

**PELLET-TYPE FOAMS OF NON-CROSSLINKED POLYPROPYLENE RESIN
HAVING LOWER MELTING POINT AND PROCESS AND DEVICE FOR
PRODUCING THE SAME AND MOLDED FOAMS THEREFROM**

5 TECHNICAL FIELD

The present invention relates to a pellet-type non-crosslinked polypropylene foam having a melting point of 125 °C to 140 °C, a process for producing said foam, a device for realizing said process and an article molded from said foam.

10 BACKGROUND ART

Due to its excellent mechanical strength and cushioning properties, a polypropylene resin foam is widely used as a packaging material, a building material, a heat shield material and the like. However, since polypropylene has a high crystallinity and a low melt viscosity and is difficult to cross-link, it has hereto been quite difficult to obtain
15 a highly expanded product from the polypropylene.

US patent No. 5,527,573 (issued June 18, 1996) discloses extruded closed-cell polypropylene resin foam and several methods for producing said foam. The foam of the US patent is in a plank form and has a minimal cross-sectional area of about 5×2.54 square centimeters, a minimal thickness of 12.7 millimeters and a density of about 5
20 pounds per a cubic foot. The form and properties make it difficult to mold the foam into desired shaped articles. US patent No. 6,051,617 (issued April 19, 2000) discloses a foamed polypropylene resin particle useful for molding a foamed, molded article and a method of preparing the same. However, the foamed polypropylene resin particle is prepared by grafting a vinyl comonomer to polypropylene resin particles to form the
25 modified copolymer resin particles and foaming the modified copolymer resin particles.

US patent No. 6,077,875 (issued June 20, 2000) discloses foamed and expanded beads of a polypropylene resin for molding prepared from a non-crosslinked propylene-ethylene random copolymer. The foamed beads of the US patent has an open cell content of at most 40%, most preferably 25% and has a melting point of at least 141 °C.

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DISCLOSURE OF INVENTION

A non-crosslinked polypropylene resin is advantageous as it can be recycled and the pellet-type foam produced from the resin can be easily molded. However, the pellet-type foam obtained through extrusion of the non-crosslinked polypropylene resin contains
10 open cells to no small extent and thus is useless. For its practicability, the pellet-type foam must contain a great amount of closed cells for mechanical strength. It is only JSP Corporation of Japan throughout the world that successfully commercially produces a pellet-type foam from a non-crosslinked polypropylene resin. However, while it is recognized that the pellet-type non-crosslinked polypropylene foam having lower melting
15 point are highly valuable owing to its easy molding and excellent recycling, a pellet-type non-crosslinked polypropylene foam having a melting point of 140 °C and less has not yet been produced.

Therefore, an object of the present invention is to provide a pellet-type polypropylene resin foam with a melting point of 140 °C or less which is produced from a
20 non-crosslinked polypropylene resin to ensure a recyclability, has a high content of closed cells to provide a satisfactory mechanical strength and can be molded into various shaped packaging materials, and a method for producing the same. The inventors have successfully produced pellet-type foams of non-crosslinked polypropylene with a melting point of 125 to 140 °C, which comprises about at least 40% of closed cells by providing a
25 tandem extruder with a plurality of temperature zones having specifically varied

temperatures, making the non-crosslinked polypropylene resin melt having a melting point of 138 to 140°C flow through the temperature zones, mechanically homogenizing the polypropylene resin melt passed through such zones at a lower temperature of 120 to 130°C, expanding the homogenized melt through a plurality of holes formed in the dies under pressure, and cutting expanded foams discharged from the holes of the dies.

In one aspect, the present invention provides a pellet-type non-crosslinked polypropylene foam having a melting point of 125 to 140°C.

In another aspect, the present invention provides a method for preparing a pellet-type non-crosslinked polypropylene foam having a melting point of 125 to 140°C, comprising steps of, (a) extruding a non-crosslinked polypropylene random copolymer having a melting point of 138 to 140°C through a tandem extruder; the tandem extruder consisting of the first extruder divided into the first temperature zone in which a temperature of 147 to 153°C is set, the second temperature zone in which a temperature of 167 to 172°C is set, the third temperature zone in which a temperature of 168 to 172°C is set, the fourth temperature zone in which a temperature of 218 to 225°C is set, the fifth temperature zone in which a temperature of 197 to 203°C is set and the sixth temperature zone in which a temperature of 188 to 193°C is set, the second extruder divided into the first temperature zone in which a temperature of 167 to 173°C is set, the second temperature zone in which a temperature of 147 to 152°C is set, the third temperature zone in which a temperature of 142 to 147°C is set, the fourth temperature zone in which a temperature of 137 to 141°C is set, the fifth temperature zone in which a temperature of 137 to 142°C is set and the sixth temperature zone in which a temperature of 132 to 137°C is set, and a guide, connecting the first extruder with the second extruder, in which a temperature of 248 to 255°C is set; (b) compulsorily flowing the extruded material at a temperature of 125 to 140°C by pumping; (c) homogenizing the extruded material at a

temperature of 120 to 130 °C; (d) expanding the homogenized material through a dies; and
(e) cutting the expanded material to obtain the pellet-type foams.

In another aspect, the present invention provides a device for producing a pellet-type non-crosslinked polypropylene foam having a melting point of 125 to 140 °C.

5 In another aspect, the present invention provides articles molded from pellet-type non-crosslinked polypropylene foams having a melting point of 125 to 140 °C.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and other advantages of the present
10 invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a view showing the overall structure of the device for producing pellet-type foams of non-crosslinked polypropylene according to the present invention;

FIG. 2 is a plan view showing a cylinder of the first extruder shown in FIG. 1;

15 FIG. 3 is a sectional view taken along the line A-A in FIG. 2;

FIG. 4 is a schematic view showing the structure of the device for supplying CO₂;

FIG. 5 is a sectional view showing the inner structure of the pumping part and the homogenizing part shown in FIG. 1;

FIG. 6A and FIG. 6B are front views showing each member of the homogenizing
20 part;

FIG. 7 is a plan view showing the structure of the die part shown in FIG. 1;

FIG. 8 is a sectional view taken along the line B-B in FIG. 7;

FIG. 9 is a sectional view taken along the line A-A in FIG. 8;

FIG. 10A is a side view showing a cylinder of the die part to which a cooling
25 device is mounted;

FIG. 10B is a front view of FIG. 10A;

FIG. 11 is a DSC curve of the pellet-type polypropylene foams (Example 1) prepared according to the present invention;

FIG. 12 is a DSC curve of the pellet-type polypropylene foams (Example 2)
5 prepared according to the present invention;

FIG. 13 is a DSC curve of RP2400 (polypropylene-polyethylene (3%)) copolymer used for preparing the pellet-type polypropylene foams of the present invention;

FIG. 14 shows the result of the FT-IR analysis of the pellet-type polypropylene foams prepared according to the present invention;

10 FIG. 15 shows the result of the FT-IR analysis of RP2400 (polypropylene-polyethylene (3%)) copolymer used for preparing the pellet-type polypropylene foams of the present invention;

FIG. 16A is a photograph taken by an optical microscope at x100 magnification and showing the pellet-type polypropylene foams prepared according to the present
15 invention;

FIG. 16B is a photograph taken by an optical microscope at x400 magnification and showing the pellet-type polypropylene foams prepared according to the present invention;

Similar reference numbers refer to similar parts throughout several views of the
20 drawings.

BEST MODE FOR CARRYING OUT THE INVENTION

Prior to the present invention, it has been impossible to prepare pellet-type foams having a melting point of 140°C or less. Pure polypropylene whose melting point is
25 138°C could not be processed at a temperature of 138°C or less, since it would be cured

rapidly at its melting point or less. Thus, it has been also considered as being impossible to prepare pellet-type foams having a melting point of 140 °C or less.

However, the inventors have developed the pellet-type non-crosslinked polypropylene foams which have a melting point of 140 °C or less and an open cell content of about 20% or less. Such pellet-type foams have been developed by combination and application of a number of discoveries. For example, the inventors have found that the content of open cells in foams can be remarkably decreased by using a tandem extruding method as a basis, setting specific temperature conditions for the first and second extruding process, and homogenizing the melt resulting from the extruder at a lower temperature of 125 to 130 °C. Also, the inventors have found that only when the temperature during the extrusion and expansion of the non-crosslinked polypropylene resin having a melting point of 138 to 140 °C is kept within a specific temperature range, closed cells of 80% or more can be formed. Further, the inventor have found that a melting point of the foams prepared from the non-crosslinked polypropylene resin having a melting point of 138 to 140 °C can be lowered to 138 °C or less by the specific working conditions according to the present invention.

