

Description

BACKGROUND OF THE INVENTION

This invention relates generally to extrusion compounding of thermoplastic resin with reinforcing fibers. More particularly, a multiple extruder apparatus and process for producing a preform suitable for subsequent use in a molding operation, such as compression molding, is disclosed.

Compounding of both thermoplastic and thermosetting resins with reinforcing fibers in an extruder is known in the prior art. However, the prior art compounding apparatus and processes present problems and disadvantages which are overcome by the particular, multiple extruder system disclosed herein.

In the known prior art compounding procedures, the fibers and resins are normally introduced together into a compounding extruder in a solid state. In such a compounding operation, the fibers are broken down into very short lengths, usually less than 0.25 cm (0.10 inches), due to both the mechanical action of the extruder screw on the fibers, and the presence of thermoplastic resins in a high viscosity state when the resin begins to melt. The fibers are thus present in the extruder when the thermoplastic resin is being initially transformed from a solid to a liquid state. Upon first being converted from a solid to a liquid by a combination of mechanical working and heat, thermoplastic resins have a relatively high viscosity, which contributes to fiber breakage as the resins are intermixed with the fibers in the extruder. U.S. Patent No. 4,422,992 discloses such a compounding extruder apparatus and process. According to the disclosure of that patent, a single, twin screw extruder is utilized for both initially melting the polymer and for blending or compounding carbon fibers with the melted polymer. In a first disclosed procedure, the polymer and reinforcing fibers are both introduced into the extruder together at a supply hopper. In a second embodiment of that patent, a thermoplastic resin polymer is introduced into a first extruder zone where it is melted, and from which it is fed into a second extruder zone where the fibers are introduced. This procedure has the disadvantage that the fibers are introduced downstream of the thermoplastic resin input point in the compounding extruder. Thus, relatively cold fibers draw heat out of the melted thermoplastic resin, thereby raising the viscosity of the resin. The resulting, somewhat more viscous thermoplastic resin contributes to fiber breakage during the extruding process. This procedure has further disadvantages. The screw speed desirable for melting the resin is not necessarily the screw speed which would be most effective for compounding resin and fibers. Also, the relative volumes of the resin and fibers must be closely controlled in order to achieve the desired composite product; and it is difficult to properly match the volumes of

those two components when compounding in a single screw of specific geometry.

Applicant's U.S. Patent No's. Re. 32,772 and 4,312,917 disclose a method and apparatus respectively for making a composite consisting of reinforcing fibers embedded in a thermoplastic resin material. The fiber-reinforced composite is formed by passing extruded plastic resin through a stationary die into which continuous lengths of reinforcing fibers are introduced in the presence of the heated, molten thermoplastic resin. The continuous length fibers are pulled through the die, in which they pass over lobes and are impregnated with the molten thermoplastic resin to form an extruded, plastic member having a predetermined shape with fiber strands extending continuously, and longitudinally therein. The extruded plastic member may be cut into short, pellet-size lengths for use as a molding compound.

U.S. Patent No's. 4,393,020 and 4,500,595 disclose methods for manufacturing a fiber-reinforced thermoplastic composite. However, both patents utilize conventional, batch processes for carrying out the step of forming the polymer-fiber composite wherein the fibers are drawn through or dipped in a bath of the molten, thermoplastic resin. In U.S. Patent No. 4,393,020 a process is disclosed in which the fibers are preferably oriented in one direction in the resin-fiber composite, and in both patents, the composite may have relatively long fibers, and is used to mold end products, as by injection molding.

Compression molding has certain advantages over injection molding, one of which is the capability of producing molded parts with significantly longer reinforcing fibers. The presence of the long reinforcing fibers creates plastic parts with improved mechanical properties. The plastic raw materials utilized in compression molding vary from sheet to bulk molding compounds (a puttylike mixture) to pellets. The bulk molding compound (BMC) and the pellet products are usually first converted to a preform prior to molding, but not always. The preform may be any desired shape, such as a sheet or "log" type of member which is introduced into the chamber of the compression mold. The molding compounds are made up of at least two components, including a reinforcing fiber, such as glass or carbon, and a plastic resin. Various fillers and additives, as well as colorants may be utilized in the molding compound. The plastic resin can be either thermosetting (requiring heat and pressure to increase molecular weight to form a solid substance), or thermoplastic (high molecular weight resins that require heat for melting and cold for solidifying). The vast majority of the compression molded parts today are made with thermosetting resins. Thermoplastic resins have some significant advantages over thermosetting resins when used in the compression molding process. Faster molding cycles and greater toughness in the molded articles are two of them. Thermo-

plastics have only recently been applied to compression molding. Raw material suppliers offer thermoplastic products for compression molding in two forms, sheets and pellets.

Thermosetting bulk molding compounds (TS-BMC) are in the form of a puttylike substance. The product is divided into chunks suitable in size for the intended application. This can be done by hand or in a commercially available machine that automatically produces chunks (preforms) of the correct size. The preform is placed into an open mold heated to the desired temperature. The resin melts, flows, chemically chain extends and cross links to a solid. The mold is opened and the part is removed so that the cycle is ready to be repeated. The mold is normally heated to approximately 149C - 177C (300 - 350° F). Thermosetting pellets, granules, or powder can be weighed and poured into an open mold heated to approximately the same temperature.

The foregoing molding methods show the inherent disadvantages of compression molding with a thermosetting resin product. In the mold, the resin must first melt, then flow, and then increase in molecular weight to a point where the product is a solid at the mold temperature. The result is a long cycle time. This long cycle time is costly to both the molder and the end user. This inherent disadvantage makes molding with the use of thermoplastics particularly attractive. Thermoplastics need only be cooled in the mold, resulting in substantial increases in productivity.

Thermoplastic sheet molding compounds (TP-SMC) are cut to sizes suitable for the intended application. The sheet is placed in an oven, the resin is melted, and the melted sheet is placed in an open mold heated to approximately 38C - 93C (100 - 200°F).

This temperature is significantly lower than the melting point of the thermoplastic resin. The mold is closed rapidly, causing the resin to flow, filling the mold cavity. The relatively cold temperature of the mold causes the resin to harden rapidly. The mold is opened and the part is removed, allowing the mold to be recycled. Two limitations as to this method include inconsistency in the sheet product, and the inability to modify the composite formulation.

The foregoing limitations are eliminated in thermoplastic bulk molding compounds (TP-BMC). This product is available in pellet form. The pellets are fed into a commercially available machine that melts the resin, mixes the product uniformly, and produces a precisely measured preform. This hot preform is then placed in the mold, pressed, cooled, and removed. The part-to-part consistency is controlled and additives can be added that will alter the formulation of the composite, as needed. This TP-BMC process is the newest form of compression molding. Although it eliminates the limitations of TP-SMC, it also creates

several new process difficulties.

First of all, in order to produce high physical properties in the molded article, long reinforcing fibers must be present. These long fibers are produced by cutting the TP-BMC pellet to lengths of one to two inches, typically. These long pellets are hard, rigid rods that do not handle particularly well in automated equipment. As the long pellet enters the preformer, it is often cut by the extruder screw flight as it passes the feed opening, thereby reducing the desired fiber length. Secondly, the long pellets cannot be dried in conventional dryers. Only resins that are nonhygroscopic can be molded at this time in the TP-BMC process. Some hygroscopic resins would make excellent finished parts in compression molding. Further disadvantages are that the molder must pay the cost of compounding the long fiber product into pellet form, as purchased by the molder, and multiple heat histories on the molding pellets reduce the physical properties of the finished part.

The foregoing problems and difficulties associated with prior art compression molding techniques would be eliminated if the molder could compound the thermoplastic molding product in-house in specially designed equipment that is connected to the preform-making equipment. The concept of in-house compounding by the molder is not new. However, the procedure is utilized primarily in the compression molding of thermosetting plastics, i.e. TS-BMC. Such compounding is done in mixers unsuitable for thermoplastics. Some thermoplastic injection molders also compound short fiber pellets in-house.

It is an object of the present invention to provide an improved apparatus and process for compounding long fiber (preferably 2.54cm (one inch) in length or greater) with a thermoplastic resin in an extrusion process.

