

METHOD FOR MANUFACTURING A MOLD

TECHNICAL FIELD

The present invention relates to a method for manufacturing a mold.

BACKGROUND ART

A group of plastics called engineering plastics exhibit high strength, and can be used in place of metal components. Among these, a group of plastics called liquid crystalline resins maintains a crystalline structure when molten. Due to the crystalline structure, high strength is one of the characteristics of liquid crystalline resins. Furthermore, liquid crystalline resins have little volumetric change between molten and solidifying states due to low change in the crystalline structure when solidifying. As a result, there is an advantage in liquid crystalline resins in having low mold shrinkage and excelling in dimensional accuracy of molded articles.

Capitalizing on the above such advantages of high strength and the dimensional accuracy being superior, liquid crystalline resin compositions have been adapted to be used in precision equipment components. However, in a case of precision equipment and optical equipment, a small amount of foreign particles, dust, etc. will affect equipment performance. As a result, for components used in precision equipment and optical equipment, e.g., components for camera

modules and the like, ultrasonic cleaning is performed using water or the like to remove small foreign particles, oil content, dust, etc. adhering to the surface of the components when those components are produced. However, for molded articles made by molding a liquid crystalline resin composition, the molecular orientation is particularly high in the surface portion, so that in a normal molding method, a surface layer is formed on a skin layer, and thus the surface relatively easily fibrillates. As a result, if the surface of a molded article peels off, it will become a main contributor to fallen debris (foreign particles). In this way, since the generation of foreign particles and the like is a problem, it is very difficult to ultrasonically clean molded articles made by molding a liquid crystalline resin composition.

The above-mentioned generation of foreign particles and the like occurs due to the molecular orientation being particularly high in the surface of the molded article as mentioned in the foregoing. Methods for preventing formation of the surface layer, which easily fibrillates, include a method of performing molding at 200°C or higher. According to this method, fibrillation can be suppressed, but the molding cycle time becomes very long, leading to occurrence of problems of a reduction in productivity and degradation of resins by retention. As a molded article with improved surface characteristics, a molded article containing liquid crystalline polymer and fiber filler has been disclosed that is characterized in having a flat surface for which a

difference in the surface roughness Ra value obtained by a specific surface tape-peeling test is 0.4 μm or less (Patent Document 1).

According to the method described in Patent Document 1, it is useful for components of electric and electronic equipment or optical equipment, and makes it to prevent surface particle (foreign particle) generation. When using the technology described in Patent Document 1 in this way, an improvement in the surface characteristics is possible.

However, as described in the Examples of Patent Document 1, foreign particle generation according to Patent Document 1 indicates foreign particles generating when cleaning a surface by gently stirring in purified water for 1 minute. With the improvement in surface characteristics according to the method described in Patent Document 1, it is difficult to suppress generation of a surface layer itself, and thus an extraordinarily great amount of foreign particles will generate when exposing the resin molded article to severe conditions such as those of ultrasonic cleaning or the like.

Patent Document 1: Japanese Unexamined Patent Application, Publication No. 2008-239950

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

The present invention has been made in order to solve the aforementioned problems, and an object thereof is to provide a method for manufacturing a mold with which the surface of a

molded article made of a resin composition containing a liquid crystalline resin can be kept from fibrillating, and which is used to make a molded article having an excellent appearance.

Means for Solving the Problems

The present inventors carried out diligent research in order to solve the above-mentioned problems. As a result, it was found that the above-mentioned problems could be solved by deriving, through heat conduction analysis, the relationship between the temperature, near the cavity surface, of a liquid-crystalline resin filled in a mold and the retention time of the liquid-crystalline resin within the mold to thereby derive a temperature range for the temperature of the resin near the cavity surface and a retention-time range for the retention time such that no surface layer is formed on the skin layer of the molded article; and providing, on the mold, a heat-insulating layer that allows the temperature range and the retention-time range to be satisfied. More specifically, the present invention provides the following.

According to a first aspect of the invention, there is provided a method for manufacturing a mold for producing a molded article made of a liquid-crystalline resin composition containing a liquid-crystalline resin, in which, by deriving, through heat conduction analysis, the relationship between the temperature, near the surface of a mold, of a liquid-crystalline resin filled in the mold and the retention time of the liquid-crystalline resin within the mold, a temperature range of the temperature near the surface of the mold and a retention-time range

of the retention time are derived such that no surface layer is formed on the skin layer of the molded article, a heat-insulating layer that allows the temperature range and the retention-time range to be satisfied is provided, and the heat conduction analysis is performed using a mold, in which a heat-insulating layer is formed on the cavity surface, and using as parameters the specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin.

According to a second aspect of the invention, in the method for manufacturing a mold as described in the first aspect, the temperature range is 230°C or higher and the retention-time range is 0.3 seconds or more.

According to a third aspect of the invention, in the method for manufacturing a mold as described in the first or second aspect, the heat conduction analysis determines the material, the placement position and the shape of the range heat-insulating layer.

According to the fourth aspect of the invention, in the method for manufacturing a mold as described in any one of the first to third aspects, the heat-insulating layer has a thermal conductivity of 0.3 W/m·K or less and a thickness of 60 μm or more.