Now, the method for preparing the pellet type foams of non-crosslinked polypropylene according to the present invention will be described in detail. The manufacturing method of the present invention comprises extruding, pumping, homogenizing, expanding and pelletizing steps.

(1) Extruding

An extruding process according to the present invention can be performed by using a tandem extruder that is commonly used and well known in the art for preparing foams as a basis or its variation. Materials used for preparing the pellet type foams of

non-crosslinked polypropylene according to the present invention comprises a non-crosslinked polypropylene random copolymer having a melting point of 138 to 140°C, a nucleating agent, a foaming agent and an additive, if necessary.

The basic resin of the present invention is the non-crosslinked propylene random
5 copolymer having a melting point of 138 to 140°C. Examples of other comonomer copolymerizable with propylene include ethylene, 1-butene, 1-pentene and 1-hexene. The propylene random copolymer can be bipolymers such as propylene-ethylene random copolymer or propylene-butene random copolymer or terpolymers such as propylene-ethylene-butene copolymer. The ratio of other comonomer component other than
10 propylene in the copolymer is preferably 0.05 to 10 % by weight.

The nucleating agent functions to disperse a foaming agent and adjust the cell size of the foams. Examples of the nucleating agent which can be used in the present invention include, but are not limited to, sodium bicarbonate, sodium carbonate, potassium bicarbonate, potassium carbonate, ammonium bicarbonate or ammonium carbonate.
15 Sodium bicarbonate is preferred. The more amount of the used nucleating agent is, the smaller the cell size of the foams is. On contrary, the less amount of the used nucleating agent is, the larger the cell size of the foams is. In the present invention, the nucleating agent of 0.1 to 0.4% based on the weight of a resin is used. When the amount of the used nucleating agent exceeds 0.4%, insufficient dispersion or agglomeration can occur, and as
20 a result, the cell grows larger than a predetermined size. On the contrary, when the amount of the used nucleating agent is 0.1% or less, the nucleation activity is excessively weak, whereby the cell diameter can not be reduced.

As a usable foaming agent in the present invention, there are organic foaming agents and inorganic foaming agents. Examples of the organic foaming agent are
25 aliphatic hydrocarbons such as propane, butane, hexane and heptane, alicyclic

hydrocarbons such as cyclobutane and cyclopentane, and halogenated hydrocarbons such as chlorofluoromethane, trifluoromethane, 1,1-difluoroethane, 1,2,2,2-tetrafluoroethane, methyl chloride, ethyl chloride and methylene chloride. Also, usable organic foaming agents include dichlorotetrafluoroethane, trichlorotrifluoroethane, trichloromonofluoromethane, 5 dichlorodifluoromethane, dichloromonofluoromethane and dibromotetrafluoroethane. Considering forming workability, nontoxicity and flame retardancy, these fluorochlorinated hydrocarbon are preferable. These organic foaming agents can be used alone or as a mixture of two or more thereof. Examples of the inorganic foaming agent include nitrogen, carbon dioxide, argon and air. These inorganic foaming agents can be 10 used alone or as a mixture of two or more thereof. Also, any mixtures of randomly selected two or more of the organic foaming agents and the inorganic foaming agents can be used. The most preferred foaming agent is an inorganic foaming agent since they do not destroy an ozoneosphere and are inexpensive. The used amount of the foaming agents depends upon the expansion ratio of the foam pellet to be obtained and the type of the used 15 resin and foaming agent. The amount of the foaming agent used in the present invention is about 20% to 30% by weight, based on the weight of the resin.

In addition, various kinds of additives can be used. Examples of such additives include an antioxidant, UV absorber, flame retardant, coloring agent, dye, metal deactivator and the like. These additives can be used in an amount of 0.1 to 0.3% by 20 weight, based on the weight of the copolymer resin. In a preferred embodiment of the present invention, paraffin wax is used. This helps the copolymer resin to flow and acts as an antistatic agent to remove static electricity of the copolymer resin. The used amount of paraffin wax is about 0.1% by weight.

The above materials used in the present invention are extruded by the tandem 25 extruder in which a specific physical condition is set according to the present invention and

the process will be described as follows. The tandem extruder is consisted of a first extruder, a second extruder and a guide connecting the first and second extruders. A screw compression ratio is generally 3:1. Usually, the inner diameter of a cylinder of the first extruder is about 60 to 70mm. The inner diameter of a cylinder of the second
5 extruder is normally about 90 to 95mm.

The first extruder is divided into six zones according to their temperatures, each zone corresponds to 300 to 400LD. The six zones are a first temperature zone of 148 to 153 °C, a second temperature zone of 167 to 172 °C, a third temperature zone of 167 to 172 °C, a fourth temperature zone of 218 to 223 °C, a fifth temperature zone of 197 to 203 °C,
10 and a sixth temperature zone of 188 to 193 °C.

The non-crosslinked polypropylene random copolymer resin and the nucleating agent are supplied at a constant speed through a hopper and then melted in the first temperature zone in which a temperature of 148 to 153 °C is set. The flowing speed can be adjusted by a rotating speed of the screw and is normally about 20 to 30 rpm. Such
15 rotating speed of the screw determines an inflow speed of raw material and a flow speed of melt. In this case, an inflow speed of the resin is about 25 km/hour. Though the copolymer resin and the nucleating agent can be supplied through one hopper at the same time, it is preferable that they are supplied independently via individual hoppers. The second and third temperature zones are maintained at a temperature of 167 to 172 °C, other
20 additives such as paraffin wax are introduced to an starting point of the third temperature zone. The paraffin wax is pumped to be introduced after it is melted. Also, the temperature of the fourth temperature zone is set to 218 to 223 °C and a foaming agent is supplied to an starting point of the fourth temperature zone by pumping operation. The melt from the fourth temperature zone is passed through the fifth temperature zone in
25 which a temperature of 218 to 223 °C is set and then introduced to the sixth temperature

zone in which a temperature of 188 to 193 °C is set.

The melt from the sixth temperature zone of the first extruder is introduced to the second extruder through the guide connecting the first and second extruders. Here, the temperature of the guide is set to 248 to 255 °C and LD of the guide is 300 to 400mm.

5 The second extruder is also divided into six zones according to a temperature, each zone corresponds to 470 to 520mm. The six zones are a first temperature zone of 168 to 173 °C, a second temperature zone of 147 to 152 °C, a third temperature zone of 143 to 147 °C, a fourth temperature zone of 137 to 142 °C, a fifth temperature zone of 137 to 142 °C, and a sixth temperature zone of 132 to 137 °C. A screw speed of the second
10 extruder is normally 8 to 12 rpm.

Each zone in the first and second extruders can be maintained at a specifically set temperature by means of any one of water-cooled type, oil-cooled type and air-cooled type method. Among them, the water-cooled method that adjusts a temperature using water pressure is preferable. For example, a water cooled type device can be used, which has a
15 cooling water body which is formed in a hollow shape, so that it can be mounted around the cylinder of the extruder and the cylinder is inserted therein, and is provided with a cooling water passage formed integrally with the body, so that cooling water is contacted directly with the surface of the cylinder.

20 (2) Pumping

The sixth temperature zone of the second extruder can correspond to a flange for connecting a means for crushing the melt according to a method of the present invention. Since the temperature of this flange is maintained peculiarly at 132 to 137 °C by the present invention and this temperature is lower than the melting point of 138 °C of the
25 polypropylene resin, an flowing speed of the melt can be remarkably lowered. Thus,

there is need for forcibly flowing the melt so that it can move smoothly. Such compulsory flow can be achieved by means of a pump. At this time, the temperature is maintained at 125 to 138°C by the water-cooled type device.

5 (3) Homogenizing

According to the present invention, the melt transferred from the extruder by pumping at a temperature of 125 to 140°C is homogenized at a temperature of 120 to 130°C. Here, to homogenize means that the melt is cut and ground at the same time in a manner of grinding stones. Also, through homogenization, the melt becomes to have a
10 uniform temperature in the inner portion and outer portion. In the course of homogenization, the temperature in the cylinder is kept at 120 to 130°C, preferably by a water cooling type or oil cooling type method, more preferably oil cooling type method. At this time, the pressure inside the cylinder reaches about 120kgf/cm².

15 (4) Expanding

The homogenized melt is expanded through dies. As described above, since a pressure inside the cylinder in which the melt are homogenized reaches about 120kgf/cm², a decompression means is installed at the dies to maintain a pressure of 0.3 to 0.7kgf/cm². The polypropylene resin is expanded through holes of the dies. Here, a diameter of each
20 hole is normally 0.5 to 1.0mm, and an expansion ratio is normally five times of a diameter of the micro hole.