According to the present invention there is provided an apparatus according to claim 1 for compounding reinforcing fibers with a thermoplastic resin comprising: a source of supply of thermoplastic resin pellets; a resin extruder having an inlet for receiving thermoplastic resin pellets from said source of supply, an outlet, and an elongated, rotatable extruding screw extending between said inlet and said outlet; pellet handling means for conveying thermoplastic resin pellets from said source of supply thereof into said resin extruder inlet, whereby thermoplastic resin pellets are mechanically pumped by said resin extruder screw from said inlet to said outlet and are thereby heated and melted; particularly characterized by a compounding extruder comprising a single, continuous straight barrel and an elongated, power screw extending therein between an inlet end and a discharge end of said barrel, said barrel having first and second inlet ports on said inlet end communicating with said power screw, said second inlet port being continuously connected in fluid flow relation to said outlet of said

resin extruder for receiving molten thermoplastic resin therefrom at a location along said elongated power screw downstream from said first inlet port, and between said first inlet port and said discharge end of said compounding extruder barrel, and said power screw having substantially continuous thread means at least along the portion thereof with which said first and second inlet ports communicate; a converging, flow restricting passage at said discharge end of said barrel of substantially less diameter than the diameter of said barrel; and a source of supply of discrete, predetermined lengths of reinforcing fibers connected to said first inlet port of said compounding extruder, and means for feeding said fibers into said first inlet port, whereby said fibers are heated and mechanically worked by said power screw and continuously confined under pressure within said screw barrel by said thread means before coming into mixing contact with molten thermoplastic resin, and said fibers are advanced by said thread means past said second inlet port for thorough initial wetting by molten thermoplastic resin, and said fibers and said thermoplastic resin intermix in said power screw to form a homogeneous, molten mass of thermoplastic resin having discrete, discontinuous lengths of reinforcing fibers randomly and homogeneously dispersed therein.

The object of the invention is realized by utilizing two separate extruders comprising a first, resin extruder and a second, compounding extruder. Discrete, predetermined lengths of reinforcing fibers are introduced into a first inlet port of the compounding extruder from a suitable source of supply. Thermoplastic resin pellets introduced into the resin extruder by pellet-handling apparatus are heated and melted therein, and forced under pressure into a second inlet port of the compounding extruder. The action of the power screw of the compounding extruder produces as an extrudate a molten mass of thermoplastic resin having discrete, discontinuous lengths of reinforcing fibers randomly dispersed therein. The mold carries out this procedure, after which the hot mixture is fed directly into the preform-making equipment and from there, directly into the compression mold, if desired.

As a result of the second inlet port being located downstream of the first inlet port, the fibers will be heated and mechanically worked by the power screw of the compounding extruder before coming into mixing contact with the molten, thermoplastic resin. This enhances the penetration and coating of the fibers by the thermoplastic resin and reduces fiber degradation at the moment of contact, which would otherwise occur if the thermoplastic resin were in a more viscous state.

A further, particularly beneficial aspect of the compounding process and apparatus resides in the weight-controlled supply of thermoplastic resin and fibers to the compounding extruder. The aforesaid

pellet-handling apparatus comprises weighing and conveying apparatus which is constructed and arranged to feed thermoplastic resin pellets into the resin extruder inlet at a predetermined weight rate. Moreover, the reinforcing fibers are also introduced from a supply source which is also weight-controlled in order to carefully monitor and control the weight rate at which the fibers are fed into the compounding extruder. Such a supply source may preferably comprise packages of continuous fiber strands from which the fibers are pulled and cut into desired, discrete lengths. The weight-controlled supply of the thermoplastic resin and reinforcing fibers can be preferably accomplished by loss-in-weight devices utilized in combination with the supply sources of the resin pellets and reinforcing fibers. By carefully controlling the raw material feeding system, the desired weight ratio of the blended mixture of thermoplastic resin and long reinforcing fibers can be achieved on a consistent basis.

Said weighing and conveying apparatus for said thermoplastic resin pellets advantageously comprises a conveyor supported on a feed scale for conveying thermoplastic resin pellets to said inlet of said resin extruder at a predetermined weight rate.

Advantageously, said source of supply of reinforcing fibers comprises continuous lengths of fibers on supply means positioned on a feed scale to serve as a fiber source, and said means for feeding said fibers comprises a pair of feed rollers rotating at a predetermined speed and positioned adjacent to said supply means, and a movable cut-off knife, and a feeder hopper positioned in fiber-receiving relation to said feed rollers and having an outlet connected to said first inlet port of said compounding extruder, whereby said feed rollers pull continuous lengths of fibers from said supply means and said cut-off knife cuts the fibers to said predetermined lengths, with the cut fibers being received in said feeder hopper, from which they are conveyed into said first inlet port of said compounding extruder.

Advantageously, a computer is connected in signal-receiving relation with said weighing apparatus for said fibers and in signal generating and sending relation with said feed rollers, said computer being programmed to provide a predetermined input feed rate of fibers, and said computer providing signals to said feed rollers to adjust said predetermined speed thereof in response to signals received by said computer from said fiber-weighing apparatus indicating the weight of fibers being fed from said source of supply.

A preforming device for forming the extrudate from said compounding extruder into a predetermined size, weight and shape of preformed mass may be connected in fluid-flow relation to said discharge end of said compounding extruder. Advantageously, said preforming device comprises an extruder having

a power screw rotatably and reciprocally movable therein, said preforming extruder having an outlet chamber in which a measured volume of a preformed mass of a homogeneous mixture of thermoplastic resin and reinforcing fibers is produced in the shape of an elongated billet. Alternatively said preforming device comprises a pair of rollers having an input side and an output side and defining a nip, said input side being in fluid-flow communication with said discharge end of said compounding extruder to receive extrudate therefrom, whereby the extrudate is formed as a sheet-shaped preform by passing through said nip between said rollers, and further including a cut-off means adjacent the output side of said pair of rollers to cut sheet preforms into desired lengths.

Advantageously shuttle means is positioned to receive a preformed mass from said preforming device; and a compression-molding machine adjacent to said shuttle means, said shuttle means being reversibly movable between said preforming device and said compression-molding machine to receive preforms from said preforming device and deliver them to said compression-molding machine.

Said screw of said resin extruder and said power screw of said compounding extruder may be of different sizes and have different volume flow capacities.

Separate, power-drive means may be independently, drivingly connected to said screw of said resin extruder and to said power screw of said compounding extruder for driving said screw and said power screw at predetermined rotational speeds, whereby said screw of said resin extruder and said power screw of said compounding extruder can be independently controlled.

The present invention further provides a process according to claim 13 for compounding reinforcing fibers with a thermoplastic resin in an apparatus comprising a resin extruder having a rotatable extruding screw extending therein and a compounding extruder having a barrel defining an inlet end and a discharge end of said compounding extruder, and an elongated power screw extending within said barrel between said inlet end and said discharge end thereof, said process comprising:

rotatably driving said extruding screw and said power screw at predetermined speeds;

introducing discrete lengths of reinforcing fibers into said compounding extruder at a first inlet port on said inlet end of said barrel, and mechanically working and heating said fibers while continuously confined within said inlet end of said barrel by said power screw;

directing thermoplastic resin material into said resin extruder and heating and melting said resin material by the rotating action of said extruding screw to form a fluid, molten mass of thermoplastic resin; and

feeding said molten thermoplastic resin in a pressurized state from said resin extruder into said

compounding extruder at a second inlet port on said inlet end of said barrel downstream from said first inlet port between said first inlet port and said discharge end of said barrel and moving the mechanically worked and treated fibers by the power screw past said second inlet port, and thereby forming a homogeneous mixture of thermoplastic resin and discrete lengths of reinforcing fibers in said compounding extruder by the rotating action of said power screw, and discharging the homogenous mixture from said discharge end of the compounding extruder.

Said reinforcing fibers may be introduced into said compounding extruder in discrete lengths of at least 2.54 cm (one inch).

The process advantageously further includes discharging said mixture of thermoplastic resin and fibers from said discharge end of said compounding extruder into a preforming device as a molten mass and forming said mixture into a preformed mass of predetermined size and shape.

The aforesaid apparatus and process is preferably utilized in a compression-molding process wherein the extrudate from the compounding extruder is fed directly into a preformer. The preformer produces a compression-molding preform of desired weight which may be directly conveyed to the molding cavity of a compression molding machine. Alternatively, the compounding extrudate may be formed as sheets suitable for subsequent use as a molding material.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1 is a vertical, elevation view of an extruder apparatus;

Fig. 2 is a top, plan view of the apparatus of Fig. 1;

Fig. 3 is a fragmentary, top plan view of a portion of the apparatus of Fig. 2, partially in section view;

Fig. 4 is a fragmentary, top plan view, partially in section, of a modified form of preformer in combination with the compounding extruder of Figs. 1 - 3; and

Fig. 5 is a fragmentary, side elevation view of a modified form of sheet preformer shown in combination with the compounding extruder of Figs. 1 - 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to Figs. 1 - 3 of the drawings, reference numeral 1 generally indicates the extruding apparatus for compounding reinforcing fibers with a thermoplastic resin material. Such apparatus may be utilized in combination with a compression-molding machine as generally indicated by reference numeral

2. As is hereinafter set forth, a preform produced from the molten extrudate discharged from the extruding apparatus and comprising a mixture of thermoplastic resin with reinforcing fibers may be conveyed to the molding machine 2 for molding an article of desired size and shape.

The extrusion apparatus is comprised of a resin extruder 4, and a compounding extruder 8 connected together in fluid flow relationship in a particularly advantageous manner as hereinafter described. The resin extruder has connected to it a source of supply of thermoplastic resin material, generally indicated by reference numeral 6; and a source of supply of reinforcing fibers indicated by reference numeral 10 is connected to the compounding extruder.

