and 1B depict in perspective and sectional views, respectively, a handlebar bar end 20 attached to the ends of the handlebars of specialty bicycles such as mountain bicycles. The bar end 20 includes a hollow cylindrical portion 22 and an attachment 24 with a bore 26 therethrough to slip over the end of the handlebar of the bicycle. A slot 28 allows the bore 26 to be deformed slightly to slip over the end of the handlebar. The bar end 20 desirably has a contoured hand grip 29 in the exterior surface of the hollow cylindrical portion 22 so that it may be comfortably gripped by the rider. The bar end is about 9 inches in overall length.

The bar end is conventionally made of aluminum metallic alloy tubing by a casting/forging, machining, and welding procedure. The resulting article is heavy, not aesthetic, and not ergonomic. Additionally, the aluminum bar end is susceptible to fatigue failures in service when loads are applied toward the end of the long lever arm. The hand grip 29 must be machined into the aluminum, adding a further manufacturing cost. As noted, such a bar end is now normally used only on expensive specialty bicycles due to its high cost of manufacture. It would be desirable to provide such a feature on less costly bicycles, but to date the
cost of manufacture of the bar end has prohibited its use on lower-cost bicycles. One alternative approach to the manufacture of the bar end is to form it from a plastic resin material, but this is not currently feasible because all known plastic resin materials have insufficient strength for this application.

Figure 2 depicts a procedure for the preparation of an article by the approach of the invention. The description, for illustrative purposes, is presented for the bar end 20, but substantially the same approach would be used for other articles as well. An injection mold and injection molding apparatus are provided, numeral 30. Figure 3 depicts a preferred embodiment of the injection mold and injection molding apparatus, for this application. An injection mold 40 is a metallic split mold, typically made of steel, with a mold cavity 42 therein defining the shape of the desired article to be produced. In this case, the interior surface of the mold cavity defines the finished exterior shape of the bar end, including the features of the hand grip region. Core inserts 43a and 43b define the interior hollow portion of the cylindrical portion 22 and the bore 26 of the final article, respectively. The mold may be cooled by water cooling lines running therethrough (not shown). The mold 40 is split so that the finished article may be removed therefrom. In this case, the mold 40 is split in the plane of the view, with a top matching half of the mold removed in Figure 3. The mold 40 has an entry port 44 so that a flowable plastic resin may be introduced into the mold cavity 42, and a vent 46 so that air and excess flowable plastic resin may flow out of the mold cavity during the injection molding operation.

An injection molding apparatus 48 includes an injector 50 and a tube 52 leading to the entry port 44 of the mold 40. The material to be injected, typically an organic resin material that is a solid at room temperature, is introduced into the injector through a material supply 54. Inside the injector, the injection resin is heated to a point at which it is fluid. Upon demand, the fluid resin is forced through the tube 52 and into the mold cavity 42. The resin cools and hardens, the split mold is opened, and the injection molded part is ejected. Injection molding apparatus and molds are known for other applications.

An insert 60 is prepared, numeral 32 of Figure 2. The insert 60, shown in Figure 4 for the preferred case of the bar end 20, may be any operable composite material structure. In the preferred approach, the insert 60 is made from a
composite material of long, continuous fibers embedded in an insert resin matrix. The fibers may be, for example, carbon, glass, or kevlar. The insert resin may be either a thermosetting or a thermoplastic resin, but a thermoplastic resin is preferred for manufacturing reasons to be discussed subsequently. Operable thermoplastic resins include, for example, polypropylene, nylon, polyurethane, ABS, polyphenol sulphide (PPS), polyetheretherketone (PEEK), and polyetherimide (PEI).

In one manufacturing approach for the insert, an insert precursor is laid up with tows of resin-impregnated fibers or sheets of prepreg material, in each case using an insert thermoplastic resin. The fibers are arranged as desired for the required strengthening of the article. In the case of the insert 60 for the handlebar bar end 20, the fibers are oriented lengthwise along the length of a flat sheet, numeral 61 of Figure 4. The precursor layup sheet is locally heated to a temperature at which the insert thermoplastic resin is solid but deformable, and bent to the "U" shape shown in Figure 4 with unequal-length arms. Alternatively, the insert may be constructed by other techniques such as a layup onto a form. (The latter is not preferred for the specific case of the bar end insert of Figure 4, but it may be useful for other types of inserts.) In any case, the insert is prepared as a freestanding article in a separate operation from (and prior to) the injection molding operation.

The insert 60 is placed into the injection molding cavity 42, numeral 34, as shown in Figure 3. In this case, the insert 60 is present in only a portion of the final article, the attachment region 24 where it provides added strength and stiffness to this region which is most susceptible to premature failure. The insert 60 may also, if desired, extend into the cylindrical portion 22 to improve its strength and stiffness. If the insert 60 extended into the cylindrical portion 22, it may be made in a locally cylindrical form. The insert 60 is typically supported in the cavity 42 in a desired position along the center of the cavity and spaced apart from its walls by small spacers 62. A clearance 64 is thereby maintained between the insert 60 and the walls of the cavity 42.

An injection thermoplastic resin is injected into the cavity 42 (with the mold halves closed) from the injector 50, numeral 36. The injection thermoplastic resin fills the clearance 64 portion of the mold cavity 42, surrounding the insert
60 so that the insert lies entirely within the interior of the finished article. After the injection thermoplastic resin cools, the mold is opened, and the article is removed (ejected) from the mold. To finish the article, it is typically necessary only to remove the excess material attached to the article at the locations of the entry port and the vent.