(5) Pelleting

The foams formed by expansion through the holes of the dies are discharged and
25 simultaneously cut by cutting members to produce pellet type foams.

A device for producing the pellet-type foams of non-crosslinked polypropylene which have a melting point of 125 to 140°C according to the present invention comprises a first extruder, a second extruder connected to the first extruder, a pumping part connected to the second extruder, a homogenizing part connected to the pumping part and a dies part connected to the homogenizing part

The first extruder comprises a cylindrical cylinder having a screw shaft rotatably mounted therein, a driving means disposed at an end of the cylinder for rotating the screw shaft and a plurality of cooling means and heating means disposed on an the circumference surface of the cylinder and is provided with inlets for supplying a polypropylene and a nucleating agent to the cylinder in an end portion of the cylinder near the driving means is and inlets for supplying an additive such as an antistatic agent and a foaming agent in a proper middle portion of the cylinder and an outlet at the other end portion of the cylinder. The polypropylene and a nucleating agent supplied to the cylinder via the inlet are transferred compulsorily toward the outlet by the screw shaft which is rotated by the driving means.

The second extruder connected to the first extruder by a guide comprises a cylinder to which the polypropylene melt discharged from the cylinder of the first extruder is supplied through the guide, and a plurality of cooling means and a heating means mounted to the outer circumference surface of the cylinder for adjusting a temperature of the melt in the cylinder.

The pumping part for moving compulsorily the polypropylene melt discharged from the second extruder to the next device comprises a casing having an inner space to which the polypropylene melt discharged from the cylinder of the second extruder is supplied, a pair of gears rotatably installed in the casing, the gears being engaged with each

other, and a driving means for rotating the gears.

The homogenizing part comprises a cylindrical first housing to which the polypropylene melt discharged from the cylinder of the pumping part is supplied, the first housing being rotatably installed rotatably, a driving means for rotating the first housing, a screw connected to a discharging end of the first housing, a second housing located on a circumference part of the screw, a frame mounted to an outer circumference of the second housing for forming an airtight space between the second housing and the frame. A spiral space is formed between the screw and the second housing along the entire length of the screw and the polypropylene melt discharged from the first housing is flow therethrough to be discharged and discharged to the outside. A heat transfer fluid oil flows in a space formed between the second housing and the frame to adjust a temperature of the polypropylene melt which flows through the second housing.

The homogenizing part comprises a homogenizing means that crushes uniformly the polypropylene melt. The homogenizing means is composed of a rotating plate rotatably mounted and a fixing plate disposed to be contacted with the rotating plate. The rotating plate is provided with a plurality of slits arranged radially and the fixing plate is provided with a plurality of circular holes. The polypropylene melt introduced to the homogenizing part arrives at the rotating plate and is cut by an edge of each opening of the rotating plate while it passes through the rotating plate. Then, the cut polypropylene melt is ground by the rotating plate in the space between the rotating plate and the fixing plate.

The ground polypropylene melt discharged from the homogenizing part is supplied to the dies part including a discharging part, a cutting part and a driving means, in which the expanded foams are cut into a predetermined dimension.

In the present invention, the cooling means mounted to the cylinders of the first or second extruder has a closed casing through which cooling water supplied from the outside

flows. The cooling water introduced to the inside of the casing flows through the casing while being in contact with the surface of the cylinder whereby the temperature of the polypropylene melt that flows within the cylinder is reduced. The heating means disposed between two casings employs a heater having a heating coil installed therein.

5 The cylinder of the first extruder is divided into six temperature zones according to a temperature condition which the polypropylene melt flowing in the cylinder should satisfy. A temperature of each zone is adjusted by the cooling means or heating means mounted on the outer circumference of the cylinder. A temperature of the polypropylene melt should be kept at 147 to 153 °C in the first temperature zone, at 167 to 172 °C in the
10 second temperature zone, at 168 to 172 °C in the third temperature zone, at 218 to 225 °C in the fourth temperature zone, at 197 to 203 °C in the fifth temperature zone and at 188 to 193 °C in the sixth temperature zone.

 The cylinder of the second extruder is also divided into six temperature zones according to a temperature condition which the polypropylene melt flowing in the cylinder
15 should satisfy. A temperature of each zone is adjusted by the cooling means or heating means mounted on an outer circumference of the cylinder. A temperature of the polypropylene melt should be at 167 to 173 °C in the first temperature zone, at 147 to 152 °C in the second temperature zone, at 142 to 147 °C in the third temperature zone, at 137 to 141 °C in the fourth temperature zone, at 137 to 142 °C in the fifth temperature zone
20 and at 132 to 137 °C in the sixth temperature zone.

 The guide connecting the first extruder and the second extruder should be kept at a temperature of 248 to 255 °C.

 The two gears disposed in the inner space of the casing of the pumping part rotate in opposite directions from each other toward a center of the inner space to make the
25 polypropylene melt move compulsorily to a next process position. Also, the first housing

of the homogenizing part is rotatably supported on supporting plates by a plurality of bearing blocks. A drive sprocket of a driving means is geared with a driven sprocket fixed to an outer circumference surface of the first housing so that the first housing is rotated in response to the operation of the driving means.

5 The discharging part of the dies part includes a hollow guide bar and a cylinder located outside of the guide bar. The guide bar has a plurality of cavities formed on the outer circumference thereof in a longitudinal direction of the guide bar. The polypropylene melts discharged from the homogenizing part flows through each cavity. A plurality of through holes are formed at portions of the cylinder corresponding to the
10 cavities, respectively.

 The cutting part of the dies part includes a supporting plate located at a rear side of the discharging part and cutting member fixed to the supporting plate and movably located outside of the cylinder. The cutting member is provided with a plurality of through holes formed at positions corresponding to the plurality of through holes on the
15 cylinder, respectively. The driving means comprises an eccentric cam being able to rotate by a motor, a crank connected to the eccentric cam and rotating in response to the rotation of the cam, and a power converting and transmitting means connected to the crank for converting a rotating movement of the crank into a linear movement and transmitting the linear movement to the supporting plate to which the cutting member is fixed, whereby the
20 cutting members are reciprocated along the outer circumference of the cylinder by the operation of the driving means and the foams expanded from the through holes of the cylinder are cut by edges of the through holes of the cutting member.

 Meanwhile, the cylinder provided with a plurality of grooves formed in a longitudinal direction on predetermined position thereof. Each groove has a reciprocating
25 rod which is movably located therein and has one end fixed to the supporting plate. A

cutting member is fixed to each reciprocating rod by a fixing means and is reciprocated on an outer circumference of the cylinder by the reciprocating rod which is reciprocated along each groove of the cylinder.

Now, a particular structure and operation of the device for producing pellet-type foams according to the present invention will be described in more detail taken in conjunction with the accompanying drawings.

FIG. 1 is a view showing an overall structure of a device for producing the pellet-type foams according to the present invention. The device for producing foams according to the present invention comprises the first extruder **100**, the second extruder **200** connected to the first extruder **100** via a guide **150**, a pumping part **300** connected to the second extruder **200**, a homogenizing part **400** connected to the pumping part **300** and a dies part **500** for forming a foam mixture discharged from the homogenizing part **400** into pellet-type foams. Hereinafter, respective parts as mentioned above will be described individually.

A. First extruder 100.

FIG. 2 is a plan view showing a cylinder of the first extruder **100** shown in FIG. 1 and FIG. 3 is a sectional view taken along the line A-A in FIG. 2. These figures show a structure of the first extruder **100**. The first extruder **100** comprises a cylindrical cylinder **101** having a certain length, a driving means **102** installed at an end of the cylinder **101**, a screw shaft **103** mounted in the cylinder **101** and being able to rotate by the driving means **102**, and a cooling means **104** and heating means **105** installed on the outer circumference surface of the cylinder **101**.

At an end portion of the cylinder **101** near the driving means **102**, entrances **101a**, **101b** (only one entrance **101a** is shown in FIG. 3 which is a sectional view) for supplying a

row polypropylene and a nucleating agent (for example, sodium bicarbonate) to the cylinder **101**, respectively, are formed. An exit **101c** is formed at another end portion of the cylinder **101**. Also, at a middle portion of the cylinder **101**, an entrance **101d** for supplying an antistatic agent (for example, paraffin wax) and an entrance **101e** for supplying a foaming agent (for example, LPG or CO₂) are formed.

On the other hand, an interior of the cylinder **101** is divided into six temperature zones according to temperature conditions of the polypropylene that is supplied to the cylinder **101**. The cooling means **104** and the heating means **105** are mounted to the outer circumference surface of the cylinder **101** at positions corresponding to respective temperature zones for adjusting the temperature of the polypropylene melt.