The resin extruder 4 comprises an elongated, rotatable mechanical screw 12 contained within the barrel or housing 14 of resin extruder 4. Screw 12 extends lengthwise through barrel 14 between an inlet port 16 and an outlet connection 18, as is best shown in Fig. 3. As is also shown in Fig. 3, an electrical heater 20 may be utilized around the barrel 14 of extruder 4 to provide supplementary heat, in addition to that provided by the mechanical action of extruder screw 12, to assist in melting thermoplastic resin pellets introduced into extruder barrel 14 through inlet port 16.

As is indicated in Fig. 1, power screw 12 of extruder 4 may be driven by a motor 22, the output shaft of which may be connected to screw 12 by an appropriate power transmitting means 24, such as a belt drive in a conventional manner.

Thermoplastic resin is supplied to extruder 4, preferably in pellet form from a drum or container 26. Any of a variety of thermoplastic resin materials may be utilized, among which by way of example, are included polypropylene, polyethylene, various nylons, polycarbonate, styrene, styreneacrylonitrile, acrylonitrile butadiene styrene, polysulfone, polyurethane, polyphenylenesulfide, acetal resins, polyesters, polyester elastomers, such as DuPont HYTREL brand, and various thermoplastic rubbers. A vacuum loader 30 is connected to resin-pellet container 26 by way of a vacuum pickup tube 28 and serves to draw resin pellets from container 26 through tube 28 and to convey them into a thermoplastic dryer 32. Dryer 32 is of conventional design, and serves to dry the thermoplastic resin pellets to a desired level before they are conveyed into resin extruder 4. The final conveying of the pellets into extruder 4 is accomplished by way of a feeder conveyer 36, for example, in belt form as shown, and comprising a part of a loss-in-weight feed scale assembly 34. Various types of pellet conveyors may be used, including augers. All of the aforesaid pellet supply apparatus comprises pellet-handling means for conveying thermoplastic resin pellets from supply drum 26 to extruder 4, the discharge of resin pellets from belt conveyor 36 being directed into a final supply hopper 38, as shown in Figs. 1 and 2. The

bottom, discharge end of hopper 38 is connected to inlet port 16 of extruder 4. The feeder/scale assembly 34 is initially programmed to deliver thermoplastic resin pellets at a desired weight rate of flow into resin extruder 4. The scale is computer controlled.

Resin extruder 4 is mounted on a base plate 48, and its outlet connection or fitting 18 is connected to an adapter conduit 40 as shown in Figs. 2 and 3. Adapter conduit 40 is connected in fluid-flow communication between outlet connection 18 on the discharge end of resin extruder 4 and an inlet fitting 42 provided on compounding extruder 8 on inlet end section 8a. An internal flow passage 44 within adapter conduit 40 is positioned to receive the extrudate discharged through outlet connection 18 of extruder 4. A similar, internal flow passage 46 within inlet fitting 42 communicates with flow passage 44 of adapter conduit 40 and has a discharge end 46a which serves as an inlet port to the inlet end 8a of compounding extruder 8.

The mechanical action, including friction, generated by power screw 12 of resin extruder 4 on the thermoplastic resin pellets, coupled with the heat from supplemental heater 20, serves to melt the thermoplastic resin pellets within the barrel 14 of extruder 4. The thermoplastic resin thus leaves extruder 4 through its outlet connection 18 in the form of a molten mass in a fluid state, and is conveyed under the pumping action of extruder screw 12 through adapter conduit 40 into compounding extruder 8 through inlet port 46a.

Compounding extruder 8 has a barrel or housing 50 within which is contained an elongated, power screw 52 extending from inlet end 8a to outlet or discharge end 8b of extruder 8. A supplemental electric heater 54 may also be utilized as shown in Fig. 3 in embracing relation to the housing of compounding extruder 8.

Compounding extruder 8 is supported on a base pad or plate 60, which also carries a drive motor 56 and power transmitting means 58 for providing rotary power to extruder screw 52 of compounding extruder 8. As with resin extruder 4, the power transmitting means 58 is contained within a housing as shown, and is connected to the output shaft of drive motor 56. Such a power-transmitting means may take various forms, including that of a conventional belt drive.

Compounding extruder 8 has a first inlet port 62 on inlet end 8a, which is positioned upstream of molten resin inlet port 46a with respect to the direction of material flow through extruder 8, for reasons hereinafter set forth.

The source of supply 10 of reinforcing fibers is connected to first inlet port 62. The source of supply of reinforcing fibers may take various forms. It is only essential that the reinforcing fibers be supplied to compounding extruder 8 as discrete lengths of reinforcing fibers of a predetermined length, preferably in

excess of one inch at a controlled rate. For that purpose, the supply source of reinforcing fibers may preferably comprise a pair of rolls 64 held within a pair of dispensing containers or packages 66 as shown in Figs. 1 and 2. The fiber supply rolls 64 and their container 66 are positioned on a base plate 68 forming a component of a loss-in-weight scale 70 indicated in Fig. 1. Continuous lengths of reinforcing fibers 72 drawn from rolls 64 are guided between a pair of friction rollers 74 which serve to pull continuous lengths of fibers from supply rolls 64. A cut-off roller 76 is provided with a plurality of cut off blades 78. These blades serve to sever the continuous strands of fiber 72 at predetermined intervals, so as to cut the reinforcing fiber to discrete, predetermined lengths. The separate, discrete lengths of reinforcing fibers are directed into hopper 82 of a cram feeder 80 having a feed auger 84. As shown in Figs. 1 and 2, feed auger 84 is driven by a drive motor 86 having a gear reduction unit. Rotating auger 84 serves to cram or force-feed the discrete lengths of reinforcing fibers through first inlet port 62 into the inlet end 8a of compounding extruder 8.

As with the loss-in-weight scale 34 utilized for the introduction of resin pellets into extruder 4, loss-in-weight scale 70 is computer programmed so as to permit the feeding of reinforcing fibers at a desired weight rate through cram feeder 80 into inlet port 62 of compounding extruder 8. To that end, the rotational speed of fiber feed rollers 74 is controlled by signals received from the loss-in-weight scale 70. In this way, rollers 74 rotate at a predetermined speed so as to pull continuous fiber strands 72 from supply packages 66 at a desired speed for cutting into discrete lengths by blades 78. A computer 75 is shown schematically in Fig. 1 for receiving weight feed signals from scales 34 and 70 and delivering feed control signals to regulate the speed of conveyor 36 as well as the speed of feed rollers 74. Computer 75 is initially programmed to provide the predetermined formulation of resin and fiber, e.g., 60% resin and 40% fiber by weight in the extrudate, as well as to control the desired total weight input of fiber and resin in pounds per time interval.

Within compounding extruder 8, the molten thermoplastic resin and the discrete lengths of reinforcing fibers are mixed and compounded intimately in order to form a homogeneous mass. The molten mass of thermoplastic resin having discrete, discontinuous lengths of reinforcing fibers randomly dispersed therein is formed in the barrel 50 of compounding extruder 8 by the mechanical action of power screw 52 and pumped to the discharge end 8b of extruder 8 by screw 52 as extrudate. The fibers within the molten extrudate discharged from compounding extruder 8 are preferably of a length greater than 2.54 cm (one inch) to thus provide maximum mechanical strength enhancement to articles which are molded from such

extrudate. The extrudate discharged from output end 8b of extruder 8 may preferably be directed into a preforming device for forming the molten mixture of thermoplastic resin and reinforcing fibers into a predetermined size and shape to be used as a preform in a molding machine.

Particular advantages and benefits are realized by locating the inlet port 46a for the introduction of molten thermoplastic resin into compounding extruder 8 at a location along the length of power screw 52 which is downstream from the first inlet port 62 through which reinforcing fibers are received. The term downstream refers to the direction of fiber and molten thermoplastic resin flow through compounding extruder 8 from its inlet end 8a to its discharge end 8b. As a result of this particular input arrangement for the molten mass of thermoplastic resin and the pre-cut lengths of reinforcing fibers, the fibers will be heated and mechanically worked by power screw 52 along the inlet end 8a of extruder 8 before coming into mixing contact with the molten thermoplastic resin. As a result, the penetration and coating of the individual filaments making up the strands or bundles of each length of fiber will be greatly enhanced. Also, since the fibers will have been preheated along the inlet end of compounding extruder 8, they will not cool the heated thermoplastic resin and increase its viscosity. The higher the viscosity of the thermoplastic resin, the greater the propensity for degradation and breaking up of the reinforcing fibers at the moment of contact. It is to be noted that the thermoplastic resin is introduced as a molten mass from resin extruder 4 into compounding extruder 8 through port 46a at an elevated temperature which may be in a range generally between 204°C and 371°C (400°F. and 700°F.), depending upon the particular thermoplastic resin utilized.

