

DESCRIPTION

Resin Molding Apparatus

[TECHNICAL FIELD]

The present invention relates to a resin molding apparatus comprising a screw, a
5 cylinder receiving the screw therein, an inlet disposed in a posterior portion of the cylinder,
and an outlet disposed in a tip portion of the cylinder.

[BACKGROUND ART]

Thermoplastic resin-based composition is generally, for example, molded from
10 molding material pellet into a molded article having a desired shape, by means of injection
molding. At this point, a residual material such as a spool, runner, and so on are produced
together with the molded article. Such residual material is separated from the final molded
article, and is further subjected to grinding and extrusion molding so as to produce a recycled
resin pellet. Thus obtained recycled resin pellet is combined with other virgin resin pellet in a
15 predetermined amount, and are further subjected to injection molding. The terms
“thermoplastic resin-based composition” and “resin composition” are interchangeably used
herein.

An exemplary resin molding apparatus generally used in such a extrusion molding
process conventionally comprises a screw comprising a screw shaft and a plurality of flights
20 extending from an outer circumferential face of the shaft, a cylinder receiving the screw
therein, an inlet being configured to supply resin composition to inside the cylinder and
being disposed in a posterior portion of the cylinder, an outlet being configured to discharge
the resin composition that is melted and kneaded inside the cylinder and being disposed a tip
portion of the cylinder, and a heater being configured to supply heat energy to the inside the
25 cylinder.

Japanese Publication of Patent Application No. 2002-234063 discloses a conventional resin molding apparatus. In above resin molding apparatus, a screw is comprised of a resin feeding portion being disposed adjacent to the inlet in the cylinder and having a shaft with a substantially constant outer diameter, an extrusion portion
5 communicating with the resin feeding portion and having a tapered shaft whose outer diameter is gradually reduced from one end thereof to the other end adjacent to the resin feeding portion, and a metering portion being disposed adjacent to the outlet in the cylinder, communicating with the extrusion portion, and having a shaft with a substantially constant outer diameter. The distance (D1) between the outer circumferential face of the shaft and the
10 tip portion of the flight at the area of the resin feeding portion is made greater than the distance (D3) between the outer circumferential face of the shaft and the tip portion of the flight in the area of the metering portion. The ratio of D1 to D3 is, for example, between 2.4 and 3.2.

In use of the afore-mentioned conventional resin molding apparatus, the residual
15 material is generally supplied via the inlet into the cylinder. Thereafter, the residual material is subjected to shear force exerted by the screw and is heated by means of the heater during the movement thereof from the inlet to the outlet within the cylinder. As a result, the residual material is fully melted and kneaded inside the cylinder. This melted resin is discharged via the outlet and is molded in a linear shape, and then is cut so as to result in a resin pellet. Thus
20 obtained recycled resin pellet can be generally used in a next or further molding process.

Meanwhile, in some cases, the afore-mentioned resin composition is generally comprised of a base resin component mainly consisting of thermoplastic resin, and a fibrous filler component such as a glass fiber and a carbon filament. To differentiate the resin composition comprising such a fibrous filler component from the afore-mentioned
25 thermoplastic resin-based resin composition, above resin composition comprising such a

fibrous filler component is referred to as a fiber-reinforced resin composition herein. The fiber filler component generally is used for imparting enhanced mechanical properties to the base resin.

However, when using the resin molding apparatus as disclosed in Japanese
5 Publication of Patent Application No. 2002-234063 for the purpose of preparation of recycled resin pellet from the residual material of the fiber-reinforced resin composition, there is problem that the fibrous filler can be easily damaged due to greater amount of shear force to be applied to the residual material. In a case where such a damaged fibrous
10 filler-containing recycled pellet is further subjected to inject molding process together with virgin resin pellet, the final molded article is produced with a deteriorated mechanical strength properties. In other words, the residual material of fiber-reinforced resin composition is hardly or never recycled.

To overcome the problem mentioned previously, there is provided a resin molding
apparatus capable of preventing the fibrous filler-containing residual material from being
15 damaged and thus maintaining the high level of mechanical strength property of the fiber-reinforced resin composition.

[DISCLOSURE OF THE INVENTION]

To solve afore-mentioned objectives, there is provided a resin molding apparatus,
20 comprising: a screw having a screw shaft and a plurality of flights extending from an outer circumferential face of the screw shaft, a cylinder receiving the screw therein, an inlet being disposed in a posterior end portion of the cylinder and being configured to supply a fiber-reinforced resin composition into the cylinder, the fiber-reinforced resin composition comprising a base resin and a fibrous filler, and an outlet being disposed in a tip portion of
25 the cylinder and being configured to discharge the fiber-reinforced resin composition

therethrough, the fiber-reinforced resin composition being melted and kneaded inside the cylinder, wherein, (a) the screw comprises a resin feeding portion being disposed adjacent to the inlet, an extrusion portion communicating with the resin feeding portion, and a metering portion communicating with the extrusion portion; (b) an outer diameter of the screw shaft is
5 kept constant throughout a length of the resin feeding portion, increases gradually toward the metering portion throughout a length of the extrusion portion, and is kept constant throughout a length of the metering portion; and (c) a ratio of a distance between the outer circumferential face of the screw shaft and a tip portion of the associated flight in an area of the resin feeding portion to a distance between the outer circumferential face of the screw
10 shaft and a tip portion of the associated flight in an area of the metering portion is between 1.2 and 1.95.

Preferably, both the resin feeding portion and the extrusion portion may be made longer than the metering portion.

Preferably, a ratio of length of the extrusion portion to length of the metering
15 portion may be between 2 and 4.

Preferably, a ratio of length of the resin feeding portion to length of the metering portion may be between 1.33 and 5.

Preferably, the afore-mentioned resin molding apparatus may further include a heater for supplying heat energy to the area of the resin feeding portion inside the cylinder,
20 wherein the heater is maintained at a temperature of from 25°C below melting point of the base resin to the melting point.

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 is a schematic view of one preferred embodiment of a resin molding
25 apparatus in accordance with the present invention.

FIG. 2 is an enlarged side view of a screw as shown in FIG. 1.

FIG. 3 is a graph showing the relationship between the ratio of D1 to D3 and the length of the glass fiber included in the recycled pellet. In further detail, D1 is defined as a distance between the outer circumferential face of the screw shaft and the tip portion of the flight in the area of the resin feeding portion, and D3 is defined as a distance between the outer circumferential face of the screw shaft and the tip portion of the flight in the area of the metering portion.