FIG. 2 is a plan view showing the cooling means **104** and the heating means **105** mounted on the outer circumference surface of the cylinder **101** of the first extruder **100** shown in FIG. 1. Now, the cooling means and heating means will be explained in detail referring to FIG. 3.

The cooling means **104** mounted on the outer circumference surface of the cylinder **101** corresponding to each zone has an airtight casing with a donut shape, through which a cooling water supplied from an outside flows. The cooling water introduced to the casing **104** flows through the casing **104** while being in contact with the surface of the cylinder **101**. Therefore, the temperature inside the cylinder **101**, that is, the temperature of the polypropylene melt that flows therein can be lowered.

The heating means **105** mounted between two casings **104** (that is, cooling means) is a heater in which a heating coil is installed. The heating means raise the temperature of the polypropylene melt which has been already lowered by the cooling means **104** to a predetermined temperature.

The function of the first extruder **100** having a structure as described above will

be described with reference to respective drawings. As the driving means **102** is activated, polypropylene and a nucleating agent are supplied to the cylinder **101** through the entrances **101a**, **101b**, respectively. The screw shaft **103** is rotated in the cylinder **101** by the action of the driving means **102** (of course, a rotating speed of the screw shaft is lowered by a speed reducer, as compared with a rotating speed of the driving means), whereby the polypropylene and the nucleating agent supplied to the cylinder **101** are melted and mixed while simultaneously being moved compulsorily toward the other end of the cylinder **101**.

In the process as described above, an antistatic agent and a foaming agent are supplied to the cylinder **101** through another entrances **101d**, **101e** formed at a mid portion of the cylinder **101** to be mixed with a polypropylene melt.

As described above, the cylinder **101** of the first extruder **100** is divided into six temperature zones **Z1** to **Z6** according to the temperature condition of the polypropylene melt which flows therein as shown in FIG. 2. Each of the temperature zones **Z1** to **Z6** has a length of about 300 to 400mm. In a preferred aspect, the cylinder **101** has an inner diameter of 65mm and LD of about 358mm and the temperature condition and other conditions of the polypropylene melt according to each temperature zone **Z1** to **Z6** of the cylinder are as follows.

1) First temperature zone **Z1** : A zone to which the polypropylene and the nucleating agent are supplied, kept at a temperature of 150°C, a length for which the above temperature is maintained, that is, a length of the first temperature zone **Z1** is 360mm.

2) Second temperature zone **Z2** : The polypropylene melt flowing through the second temperature zone **Z2** is maintained at a temperature of 170°C.

3) Third temperature zone **Z3** : The polypropylene melt flowing through the third

temperature zone **Z3** is maintained at a temperature of 170°C which is the same as in the second temperature zone **Z2**. Paraffin wax as an antistatic agent is supplied to the third temperature zone **Z3**.

4) Fourth temperature zone **Z4** : The polypropylene melt flowing through the fourth temperature zone **Z4** is maintained at a temperature of 220°C. CO₂ or LPG as a foaming agent is supplied to the cylinder **101** at the fourth temperature zone **Z4**.

5) Fifth temperature zone **Z5** : The polypropylene melt flowing through the fifth temperature zone **Z5** is maintained at a temperature of 200°C.,

6) Sixth temperature zone **Z6** : The polypropylene melt is maintained at a temperature of 190°C.

In order to meet the temperature conditions of the polypropylene melt at respective temperature zones **Z1** to **Z6**, the cooling means **104** and the heating means **105** mounted on the temperature zones are properly operated. That is, the temperatures of the polypropylene melt at the respective temperature zones **Z1** to **Z6** are adjusted to meet the condition described above by controlling an amount and a temperature of a coolant supplied to the casing of the cooling means **104** or a current applied to the heating wire constituting the heating means **105** and a time to apply a current.

On the other hand, in the case of using CO₂ as a foaming agent which is supplied to the cylinder **101** of the first extruder **100**, an additional device for supplying CO₂ is used. The device for supplying CO₂ used in the present invention is as follow:

Referring to FIG. 4 which is a schematic view showing a structure of the device for supplying CO₂, the device **110** for supplying CO₂ comprises a tank **110A** for storing CO₂, an unit for vaporizing and freezing **110B**, an unit for supplying CO₂ **110C**, an unit for stabilizing **110D** and a storage unit **110E**. CO₂ stored in the storing CO₂ tank **110A** is

transferred to the unit **110B** for vaporizing and freezing, in which it is converted into the vapor phase. That is, in the course of passing through a refrigerator of the unit for vaporizing and freezing **110B**, CO₂ is gasified and vaporized, and then supplied to the unit **110D** for stabilizing by a pump, the unit **110C** for supplying CO₂. In the unit **110D** for
5 stabilizing, CO₂ in the form of vapor is converted to the gas phase. CO₂ in the gas phase is stored in the storage unit **110E**. When a process is started, CO₂ stored in the storage unit **110E** is supplied to the first cylinder **101** of the first extruder **100** described above.

The polypropylene melt which meets the temperature conditions in the temperature zones **Z1** to **Z6** is moved (moved by the screw shaft **103**) toward an end of the
10 cylinder **101** and then supplied to the second extruder **200** through the guide **150**. The polypropylene melt passing through the guide **150** is maintained at a temperature of 250 °C.

B. Second extruder 200

The second extruder **200** to which the polypropylene melt is supplied through the
15 guide **150** has the same structure with the first extruder **100**. That is, the cylinder **201** constituting the second extruder **200** is divided into six temperature zones according to the temperature condition of the polypropylene melt that flows in the cylinder **201**. A cooling means and a heating means are mounted on the outer circumference surface of the cylinder **201** at positions corresponding to the temperature zone for adjusting the
20 temperature of the polypropylene melt.

The cooling means and heating means also have the same structure with the cooling means **104** and the heating means **105** mounted on the outer circumference surface of the cylinder **101** of the first extruder **100** shown in FIG. 2. Therefore, the description on the structures of the cooling means and heating means is omitted.

25 The cylinder **201** of the second extruder **200** is divided into six temperature zones

according to the temperature condition of the polypropylene melt which flows therein. Each temperature zone has a length of about 470 to 520mm. In a preferred aspect, the cylinder **201** has an inner diameter of 90mm and LD is about 495mm. The temperature conditions of the polypropylene melt in the cylinder **201** at the temperature zones are as follows.

- 1) First temperature zone (the entrance portion) : 170 °C.
- 2) Second temperature zone : 150 °C.
- 3) Third temperature zone : 145 °C.
- 4) Fourth and fifth temperature zones : 140 °C.
- 5) Sixth temperature zone (the exit portion) : 135 °C.

C. Pumping part 300

The polypropylene melt at a temperature of 135 °C discharged from the second extruder **200** is supplied to the pumping part **300**. Since the melting point of the polypropylene is 138 °C, the polypropylene melt discharged from the second extruder **200** has been considerably reduced in its flowing speed. In the present invention, the pumping part **300** is used for moving compulsorily such polypropylene melt to a subsequent process.

FIG. 5 is a sectional view showing the inner structure of the pumping part **300** and homogenizing part **400** shown in FIG. 1. The left side shows the inner structure of the pumping part **300** and the right side shows an inner structure of the homogenizing part **400**, respectively.

The pumping part **300** to which the polypropylene melt discharged from the cylinder **201** of the second extruder **200** is supplied comprises a casing **301** having an inner space, a pair of gears **302A** and **302B** engaged with each other and installed rotatably in the inner space of the casing **301**, and a driving means **303** for rotating the gears **302A** and

302B. An entrance portion of the casing **301** is connected to the cylinder **201** of the second extruder **200** by a flange **304**.

The polypropylene melt discharged from the cylinder **201** of the second extruder **200** is supplied to the inner space of the casing **301** via the entrance portion, and then discharged compulsorily to an exit portion by the two gears **302A** and **302B** which rotate in opposite directions toward a center of the inner space of the casing. The polypropylene melt discharged from the cylinder **201** of the second extruder **200** has a temperature of 135°C, and a considerably reduced fluidity. Therefore, the pumping part **300** serves to compulsorily transfer the polypropylene melt to the next process.

D. Homogenizing part 400

The homogenizing part **400** connected to the exit portion of the casing **301** of the pumping part **300** is divided into a rotating part **400A** and a crushing part **400B**. The rotating part **400A** is composed of a first housing **401** of a hollow cylindrical shape, a driven sprocket **402** fixed to the outer surface of the first housing **401** and a driving means **404** to which a driving sprocket **403** is fixed.