As noted above, the extrudate mixture of molten thermoplastic resin and discrete lengths of reinforcing fibers discharged from compounding extruder 8 may be directed into a preforming device, such a device being indicated generally by reference numeral 88 in Figs. 1, 2, and 3.

The preforming device may take various forms, depending upon the particular type and shape of preform desired for a molding operation. If a log or billet-shaped preform is desired, of generally cylindrical shape, an extruding preformer comprised of a barrel or housing 90 and having a power screw 92 may be utilized. Such an extruder is provided with a drive unit 94 comprising a motor and a power transmission means for providing rotary power to screw 92 as well as reciprocal movement. An external heater 96 may also be utilized around the outside of preform extruder housing 90. An adapter fitting 98 formed with a converging internal passage 100, is preferably utilized to force the homogeneous mixture of molten thermoplastic resin and long, chopped reinforcing fib-

ers into a side port 102 of preformer extruder housing 90. Adapter 98 is connected as shown between the outlet or discharge end 8b of barrel 50 of compounding extruder 8 and side port 102 of preformer extruder housing 90. At the discharge end of extruder barrel 90, a preform chamber 104 is provided. Preferably, extruder screw 92 not only rotates, but is provided with a drive arrangement which reciprocates it back and forth along the length of extruder barrel 90, as indicated by the directional arrows in Fig. 3. A cut off knife 106 is provided across the discharge end of extruder housing 90. In operation, the rotational movement of extruder screw 100 forces molten extrudate received through adapter fitting internal passage 92 into preform chamber 104 to form a log or billet-shaped preform against the cut off knife 106. Cut off knife 106 is then raised vertically, and power screw 92 reciprocates forwardly towards preform chamber 104 so as to force a billet-shaped preform out onto a shuttle plate 108. Knife 106 is then actuated to move downwardly and cut off the preform billet to the desired length. The rotation of screw 92 causes a pressure build-up within chamber 104, in response to which screw 92 then reciprocates rearwardly to receive another charge of molten, preform extrudate from the discharge end of compounding extruder 8. Shuttle plate 108 may be arranged to reciprocate laterally back and forth on conveyor means generally indicated by reference numeral 109 in Figs. 1 and 2. Such an arrangement is used where it is desired to provide the compounding apparatus and the preformer in direct association with a molding machine indicated by reference numeral 2 for direct, combined operation by a molder. The molding machine 2 indicated generally in Figs. 1 and 2 is a compression molding machine comprised of a compression press 110 carrying a male mold-head 112 adapted to be received within a molding cavity 114. Compression press 110 is reciprocated upwardly and downwardly on guide rods 118 by a reciprocating power cylinder 116.

Thus, the preform molding material comprised of a log or billet received from preformer 88 on shuttle plate 108 is deposited into mold cavity 114. Thereafter, the mold press is operated to compress the molding material into the desired shape. The shuttle plate 108 is then conveyed back laterally on the conveyor means 109 to the position shown in Figs. 1 and 2 to receive a further preformed log or billet from the discharge end of preformer 88. The conveyor means 109 may be any type of conveyor, such as a roller or belt conveyor.

In Fig. 4 there is shown in a fragmentary, section view an alternative form of a preforming device. The preforming device as shown in Fig. 4 is generally indicated by reference numeral 120, and is shown as comprising an elongated accumulator/cylinder 122 within which a piston 124 is reciprocally mounted. A side port 128 is provided in cylinder 122 to receive

adapter fitting 98 of the same shape and configuration as shown and described above with respect to the embodiment of Figs. 1 - 3. A preform chamber 126 is provided between piston 124 and the discharge end of cylinder 122, as shown. Thus, the extrudate mixture of molten, fluid thermoplastic resin having discrete lengths of reinforcing fibers mixed therein is forced from the discharge end 8b of compounding extruder 8 by compounding screw 52 and through converging passage 100 of adapter fitting 98 and into preform chamber 126. Within chamber 126, the aforesaid extrudate is compressed against cut off knife 106 to form a preform molding charge of desired, cylindrical shape. Cut off knife 106 functions in the same way as described above with respect to Figs. 1, 2, and 3 so as to cut off the preform to a desired length as piston 124 reciprocates back and forth. The forward movement of piston 124 discharges the preform when cut off knife 106 is raised, the knife then being moved downwardly to cut off the preform to the desired length.

In some instances, it may be desirable to form the extrudate of thermoplastic resin and reinforcing fibers from compounding extruder 8 into the shape of a sheet. Such a sheet product could be utilized for compression molding as a thermoplastic, sheet-molding compound (TP-SMC). In order to accomplish this, the preform device or equipment would comprise a pair of calendaring rollers 130 and 132 which are spaced apart a predetermined distance to form a nip 134 to shape sheets of the desired thickness. The rotatably mounted rollers 130 and 132 are disposed adjacent to a special adapter fitting 136 affixed to the discharge end 8b of compounding extruder 8 as shown in Fig. 5. Adapter fitting 136 is actually a sheet-forming die and has an internal passage 138 converging at its outer end to the shape of a slot 139 of the desired length for forming sheets from the extrudate forced from the discharge end of compounding extruder 8 by power screw 52. A sheet formed in such a manner is indicated by reference numeral 140. A reciprocating cut off knife 142 is mounted as shown at the output side of nip 134 between rollers 130 and 132 to cut off the sheets to the desired length. A receiving table or plate 144 is positioned to receive the sheets 140, with the rear edge of the table serving as a guide for cut off knife 142.

Those skilled in the art will appreciate that particular advantages flow from the multiple extruder apparatus and method disclosed herein for compounding thermoplastic resin with relatively long reinforcing fibers (over one inch in length) so as to make a molding preform. In addition to the particular benefits discussed above with respect to the use of a separate thermoplastic resin extruder 4 in combination with a compounding extruder 8 into which the thermoplastic resin is introduced in a molten state for mixture with reinforcing fibers introduced through a separate port,

the use of a separate, resin heating and melting extruder 4 in combination with the compounding extruder 8, with the screws of the two extruders being independently driven, permits the screw speeds of the two extruders to be controlled independently of one another. The speed of the compounding extruder screw 52 may well not be the same as the speed of the resin-melting extruder screw 12. The extruders 4 and 8 are also of different sizes with respect to their internal diameters and lengths so that at maximum output speeds, the extrudate from resin extruder 4, together with the added fiber introduced through port 62 into compounding extruder 8 will match the output rate of the compounding extruder 8.

The loss-in-weight scales 34 and 70, also known as gravimetric weight scales, ensure that thermoplastic resin pellets and chopped fibers are consistently and accurately supplied on a minute-to-minute basis over extended periods of time. The raw material feeding systems 6 and 10 are very important to the operation of the entire system so as to establish and maintain the proper blend of thermoplastic resin and reinforcing fibers. Once the extrudate has been formed from the compounding of the raw materials in compounding extruder 8, further blending of the extrudate is not possible.

The multiple extruder apparatus and method as disclosed herein brings particular operating efficiencies and cost savings to molding operations requiring a measured preform. The molder's raw material costs are significantly reduced, since he does not have to pay for the cost of precompounded pellets or sheet. The compounding takes place on the molding site as a continuous operation integral to the molding process. The system is also very flexible. The reinforcing fiber content can be varied as desired by the initial programming of the fiber feed system 10. Additives can be provided to the thermoplastic resin system prior to extrusion and various forms of reinforcement can be run alone or multiple reinforcements can be run to form a hybrid composite. This system also provides flexibility with respect to multiple sources of supply of reinforcing fiber materials. The molder can provide any particular fiber supply desired in fiber-supply packages 66, such as glass, carbon, etc. Hygroscopic resins can be easily handled and dried, utilizing the dryer 32 described above with respect to the resin supply system 6. Also, the system keeps total control of the process for compounding thermoplastic resin materials and reinforcing fibers and making the preform in the hands of the molder.

An embodiment of the invention advantageously provides for the compounding of thermoplastic resin with reinforcing fibers in a multiple extruder system in such a way as to produce measured preforms of a predetermined size and shape consisting of discontinuous lengths of reinforcing fibers randomly dispersed in thermoplastic resin.

The embodiment further advantageously provides a blended mixture of thermoplastic resin with reinforcing fibers wherein the structural integrity of the discrete fibers is maintained in lengths preferably of 2.54 cm (one inch) or more.