FIG. 4 is a graph showing the relationship between the ratio of L2 to L3 and the proportion (%) of the molten fiber-reinforced resin composition based on the total of the fiber-reinforced resin composition used (100%). In further detail, L2 is defined as the length of the extrusion portion, and L3 is defined as the length of the metering portion.

FIG. 5 is a graph showing the relationship between the ratio of L1 to L3 and the temperature of the preheated fiber-reinforced resin composition. In further detail, the L1 is defined as the length of the resin feeding portion, and the L3 is defined as the length of the metering portion.

FIG. 6 is a graph showing the relationship between the temperature of the heater for supplying heat energy to the resin feeding portion and the temperature of the preheated fiber-reinforced resin composition.

[DETAILED DESCRIPTION OF THE INVENTION]

With reference to FIGS. 1 through 6, one preferred embodiment of the present invention will be hereinafter illustrated in great detail. A resin molding apparatus 1 in accordance with a preferred embodiment of the present invention is provided for recycling a residual material such as a spool and a runner that is generally produced as a by-product during the injection molding process of fiber-reinforced resin composition. In particular, the

resin molding apparatus 1 is used for preparing a recycled pellet of fiber-reinforced resin composition. The resin molding apparatus 1 comprises a screw 2, a cylinder 3, an inlet 4, an outlet 5, a screw-actuating member (now shown), and a heater 7. A fiber-reinforced resin composition is generally comprised of a base resin and a fibrous filler.

5 The screw 2 is overall cylindrically formed. The screw 2 is generally formed of metal material of high abrasive resistance for the purpose of decreasing the wear caused by use of the fibrous filler. As shown in FIG. 2, the outer diameter of the screw 2 is kept substantially constant throughout its overall length. In this case, the outer diameter of the screw 2 is made twice as long as the distance between the shaft center and the tip portion 22a
10 of the flight 22. In a preferred embodiment, the ratio of the length of the screw 2 to the outer diameter of the screw 2 is from 25 to 30. This is because the fiber-reinforced resin composition is preferably subjected to relatively less level of shear force. The screw 2 is comprised of a screw shaft 21, a flight 22, and a groove 23.

 The screw shaft 21 is generally cylindrically shaped. The flight 22 extends from the
15 outer circumferential face 21a of the screw shaft 21. The flight 22 is spirally formed throughout the overall length of the screw shaft 21. The groove 23 is defined by the outer circumferential face 21a of the screw shaft 21, and the outer faces of the flights 22. These flights are disposed apart from each other and extend approximately perpendicular to the outer circumferential face 21a of the screw shaft 21. The groove 23 has an approximately
20 U-shaped cross section. The groove 23 is formed between spirally-formed flights 22, and is also spirally formed on the outer circumferential face of the screw 2 likewise the flight 22. The fiber-reinforced resin composition moves along the groove 23 from the inlet 4 toward the outlet 5.

 Furthermore, the screw 2 is shown to include a resin feeding portion 24 being
25 disposed adjacent to the inlet 4, an extrusion portion 25 communicating with the resin

feeding portion 24, and a metering portion 26 being disposed adjacent to the outlet 5 and communicating with the extrusion portion 25. In other words, while the screw 2 is divided into these three portions (i.e., the resin feeding portion 24, the extrusion portion 25, and the metering portion 26) along its longitudinal direction, these three portions are basically
5 designated for convenience of illustration of the screw 2. The resin feeding portion 24, the extrusion portion 25, and the metering portion 26 are serially arranged along the longitudinal direction of the screw 2.

The resin feeding portion 24 moves the fiber-reinforced resin composition, which is supplied from the inlet 4 into the cylinder 4, toward the extrusion portion 25. During such a
10 movement of the fiber-reinforced resin composition, the fiber-reinforced resin composition is preheated by means of a heater 7. The outer diameter of the screw shaft 21 of the resin feeding portion 24 is uniformly formed throughout its full length. The resin feeding portion 24 has a length L1 longer than the length L3 of the metering portion 26. The ratio of L1 to L3 is generally from 1.33 to 5. If the ratio is less than the lower limit 1.33, the
15 fiber-reinforced resin composition cannot be preheated sufficiently. To the contrary, if the ratio is greater than the upper limit 5, the metering portion 25 having a sufficient length cannot be ensured.

The extrusion portion 25 is configured to melt the fiber-reinforced resin composition delivered from the resin feeding portion 24 and to pass therethrough by means of
20 shear force generated between the extrusion portion 25 and the inner face of the cylinder 3, and heat energy supplied by the heater 7 during the movement of the fiber-reinforced resin composition 24 toward the metering portion 26. The screw shaft 21 of the extrusion portion 25 has a gradually increasing outer diameter, as it approximates to the metering portion 26. In other words, in the area of the extrusion portion 25, the outer diameter of the screw shaft
25 has a value of minimum at a boundary with the resin feeding portion 24 and a value of

maximum at a boundary with the metering portion 26. The extrusion portion 25 has a length L2 longer than the length L3 of the metering portion 26. The ratio of L2 to L3 is generally from 2 to 4. If the ratio is less than the lower limit value 2, the fiber-reinforced resin composition cannot be fully melted. To the contrary, if the ratio is greater than the upper
5 limit value 4, the metering portion 26 having a sufficient length cannot be ensured.

The metering portion 26 is configured to move the molten the fiber-reinforced resin composition in a predetermined amount toward the outlet 5 for a predetermined period of time. In the metering portion 26, the outer diameter of the screw shaft 21 is designed to be substantially constant in its longitudinal direction and simultaneously greater than the outer
10 diameter of the screw shaft 21 of in the area of the resin feeding portion 24. In this configuration, D1 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 in the area of the resin feeding portion 24, and D3 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 in the area of the metering portion 26. In a
15 preferred embodiment of the invention, the ratio of D1 to D3 is generally from 1.2 to 1.95. As a result, compression ratio of the screw 2 can be set at lower value in comparison with the conventional resin molding apparatus. In this case, the term compression ratio as used herein is defined as a ratio of the spatial volume of the groove 23 within the area of the resin feeding portion 24 to the spatial volume of the groove 23 within the area of the metering portion 26
20 in accordance with JIS B8650. If the ratio is less than the lower limit value 1.2, the fiber-reinforced resin composition cannot be melted sufficiently due to corresponding small amount of shear force. To the contrary, the ratio is greater than the upper limit value 1.95, the fibrous filler is easily damaged due to the corresponding large amount of shear force.

