

TITLE OF THE INVENTION

PROCESS FOR PRODUCING EXPANDED MOLDING PRODUCTS HAVING
HIGH-DENSITY SKIN

BACKGROUND OF THE INVENTION

The present invention relates to a process for producing expanded molding products having a high-density skin, and more particularly, it relates to a process for producing the expanded molding products having a uniform and high-density hard skin at the surface and suffering little or no shrinkage in the production process.

The expanded molding products produced by fusing the expanded resin beads (hereinafter referred to as expanded beads) in a mold comprising a female mold and a male mold, each having one or more steam chambers, have a closed-cell structure, have excellent heat insulation and cushioning characteristics and are also light in weight, so that they are popularly used as cushioning materials, heat insulators, heat insulating containers and other like functional elements.

These molding products, however, involve the problems that the small inter-bead spaces remaining in the molding surface collect dust and other contaminants to spoil the molding product appearance and also tend to cause cracking of the moldings in repeated use particularly as containers or the like, and that the molding surface is vulnerable to scratches because of its soft texture. Therefore, an

2-832407e

production of these molding products according to the conventional methods, it has indispensable to apply coating on the inside surface of the molding product such as container or to conduct integral molding with a resin sheet or the like. As a result, the cost of the produced molding products is elevated.

In order to solve these problems, Japanese Patent Application Laid-Open (KOKAI) Nos. 48-28060 and 52-47866 propose the methods for forming a skin at the molding product surface by fusing the expanded beads in a mold. In these methods is used a specific mold comprising a female mold and a male mold each having a steam chamber, with a plurality of steam passing holes formed in the wall of each steam chamber facing the female mold. After the mold has been filled with the expanded beads, steam with a temperature lower than the fusion point of the said beads is introduced into each steam chamber to cause thermal adhesive of the particles, and then steam with a temperature higher than the fusion point of the said beads is introduced into the steam chambers to fuse the surface portion of the molding, followed by hardening thereof, thereby forming a skin at the molding product surface.

According to the above method, however, since the beads located near the steam holes are fused excessively, a difference in skin thickness is made between the portion near the steam holes and the other portion, resulting in forming a generally non-uniform skin. Also, since the expanded beads

are first fused, the binding of the individual beads arises and their free expanding is prevented, making it unable to fully fill up the voids. Further, these molding products have a problem that the voids are created locally as the skin thickness increases. Thus, molding products having a uniform skin with few voids has been unobtainable by the above prior art.

Japanese Patent Application Laid-Open (KOKAI) No. 5-124126 proposes a expanded resin molding product produced by contacting the resin beads with the mold surface heated to a temperature above the fusion point of the resin beads to form a fused resin layer, and hardening this fused resin layer to form a continuous hardened surface layer.

However, since the method disclosed in the above-mentioned Japanese KOKAI makes use of excessive cracking filling for forming a skin, this is unapplicable to the production of the molding products having a complicate configuration. Also, the bead filling percentage lowers at the rising part of a box shape to cause shrinkage of the molding product.

As a result of the present inventor's earnest studies for solving the above problem, it has been found that a molding product having a uniform and high-density hard skin at the surface portion, suffering little or no shrinkage and having a good appearance can be obtained from a process comprising filling the expanded resin beads by compression-

filling in a mold comprising a female mold and a male mold each of which has a steam chamber or steam chambers, introducing steam into the said steam chamber of the female mold or male mold which is provided with steam holes to heat the mold to a temperature above the fusion point of the said resin beads while fusing the expanded resin beads which bring into contact with the said mold to form a skin at the surface portion, discharging air remaining in the spaces between the beads (inter-bead spaces) in the mold when the pressure of the said beads filled in the mold is in the range of 0.01 to 1.5 kg/cm²G, and introducing steam of a temperature below the fusion point of the resin beads into the spaces between the said beads through the steam holes from another steam chamber to cause their thermal adhesive. The present invention has been achieved based on this finding.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a process for producing the molding products which, even though having a complicate configuration, have a uniform and high-density hard skin at the surface portion, suffer little shrinkage and also have a good appearance.