The first housing **401** is supported rotatably to support plates **407** and **408** through a plurality of bearing blocks **405** and **406**. The drive sprocket **403** of the driving means **404** is geared with the driven sprocket **402** fixed to the outer surface of the first housing **401**, whereby the first housing **401** is rotated in response to the operation of the driving means **404**. An end of the first housing **401** corresponds to the exit portion of the casing **301** of the pumping part **300** and thus, the polypropylene melt discharged from the pumping part **300** flows in the first housing **401**. In the first housing **401**, the temperature of the polypropylene melt are varied according to the location (that is, a central portion and outer portion of the inner space of the first housing). However, since the polypropylene

melt is mixed by the rotation movement of the first housing **401**, the whole polypropylene melt is maintained constantly at a temperature. Here, since new polypropylene melt is supplied compulsorily and continuously by the pumping part **400**, the polypropylene melt is rotated and moved at the same time.

5 The crushing part **400B** is composed of a screw **410** connected to the exit portion of the first housing **401**, a second housing **411** located on the outer circumference of the screw **410** and a frame **412** mounted on the outer circumference of the second housing **411** for forming an airtight space between the second housing **411** and the frame **412**. The screw **410** is a cylindrical member having a spiral with a certain depth formed on the outer
10 circumference surface thereof and a spiral-shaped space is formed between the screw **410** and the second housing **411** and extended to the entire length of the screw **410**. Therefore, the polypropylene melt discharged from the first housing **401** of the rotating part **400A** under a high pressure, is moved along the spiral-shaped space between the screw **410** and the second housing **411** and discharged out of the crushing part **400B**.

15 Meanwhile, a heat transfer oil flows in the space formed between the second housing **411** and the frame **412**. That is, an inlet port **412A** through which the heat transfer oil is supplied is formed at a side of the frame **412**, an outlet **412B** through which the heat transfer oil is discharged is formed at the other side of the frame **412**. The heat transfer oil that introduced to the space between the second housing **411** and the frame **412**
20 via the inlet port **412A** contacts directly with the surface of the second housing **411** to adjust the temperature of the polypropylene melt that flows in the second housing **411**. The heat transfer oil that flows in the space between the second housing **411** and the frame **412** to adjust the temperature of the polypropylene melt is discharged via the outlet port **412B**. Processes for inflow, adjustment of temperature and discharge are proceeded
25 continuously, whereby the temperature of the polypropylene melt which flows in the

spiral-shaped space between the second housing 411 and the screw 410 is adjusted to a predetermined temperature.

At the rear end of the homogenizing part 400, that is, the exit part of the second housing 411, a homogenizing means 450 is disposed for crushing and homogenizing a mixture of the discharged polypropylene melt and a nucleating agent.

FIG. 6A and FIG. 6B are front views of a rotating plate 451 and a fixing plate 452 constituting the homogenizing means 450, respectively. The rotating plate 451 and the fixing plate 452 have same shape and are mounted in a state that they are contacted with each other, provided that the rotating plate 451 is mounted rotatably.

A plurality of openings 451A are formed radially on the rotating plate 451, each opening 451A is slanted toward a center of the rotating plate 451. Also, a plurality of circular holes 452A are formed on the fixing plate 452.

The polypropylene melt discharged from the second cylinder 411 arrives at the rotating plate 451 which is rotating and passes through each opening 451A formed on the rotating plate 451. At this point, the polypropylene melt is cut by an edge of each opening 451A, whereby all polypropylene melts are crushed homogeneously. The crushed polypropylene melt is ground by the rotating plate 451 which rotates in the space between the rotating plate 451 and the fixing plate 452 and discharged through the holes 452A of the fixing plate 452.

E. Dies part 500

The temperature-controlled polypropylene melts discharged from the homogenizing part 400 is supplied to the dies part 500 to produce pellet-type foams.

FIG. 7 is a plan view showing a structure of the dies part shown in FIG. 1 and FIG. 8 is a sectional view taken along the line B-B in FIG. 7, and FIG. 9 is a sectional view

taken along the line C-C in FIG. 8. The dies part **500** is divided into a discharging part **500A**, a cutting part **500B** and a driving means **500C**.

The discharging part **500A** is composed of a hollow cylinder-shaped guide bar **501** and a cylinder **502** located outside the guide bar **501**. On the outer circumference of the guide bar **501**, a plurality of cavities **501A** are formed in a longitudinal direction of the guide bar **501**. The polypropylene melt discharged from the homogenizing part **400** flows in each cavity **501A**. The plurality of through holes **502A** are formed at portions of the cylinder **502** corresponding to the respective cavities **501A**.

The cutting part **500B** is composed of a supporting plate **506** located at the rear side of the discharging part **500A** and a cutting member **503** fixed to the supporting plate **506**. The cutting member **503** is located movably on the outside of the cylinder **502** and has a plurality of through holes **503A** formed at positions corresponding to the plurality of through holes **502A** of the cylinder **502**, as shown in FIG. 9. As shown in figures, a diameter of the through holes **502A** formed on the cylinder **502** is less than that of the through holes **503A** formed on the cutting member **503**. At an initial position, each through hole **502A** of the cylinder **502** is located on a central portion of the corresponding through hole **503A** of the cutting member **503**.

Meanwhile, a plurality of grooves **502B** are formed on the outer circumference of the cylinder **502** in a longitudinal direction and reciprocating rods **505** are located in the grooves **502B**, respectively. The cutting member **503** is fixed to reciprocating rods **505** by fixing means such as a bolt, whereby the cutting member **503** is reciprocated on the outer circumference of the cylinder **502** by the reciprocating rod **505** which is reciprocated along the groove **502B** of the cylinder **502**.

The driving means **500C** of the dies part **500** is composed of an eccentric cam **511** which is rotated by a motor **510**, a crank **512** that is connected to the eccentric cam **511** and

rotated in response to the rotation of the cam **511** and a power converting and transmitting means **513** connected to the crank **512** for converting rotation movement of the crank **512** to linear movement and transmitting the linear movement to the supporting plate **506**.

Once the eccentric cam **511** is rotated by the operation of the motor **510**, the rotation movement of the crank **512** is converted to the linear movement by the power converting and transmitting means **513**, and then transmitted to the supporting plate **506** to which ends of reciprocating rods **505** are fixed. Therefore, the cutting member **503** is reciprocated along the outer circumference of the cylinder **502**.

Meanwhile, the polypropylene melt discharged from the homogenizing part **400** is injected under pressure to the plurality of cavities **501A** formed on the guide bar **501** and then expanded through the through holes **502A** of the cylinder **502**. At this time, when each through hole **502A** of the cylinder **502** corresponds to each through hole **503A** of the cutting member **503** by the reciprocation of the cutting member **503** by the operation of the driving means **510**, the polypropylene melt passes through the through holes **502A** and **503A** and then is expanded to the outside of the cutting member **503** with a certain length. Then, when through holes **502A** of the cylinder **502** are released from the corresponding state with the through holes **503A** of the cutting member **503** by the movement of the cutting member **503**, the expanded polypropylene melt is cut by edges of the through holes **503A** of the cutting member **503**. Here, a dimension (length) of the cut foams is determined by a moving speed of the cutting members **503**.

Thus, after the polypropylene melt is expanding through the through holes **502A** of the cylinder **502** and cut by the cutting member **503**, the pellet-type foams are formed. A diameter of each through hole **502A** of the cylinder **502** is 0.7mm and the expansion rate is about 5 times of a diameter of the through hole. Also, the cutting member **503** is reciprocated at a speed of 600 revolutions per minute.

The polypropylene melt transferred from the crushing part **400B** are subjected under a pressure of 120kgf/cm^2 in the dies part. If the polypropylene melt in the dies is exposed directly to the atmosphere, most of the foams are open cells. In order to prevent production of open cells, in the present invention, a decompression means is installed at the
5 outside of the dies part.

In FIG. 7, an example of the decompression means installed at the dies part is shown. The decompression means **600** is a casing **601** for isolating the discharging part **500A** and the cutting part **500B** of the dies part **500** from the outside (the atmosphere). It is to be understood that a shape of the casing **601** is not limited. An entrance port **602**
10 through which air is introduced is formed at an side of the casing **601**, an exit port **603** through which air is exhausted is formed at the other side of the casing **601**.

A temperature of the air which is supplied to the casing **601** is room temperature or less and can be maintained by a cooling means (not shown). Also, it goes without saying that, in order to maintain properly a pressure in the casing **601** (for example,
15 0.8Kgf/cm^2), an amount of the air supplied to the casing **601** can be controlled by a pump (not shown). Meanwhile, the exit port **603** can be connected to a storage means for storing the prepared pellet-type foams along with discharged air.