As mentioned previously, because the metering portion 26 is made shorter in
25 comparison with the metering portion of the conventional resin molding apparatus, there is a

possibility that the molten fiber-reinforced resin composition in a desired amount cannot be moved toward the outlet 5 within a desired period of time, resulting in incompletely shaped final article. In addition, because the compression ratio is made lower in comparison with the conventional apparatus, the fiber-reinforced resin composition cannot be sufficiently melted and kneaded. However, even if the afore-mentioned phenomenon occurs, (insomuch as a resin molding apparatus 1 corresponding to an extrusion molding machine being suited for pelletization is used) precise or rigid standard regarding the shape of the molded article is not required. In other words, it is only important for the fiber-reinforced resin composition to be fully melted.

As shown in FIG. 1, the cylinder 3 is cylindrically formed and is configured to receive the screw 2 therein. The cylinder 3 is formed of metal material having a high level of abrasive resistance. This is because any friction caused by the use of the fibrous filler can be avoided or decreased. The inner diameter of the cylinder 3 is generally formed constant and is slightly larger than the outer diameter of the screw 2.

The inlet 4 is formed in communication with the inside the cylinder 3. The inlet 4 is formed in the posterior portion 3a of the cylinder 3. The fiber-reinforced resin composition is supplied to the cylinder via the inlet 4. The inlet 4 is provided with a hopper 41 disposed perpendicularly thereto or extending perpendicularly therefrom. The hopper 41 is generally formed in a funnel shape. The fiber-reinforced resin composition, which is achieved by grinding the afore-mentioned residual material, is stored inside the hopper 41, and is in turn supplied to the inlet 4.

The outlet 5 is an opening in communication with the inside of the cylinder 3. The outlet 5 is formed in the tip portion 3b of the cylinder 3. The fiber-reinforced resin composition is sufficiently molted and kneaded in the cylinder 3, and then is discharged via the outlet 5 from the cylinder 3. The outlet 5 is also provided with a breaker plate 51 and a

die 54.

The breaker plate 51 is generally made of metal material, and is formed in a plane. The breaker plate 51 is provided with a plurality of through-holes along the thickness of the breaker plate 51. A wire-woven screen pack 53 is engaged to the breaker plate 51. The
5 fiber-reinforced resin composition which is melted in the metering portion 26 of the screw 2 is filtrated via the through holes disposed in the breaker plate 51 and via the screen pack 53, and is then extruded toward the die 54.

The afore-mentioned breaker plate 51 and the screen pack 53 are configured to remove foreign substance from the molten fiber-reinforced resin composition and are also
10 configured to control the flow of the fiber-reinforced resin composition by elevating the back pressure inside the cylinder 3, resulting in fully melted fiber-reinforced resin composition. Accordingly, even if the screw 2 having a relatively low level of the compression ratio is used (in other words, a relatively low level of shear force is applied), the screw 2 is able to securely and fully melt the fiber-reinforced resin composition.

15 The die 54 is made of metal material and is, for example, cylindrically formed. The molten fiber-reinforced resin composition which has passed both the breaker plate 51 and the screen pack 53 is molded into a predetermined shape by means of the die 54.

The screw-actuating member includes, for example, a motor. The screw-actuating member is configured to rotatably journal the screw 2 received within the cylinder 3 about
20 the shaft center thereof, and is also configured to rotatably actuate or drive the screw 2 about the shaft center thereof.

The heater 7 is generally embedded in the outer wall of the cylinder 3, as shown in FIG. 1. The heater 7 may be made in a shape of band plates. The heater 7 may be a plurality of heaters arranged in a shape of band. The heater 7 is configured to provide the cylinder 3
25 with heat energy so as to melt the fiber-reinforced resin composition received in the cylinder

3. A plurality of the heaters 7 may be serially arranged along the longitudinal direction of the cylinder 3.

The heater 7 is provided with a heater 71 for supplying heat energy to the area of the resin feeding portion 24 of the screw 2 inside the cylinder 3, a heater 72 for supplying
5 heat energy to the area of the extrusion portion 25, and a heater 73 for supplying heat energy to the area of the metering portion 26, and a heater 74 for supplying heat energy to the area of the breaker-plate 51 and the die 54, which means The heater 7 can supply different levels of heat energy to different areas of the resin molding apparatus 1, respectively. The heater 71 for supplying heat energy to the area of the resin feeding portion 24 is maintained at a
10 temperature lower than or equivalent to a melting point of the base resin used in the present invention, and is also maintained at a temperature higher than or equivalent to the temperature of 25°C below the melting point (i.e., the melting point - 25°C) of the base resin so as to only preheat the fiber-reinforced resin composition without substantially melting the same resin composition. Furthermore, the heaters 72, 73, and 74 are respectively set at a
15 temperature greater than the melting point of the base resin. For example, when polybutylene terephthalate having the melting point of about 225°C is used as the base resin, the heater 71 may be set at a temperature from about 200°C to about 225°C, and the heaters 72, 73 and 74 are respectively set at a temperature higher than about 225 °C.

The fiber-reinforced resin composition is generally comprised of the base resin and
20 the fibrous filler. In a preferred embodiment, unsaturated polyester resins may be used as the base resin. As above unsaturated polyester resins, polyethylene terephthalate, polybutylene terephthalate, polycyclohexane terephthalate, and so on can be utilized. In addition to the afore-mentioned unsaturated polyester resins, the base resin includes epoxy resins, polyamide resins, phenol resins, and so on. Furthermore, since the base resin is not limited to
25 the resin as mentioned previously, the resin other than the resin as mentioned above that is

not against the objective of the present invention can apparently be used as the base resin in the implementation of the present invention.

The fibrous filler includes, for example, a glass fiber, a carbon filament, an aramid fiber, and so on. The fibrous filler is generally added to the base resin so as to reinforce or
5 enhance the mechanical strength properties of the base resin. If the fibrous filler having a relatively high level of hardness is used, the fibrous filler is easily damaged during a period of time when the fiber-reinforced resin composition is subjected to a relatively high level of shear force to produce the completely melted fiber-reinforced resin composition within the cylinder 3. In this case, enhanced mechanical strength properties of the fiber-reinforced resin
10 composition cannot be maintained. The fibrous filler is never limited to the material mentioned previously as a preferred embodiment, the fibrous filler other than the material as mentioned above that is not against the objective of the present invention can apparently be used as the fibrous filler in the implementation of the present invention.