To accomplish the aim, in an aspect of the present invention, there is provided a process for producing a expanded molding product having a high-density skin by filling and fusing expanded resin beads in a mold comprising

a female mold and a male mold each having one or more steam chambers, which process comprises:

compression-filling the expanded resin beads in a cavity formed between the female mold and male mold,

introducing steam into the steam chamber(s) of the female mold or male mold which is provided with no steam holes to heat the mold to a temperature above the fusion point of the said expanded resin beads while fusing the resin beads contacted with the mold to form a skin at the surface of the molding,

detecting the surface pressure of the expanded resin beads filled in the mold,

discharging the air remaining in the inter-bead spaces in the mold while the surface pressure of the said beads is in the range of 0.01 to 1.5 kg/cm²G, and

introducing steam of a temperature below the fusion point of the said resin beads into the inter-bead spaces through the steam holes to heat and fuse the beads together.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic sectional illustration of an example of mold used in the production of molding products according to the present invention.

FIG. 2 is the curves showing the relation between heating time and surface pressure in Examples 1 and 2.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is described in detail below with reference to the accompanying drawings. FIG. 1 is a schematic sectional illustration of an example of mold used in the process of the present invention. The mold used in the present invention comprises a female mold and a male mold each of which has a steam chamber or steam chambers.

The mold shown in FIG. 1 comprises a female mold 1 which is concave in sectional shape and a male mold 2 having a corresponding convex sectional shape, and has a cavity 3 with a box-like sectional shape. An end of a filling nozzle 5 extending from an expanded bead storage tank 4 and passing through the female mold 1 opens into the cavity 3.

A steam chamber 1a is provided in the female mold 1, and a plurality of steam holes 1b are formed in the wall of the said steam chamber 1a facing the cavity 3. The steam chamber 1a has connected thereto a steam pipe 6, a vacuum pipe 7, a cooling water pipe 8 and a drain pipe 9 each of which is provided with an on-off valve.

The male mold 2 has a first steam chamber 2a and a second steam chamber 2b. The first steam chamber 2a is positioned on the cavity side of the male mold and the second steam chamber 2b is located outside of the first steam chamber 2a. These steam chambers are not communicated with each but have a perfectly independent structure. Into the

first steam chamber 2a are connected a steam pipe 10, a cooling water pipe 11 and a drain pipe 12 each of which is provided with an on-off valve. Into the second steam chamber 2b are connected a steam pipe 13, a cooling water pipe 14 and a drain pipe 15 each having an on-off valve.

In the mold shown in Fig. 1 as a preferred example, since there is provided the steam holes 1b on the wall of the said steam chamber 1a, which wall faces the cavity 3 and which steam holes are used as the holes for introducing steam which has the temperature of less than fusion point of expanded beads and fuses the expanded beads to thermal-adhere each other bead after forming of the skin at the surface portion of molding product, the said steam for forming the skin is introduced into the first steam chamber 2a and the second steam chamber 2b of male mold 2 which is provided with no steam holes. On the contrary, in case where the holes for introducing steam which is used for thermal-adhering the expanded beads each other, are provided on the opposite side, that is, on the wall of the steam chamber 2a, which wall faces the cavity 3, the said steam for forming the skin is introduced into the steam chamber 1a of female mold 1 which is provided with no steam holes. In the present invention, the mold mentioned in the above both cases are acceptable.

The expanded resin beads usable in the present invention include polystyrene resin beads, polyethylene resin beads, polypropylene resin beads and the like. These resin

beads are compression-filled in the tank 4 by compressed air and then uniformly filled in the cavity 3.

First, the expanded beads are filled into cavity 3 of the mold by compression filling, steam is introduced into one of the above-mentioned steam chamber to heat the chamber to a temperature above the fusion point of the said bead, and the portion of the said beads contacted with the heated mold are fused to form a skin at the surface portion of the molding product.