A temperature in the cylinder **502** constituting the dies part **500** is very high and therefore, the temperature of the cylinder **502** should be properly maintained. For this,
20 the present invention uses a cooling device **700** using the heat transfer oil, which is mounted on the dies part.

FIG. 10A is a side view showing a cylinder of the dies part to which a cooling device is mounted and FIG. 10B is the front view of FIG. 10A. The casing **601** of the decompression means **600** illustrated in FIG. 7 is not shown for conveniences' sake.

25 The cooling device **700** used in the present invention comprises a ring-type

supplying pipe **701** located at the front of the cylinder **502**, and through which heat transfer oil is supplied from the outside, a plurality of flowing pipes **702** connected to the supplying pipe **701** via an entrance end **702A** thereof and installed in the cylinder **502**, and an discharging pipe **703** located at the front of the cylinder **502** and connected to an exit end
5 **702B** of the flowing pipe **702**.

The ring-type pipe **701** for supplying the heat transfer oil, located at the front of the cylinder **502**, is connected at one end to a compulsory flowing means (not shown) such as a pump so that the heat transfer oil is supplied to the supplying pipe at a constant pressure. The heat transfer oil is injected to the plurality of flowing pipes **702** through
10 entrance ends **702A** of the flowing pipes **702** connected to the supplying pipe **701**.

The plurality of the flowing pipes **702** disposed at a regular interval on the entire outer circumference of the cylinder **502** are extended along the entire length of the cylinder **502**, and each entrance end **702A** and each exit end **702B** of the flowing pipes **702** are exposed to the front end of the cylinder **502**. Therefore, the heat transfer oil supplied
15 through each entrance end **702A** from the heat transfer oil supplying pipe **701** flows through the flowing pipes **702** along the entire length of the cylinder **502** (that is, after performing the heat exchange), and then is discharged via each exit end **702B**.

The ring-type pipe **703** for discharging the heat transfer oil located at the front of the cylinder **502** is connected at one end to the heat transfer oil storage tank (not shown).
20 Thus, the heat transfer oil after performing heat exchange with the cylinder **502** while flowing through the flowing pipes **702** flows into the heat transfer oil discharging pipe **703** through the exit end **702B** and then is directed to the heat transfer oil storage tank.

As described above, in the course of flowing through the heat transfer oil supplying pipe **701**, the flowing pipes **702** installed in the cylinder **702** and the heat
25 transfer oil discharging pipe **703**, the heat exchange between the heat transfer oil and the

cylinder **502** is accomplished, whereby the cylinder can be constantly kept at a suitable temperature for the production of foams.

Meanwhile, the supplying pipe **701** for supplying the heat transfer oil to the flowing pipes **702** and the discharging pipe **703** to which the heat transfer oil from the flowing pipes **702** is supplied have a ring shape so that the heat transfer oil is simultaneously supplied to and received from the flowing pipes **702** mounted on the circumference of the cylinder **502** whose section is a circular shape. However, the shape of the supplying pipe **701** and the discharging pipe **703** is not limited to a ring and can have a different shape, for example polygonal shape.

Now, the present invention will be described in more detail by the following Examples. However, it is to be understood that the following examples are presented to illustrate further various aspects of the present invention, but are not intended to limit the scope of the invention in any aspects.

Example 1

In order to prepare the pellet-type foams of non-crosslinked polypropylene according to the invention, a tandem extruder having a first extruder with the inner diameter of 65mm and a second extruder with the inner diameter of 900mm was modified. A gear pump and a dies part were connected successively to the rear end of the second extruder. A homogenizing means as shown in FIG. 3 was installed at a position where the melt is discharged from the gear pump, a compression means is provided outside the dies. Through holes of the dies had a diameter of 0.7mm and a pressure in the dies was maintained at 0.5kgf/cm². A rotating speed of the first extruder was set at 24 rpm and a rotating speed of the second extruder was set at 9 rpm.

40 kg of random copolymer RP2400 (polypropylene-3 weight % ethylene;

melting index 0.25; melting point 138°C) commercially obtained from Yuhwa Korea Petrochemical Ind. Co., Ltd. and 800 g of sodium carbonate commercially obtained from Keum Yang Co., Ltd. were supplied to the extruder through respective hoppers. 300 g of paraffin wax M1 commercially obtained from Leochemical Co., Ltd (Kimhae, Korea) was supplied to the third temperature zone of the first extruder. 12 kg of LPG was supplied to the fourth temperature of the extruder by using a metering pump. Temperature conditions specified from the extruder through the homogenizing device are shown in Table 1, and LD of the each temperature zone was 360mm.

10 Table 1: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
First Extruder	1 st	150
	2 nd	170
	3 rd	170
	4 th	220
	5 th	200
	6 th	190
Guide *		250
Second Extruder	1 st	170
	2 nd	150
	3 rd	144
	4 th	139
	5 th	138
	6 th	136
Gear pump		133
Homogenizing device		130

* installed between the first extruder and second extruder for guiding the melt that have

passed from the sixth temperature zone of the first extruder to the first temperature zone of the second extruder.

Example 2

- 5 The temperature conditions in the device were set as described in Table 2 and the pellet-type foams were prepared by using the same procedure and materials as in Example 1.

Table 2: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
First Extruder	1 st	150
	2 nd	170
	3 rd	170
	4 th	220
	5 th	200
	6 th	190
Guide		250
Second Extruder	1 st	170
	2 nd	150
	3 rd	145
	4 th	140
	5 th	138
	6 th	135
Gear pump		130
Homogenizing device		125

Example 3

The temperature conditions in the device were set as described in Table 3 and the pellet-type foams were prepared by using the same procedure and materials as in Example 1.

5 Table 3: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
First Extruder	1 st	147
	2 nd	167
	3 rd	168
	4 th	218
	5 th	202
	6 th	188
Guide		248
Second Extruder	1 st	167
	2 nd	147
	3 rd	142
	4 th	137
	5 th	137
	6 th	132
Gear pump		130
Homogenizing device		129

Example 4

The temperature conditions in the device were set as described in Table 4 and the pellet-type foams were prepared by using the same procedure and materials as in Example

Table 4: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
First Extruder	1 st	151
	2 nd	170
	3 rd	170
	4 th	219
	5 th	202
	6 th	190
Guide		252
Second Extruder	1 st	170
	2 nd	150
	3 rd	146
	4 th	141
	5 th	140
	6 th	135
Gear pump		130
Homogenizing device		127

Example 5

The temperature conditions in the device were set as described in Table 5 and the pellet-type foams were prepared by using the same procedure and materials as in Example 1.

Table 5: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
	1 st	153
	2 nd	172

First Extruder	3 rd	172
	4 th	225
	5 th	203
	6 th	193
Guide		255
Second Extruder	1 st	173
	2 nd	152
	3 rd	147
	4 th	141
	5 th	142
	6 th	137
Gear pump		134
Homogenizing device		130

Example 6

The temperature conditions in the device were set as described in Table 6 and the pellet-type foams were prepared by using the same procedure and materials as in Example

5 1.

Table 6: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
First Extruder	1 st	149
	2 nd	170
	3 rd	171
	4 th	224
	5 th	200
	6 th	191
Guide		250

Second Extruder	1 st	170
	2 nd	150
	3 rd	145
	4 th	140
	5 th	140
	6 th	135
Gear pump		134
Homogenizing device		130

Example 7

The temperature conditions in the device were set as described in Table 7 and the pellet-type foams were prepared by using the same procedure and materials as in Example

5 1.

Table 7: Temperature condition

Device	Temperature Zone No.	Temperature (°C)
First Extruder	1 st	150
	2 nd	170
	3 rd	170
	4 th	220
	5 th	200
	6 th	190
Guide		250
Second Extruder	1 st	167
	2 nd	152
	3 rd	142
	4 th	141
	5 th	137

	6 th	132
Gear pump		134
Homogenizing device		130

Comparative example 1

Pellet-type foams were prepared by using the same procedure and materials as in Example 1 and setting the temperature conditions in the device as described in Table 1 except that the homogenizing device was not operated. The homogenizing device was maintained at a temperature of 130 °C but was not activated. Therefore, the melt from the gear pump passed through the temperature zone of 130 °C without homogenization to be introduced to the dies.

10 Comparative example 2

Pellet-type foams were prepared by using the same procedure and materials as in Example 1 and setting the temperature conditions in the device as described in Table 1 except for the first temperature zone of the first extruder, which was set to 146 °C.

15 Comparative example 3

Pellet-type foams were prepared by using the same procedure and materials as in Example 1 and setting the temperature conditions in the device as described in Table 1 except for the second temperature zone of the first extruder, which was set to 173 °C.