Claims

1. Apparatus for compounding reinforcing fibers with a thermoplastic resin comprising: a source of supply (6) of thermoplastic resin pellets; a resin extruder (4) having an inlet (38) for receiving thermoplastic resin pellets from said source of supply, an outlet (18), and an elongated, rotatable extruding screw (12) extending between said inlet and said outlet; pellet handling means (34) for conveying thermoplastic resin pellets from said source of supply (6) thereof into said resin extruder inlet (38), whereby thermoplastic resin pellets are mechanically pumped by said resin extruder screw (12) from said inlet to said outlet and are thereby heated and melted; particularly provided with a compounding extruder (8) comprising a single, continuous straight barrel and an elongated, power screw (52) extending therein between an inlet end (8a) and a discharge end (8b) of said barrel, said barrel (8a) having first and second inlet ports (62, 46a) on said inlet end communicating with said power screw (52), said second inlet port (46a) being continuously connected in fluid flow relation to said outlet (18) of said resin extruder (4) for receiving molten thermoplastic resin therefrom at a location along said elongated power screw downstream from said first inlet port (62), and between said first inlet port (62) and said discharge end (8b) of said compounding extruder barrel, and said power screw (52) having substantially continuous thread means at least along the portion thereof with which said first and second inlet ports (62, 46a) communicate; a converging, flow restricting passage (100) at said discharge end (8b) of said barrel of substantially less diameter than the diameter of said barrel; and a source of supply (10) of discrete, predetermined lengths of reinforcing fibers connected to said first inlet port (62) of said compounding extruder, and means (74) for feeding said fibers into said first inlet port (62), whereby said fibers are heated and mechanically worked by said power screw (52) and continuously confined under pressure within said screw barrel by said thread means before coming into mixing contact with molten thermoplastic resin, and said fibers are advanced by said thread means past said second inlet port (46a) for thorough initial wetting by molten thermoplastic resin, and said fibers and said thermoplastic resin intermix in said power screw to form



the use of a separate, resin heating and melting extruder 4 in combination with the compounding extruder 8, with the screws of the two extruders being independently driven, permits the screw speeds of the two extruders to be controlled independently of one another. The speed of the compounding extruder screw 52 may well not be the same as the speed of the resin-melting extruder screw 12. The extruders 4 and 8 are also of different sizes with respect to their internal diameters and lengths so that at maximum output speeds, the extrudate from resin extruder 4, together with the added fiber introduced through port 62 into compounding extruder 8 will match the output rate of the compounding extruder 8.

The loss-in-weight scales 34 and 70, also known as gravimetric weight scales, ensure that thermoplastic resin pellets and chopped fibers are consistently and accurately supplied on a minute-to-minute basis over extended periods of time. The raw material feeding systems 6 and 10 are very important to the operation of the entire system so as to establish and maintain the proper blend of thermoplastic resin and reinforcing fibers. Once the extrudate has been formed from the compounding of the raw materials in compounding extruder 8, further blending of the extrudate is not possible.

The multiple extruder apparatus and method as disclosed herein brings particular operating efficiencies and cost savings to molding operations requiring a measured preform. The molder's raw material costs are significantly reduced, since he does not have to pay for the cost of precompounded pellets or sheet. The compounding takes place on the molding site as a continuous operation integral to the molding process. The system is also very flexible. The reinforcing fiber content can be varied as desired by the initial programming of the fiber feed system 10. Additives can be provided to the thermoplastic resin system prior to extrusion and various forms of reinforcement can be run alone or multiple reinforcements can be run to form a hybrid composite. This system also provides flexibility with respect to multiple sources of supply of reinforcing fiber materials. The molder can provide any particular fiber supply desired in fiber-supply packages 66, such as glass, carbon, etc. Hygroscopic resins can be easily handled and dried, utilizing the dryer 32 described above with respect to the resin supply system 6. Also, the system keeps total control of the process for compounding thermoplastic resin materials and reinforcing fibers and making the preform in the hands of the molder.

An embodiment of the invention advantageously provides for the compounding of thermoplastic resin with reinforcing fibers in a multiple extruder system in such a way as to produce measured preforms of a predetermined size and shape consisting of discontinuous lengths of reinforcing fibers randomly dispersed in thermoplastic resin.

The embodiment further advantageously provides a blended mixture of thermoplastic resin with reinforcing fibers wherein the structural integrity of the discrete fibers is maintained in lengths preferably of 2.54 cm (one inch) or more.

Claims

1. Apparatus for compounding reinforcing fibers with a thermoplastic resin comprising: a source of supply (6) of thermoplastic resin pellets; a resin extruder (4) having an inlet (38) for receiving thermoplastic resin pellets from said source of supply, an outlet (18), and an elongated, rotatable extruding screw (12) extending between said inlet and said outlet; pellet handling means (34) for conveying thermoplastic resin pellets from said source of supply (6) thereof into said resin extruder inlet (38), whereby thermoplastic resin pellets are mechanically pumped by said resin extruder screw (12) from said inlet to said outlet and are thereby heated and melted; particularly provided with a compounding extruder (8) comprising a single, continuous straight barrel and an elongated, power screw (52) extending therein between an inlet end (8a) and a discharge end (8b) of said barrel, said barrel (8a) having first and second inlet ports (62, 46a) on said inlet end communicating with said power screw (52), said second inlet port (46a) being continuously connected in fluid flow relation to said outlet (18) of said resin extruder (4) for receiving molten thermoplastic resin therefrom at a location along said elongated power screw downstream from said first inlet port (62), and between said first inlet port (62) and said discharge end (8b) of said compounding extruder barrel, and said power screw (52) having substantially continuous thread means at least along the portion thereof with which said first and second inlet ports (62, 46a) communicate; a converging, flow restricting passage (100) at said discharge end (8b) of said barrel of substantially less diameter than the diameter of said barrel; and a source of supply (10) of discrete, predetermined lengths of reinforcing fibers connected to said first inlet port (62) of said compounding extruder, and means (74) for feeding said fibers into said first inlet port (62), whereby said fibers are heated and mechanically worked by said power screw (52) and continuously confined under pressure within said screw barrel by said thread means before coming into mixing contact with molten thermoplastic resin, and said fibers are advanced by said thread means past said second inlet port (46a) for thorough initial wetting by molten thermoplastic resin, and said fibers and said thermoplastic resin intermix in said power screw to form



a homogeneous, molten mass of thermoplastic resin having discrete, discontinuous lengths of reinforcing fibers randomly and homogeneously dispersed therein.

2. Apparatus as defined in claim 1 wherein: said thermoplastic resin pellet handling means comprises weighing and conveying apparatus positioned to receive thermoplastic resin pellets from said source of supply thereof and to feed thermoplastic resin pellets into said resin extruder inlet at a predetermined weight rate; and said means for feeding said fibers into said first inlet port of said compounding extruder comprises weighing apparatus on which fibers are received and weighed and conveying apparatus positioned adjacent to said weighing apparatus to feed discrete lengths of reinforcing fibers into said first inlet port of said compounding extruder at a predetermined weight rate.
3. Apparatus as defined in claim 2 wherein: said weighing apparatus for said thermoplastic resin pellets and said weighing apparatus for said reinforcing fibers each comprises a loss-in-weight feed scale.
4. Apparatus as defined in claim 2 or claim 3 wherein: said weighing and conveying apparatus for said thermoplastic resin pellets comprises a conveyor supported on a feed scale for conveying thermoplastic resin pellets to said inlet of said resin extruder at a predetermined weight rate.
5. Apparatus as defined in any one of the preceding claims wherein: said source of supply of reinforcing fibers comprises continuous lengths of fibers on supply means positioned on a feed scale to serve as a fiber source, and said means for feeding said fibers comprises a pair of feed rollers rotating at a predetermined speed and positioned adjacent to said supply means, and a movable cut-off knife, and a feeder hopper positioned in fiber-receiving relation to said feed rollers and having an outlet connected to said first inlet port of said compounding extruder, whereby said feed rollers pull continuous lengths of fibers from said supply means and said cut-off knife cuts the fibers to said predetermined lengths, with the cut fibers being received in said feeder hopper, from which they are conveyed into said first inlet port of said compounding extruder.
6. Apparatus as defined in claim 5 when dependent on claim 2 wherein: a computer is connected in signal-receiving relation with said weighing apparatus for said fibers and in signal generating and sending relation with said feed rollers, said com-

puter being programmed to provide a predetermined input feed rate of fibers, and said computer providing signals to said feed rollers to adjust said predetermined speed thereof in response to signals received by said computer from said fiber-weighing apparatus indicating the weight of fibers being fed from said source of supply.

7. Apparatus as defined in any one of the preceding claims wherein: a preforming device for forming the extrudate from said compounding extruder into a predetermined size, weight and shape of preformed mass is connected in fluid-flow relation to said discharge end of said compounding extruder.
8. Apparatus as defined in claim 7 wherein: said preforming device comprises an extruder having a power screw rotatably and reciprocally movable therein, said preforming extruder having an outlet chamber in which a measured volume of a preformed mass of a homogeneous mixture of thermoplastic resin and reinforcing fibers is produced in the shape of an elongated billet.
9. Apparatus as defined in claim 7 wherein: said preforming device comprises a pair of rollers having an input side and an output side and defining a nip, said input side being in fluid-flow communication with said discharge end of said compounding extruder to receive extrudate therefrom, whereby the extrudate is formed as a sheet-shaped preform by passing through said nip between said rollers, and further including a cut-off means adjacent the output side of said pair of rollers to cut sheet preforms into desired lengths.
10. Apparatus as defined in any one of claims 7 to 9 wherein: shuttle means is positioned to receive a preformed mass from said preforming device; and a compression-molding machine adjacent to said shuttle means, said shuttle means being reversibly movable between said preforming device and said compression-molding machine to receive preforms from said preforming device and deliver them to said compression-molding machine.
11. Apparatus as defined in any one of the preceding claims wherein: said screw of said resin extruder and said power screw of said compounding extruder are of different sizes and have different volume flow capacities.
12. Apparatus as defined in any one of the preceding claims wherein: separate, power-drive means are independently, drivingly connected to said screw



of said resin extruder and to said power screw of said compounding extruder for driving said screw and said power screw at predetermined rotational speeds, whereby said screw of said resin extruder and said power screw of said compounding extruder can be independently controlled.