In more detailed embodiment, first the valves of the steam pipes 10, 13 and the drain pipes 12, 15 are opened to introduce high-temperature steam into the first and second steam chambers 2a, 2b to preheat the male mold, and then the male mold and the female mold are joined together to close the mold. Then the expanded beads stored in the tank 4 are filled the cavity 3 from the filling nozzle 5 by compression filling. The filling rate of the beads is determined from compressibility of the beads.

When the temperature of the male mold comprising the first and second steam chambers 2a, 2b reached a specified level, the valves of the drain pipes 12 and 15 are closed. The male mold on the side of the first steam chamber 2a contacted with the resin beads in the cavity 3 is heated to a temperature above the fusion point of the said beads by the high-temperature steam staying in the male mold.

In the present invention, in order to secure the aimed strength and quality of the molding product to be produced, the thickness of the skin, the density of the skin and the density of the molding portion other than the skin are set before filling the beads, and compressibility of the beads determined from the following equation (I) is applied:

$$C = (1 - \rho_1 / ((\rho_2 \times t_2 + \rho_3 \times t_3) / t_1)) \times 100 \quad (I)$$

wherein C: compressibility (%)

ρ_1 : density of expanded resin beads before
filling (kg/m^3)

ρ_2 : density of the skin portion (kg/cm^3)

ρ_3 : density of the other portion than the skin
(kg/cm^3)

t_1 : thickness of the molding (mm)

t_2 : thickness of the skin portion (mm)

t_3 : thickness of the other portion than the skin (mm)

The solid state density of the expanded beads is used as the density of the skin. Incidentally, the solid state density of the expanded polystyrene beads is 950 to 1,000 kg/m^3 , and that of the expanded polypropylene beads is 850 to 900 kg/m^3 .

In the present invention, compressibility of the expanded beads is set to be 3 to 70%, preferably 10 to 65%.

When compressibility is less than 3%, the bead fill becomes insufficient for forming a skin, and the molding may be shrunk. When compressibility exceeds 70%, although it becomes possible to increase the skin thickness, the time required for fusion is prolonged and also the amount of compressed air required for filling increases to elevate the production cost.

The expanded beads filled in the mold have a surface pressure higher than the atmospheric pressure, but since the volume of the beads decreases in accordance with formation of the skin, the surface pressure of the beads which was higher than the atmospheric pressure lowers with formation of the skin.

In the present invention, the surface pressure of the beads in cavity 3 is detected. When the surface pressure is within the range of 0.01 to 1.5 kg/cm²G(Gauge), preferably 0.1 to 1.0 kg/cm²G, in order to obtain a molding product showing good fusion of inside beads after formation of the skin, the air remaining in the inter-bead spaces in the mold is discharged and then steam with a temperature usually below the fusion point, preferably between the fusion point and the expanding temperature, is directly introduced into the inter-bead spaces to fuse the beads.

In more detailed embodiment, when the surface pressure of the beads filled in the cavity 3 dropped from a given value with formation of the skin and reached the above

specified value, the valve of the vacuum pipe 7 is opened while the valve of the drain pipe 9 is closed, and after evacuating the steam chamber 1a and the cavity 3, the valve of the vacuum pipe 7 is closed and the steam of a temperature necessary for fusing the beads in the mold is introduced from the steam pipe 6 to heat the beads. The steam is passed through the steam pipe 6, the steam chamber 1a and the steam holes 1b to enter the cavity 3 and heat the beads therein. Steam can also act as a heating medium for the mold. Thus, steam heating makes it possible to conduct heating at a uniform temperature efficiently in a short period of time by availing of its large heat capacity.

In case where the surface pressure is less than $0.01 \text{ kg/cm}^2\text{G}$, when the expanded beads are heated and fused by steam, they are expanded to an excess degree to lower the filling density, resulting in a reduced expanding force to cause improper fusion, shrinkage of the molding product and separation of the skin from the body of the molding product, so that no good molding product can be obtained. In case where the surface pressure exceeds $1.5 \text{ kg/cm}^2\text{G}$, since the steam introduced for fusing the expanded beads is unable to penetrate into the inside of the beads, the beads are not properly fused due to insufficient heating, and in this case again, no good molding product can be obtained.