20 Comparative example 4

Pellet-type foams were prepared by using the same procedure and materials as in Example 1 and setting the temperature conditions in the device as described in Table 1

except for third temperature zone of the first extruder, which was set to 173°C.

Comparative example 5

Pellet-type foams were prepared by using the same procedure and materials as in
5 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the fourth temperature zone of the first extruder, which was set to 226°C.

Comparative example 6

Pellet-type foams were prepared by using the same procedure and materials as in
10 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the fifth temperature zone of the first extruder, which was set to 205°C.

Comparative example 7

Pellet-type foams were prepared by using the same procedure and materials as in
15 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the sixth temperature zone of the first extruder, which was set to 187°C.

Comparative example 8

Pellet-type foams were prepared by using the same procedure and materials as in
20 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the guide, which was set to 256°C.

Comparative example 9

Pellet-type foams were prepared by using the same procedure and materials as in
25 Example 1 and setting the temperature conditions in the device as described in Table 1

except for the first temperature zone of the second extruder, which was set to 174 °C.

Comparative example 10

Pellet-type foams were prepared by using the same procedure and materials as in
5 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the second temperature zone of the second extruder, which was set to 153 °C.

Comparative example 11

Pellet-type foams were prepared by using the same procedure and materials as in
10 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the third temperature zone of the second extruder, which was set to 148 °C.

Comparative example 12

Pellet-type foams were prepared by using the same procedure and materials as in
15 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the fourth temperature zone of the second extruder, which was set to 142 °C.

Comparative example 13

Pellet-type foams were prepared by using the same procedure and materials as in
20 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the fifth temperature zone of the second extruder, which was set to 143 °C.

Comparative example 14

Pellet-type foams were prepared by using the same procedure and materials as in
25 Example 1 and setting the temperature conditions in the device as described in Table 1

except for the sixth temperature zone of the second extruder, which was set to 138 °C.

Comparative example 15

Pellet-type foams were prepared by using the same procedure and materials as in
5 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the gear pump, which was set to 141 °C.

Comparative example 16

Pellet-type foams were prepared by using the same procedure and materials as in
10 Example 1 and setting the temperature conditions in the device as described in Table 1
except for the homogenizing device, which was set to 131 °C.

Experimental example 1

The pellet-type foams obtained from Example 1 and Example 2 were measured
15 for DSC (differential scanning calorimeters; 10 °C/min. to 200 °C, 50cc/min. to N₂
purge) transition temperature according to the test method KSM3050-2001. The results
are shown in FIG. 11 and FIG. 12. As shown in the DSC curves of FIG. 11 and FIG. 12,
the foams of Example 1 and Example 2 had melting points of 137.62 °C and 128.38 °C,
respectively, which are lower than the melting point of 138 °C of the random copolymer
20 (RP2400 (polypropylene-polyethylene(3%) random copolymer) used as the row material.
RP2400 random copolymer as control was measured for the DSC transition temperature.
The results are shown in FIG. 13.

Experimental example 2

25 The pellet-type foams obtained from Example 1 and RP2400 (polypropylene-

polyethylene(3%)) random copolymer as control were subject to the elementary analysis. The analysis was performed by using the CE EA-1110 elementary analyzer. The results are shown in Table 8 given below.

5 Table 8: Results of the elementary analysis

Sample	analysis item		
	C (%)	H (%)	N (%)
RP2400 random copolymer	85.1	15.0	N.D.*
Pellet-type foams of Example 1	84.2	14.8	0.5

N.D. means "non-detectable". The detecting limit of N is 0.1%.

Experimental example 3

The pellet-type foams obtained from Example 1 and RP2400 (polypropylene-
 10 polyethylene(3%)) random copolymer as control were subjected to the FT-IR analysis. The analysis was performed by using the Bio-Rad Digilab FTS-165 FT-IR Spectrophotometer. The results are shown in FIG. 14 and FIG. 15, respectively. According to the results, it is noted that the pellet-type foams obtained from Example 1 and RP2400 random copolymer have a main component of polypropylene.

15

Experimental example 4

The open cell contents of the pellet-type foams prepared in the Examples and Comparative Examples were measured according to the procedure C described in the ASTM D 2856-70. The results are shown in Table 9 given below.

20

Table 9

	No.	Open cell content
Example	1	6%
	2	13%
	3	12%
	4	16%
	5	14%
	6	7%
	7	12%
Comparative example	1	68%
	2	49%
	3	52%
	4	38%
	5	44%
	6	39%
	7	52%
	8	40%
	9	37%
	10	36%
	11	31%
	12	53%
	13	29%
	14	28%
	15	26%

Experimental example 5

Other physical properties of the foams prepared in Example 1 were measured according to a conventional method. The results are shown in Table 10 given below.

Item	Foams of Example 1
Magnification	25
Appearance color	Light ivory
Cell Size	300 μm
Compressive strength	0.81 kgf/cm ²

Experimental example 6

The pellet-type foams obtained from Example 1 was molded by using a molder, 500GF 4, produced by Daekong Machinery Co., Ltd., with a molding pressure set to 2.5kgf/cm² (temperature of about 138°C), to produce a well-molded article. Through production of such a well-molded article, it is proved that the pellet-type foams according to the present invention are melted at a temperature of 138°C to adhere to each other, leading to solid bonding between foams.

Experimental example 7

The pellet-type foams obtained from Example 2 was molded by using a molder, 500GF 4, produced by Daekong Machinery Co., Ltd., with a molding pressure set to 2.4kgf/cm² (temperature of about 132°C), to produce a well-molded article. Through production of such well-molded article, it is proved that the pellet-type foams according to the present invention are melted at a temperature of 132°C to adhere to each other, leading to solid bonding between foams.

From the above description, it will be appreciated that the present invention can be embodied as other specific forms by those skilled in the art without departing from the spirit and indispensable features of the present invention. With regard this, it should be understood that the examples and experimental examples described above have been made

by way of example and not as a limitation. It should be construed that all modification and change derived from the meaning and scope of the claims described below and equivalent rather than the above description and equivalents thereof are intended to be included within the scope of this invention.

- 5 The pellet-type foams of non-crosslinked polypropylene according to the present invention has a closed cell content of 80% or more and a melting point of 125 to 140°C so that the pellet-type foams of the invention is much available in a standpoint of formation and regeneration.

WHAT IS CLAIMED IS:

1. A pellet-type non-crosslinked polypropylene foam having a melting point of 125 to 140°C.

5 2. The pellet-type non-crosslinked polypropylene foam of claim 1, wherein the content of closed cells is 80% or more.

3. The pellet-type non-crosslinked polypropylene foam of claims 1 or 2, wherein a melting point is from 125 to 130°C.

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4. A method for preparing a pellet-type non-crosslinked polypropylene foam having a melting point of 125 to 140°C, comprising steps of;

(a) extruding a non-crosslinked polypropylene random copolymer having a melting point of 138 to 140°C through a tandem extruder; said tandem extruder consisting
15 of the first extruder divided into the first temperature zone in which a temperature of 147 to 153°C is set, the second temperature zone in which a temperature of 167 to 172°C is set, the third temperature zone in which a temperature of 168 to 172°C is set, the fourth temperature zone in which a temperature of 218 to 225°C is set, the fifth temperature zone in which a temperature of 197 to 203°C is set, and the sixth temperature zone in which a
20 temperature of 188 to 193°C is set, the second extruder divided into the first temperature zone in which a temperature of 167 to 173°C is set, the second temperature zone in which a temperature of 147 to 152°C is set, the third temperature zone in which a temperature of 142 to 147°C is set, the fourth temperature zone in which a temperature of 137 to 141°C is set, the fifth temperature zone in which a temperature of 137 to 142°C is set, and the sixth
25 temperature zone in which a temperature of 132 to 137°C is set, and a guide connecting

the first extruder and the second extruder with a temperature of 248 to 255 °C;

(b) flowing the extruded material compulsorily by a pumping at a temperature of 125 to 140 °C;

(c) homogenizing the extruded material at a temperature of 120 to 130 °C;

5 (d) expanding the homogenized material through a dies; and

(e) cutting the expanded material to obtain pellet-type foams.

5. The method for preparing a pellet-type non-crosslinked polypropylene foam of claim 4, wherein said foam has closed cells of 80% or more.

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6. The method for preparing a pellet-type non-crosslinked polypropylene foam of claims 4 or 5, wherein said foam has a melting point of 125 to 130 °C.