The injection thermoplastic resin may be the same material as the insert thermoplastic resin, or different thermoplastic resins may be used. Preferably, the injection thermoplastic resin and the insert thermoplastic resin are the same, to avoid chemical and physical incompatibility. On the other hand, in some articles it may be desirable to use a strong, hard resin for the insert thermoplastic resin, and a softer, more pliable and more comfortable feeling thermoplastic resin as the injection thermoplastic resin.

This approach is distinct from the known co-injection approach of mixing particles or fibers into the injection resin in the injection molding apparatus 48, and then injecting the mixture into the mold 40. In the present approach, the insert 60 is prepared as a freestanding article prior to its insertion into the mold 40, so that its geometry and orientation of fibers may be carefully tailored to yield exactly the required properties in the final product. There is no reliance on orienting the fibers during the injection molding operation. In the prior co-injection approach, the locations and orientations of the fibers cannot be readily controlled, and the lengths of the fibers which may be co-injection are limited by the requirements of the injection-molding operation. The co-injection approach may be used in conjunction with the present invention, so that a mixture of particles or short fibers is mixed into the injection thermoplastic resin in the injection molding apparatus 48, and injected into the mold cavity 42 where the composite insert is already present.

The present approach is also distinct from the known approach wherein loose fibers (i.e., not in the form of a freestanding insert) are placed into the mold 40 prior to the adding of the injection resin. In this prior approach, as in co-injection, the locations and orientations of the fibers cannot be readily controlled.

The insert 60 used for the bar end 20 is a relatively non-complex piece, as dictated by the requirements of the bar end. The insert 60 may be more complex. Figure 5 shows a Y-shaped hollow tubular insert 70 which is fabricated as three
freestanding pieces and thereafter placed into the mold cavity prior to injection of
the injection thermoplastic resin, as shown in Figure 6. The insert 70 is preferably
prepared by laying up (collating) pre-impregnated tows or prepreg precursor
composite materials onto appropriate forms, and thereafter curing the laid-up
composite material. In this case, the final article 72, shown in dashed lines in
Figure 6, is a Y-shaped piece that would be used as a joint, with the interior insert
providing strength, at the joint region, in the precise location where most needed.
Composite material fabrication technology allows the preparation of many
different types of articles with carefully tailored properties. Such articles may be
used as inserts in the present invention.

The combining of composite materials technology to prepare and form
freestanding inserts, with injection molding technology to incorporate the inserts
into functional final articles, allows complex plastic parts with selectively
designed mechanical properties to be prepared.

Although a particular embodiment of the invention has been described in
detail for purposes of illustration, various modifications and enhancements may
be made without departing from the spirit and scope of the invention. Accordingly, the invention is not to be limited except as by the appended claims.
CLAIMS

What is claimed is:

1. A method for fabricating an injection molded reinforced structure, comprising the steps of:
   providing an injection mold having an injection molding cavity;
   preparing an injection-mold insert made of a nonmetallic composite material having reinforcement embedded in a matrix;
   placing the insert into the injection molding cavity; and
   injecting an injection thermoplastic resin into the injection molding cavity and thence around the insert, thereby forming the injection molded reinforced composite structure.

2. The method of claim 1, wherein the step of preparing an injection-mold insert includes the step of
   providing an insert comprising a composite material of directionally oriented fibers embedded in a matrix.

3. The method of claim 1, wherein the step of preparing an injection-mold insert includes the step of
   providing an insert comprising a composite material of a reinforcement embedded in an insert thermoplastic resin matrix.

4. The method of any of claims 1-3, wherein the step of preparing an injection-mold insert includes the steps of
   providing a piece of a composite material of reinforcing fibers embedded in an insert thermoplastic resin matrix,
   heating the piece of composite material to a forming temperature at which the resin matrix becomes plastically formable, and
   press forming the piece of the composite material to a shape of about that of the mold cavity, while the piece is at the forming temperature.
5. The method of any of claims 1-3, wherein the step of preparing an injection-mold insert includes the steps of providing a piece of a composite material of reinforcing fibers embedded in an insert thermoplastic resin matrix, and cutting the insert from the piece.

6. The method of any of claims 1-3, wherein the step of preparing an injection-mold insert includes the step of preparing the insert by a composite layup procedure.

7. The method of any of claims 1-6, wherein the step of preparing an injection-mold insert includes the steps of providing an insert comprising a fiber-reinforced composite material wherein the fibers are selected from the group consisting of carbon, glass, and kevlar.

8. The method of any of claims 1-7, wherein the step of preparing an injection-molding insert includes the steps of providing an insert comprising at least in part an insert thermoplastic resin material selected from the group consisting of polypropylene, nylon, polyurethane, polyphenol sulphide, polyetheretherketone, and polyetherimide.

9. An article comprising an injection molded body made of an injection thermoplastic organic material, and an insert embedded in an interior of the body, the insert comprising fibers embedded in an insert organic matrix.

10. The article of claim 9, wherein the fibers are selected from the group consisting of carbon, glass, and kevlar.

11. The article of either of claims 9 or 10, wherein the insert organic
matrix is an insert thermoplastic material.

12. The article of any of claims 9-11, wherein the insert organic matrix is an insert thermoplastic material selected from the group consisting of polypropylene, nylon, polyurethane, polyphenol sulphide, polyetheretherketone, and polyetherimide.
FIG. 5

FIG. 6

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

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Date of the actual completion of the international search: 10 APRIL 1998

Date of mailing of the international search report: 22 APR 1998

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A. CLASSIFICATION OF SUBJECT MATTER:
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