13. A process for compounding reinforcing fibers with a thermoplastic resin in an apparatus comprising a resin extruder (4) having a rotatable extruding screw (12) extending therein and a compounding extruder (8) having a barrel defining an inlet end (8a) and a discharge end (8b) of said compounding extruder, and an elongated power screw (52) extending within said barrel between said inlet end (8a) and said discharge end (8b) thereof, said process comprising:

rotatably driving said extruding screw (12) and said power screw (52) at predetermined speeds;

Introducing discrete lengths of reinforcing fibers into said compounding extruder (8) at a first inlet port (62) on said inlet end (8a) of said barrel, and mechanically working and heating said fibers while continuously confined within said inlet end of said barrel by said power screw;

directing thermoplastic resin material into said resin extruder (4) and heating and melting said resin material by the rotating action of said extruding screw (12) to form a fluid, molten mass of thermoplastic resin; and

feeding said molten thermoplastic resin in a pressurized state from said resin extruder (4) into said compounding extruder (8) at a second inlet port (46a) on said inlet end (8) of said barrel downstream from said first inlet port (62) between said first inlet port (62) and said discharge end (8b) of said barrel and moving the mechanically worked and treated fibers by the power screw past said second inlet port (46a), and thereby forming a homogeneous mixture of thermoplastic resin and discrete lengths of reinforcing fibers in said compounding extruder by the rotating action of said power screw (52), and discharging the homogeneous mixture from said discharge end (8b) of the compounding extruder.

14. The process of claim 13 wherein: said reinforcing fibers are introduced into said compounding extruder in discrete lengths of at least 2.54cm (one inch).
15. The process of claim 13 or claim 14, and further including: discharging said mixture of thermoplastic resin and fibres from said discharge end of said compounding extruder into a preforming device as a molten mass and forming said mixture into a preformed mass of predetermined size

and shape.

5 Patentansprüche

1. Vorrichtung für das Mischen von Verstärkungsfasern mit einem thermoplastischen Harz, umfassend: eine Speisequelle (6) von Pellets thermoplastischen Harzes; einen Harzextruder (4) mit einem Einlaß (38) für die Aufnahme von Pellets thermoplastischen Harzes von der Speisequelle; einen Auslaß (18) und einer langgestreckten drehbaren Extrudierschnecke (12), die sich zwischen dem Einlaß und dem Auslaß erstreckt; Pellet-Handhabungsmittel (34) für die Überführung von Pellets thermoplastischen Harzes von der Speisequelle (6) derselben in den Einlaß (38) des Harzextruders, wodurch Pellets thermoplastischen Harzes mechanisch mittels der Harzextruderschnecke (12) von dem Einlaß zu dem Auslaß gepumpt werden und dadurch erhitzt und aufgeschmolzen werden; im einzelnen versehen mit einem Mischextruder (8), umfassend einen einzigen kontinuierlichen geraden Lauf und eine langgestreckte Leistungsschnecke (52), die sich darin zwischen einem Einlaßende (8a) und einem Austragende (8b) des Laufs erstreckt, welcher Lauf (8a) eine erste Einlaßöffnung und eine zweite Einlaßöffnung (62, 46a) an dem Einlaßende aufweist in Kommunikation mit der Leistungsschnecke (52), wobei die zweite Einlaßöffnung (46a) kontinuierlich in Fluidströmungsbeziehung verbunden ist mit dem Auslaß (18) des Harzextruders (4) für die Aufnahme von aufgeschmolzenem thermoplastischem Harz von diesem an einer Stelle längs der langgestreckten Leistungsstrecke stromabwärts der ersten Einlaßöffnung (62), und zwischen der ersten Einlaßöffnung (62) und dem Austragende (8b) des Mischextruderlaufes, wobei die Leistungsschnecke (52) im wesentlichen kontinuierliche Gewindgänge aufweist zumindest längs des Abschnitts derselben, mit welchem die erste und die zweite Einlaßöffnung (62, 46a) kommunizieren; eine konvergierende, strömungsdrosselnde Passage (100) an dem Austragende (8b) des Laufes von wesentlich kleinerem Durchmesser als dem Durchmesser des Laufes; und eine Speisequelle (10) von diskreten vorbestimmten Längen von Verstärkungsfasern, verbunden mit der ersten Einlaßöffnung (62) des Mischextruders, und Mittel (74) für das Zuführen der Fasern in die erste Einlaßöffnung (62), wodurch die Fasern erhitzt und mechanisch bearbeitet werden durch die Leistungsschnecke (52) und kontinuierlich unter Druck innerhalb des Schneckenlaufes durch die Gewindemittel eingeschlossen sind, bevor sie in Mischkontakt mit dem aufgeschmolzenen thermoplastischen Harz



- gelangen, und wodurch die Fasern durch die Gewindegänge hinter die zweite Einlaßöffnung (46a) gefördert werden für gründliche anfängliche Befeuchtung durch aufgeschmolzenes thermoplastisches Harz, und wodurch die Fasern und das thermoplastische Harz in der Leistungsschnecke durchmischt werden zur Bildung einer homogenen geschmolzenen Masse von thermoplastischem Harz mit diskreten diskontinuierlichen Längen von Verstärkungsfasern, die darin zufällig und homogen dispergiert sind.
2. Vorrichtung nach Anspruch 1, bei welcher die Handhabungsmittel für Pellets thermoplastischen Harzes Wäge- und Fördervorrichtungen umfassen, positioniert zur Aufnahme von Pellets thermoplastischen Harzes von der Speisequelle derselben und zum Zuführen von Pellets thermoplastischen Harzes in den Harzextrudereinlaß mit einer vorbestimmten Gewichtsrate; und bei welcher die Mittel für das Zuführen von Fasern in die erste Einlaßöffnung des Mischextruders Wägevorrrichtungen umfassen, auf denen Fasern aufgenommen und gewogen werden, und Fördervorrichtungen, positioniert nahe der Wägevorrrichtung zum Zuführen diskreter Längen von Verstärkungsfasern in die erste Einlaßöffnung des Mischextruders mit einer vorbestimmten Gewichtsrate.
 3. Vorrichtung nach Anspruch 2, bei der die Wägevorrrichtung für die Pellets thermoplastischen Harzes und die Wägevorrrichtung für die Verstärkungsfasern jeweils eine Gewichtsverlustförderwaage umfassen.
 4. Vorrichtung nach Anspruch 2 oder Anspruch 3, bei der die Wäge- und Fördervorrichtung für die Pellets thermoplastischen Harzes einen Förderer umfassen, der auf einer Zufuhrwaage abgestützt ist für das Fördern von Pellets thermoplastischen Harzes zu dem Einlaß des Harzextruders mit einer vorbestimmten Gewichtsrate.
 5. Vorrichtung nach einem der vorangehenden Ansprüche, bei der die Speisequelle für Verstärkungsfasern kontinuierliche Längen von Fasern auf Zufuhrmitteln umfaßt, positioniert auf einer Förderwaage, um als Faserquelle zu dienen, und die Mittel für das Zuführen der Fasern ein Paar von Förderwalzen umfassen, die mit vorbestimmter Drehzahl laufen und positioniert sind nahe den Zufuhrmitteln, sowie ein bewegliches Abtrennmesser, und einen Zufuhrtrichter, der in fasseraufnehmender Beziehung mit den Zufuhrwalzen positioniert ist und mit einem Auslaß mit der ersten Einlaßöffnung des Mischextruders verbunden ist, wodurch die Zufuhrwalzen kontinuierliche Längen von Fasern von den Zufuhrmitteln abziehen und das Abtrennmesser die Fasern in die vorbestimmten Längen schneidet, wobei die geschnittenen Fasern in dem Zufuhrtrichter aufgenommen werden, von welchem sie in die erste Einlaßöffnung des Mischextruders gefördert werden.
 6. Vorrichtung nach Anspruch 5, soweit von Anspruch 2 abhängig, bei der ein Rechner in signalempfangender Beziehung mit der Wägevorrrichtung für die Fasern verbunden ist und in Signalerzeugungs- und -übertragungsbeziehung mit den Zufuhrwalzen steht, welcher Rechner programmiert ist zum Bereitstellen einer vorbestimmten Eingabezufuhr rate von Fasern, und welcher Rechner Signale bereitstellt für die Zufuhrwalzen zum Einstellen der vorbestimmten Geschwindigkeit derselben in Reaktion auf Signale, empfangen durch den Rechner von der Faserwägeeinrichtung, welche das Gewicht an Fasern angibt, die von der Speisequelle zugeführt werden.
 7. Vorrichtung nach einem der vorangehenden Ansprüche, bei der eine Präformeinrichtung für die Formung des Extrudats von dem Mischextruder in eine vorbestimmte Größe, Gewicht und Form der vorgeformten Masse in Fluidströmungsbeziehung verbunden ist mit dem Austragende des Mischextruders.
 8. Vorrichtung nach Anspruch 7, bei der die Präformeinrichtung einen Extruder umfaßt mit einer Leistungsschnecke, die drehbar und hin- und herbeweglich darin aufgenommen ist, welcher Präformextruder eine Auslaßkammer aufweist, in der ein bemessenes Volumen einer vorgeformten Masse eines homogenen Gemisches von thermoplastischem Harz und Verstärkungsfasern in Form eines langgestreckten Klotzes erzeugt wird.
 9. Vorrichtung nach Anspruch 7, bei der die Präformeinrichtung ein Paar von Walzen umfaßt mit einer Eingabeseite und einer Ausgabeseite unter Begrenzung eines Walzspalts, wobei die Eingabeseite in Fluidströmungsverbindung steht mit dem Austragende des Mischextruders zur Aufnahme von Extrudat von diesem, wodurch das Extrudat als eine bahnförmige Vorform gebildet wird mittels Durchlaufs durch den Walzspalt zwischen den Walzen, und ferner umfassend eine Abtrenneinrichtung nahe der Ausgabeseite des Walzenpaares zum Schneiden der Vorformbahn in gewünschte Längen.
 10. Vorrichtung nach einem der Ansprüche 7 bis 9,