In a preferred embodiment, as the fiber-reinforced resin composition in accordance
15 with the present invention, for example, Toraycon 1010-G30 (trademark) available from Toray Industries, Inc. including a glass fiber as the fibrous filler in an amount of 30% in polybutylene terephthalate employed as the base resin may be employed. Afore-mentioned fiber-reinforced resin composition is initially produced in the shape of a pellet. However, the fiber-reinforced resin composition is not limited to such a resin composition as previously
20 mentioned, the fiber-reinforced resin composition other than such a resin composition can be apparently used as the fiber-reinforced resin composition in accordance with the present invention, in so much as it is not against the objective of the subject application.

When molding the fiber-reinforced resin composition by use of the afore-mentioned resin molding apparatus 1, the residual material as mentioned previously is
25 fed into the hopper 41, and then is carried to the inside the cylinder 3 via the inlet 4. The

fiber-reinforced resin composition is fed into the groove 23 disposed in the area of the resin feeding portion 24 of the screw 2. Thereafter, as the screw rotates, the fiber-reinforced resin composition is carried to the groove 23 disposed in the area of the extrusion portion 25 of the screw 2, and then carried to the groove 23 disposed in the area of the metering portion 26 of the screw 2.

In the resin feeding portion 24, the fiber-reinforced resin composition is preheated sufficiently by the heater 71 which is set at a temperature equivalent or below the melting point of the base resin used. This predetermined range of temperature of the heater 71 ensures that the fiber-reinforced resin composition cannot be molted in this step. Next, in the area of the extrusion portion 25, the fiber-reinforced resin composition is melted by means of heat energy supplied from the heater 72 which is set at a temperature higher than the melting point of the base resin used, and also by means of the reduced level of shear force in comparison with the conventional apparatus.

Subsequently, the molten fiber-reinforced resin composition passes the area of the metering portion 26, which is made shorter in comparison with the resin feeding portion 24 and the extrusion portion 25, and is in turn carried to the breaker plate 51, and then the screen pack 53 and the die 54. The fiber-reinforced resin composition cools and hardens after passing through the die 54. After cooling, the fiber-reinforced resin composition is molded into a linear shape, is cut, and then is subjected to pelletization once more. In other words, the fiber-reinforced resin composition is finally produced into a recycled pellet.

In accordance with the preferred embodiment of the present invention, the screw 2 is shown to include the resin feeding portion 24 disposed adjacent to the inlet 4, the extrusion portion 25 communicating with the resin feeding portion 24, and the metering portion 26 disposed adjacent to the outlet 5 and communicating with the extrusion portion 25. With respect to outer diameter, the resin feeding portion 24 and the metering portion 26 are

designed to be constant in their respective longitudinal direction, and the extrusion portion 25 is designed to increase gradually toward the metering portion 26. In other words, the extrusion portion 25 of the screw 2 has a tapered shape whose outer diameter is gradually reduced from its one end adjacent to the metering portion 26 to the other end adjacent to the resin feeding portion 24. In this configuration, D1 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the resin feeding portion 24, and D3 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the metering portion 26. In a preferred embodiment of the invention, the ratio of D1 to D3 is generally from 1.2 to 1.95. As a result, a relatively lower level of shear force is applied to the fiber-reinforced resin composition and thus preventing the fibrous filler from being damaged. Accordingly, the fiber-reinforced resin composition can show remarkably enhanced mechanical strength properties before and after its pelleting process.

Since both the resin feeding portion 24 and the extrusion portion 25 are respectively designed to have their length longer than the overall length of the metering portion 26, the fiber-reinforced resin composition is allowed to be preheated sufficiently at the area of the resin feeding portion 24 and then to be fully molted at the area of the extrusion portion 25 by means of heat energy supplied from the heater. Moreover, since the metering portion 26 is designed to be shorter, the molten fiber-reinforced resin composition is subjected to less shear force in the area of the metering portion 26.

The extrusion portion 25 generally has a length L2 longer than the length L3 of the metering portion 26. The ratio of L2 to L3 is generally from 2 to 4. In accordance with such a configuration, the fiber-reinforced resin composition can be sufficiently melted in the area of the extrusion portion 25 by means of heat energy supplied from the heater. Furthermore, since the metering portion 26 is formed shorter, the molten fiber-reinforced resin

composition is subjected to less shear force in the area of the metering portion 26.

The resin feeding portion 24 generally has the length L1 longer than the length L3 of the metering portion 26. The ratio of L1 to L3 is generally from 1.33 to 5. In accordance with such a configuration, the fiber-reinforced resin composition can be sufficiently preheated in the area of the resin feeding portion 24. Moreover, since the metering portion 26 is made shorter, the molten fiber-reinforced resin composition is thus subjected to less shear force in the area of the metering portion 26.

The heater 7 for supplying heat energy is disposed inside the cylinder 3. The heater 71 for supplying heat energy to the area of the resin feeding portion 24 is designed to maintain a temperature of from -25°C below the melting point (i.e., the melting point - 25°C) of the base resin used to the melting point of the same base resin. In accordance with such a configuration, the fiber-reinforced resin composition is allowed to be sufficiently preheated at the area of the resin feeding portion 24, without being substantially melted. Accordingly, the fiber-reinforced resin composition will be subjected to less shear force at the area of the metering portion 26.

The inventor of the present invention prepared the afore-mentioned resin molding apparatus 1, and also carried out the following several experiments so as to test and evaluate the same.

[EXAMPLES]

EXAMPLE 1

Several screws 2 were prepared such that their respective ratio of D1 to D3 was different to each other. As mentioned previously, D1 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the resin feeding portion 24, and D3 is defined as a distance between the outer

circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the metering portion 26. By use of the resin molding apparatus 1 respectively equipped with the screw 2 having such a different D1/D3 ratio, the residual material of the fiber-reinforced resin composition is subjected to pelletization. In other words, the recycled
5 pellet was prepared from the residual material of the fiber-reinforced resin composition, by means of the resin molding apparatus 1 in accordance with the present invention. Only base resin component of thus-obtained recycled pellet was solved in the specified solvent in order to collect only the glass fiber included in the recycled pellet. Microscopic analysis was carried out on the collected glass fiber. In this microscopic analysis, the full length of the
10 glass fiber was measured.