7. An article molded from the foam of claim 1.

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8. A device for producing a pellet-type non-crosslinked polypropylene foam having a melting point of 125 to 140 °C, comprising the first extruder, the second extruder connected to the first extruder, a pumping part connected to the second extruder, a homogenizing part connected to the pumping part and a dies part connected to the
20 homogenizing part, wherein

the first extruder comprises a cylindrical cylinder in which a screw shaft is mounted rotatably, a driving means installed at an end of the cylinder for rotating the screw shaft and a plurality of cooling means and heating means mounted on an outer circumference of the cylinder, the cylinder has entrances formed at an end portion thereof
25 corresponding to the driving means for supplying a row polypropylene and a nucleating

agent thereto, an exit formed at another end portion thereof, entrances formed at a mid portion thereof for supplying an additive and a foaming agent, respectively, whereby the row material supplied to the cylinder via the entrances is flow compulsorily toward the exit by the screw shaft rotated according to the driving means;

5 the second extruder comprises a cylinder into which the polypropylene melt discharged from the cylinder of the first extruder is supplied through the guide, and a plurality of cooling means and a heating means mounted to an outer circumference surface of the cylinder for adjusting a temperature of the polypropylene melt in the cylinder.;

 the pumping part comprises a casing having an inner space into which the
10 polypropylene melt discharged from the cylinder of the second extruder is supplied, a pair of gears installed rotatably and meshed with each other in the inner space of the casing and a driving means for rotating the gears, whereby the polypropylene melt supplied therein is flow compulsorily;

 the homogenizing part comprises a first cylindrical housing into which the
15 polypropylene melt discharged from the cylinder of the pumping part is supplied, the first housing being installed rotatably, a driving means for rotating the first housing, a screw connected to an exit end of the first housing, a second housing located on an outer circumference of the screw, a frame mounted to an outer circumference of the second housing for forming an airtight space between the second housing and the frame, and a
20 homogenizing means installed at a rear end of the second housing; wherein a spiral space is formed between the screw and the second housing along the entire length of the screw so that the polypropylene melt discharged from the first housing is flow in the space formed between the screw and the second housing and discharged to an outside, a heat transfer fluid oil flows in a space formed between the second housing and the frame to adjust a
25 temperature of the polypropylene melt which flows in the second housing, and the

homogenizing means crushes the polypropylene melt;

the dies part into which the polypropylene melt discharged from the homogenizing part is supplied is consisted of a discharging part , a cutting part and a driving means so that expanded foams are cut at a certain size.

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9. The device for producing a pellet-type foam of claim 8, wherein each cooling means mounted to the cylinders of the first and second extruders is a casing in which a cooling water supplied from an outside flows, the cooling water supplied to the casing is contacted with a surface of the cylinder and flow along the casing so that a temperature of the polypropylene melt that flows in the cylinder becomes lower, each heating means mounted between two casings is a heater in which a heating coil is installed.

10. The device for producing a pellet-type foam of claim 8, wherein the cylinder of the first extruder is divided into six temperature zones according to the temperature condition of the polypropylene melt supplied to the cylinder, a temperature of each zone is adjusted by the cooling means and heating means mounted to an outer circumference of the cylinder, a temperature of the polypropylene melt is 147 to 153 °C at the first temperature zone, 167 to 172 °C at the second temperature zone, 168 to 172 °C at the third temperature zone, 218 to 225 °C at the fourth temperature zone, 197 to 203 °C at the fifth temperature zone and 188 to 193 °C at the sixth temperature zone.

11. The device for producing a pellet-type foam of claims 8 or 10, wherein a polypropylene and a nucleating agent are supplied to the first temperature zone of the cylinder of the first extruder, an antistatic agent is supplied to the third temperature zone, and a foaming agent is supplied to the fourth temperature zone.

12. The device for producing a pellet-type foam of claim 11, wherein the foaming agent to be supplied to the cylinder of the first extruder is CO₂ discharged from a device for supplying CO₂, the device for supplying CO₂ comprises a tank for storing CO₂,
5 an unit for vaporizing and freezing CO₂ connected to the tank, a stabilizing unit for transforming CO₂ supplied from the unit for vaporizing and freezing into a vapor; and a storage unit for storing CO₂ supplied from the stabilizing unit to supply CO₂ into the first cylinder of the first extruder.

10 13. The device for producing a pellet-type foam of claim 8, wherein the cylinder of the second extruder is divided into six temperature zones according to the temperature condition of the polypropylene melt supplied to the cylinder, a temperature of each zone is adjusted by the cooling means and heating means mounted to an outer circumference of the cylinder, a temperature of the polypropylene melt is 167 to 173°C at
15 the first temperature zone, 147 to 152°C at the second temperature zone, 142 to 147°C at the third temperature zone, 137 to 141°C at the fourth temperature zone, 137 to 142°C at the fifth temperature zone and 132 to 137°C at the sixth temperature zone.

14. The device for producing a pellet-type foam of claim 8, wherein the two
20 gears mounted in the inner space of the casing of the pumping part are rotated in an opposite direction from each other toward a center of the inner space to make the polypropylene melt move compulsorily to a next process position.

15. The device for producing a pellet-type foam of claim 8, wherein the first
25 housing of the homogenizing part is supported rotatably to support plates through a

plurality bearing blocks, a drive sprocket of the driving means is geared with a driven sprocket fixed to an outer circumference surface of the first housing so that the first housing is rotated in response of an operation of the driving means.

5 16. The device for producing a pellet-type foam of claim 8, wherein the homogenizing means of the homogenizing part is consisted of a rotating plate mounted rotatably and a fixing plate contacted with the rotating plate, the rotating plate has a plurality of openings arranged radially and the fixing plate has a plurality of circular holes, whereby after the supplied polypropylene melt is arrived at the rotating plate and passed
10 through each opening formed on the rotating plate, the polypropylene melt is cut by an edge of each opening of the rotating plate, and then the crushed polypropylene melt is ground between the rotating plate and the fixing plate by the rotating plate.

 17. The device for producing a pellet-type foam of claim 8, wherein
15 the discharging part of the dies part is consisted of a hollow guide bar and a cylinder located on an outside of the guide bar, the guide bar has a plurality of cavities formed on the outer circumference thereof in a longitudinal direction of the guide bar so that the polypropylene melts discharged from the homogenizing part flows in each cavity, a plurality of through holes are formed at portions of the cylinder which are corresponded to
20 the cavities, respectively;.

 the cutting part comprises a supporting plate located at a rear side of the discharging part and cutting members fixed to the supporting plate and located movably on an outside of the cylinder, each cutting member has a plurality of through holes formed at positions where are corresponded to the plurality of through holes of the cylinder,
25 respectively; and

the driving means comprises an eccentric cam being able to rotate by a motor, a crank connected to the eccentric cam and rotated in response to a rotation of the cam and a power converting and transmitting means connected to the crank for converting a rotating movement of the crank into a linear movement and transmitting the linear movement to the supporting plate to which the cutting member is fixed; whereby each cutting member is reciprocated along the outer circumference of the cylinder according to an operation of the driving means so that the polypropylene foams expanded through each through hole of the cylinder is cut by edges of the through holes of the cutting member.

18. The device for producing a pellet-type foam of claim 17, wherein a diameter of each through hole formed on the cylinder is less than that of each through hole of the cutting member, each through hole of the cylinder is located on a central portion of the corresponding through hole of the cutting member at an initial position.

19. The device for a producing pellet-type foam of claim 17, wherein the cylinder has a plurality of grooves are formed an outer circumference thereof in a longitudinal direction, reciprocating rods whose ends are fixed to the support plate are located movably in the grooves, respectively, and each cutting member is fixed to each reciprocating rod by fixing means so that each cutting member is reciprocated on an outer circumference of the cylinder by the each reciprocating rod which is reciprocated along each groove of the cylinder.

20. The device for producing a pellet-type foam of claim 17, wherein the dies part further comprises a decompression means for preventing a rapid change of a temperature and pressure to the expanded and extruded foams, the decompression means is

a casing which is able to isolate the discharging part and cutting part from an outside (atmospheric), the casing has an entrance port through which an air is flow and an exit port through which an air is exhausted at both sides.

5 21. The device for producing a pellet-type foam of claim 17, wherein the dies part further comprises a cooling device for cooling the cylinder, the cooling device comprises;

 a supplying pipe into which a heat transfer fluid oil is supplied from an outside, the supplying pipe being located at a front of the cylinder;

10 a plurality of flowing pipes having entrance ends connected to the supplying pipe and mounted in the cylinder along the entire length of the cylinder; and

 a discharging pipe being located at a front of the cylinder and connected to exit ends of the flowing pipes for receiving the heat transfer fluid which exchanged a heat with the cylinder.

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