Then, the valves of the steam pipes 6, 10 and 13 are closed while the valves of the drain pipes 9, 12 and 15 are

opened. The valves of the cooling water pipes 8, 11 and 14 are also opened to introduce cooling water into the steam chamber 1a, the first steam chamber 2a and the second steam chamber 2b to cool the mold, after which the molding is withdrawn from the mold.

As described above, according to the process of the present invention, it is possible to obtain molding products having a uniform and high-density hard skin at the surface and very limited in or almost free of shrinkage, and such molding products can be produced at low cost with no need of integral molding with a resin sheet.

EXAMPLES

The present invention is further illustrated by the following examples, but it should be understood that these examples are merely intended to be illustrative and not to be construed as limiting the scope of the invention. In the following Examples, a molding apparatus illustrated in FIG. 1 using a mold capable of forming 200 mm x 400 mm x 250 mm high box-like moldings with a thickness of 20 mm was used. Compressibility, degree of fusion and shrinkage of the molding product in the Examples were determined in the following ways.

<Compressibility>

Compressibility was determined from the formula: $(1 - \text{expanded beads density/molding product density}) \times 100\%$.

<Degree of fusion>

The degree of fusion was evaluated by breaking the molding product and determining the ratio (%) of the ruptured area at other parts than the interface of the beads to the overall area of rupture. In the present invention, it is essential that the degree of fusion is not less than 30%.

<Shrinkage>

When the molding product diminished by 5/100 or more in dimension, it was indicated as "shrunk", and when the dimensional diminishment of the molding was less than 5/100, it was described as suffering "no shrinkage". The moldings produced according to the present invention should fall in the category of "no shrinkage".

<Appearance>

In the molding product of the present invention, warp, deformation and separation of the skin from the body of the molding product were investigated by the naked eye. When any one of the warp, deformation or separation was present, the appearance was evaluated as "bad". When no warp, no deformation or no separation was present, the appearance was

evaluated as "good". The molding product according to the present invention should have "good" appearance.

Example 1

In order to obtain a molding product having a skin thickness of 0.5 mm, a skin density of 850 kg/m^3 , a density of the other part than the skin of 50 kg/m^3 and an overall thickness of 20 mm, compressibility was determined to be about 54% from the above-shown equation (I).

The expanded polypropylene beads having a density of 32 kg/m^3 were filled in tank 4 and the valves of steam pipes 10, 13 and the valves of drain pipes 12, 15 were opened to introduce steam of 175°C into first steam chamber 2a and steam of 150°C into second steam chamber 2b to preheat the mold, and the mold was closed in this state.

The expanded beads in tank 4 were filled into cavity 3 from nozzle 5. When the mold temperature of first steam chamber 2a and second steam chamber 2b reached 100°C or above, the valves of drain pipes 12, 15 were closed. Male mold 2 comprising first steam chamber 2a and second steam chamber 2b was further heated by the steam existing in the male mold. The temperature of the mold portion on the first steam chamber (2a) side contacted with the expanded beads in cavity 3 rose up rapidly till reaching 170°C and was stabilized thereat.

At this point, the surface pressure of the beads filled in cavity 3 was $1.6 \text{ kg/cm}^2\text{G}$. Then the surface pressure dropped as shown in FIG. 2. When the surface pressure reached $0.5 \text{ kg/cm}^2\text{G}$, the valve of vacuum pipe 7 was opened while the valve of drain pipe 9 was closed to evacuate steam chamber 1a and cavity 3, after which the valve of vacuum pipe 7 was closed and steam of a temperature below the fusion point of the beads was introduced from steam pipe 6. The beads were heated by the steam which has entered cavity 3 after passing through steam pipe 6, steam chamber 1a and steam holes 1b. Steam temperature was 150°C and retention time was 20 seconds.

Then the valves of steam pipes 6, 10, 13 were closed while the valves of drain pipes 9, 12, 15 and the valves of cooling water pipes 8, 11, 14 were opened to introduce cooling water into steam chamber 1a, first steam chamber 2a and second steam chamber 2b to cool the mold to 40°C . Then the molding product was withdrawn from the mold. The results are shown in Table 1.