bei der ein Pendelmittel positioniert ist zum Aufnehmen einer vorgeformten Masse von der Präformeinrichtung; und eine Druckformmaschine nahe dem Pendelmittel, welches Pendelmittel reversibel beweglich ist zwischen der Präformeinrichtung und der Kompressionsformmaschine zum Aufnehmen von Vorformlingen von der Präformeinrichtung und Übergabe derselben zu der Kompressionsformmaschine.

11. Vorrichtung nach einem der vorangehenden Ansprüche, bei der die Schnecke des Harzextruders und die Leistungsschnecke des Mischextruders von unterschiedlichen Größen sind und unterschiedliche Volumenströmungskapazitäten besitzen.

12. Vorrichtung nach einem der vorangehenden Ansprüche, bei der getrennte Kraftantriebsmittel unabhängig voneinander in Antriebsverbindung mit der Schnecke des Harzextruders und der Leistungsschnecke des Mischextruders stehen für den Antrieb der Schnecke und der Leistungsschnecke mit vorbestimmten Drehzahlen, wodurch die Schnecke des Harzextruders und die Leistungsschnecke des Mischextruders unabhängig voneinander steuerbar sind.

13. Ein Verfahren für das Mischen von Verstärkungsfasern mit einem thermoplastischen Harz in einer Vorrichtung, umfassend einen Harzextruder (4) mit einer drehbaren Extruderschnecke (12), die sich darin erstreckt, und mit einem Mischextruder (8) mit einem Lauf, der ein Einlaßende (8a) und ein Austragende (8b) des Mischextruders aufweist, und einer langgestreckten Leistungsschnecke (52), die sich innerhalb des Laufs zwischen dem Einlaßende (8a) und dem Austragende (8b) desselben erstreckt, welches Verfahren umfaßt:

Drehantrieb der Extruderschnecke (12) und der Leistungsschnecke (52) mit vorbestimmten Drehzahlen;

Einspeisen diskreter Längen von Verstärkungsfasern in den Mischextruder (8) an einer ersten Einlaßöffnung (62) an dem Einlaßende (8a) des Laufs und mechanisches Bearbeiten und Erhitzen der Fasern, während sie kontinuierlich eingeschlossen sind innerhalb des Einlaßendes des Laufs durch die Leistungsschnecke;

Einführen von thermoplastischem Harzmaterial in den Harzextruder (4) und Erhitzen und Aufschmelzen des Harzmaterials durch die Rotationswirkung der Extruderschnecke (12) zur Bildung einer fluiden geschmolzenen Masse von thermoplastischem Harz; und

Einspeisen des geschmolzenen thermoplastischen Harzes unter Druck aus dem Harz-

extruder (4) in den Mischextruder (8) an einer zweiten Einlaßöffnung (46a) an dem Einlaßende (8) des Laufs stromab von der ersten Einlaßöffnung (62) zwischen der ersten Einlaßöffnung (62) und dem Austragende (8b) des Laufs, und Bewegen der mechanisch bearbeiteten und behandelten Fasern durch die Leistungsschnecke hinter die zweite Einlaßöffnung (46a), und dadurch Bilden eines homogenen Gemisches von thermoplastischem Harz und diskreten Längen von Verstärkungsfasern in dem Mischextruder durch die Rotationswirkung der Leistungsschnecke (52) sowie Austrag des homogenen Gemisches von dem Austragende (8b) des Mischextruders.

14. Das Verfahren nach Anspruch 13, bei dem die Verstärkungsfasern in den Mischextruder in diskreten Längen von mindestens 2,54 cm (ein Zoll) eingesetzt werden.

15. Das Verfahren nach Anspruch 13 oder Anspruch 14, ferner umfassend: Austrag des Gemisches aus thermoplastischem Harz und Fasern vom Austragende des Mischextruders in eine Präformeinrichtung als geschmolzene Masse und Formen des Gemisches in eine vorgeformte Masse vorbestimmter Größe und Form.

Revendications

1. Dispositif pour mélanger des fibres de renfort à une résine thermoplastique, comprenant : une source (6) d'alimentation de pastilles de résine thermoplastique; une extrudeuse (4) pour extruder une résine possédant une entrée (38) servant à recevoir des pastilles de résine thermoplastique à partir de ladite source d'alimentation, une sortie (18), et une vis rotative allongée d'extrusion (12) qui s'étend entre ladite entrée et ladite sortie; des moyens (34) de manipulation des pastilles servant à transporter des pastilles de résine thermoplastique depuis ladite source (6) d'alimentation en pastilles dans ladite entrée (38) de l'extrudeuse servant à extruder la résine, ce qui a pour effet que des pastilles de résine thermoplastique sont entraînées par pompage mécanique par ladite vis (12) d'extrusion de la résine depuis ladite entrée à ladite sortie et sont de ce fait chauffées et fondues; le dispositif étant notamment équipé d'une extrudeuse de mélange (8) comprenant un seul cylindre continu rectiligne et une vis mécanique allongée (52) s'étendant entre une extrémité d'entrée (8a) et une extrémité d'évacuation (8b) dudit cylindre, ledit cylindre (8a) comportant des premier et second orifices d'entrée (62, 46a) situés sur ladite extrémité d'en-



trée et communiquant avec ladite vis mécanique (52), ledit second orifice d'entrée (46a) étant raccordé en continu, selon une liaison fluïdique, à ladite sortie (18) de ladite extrudeuse (4) servant à extruder la résine de manière à recevoir une résine thermoplastique fondue provenant de cette extrudeuse, en un emplacement situé le long de ladite vis mécanique allongée, à partir dudit premier orifice d'entrée (62), et entre ledit premier orifice d'entrée (62) et ladite extrémité d'évacuation (8b) dudit cylindre de l'extrudeuse de mélange, et ladite vis mécanique (52) possédant des moyens en forme de filetage sensiblement continus au moins sur sa partie avec laquelle communiquent lesdits premier et second orifices d'entrée (62, 46a); un passage convergent (100), qui limite l'écoulement, situé au niveau de ladite extrémité d'évacuation (8b) dudit cylindre et possédant un diamètre nettement inférieur au diamètre dudit cylindre; et une source (10) d'alimentation de longueurs discrètes prédéterminées de fibres de renfort, raccordée audit orifice d'entrée (62) ladite extrudeuse de mélange, et des moyens (74) pour introduire lesdites fibres dans ledit premier orifice d'entrée (62), ce qui a pour effet que lesdites fibres sont chauffées et travaillées mécaniquement par ladite vis mécanique (52) et confinées en permanence sous pression dans ledit cylindre à vis par lesdits moyens en forme de filetage avant de venir en contact, pour l'obtention du mélange, avec la résine thermoplastique fondue, et lesdits moyens en forme de filetage font avancer les fibres au niveau dudit second orifice d'entrée (46a) de manière qu'elle subisse un mouillage initial soigneux par une résine thermoplastique fondue, et lesdites fibres et ladite résine thermoplastique se mélangent dans ladite vis mécanique de manière à former une masse fondue homogène de résine thermoplastique, dans laquelle sont dispersées de façon aléatoire et homogène des longueurs discrètes discontinues de fibres de renfort.