The screws 2 were prepared such that their ratios of D1 to D3 were set to different four values 1.5, 1.8, 3.0 and 3.8 respectively. All of the screws 2 were designed to have an outer diameter of 20 mm, L/D value of 25, L1 value (i.e., the length of the resin feeding portion 24) of 200 mm, L2 value (i.e., the length of the extrusion portion 25) of 240 mm, and
15 L3 value (i.e., the length of the metering portion 26) of 80 mm, and a rotating speed at 150 rpm.

The resin molding apparatus 1 used in this example was D2025-type available from Toyo Seiki Seisaku-sho, Ltd. The heater 71, 72 73, and 74 were respectively set at temperature of 200, 250, 260, and 270°C. Furthermore, Toraycon 1010-G30 (trademark)
20 available from Toray Industries, Inc. was employed as the fiber-reinforced resin composition in accordance with the present invention.

The results of Example 1 were shown in FIG. 3. The numerical values in FIG. 3 were the average of five specimens, respectively. More specifically, in FIG. 3, a lateral axis represents the ratio of D1 to D3, and a vertical axis represents the length (μm) of the glass
25 fiber included in the recycled pellet. With reference to FIG. 3, when the ratio of D1 to D3 is

1.5, the length of the glass fiber is 399 μm , which means that the length of the glass fiber included in the recycled pellet is substantially identical to the length (about 413 μm) of the glass fiber included in the virgin resin pellet. When the ratio of D1 to D3 is 1.8, the length of the glass fiber is 330 μm included in the recycled pellet, which means that the length of the glass fiber included in the recycled pellet corresponded to about 80% of the length of the virgin resin pellet. Also, the ratio of D1 to D3 is less than 1.2, the fiber-reinforced resin composition cannot be sufficiently melted, and therefore is not considered to be suited for further extrusion molding. On the contrary, the ratio of D1 to D3 is greater than 1.95, the glass fiber in an amount of more than 25% is damaged. Conclusively, if the ratio of D1 to D3 is from 1.2 to 1.95, the glass fiber can be protected from such damage or breakage.

EXAMPLE 2

Several screws 2 were prepared such that the ratios of L2 to L3 of the screws 2 were set at different values, respectively. As mentioned previously, L2 is the length of the extrusion portion 25, and L3 is the length of the metering portion 26. By means of the resin molding apparatus 1 equipped with above screw 2, the residual material of the fiber-reinforced resin composition was subjected to pelletization. In other words, the recycled pellet was prepared from the residual material of the fiber-reinforced resin composition. During the pelleting process, the proportion (%) of the molten fiber-reinforced resin composition based on the total of the fiber-reinforced resin composition used (100%) was measured in the area of the extrusion portion 25.

Each of screws 2 was prepared such that the ratio of D1 to D3 was 1.8. As mentioned previously, D1 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the resin feeding portion 24, and D3 is defined as a distance between the outer circumferential face 21a of the

screw shaft 21 and the tip portion 22a of the flight 22 at the area of the metering portion 26. Example 2 was carried out in the similar manner to Example 1, except for the length L1 of the resin feeding portion 24, the length L2 of the extrusion portion 25, the length L3 of the metering portion 26, and the ratio of L2 to L3. Specifically, for one, the values L1, L2, L3, and L2/L3 were set to 200 mm, 200 mm, 120 mm, and 1.7, for another, the values L1, L2, L3, and L2/L3 were set to 200 mm, 240 mm, 80 mm, and 3, and for the other, the values L1, L2, L3, and L2/L3 were set to 200 mm, 260 mm, 60 mm, and 4.3, respectively. In other words, three different screws 2 were prepared as such.

The results of Example 2 were shown in FIG. 4. The numerical values in FIG. 4 were the average of five specimens, respectively. In FIG. 4, a lateral axis represents the ratio of L2 to L3, and a vertical axis represents the proportion (%) of the molten fiber-reinforced resin composition based on the total of the fiber-reinforced resin composition used (100%). With reference to FIG. 4, if the ratio is from 2 to 4, the fiber-reinforced resin composition was melted in an amount of more than or equivalent to about 98%, which means that the fiber-reinforced resin composition is sufficiently melted.

EXAMPLE 3

Screws 2 were prepared such that their ratios of the length L1 of the resin feeding portion 24 to the length L3 of the metering portion 26 were different to each other. By use of the resin molding apparatus 1 each equipped with these different screws 2, the residual material of fiber-reinforced resin composition was subjected to pelletization. In other words, a recycled pellet was prepared from the residual material of the fiber-reinforced resin composition. During the pelletization, the temperature of the fiber-reinforced resin composition preheated at the area of the resin feeding portion 24 was measured.

The screw 2 was prepared such that the ratio of D1 to D3 was 1.8. As mentioned

previously, D1 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the resin feeding portion 24, and D3 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 at the area of the metering portion 26.

5 Example 3 was carried out in the similar manner to Example 1, except for the length L1 of the resin feeding portion 24, the length L2 of the extrusion portion 25, the length L3 of the metering portion 26, and the ratio of L1 to L3. Specifically, for one, the values L1, L2, L3, and L1/L3 were set to 240 mm, 200 mm, 80 mm, and 3, for another, the values L1, L2, L3, and L1/L3 were set to 180 mm, 200 mm, 140 mm, and 1.29, and for the other, the values L1,
10 L2, L3, and L1/L3 were set to 170 mm, 200 mm, 150 mm, and 1.13, respectively. In other words, three different screws 2 were prepared as such.

The results of Example 3 were shown in FIG. 5. The numerical values in FIG. 5 were the average of five specimens, respectively. In FIG. 5, a lateral axis represents the ratio of L1 to L3, and a vertical axis represents the temperature of the fiber-reinforced resin
15 composition. With reference to FIG. 5, if the ratio (L1/L3) is less than 1.33, the fiber-reinforced resin composition is not sufficiently preheated. If the ratio is from 1.33 to 5, the temperature of the fiber-reinforced resin composition is from about 198 °C to about 200 °C, which means that the fiber-reinforced resin composition is sufficiently preheated.