Example 2

By the conditions shown in Table 1, the same molding procedure as in Example 1 was conducted except that 48 kg/m^3 of expanded polypropylene beads were filled in cavity 3, and that the cavity was evacuated when the surface pressure of

the beads reached 0.4 kg/cm²G as shown in FIG. 2. The results are shown in Table 1.

Comparative Example 1

Molding under the same conditions as in Example 1 was conducted except that the cavity was evacuated when the surface pressure of the beads dropped to 0 kg/cm²G. The results are shown in Table 1.

Comparative Example 2

Molding under the same conditions as in Example 1 was conducted except that evacuation was conducted when the surface pressure of the beads became 1.6 kg/cm²G. The results are shown in Table 1.

Comparative Example 3

The same molding procedure as in Example 1 was conducted except for use of 20-mm cracking filling instead of the mold and use of such molding conditions that the compressibility of the portion corresponding to the bottom of a box-like molding would become 50% and the average compressibility of the rising portion of the side would become 7.4%. The results are shown in Table 1.

Table 1

	Ex.1	Ex.2	Comp. Ex 1	Comp. Ex 2	Comp. Ex. 3	
Bead density (kg/m ³)	32	48	32	32	32	32
Compressi- bility (%)	54	30	54	54	50	7.4
Molding density (kg/m ³)	70	69	70	70	64	35
Surface pressure (kg/cm ² G)	0.5	0.4	0	1.6	-	-
Skin density (kg/m ³)	850	850	850	850	850	850
Skin thickness (mm)	0.5	0.3	-	-	0.5	-
Density of other part than skin (kg/m ³)	50	57	-	-	44	-
Thickness of other part than skin (mm)	19.5	19.7	-	-	19.5	-
Degree of fusion (%)	95	95	-	5>	5>	-
Shrinkage	No shrinkage	No shrinkage	Shrunk	No shrinkage	No shrinkage	Shrunk
Appearance	Good	Good	Bad	Bad	Bad	Bad

Left column of Comp. Example 3: bottom of box-like molding

Right column of Comp. Example 3: rising portion of the side
other than bottom of the
box-like molding

∴ unmeasurable

The molding products obtained in Examples 1 and 2 had a uniform skin and good appearance and suffered no shrinkage. The molding products obtained in Comparative Examples 1-3 were unsatisfactory in fusion and poor in appearance.

WHAT IS CLAIMED IS:

1. A process for producing a expanded molding product having a high-density skin by filling and fusing expanded resin beads in a mold comprising a female mold and a male mold each having one or more steam chambers, which process comprises:

compression-filling the expanded resin beads in a cavity formed between the female mold and male mold,

introducing steam into the steam chamber(s) of the female mold or male mold to heat the mold to a temperature above the fusion point of said expanded resin beads while fusing the resin beads contacted with the mold to form a skin at the surface of the molding,

detecting the surface pressure of the expanded resin beads filled in the mold,

discharging the air remaining in the inter-bead spaces in the mold while the surface pressure of said beads is in the range of 0.01 to 1.5 kg/cm²G, and

introducing steam of a temperature below the fusion point of said resin beads into the inter-bead spaces to heat and fuse the beads together.

2. The process according to claim 1, wherein filling the expanded resin beads is conducted in such a manner that the compressibility given by the following equation (I) falls in the range of 3 to 70%:



* C L M S *

$$C = (1 - \rho_1 / ((\rho_2 \times t_2 + \rho_3 \times t_3) / t_1)) \times 100 \quad (I)$$

wherein C: compressibility (%)

ρ_1 : density of expanded resin beads before
filling (kg/m³)

ρ_2 : density of the skin portion (kg/cm³)

ρ_3 : density of the other portion than the skin
(kg/cm³)

t_1 : thickness of the molding (mm)

t_2 : thickness of the skin portion (mm)

t_3 : thickness of the other portion than the skin (mm)

3. The process according to claim 1, wherein the expanded resin beads are at least one type of beads selected from the group consisting of polystyrene resin beads, polyethylene resin beads and polypropylene resin beads.