2. Dispositif selon la revendication 1, dans lequel : lesdits moyens de manipulation de pastilles de résine thermoplastique comprennent un dispositif de pesée et de transport disposé de manière à recevoir des pastilles de résine thermoplastique délivrée par ladite source d'alimentation en pastilles et à introduire des pastilles de résine thermoplastique dans ladite entrée de l'extrudeuse servant à extruder la résine, à un débit pondéral prédéterminé; et lesdits moyens servant à introduire lesdites fibres dans ledit premier orifice d'entrée de ladite extrudeuse de mélange comprennent un dispositif de pesée, sur lequel les fibres sont reçues et pesées, et un dispositif de transport disposé au voisinage dudit dispositif

de pesée pour envoyer des longueurs discrètes de fibres de renfort dans ledit premier orifice d'entrée de ladite extrudeuse de mélange, à un débit pondéral prédéterminé.

3. Dispositif selon la revendication 2, dans lequel : ledit dispositif de pesée desdites pastilles de résine thermoplastique et ledit dispositif de pesée desdites fibres de renfort comprennent chacun une bascule d'alimentation gravimétrique.
4. Dispositif selon la revendication 2 ou 3, dans lequel : ledit dispositif de pesée de transport desdites pastilles de résine thermoplastique comprend un convoyeur supporté par une bascule d'alimentation pour transférer des pastilles de résine thermoplastique à ladite entrée de ladite extrudeuse servant à extruder la résine, avec un débit pondéral prédéterminé.
5. Dispositif selon l'une quelconque des revendications précédentes, dans lequel : ladite source d'alimentation en fibres de renfort comprend des longueurs continues de fibres sur des moyens d'alimentation disposés sur une échelle d'alimentation de manière à servir de source de fibres, et lesdits moyens servant à faire avancer lesdites fibres comprennent un couple de cylindres d'avance tournant à une vitesse prédéterminée et disposés au voisinage desdits moyens d'alimentation, et un couteau de sectionnement mobile, et une trémie d'alimentation disposée selon une relation de réception des fibres par rapport auxdits cylindres d'avance et comportant une sortie raccordée audit premier orifice d'entrée de ladite extrudeuse de mélange, ce qui a pour effet que lesdits cylindres d'avance tirent des longueurs continues de fibres à partir desdits moyens d'alimentation et ledit couteau de sectionnement coupe les fibres auxdites longueurs prédéterminées, les fibres découpées étant reçues dans ladite trémie d'alimentation, à partir de laquelle elles sont envoyées audit premier orifice d'entrée de ladite extrudeuse de mélange.
6. Dispositif selon la revendication 5, considérée comme dépendante de la revendication 2, dans lequel : un ordinateur est raccordé, de manière à recevoir des signaux, audit dispositif de pesée desdites fibres et envoyer des signaux auxdits cylindres d'avance, ledit ordinateur étant programmé de manière à produire un débit d'alimentation d'entrée prédéterminé en fibres, et ledit ordinateur envoyant des signaux auxdits cylindres d'avance pour régler ladite vitesse prédéterminée des fibres en réponse à des signaux reçus par ledit ordinateur en provenance dudit dispositif de pesée des fibres indiquant le poids des fibres



qui sont délivrées par ladite source d'alimentation.

7. Dispositif selon l'une quelconque des revendications précédentes, dans lequel : un dispositif de préformage servant à amener le produit extrudé délivré par ladite extrudeuse de mélange à avoir une taille, un poids et une forme prédéterminés d'une masse préformée et raccordé selon une liaison fluide à ladite extrémité d'évacuation de ladite extrudeuse de mélange.

8. Dispositif selon la revendication 7, dans lequel : ledit dispositif de préformage comporte une extrudeuse possédant une vis mécanique déplaçable en rotation et en va-et-vient à l'intérieur de l'extrudeuse, ladite extrudeuse de préformage possédant une chambre de sortie dans laquelle un volume mesuré d'une masse préformée d'un mélange homogène d'une résine thermoplastique et de fibres de renfort est produit sous la forme d'un lingot allongé.

9. Dispositif selon la revendication 7, dans lequel : ledit dispositif de préformage comprend un couple de cylindres possédant un côté d'entrée et un côté de sortie et définissant un passage, ledit côté d'entrée étant en communication fluide avec ladite extrémité de refoulement de ladite extrudeuse de mélange pour recevoir le produit extrudé de cette dernière, le produit extrudé étant mis sous la forme d'une préforme en forme de feuille par passage dans ledit interstice entre lesdits cylindres, et comprenant en outre des moyens de sectionnement adjacents au côté de sortie dudit couple de cylindres pour sectionner les préformes en forme de feuilles aux longueurs désirées.

10. Dispositif selon l'une quelconque des revendications 7 à 9, dans lequel : des moyens formant navette sont disposés de manière à recevoir une masse préformée provenant dudit dispositif de préformage; et une machine de moulage par compression adjacente auxdits moyens en forme de navette, lesdits moyens formant navette étant déplaçables de façon réversible entre ledit dispositif de préformage et ladite machine de moulage par compression pour recevoir des préformes provenant dudit dispositif de préformage et les envoyer à ladite machine de moulage par compression.

11. Dispositif selon l'une quelconque des revendications précédentes, dans lequel : ladite vis de ladite extrudeuse servant à extruder la résine et ladite vis mécanique de ladite extrudeuse de mélange possèdent des dimensions différentes et

ont des capacités différentes du point de vue débit volumique.

12. Dispositif selon l'une quelconque des revendications précédentes, dans lequel : des moyens séparés d'entraînement mécanique sont raccordés d'une manière indépendante, selon une liaison motrice, à ladite vis de ladite extrudeuse servant à extruder la résine et à ladite vis mécanique de ladite extrudeuse de mélange pour entraîner ladite vis et ladite vis mécanique à des vitesses de rotation prédéterminées, ladite vis de ladite extrudeuse servant à extruder la résine et ladite vis mécanique de ladite extrudeuse de mélange pouvant être commandées d'une manière indépendante.

13. Procédé pour mélanger des fibres de renfort à une résine thermoplastique dans un dispositif comprenant une extrudeuse (4) servant à extruder une résine et possédant une vis rotative d'extrusion (12) s'étendant à l'intérieur de l'extrudeuse, et une extrudeuse de mélange (8) possédant un cylindre définissant une extrémité d'entrée (8a) et une extrémité d'évacuation (8b) de ladite extrudeuse de mélange, et une vis mécanique allongée (52) s'étendant à l'intérieur dudit cylindre entre ladite extrémité d'entrée (8a) et ladite extrémité d'évacuation (8b) du cylindre, ledit procédé comprenant :

l'entraînement en rotation de ladite vis d'extrusion (12) et de ladite vis mécanique (52) à des vitesses prédéterminées;

l'introduction de longueurs discrètes de fibres de renfort dans ladite extrudeuse de mélange (8) au niveau d'un premier orifice d'entrée (62) sur ladite extrémité d'entrée (8a) dudit cylindre, et le traitement mécanique et le chauffage desdites fibres moyennant un confinement continu de ces dernières dans ladite extrémité d'entrée dudit cylindre par ladite vis mécanique;

l'introduction du matériau formé par la résine thermoplastique dans ladite extrudeuse (4) servant à extruder la résine et le chauffage et la fusion dudit matériau formé par la résine sous l'action de rotation de ladite vis d'extrusion (12) de manière à former une masse fondue fluide de résine thermoplastique; et

l'envoi de ladite résine thermoplastique fondue à l'état sous pression, par ladite extrudeuse (4) servant à extruder la résine dans ladite extrudeuse de mélange (8), au niveau d'un second orifice d'entrée (46a) sur ladite extrémité d'entrée (8) dudit cylindre en aval dudit premier orifice d'entrée (62) entre ledit premier orifice d'entrée (62) et ladite extrémité d'évacuation (8b) dudit cylindre, et le déplacement des fibres travaillées mécaniquement et traitées, par la vis mécanique



de manière à leur faire franchir ledit second orifice d'entrée (46a), et de ce fait la formation d'un mélange homogène de la résine thermoplastique et de longueurs discrètes de fibres de renfort dans ladite extrudeuse de mélange sous l'action de rotation de ladite vis mécanique (52), et l'évacuation du mélange homogène à partir de ladite extrémité d'évacuation (8b) de l'extrudeuse de mélange.

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14. Procédé selon la revendication 13, selon lequel : lesdites fibres de renfort sont introduites dans ladite extrudeuse de mélange selon des longueurs discrètes égales à au moins 2,54 cm (un pouce).

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15. Procédé selon la revendication 13 ou 14, comprenant en outre : l'évacuation dudit mélange de la résine thermoplastique et des fibres à partir de ladite extrémité d'évacuation de ladite extrudeuse de mélange et leur introduction dans un dispositif de préformage sous la forme d'une masse fondue, et l'amenée dudit mélange sous la forme d'une masse préformée ayant des dimensions et une forme prédéterminées.

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