20 EXAMPLE 4

The recycled pellet was prepared from the residual material of the fiber-reinforced resin composition by varying the temperature of the heater 71, the heater 71 being configured to supply heat energy to the area of the resin feeding portion 24 inside the cylinder 3. During the pelletization, the temperature of the fiber-reinforced resin composition
25 preheated in the area of the resin feeding portion 24 was measured.

Further, the temperature of the heater 71 was respectively set to 200°C, 230°C, and 260°C. The screw 2 was prepared such that the ratio of D1 to D3 was 1.8. As mentioned previously, D1 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 in the arc of the resin feeding portion 24, and D3 is defined as a distance between the outer circumferential face 21a of the screw shaft 21 and the tip portion 22a of the flight 22 in the area of the metering portion 26. Except for above setting, Example 4 was carried out in a similar manner to Example 1.

The results of Example 4 were shown in FIG. 6. The numerical values in FIG. 6 were the average of five specimens, respectively. In FIG. 6, a lateral axis represents the temperature of the heater 71, and a vertical axis represents the temperature of the fiber-reinforced resin composition. With reference to FIG. 6, if the temperature of the heater 71 is set to 200°C, the temperature of the fiber-reinforced resin composition is at about 195°C. Further, if the temperature of the heater 71 is set to 225°C, the temperature of the fiber-reinforced resin composition is at about 220°C. FIG 6 shows that the heater 71 having a temperature lower than 200°C cannot preheat the fiber-reinforced resin composition sufficiently, and the heater 71 having a temperature higher than 225°C make the fiber-reinforced resin composition molten. Conclusively, the heater 71 having a temperature of from about 200°C to about 225°C can preheat the fiber-reinforced resin composition sufficiently, without melting the same resin composition.

In above Examples, the resin molding apparatus 1 was equipped with one screw 2. Meanwhile, in the implementation of the present invention, a resin molding apparatus 1 equipped with a plurality of screws 2 can be also utilized. In this case, a plurality of the screws 2 may have their shafts parallel to each other. Otherwise, a plurality of the screws 2 may have their shafts being inclined to each other.

Accordingly, while the present invention has been described herein in relation to

several embodiments, the foregoing disclosure is not intended or to be construed to limit the present invention or otherwise to exclude any such other embodiments, arrangements, variations, or modifications and equivalent arrangements. Rather, the present invention is limited only by the claims appended hereto and the equivalents thereof.

5

[INDUSTRIAL APPLICABILITY]

In accordance with one aspect of the present invention, (a) the screw comprises a resin feeding portion being disposed adjacent to the inlet, an extrusion portion communicating with the resin feeding portion, and a metering portion communicating with
10 the extrusion portion; (b) an outer diameter of the screw shaft disposed in the screw is kept constant in the area of the resin feeding portion, is gradually reduced toward the metering portion in the area of the extrusion portion, and is kept constant in the area of the metering portion; and (c) a ratio of a distance between the outer circumferential face of the screw shaft and a tip portion of the flight in the area of the resin feeding portion to a distance between the
15 outer circumferential face of the screw shaft and the tip portion of the flight in the area of the metering portion is set to value of from 1.2 to 1.95. Accordingly, it is advantageous that a relatively lower level of shear force is applied to the fiber-reinforced resin composition and thus preventing the fibrous filler included in the fiber-reinforced resin composition from being damaged. Moreover, the fiber-reinforced resin composition can advantageously
20 maintain its remarkably enhanced mechanical strength properties before and after its pelletization.

In accordance with one preferred embodiment of the invention, since the resin feeding portion and the extrusion portion are made longer than the metering portion, the fiber-reinforced resin composition can be sufficiently preheated in the area of the resin
25 feeding portion, can also be sufficiently molted in the area of the extrusion portion, and is

subjected to less level of shear force in the area of the metering portion.

In accordance with one preferred embodiment of the invention, since a ratio of length of the extrusion portion to length of the metering portion is from 2 to 4, the fiber-reinforced resin composition can be sufficiently heated and melted in the area of the
5 extrusion portion, and the molten fiber-reinforced resin composition is subjected to less level of shear force in the area of the metering portion.

In accordance with one preferred embodiment of the invention, since a ratio of length of the resin feeding portion to length of the metering portion is from 1.33 to 5, the fiber-reinforced resin composition can be sufficiently preheated in the area of the resin
10 feeding portion, and the molten fiber-reinforced resin composition is subjected to less level of shear force in the area of the metering portion.

In accordance with one preferred embodiment of the invention, since the afore-mentioned resin molding apparatus further includes a heater for supplying heat energy to inside the cylinder, and the heater is maintained at a temperature of from 25°C below
15 melting point of the base resin to the melting point, the fiber-reinforced resin composition can be sufficiently preheated without substantial melting, and is subjected to less level of shear force in the area of the resin feeding portion.

CLAIMS

1. A resin molding apparatus, comprising:

5 a screw having a screw shaft and a plurality of flights extending from an outer circumferential face of the screw shaft,

a cylinder receiving the screw therein,

an inlet being disposed in a posterior end portion of the cylinder and being configured to supply a fiber-reinforced resin composition into the cylinder, the

10 fiber-reinforced resin composition comprising a base resin and a fibrous filler, and

an outlet being disposed in a tip portion of the cylinder and being configured to discharge the fiber-reinforced resin composition therethrough, the fiber-reinforced resin composition being melted and kneaded inside the cylinder,

wherein, (a) the screw comprises a resin feeding portion being disposed adjacent to the inlet,

15 an extrusion portion communicating with the resin feeding portion, and a metering portion communicating with the extrusion portion; (b) an outer diameter of the screw shaft is kept constant throughout a length of the resin feeding portion, increases gradually toward the metering portion throughout a length of the extrusion portion, and is kept constant throughout a length of the metering portion; and (c) a ratio of a distance between the outer
20 circumferential face of the screw shaft and a tip portion of the associated flight in an area of the resin feeding portion to a distance between the outer circumferential face of the screw shaft and a tip portion of the associated flight in an area of the metering portion is from 1.2 to 1.95.

2. The resin molding apparatus according to claim 1, wherein both the resin feeding

25 portion and the extrusion portion are made longer than the metering portion.

3. The resin molding apparatus according to claim 1 or 2, wherein a ratio of the length of the extrusion portion to the length of the metering portion is from 2 to 4.

4. The resin molding apparatus according to any of claims 1 to 3, wherein a ratio of the length of the resin feeding portion to the length of the metering portion is from 1.33 to 5.

5 5. The resin molding apparatus according to any of claims 1 to 4, further including a heater for supplying heat energy to the area of the resin feeding portion inside the cylinder, wherein the heater is maintained at a temperature of from 25°C below melting point of the base resin to the melting point.

FIG. 2

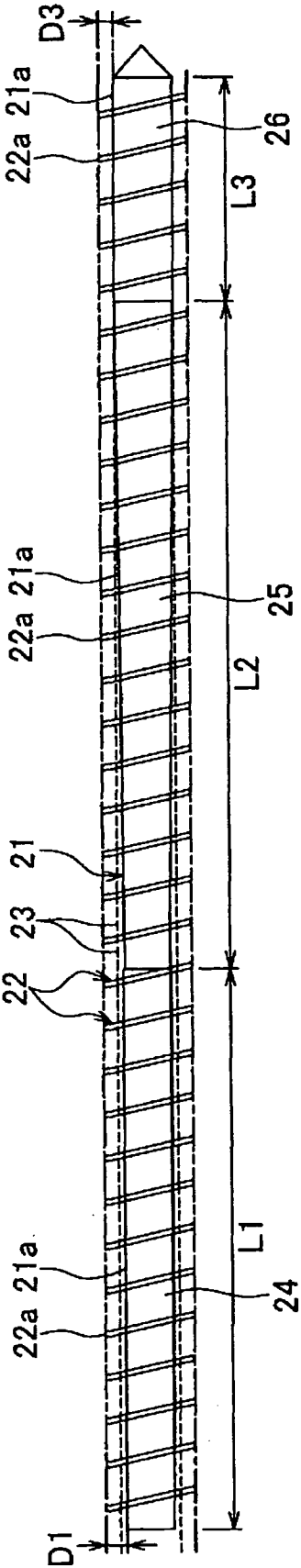


FIG. 3

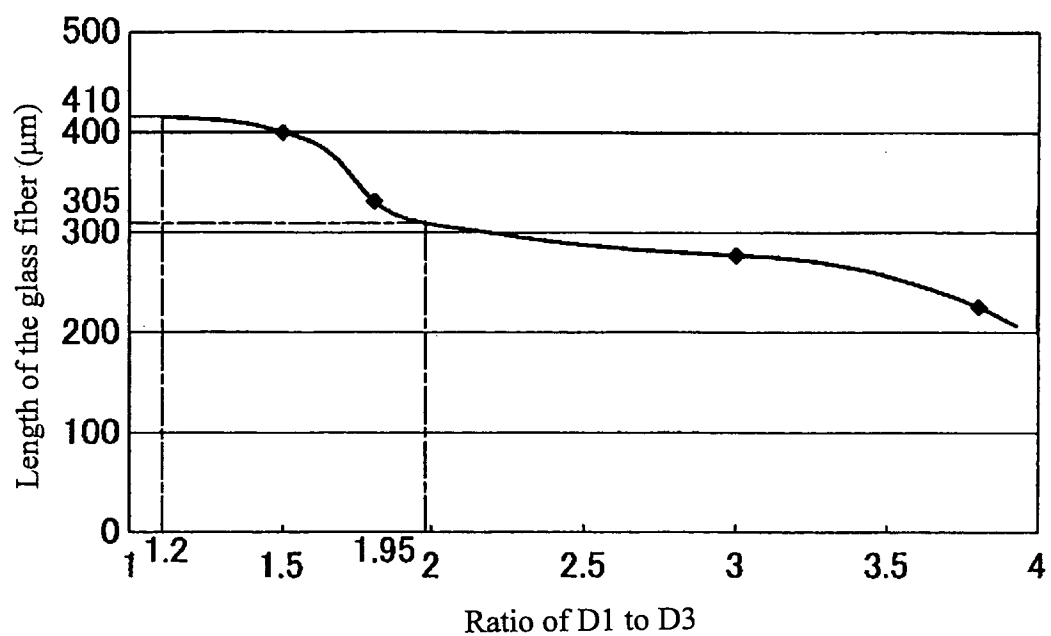


FIG. 4

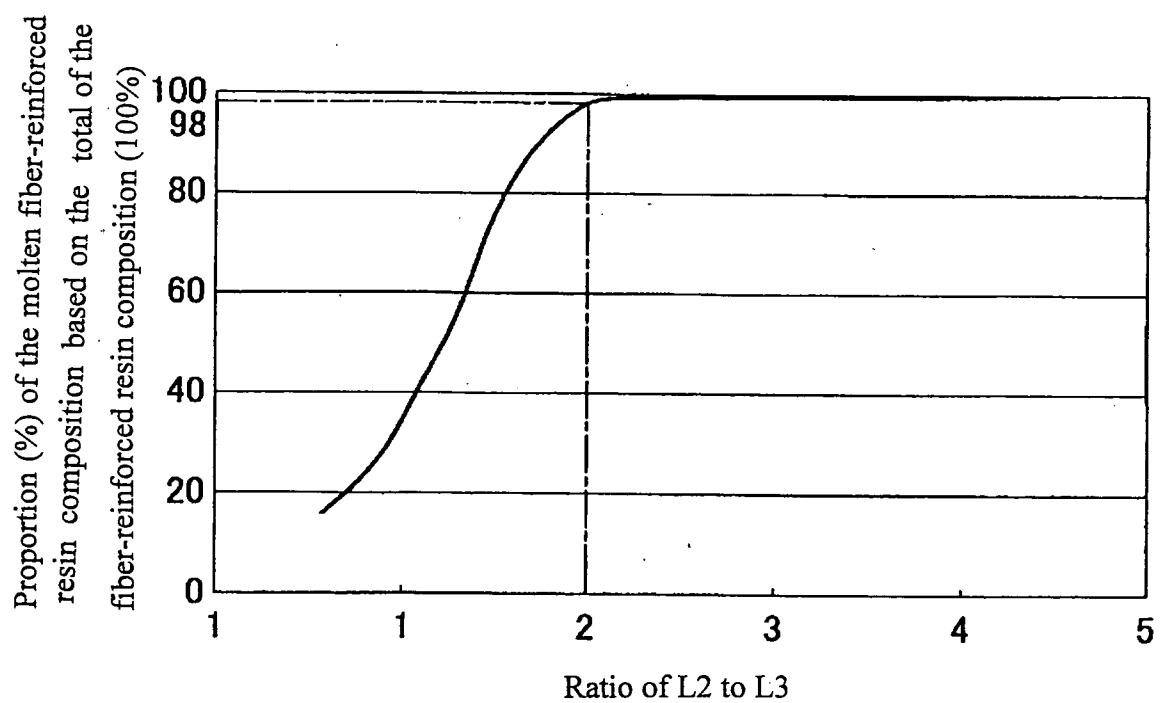


FIG. 5

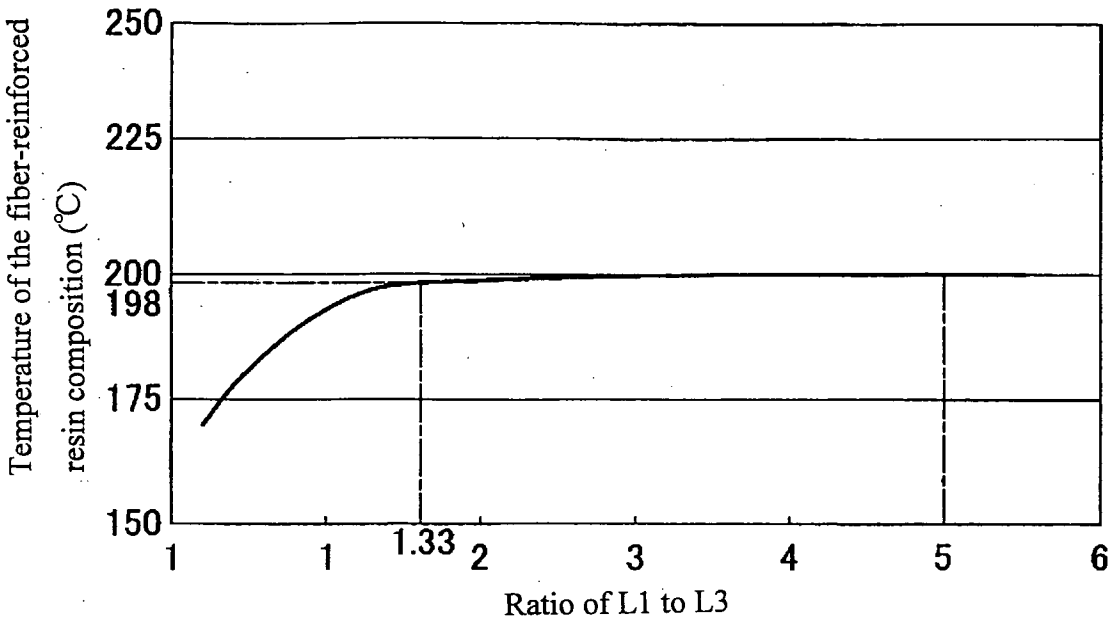
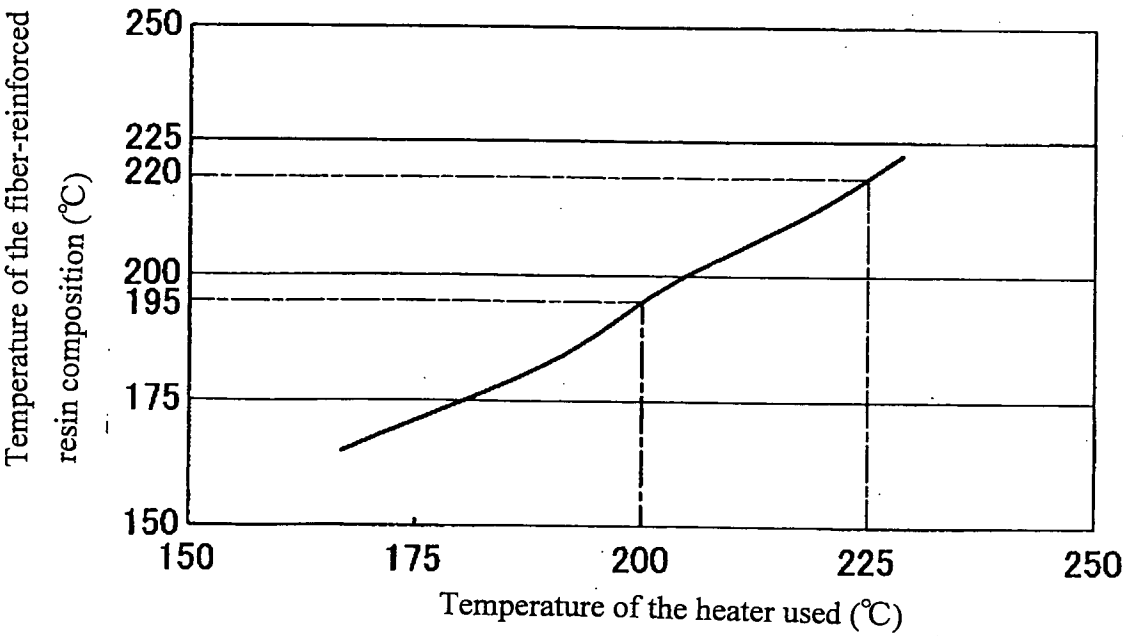


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/068133

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B29B7/42 (2006.01) i, B29C47/60 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B29B7/00-7/94, B29C47/00-47/96, B29C45/00-45/84

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2008
 Registered utility model specifications of Japan 1996-2008
 Published registered utility model applications of Japan 1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 920971 A1 (KAWASAKI STEEL CORPORATION) 1999.06.09, column 1, 3, 4, 30, 47; figure 2 & JP 11-34131 A & US 6228308 B1 & WO 1998/052736 A1 & CA 2261584 A	1-5
X	EP 706873 A2 (SUMITOMO CHEMICAL COMPANY LIMITED) 1996.04.17, claim 1-2, page 2, line 2-4, page 6, line 6-7, line 38-44 & JP 8-156055 A & US 5653534 A & EP 960715 A2 & DE 69524915 T	1-5
X A	US 5041258 A (POLYPLASTICS CO., LTD.) 1991.08.20, claim 2 & JP 2-292008 A & JP 2-292009 A & BR 9001949 A & KR 10-1992-0011079 B & CA 2015375 A1	1 2-5



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15.12.2008

Date of mailing of the international search report

22.12.2008

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/068133

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 8-318561 A (MITSUBISHI HEAVY IND LTD) 1996.12.03, column 6, 7; figure 4 (none of patent family members)	1 2-5