According to the fifth aspect of the invention, in the method for manufacturing a mold as described in any one of the first to fourth aspects, the heat-insulating layer contains at

least one resin selected from polybenzimidazole, polyimide and polyether ether ketone.

According to the sixth aspect of the invention, in the method for manufacturing a mold as described in any one of the first to fourth aspects, the heat-insulating layer is a ceramic material constituted by porous zirconia.

According to the seventh aspect of the invention, in the method for manufacturing a mold as described in any one of the first to fifth aspects, the heat-insulating layer has a metal layer on the surface.

Effects of the Invention

When a molded article made of a resin composition containing a liquid-crystalline resin is produced using a mold produced according to the present invention, a molded article, the surface of which can be kept from fibrillating when subjected to ultrasonic cleaning and which has an excellent appearance, is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view schematically showing the cross section of a mold in which a heat-insulating layer is formed, wherein FIG. 1A is a schematic view of the cross section of a divided mold in which a heat-insulating layer is formed on the entire surface of a cavity, FIG. 1B is a schematic view of the cross section of a divided mold in which a heat-insulating layer is formed on a part of the cavity surface, and FIG. 1C is a schematic view of the cross section of a divided mold in which

a metal layer is formed on a heat-insulating layer.

FIG. 2 is a schematic view of the cross section of a divided mold, in which a heat-insulating layer is formed, for illustrating the thickness of a heat-insulating layer, the thickness of a cavity and the thickness of a mold.

FIG. 3 is a view showing the relationship between the temperature near the cavity surface and the retention-time under a plurality of molding conditions.

FIG. 4 is a view showing a mold used in Example 1.

FIG. 5 is a view showing the relationship between the temperature of a resin at a depth of 7 μm from the cavity surface and the retention-time of the resin within the mold in Example 1.

FIG. 6 is a view showing a mold used in Example 2.

PREFERRED MODE FOR CARRYING OUT THE INVENTION

An embodiment of the present invention will be explained in detail hereinafter. The present invention is not limited to the following embodiment.

In a method for manufacturing a mold according to the present invention, by deriving, through heat conduction analysis, the relationship between the temperature, near the cavity surface, of a liquid-crystalline resin filled in a mold and the retention time of the liquid-crystalline resin within the mold, a temperature range of the temperature near the cavity surface and a retention-time range of the retention time are derived such that no surface layer is formed on a

skin layer of a molded article, and a heat-insulating layer that allows the temperature range and the retention-time range to be satisfied during molding is provided on the mold. The heat conduction analysis is performed using a mold, in which a heat-insulating layer is formed on the cavity surface, and using as parameters the specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin.

A distinction is made between such a molding condition that a surface layer formed on a skin layer is present and such a molding condition that the surface layer is absent using the relationship between the temperature, near the cavity surface, of a liquid-crystalline resin filled in a mold and the retention time of the liquid-crystalline resin within the mold, which is derived by heat conduction analysis. Since the ease with which the temperature of the resin near the cavity surface reduces has influences on whether the surface layer is formed or not, a distinction can be made between the above-mentioned conditions. By providing a heat-insulating layer on the mold so that the relationship between the temperature near the cavity surface and the retention time shows a desired behavior, the mold allows preparation of a molded article, the surface of which is hard to fibrillate and which has an excellent appearance.

The method for manufacturing a mold according to the present invention will be explained further in detail

hereinafter.

Determination of resin material

The resin material may be a resin composition containing a liquid-crystalline resin, and the type of the liquid-crystalline resin is not particularly limited. Incidentally, a surface layer is easily formed especially when the liquid-crystalline resin constitutes 50% by mass of the total resin composition. Other resins, and additives such as an antioxidant, a pigment, a stabilizer and an inorganic filler may be blended in the resin composition within the bound of not impairing the effect of the present invention. Specific examples of the liquid-crystalline resin may include the liquid-crystalline resin (liquid-crystalline polymer) described in Japanese Unexamined Patent Application Publication No. 2010-106165.

Placement of heat-insulating layer

For placement of a heat-insulating layer, first a temperature range and a retention-time range of a resin near the cavity surface are derived such that no surface layer is formed on a skin layer of a molded article (first step).

Then, a heat-insulating layer is provided on a mold so that the temperature range and the retention-time range are satisfied (second step).

Hereinafter, the method for manufacturing a mold according to the present invention will be explained for each of the first step and the second step.

First step

In the first step, the relationship between the temperature, near the cavity surface, of a liquid-crystalline resin filled in a mold and the retention time of the liquid-crystalline resin within the mold is derived through heat conduction analysis. Here, the heat conduction analysis is performed using a mold, in which a heat-insulating layer is formed on the cavity surface, and using as parameters the specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin. Specifically, the above-mentioned relationship is derived in the following manner.

First, parameters used for performing heat conduction analysis will be explained. A heat-insulating layer is used for suppressing a reduction in the temperature of a resin near the cavity surface. Here, for considering transfer of heat of the resin that has flowed into a mold, it is necessary to consider the thermal conductivity of the heat-insulating layer and the thermal capacity of the heat-insulating layer. Therefore, it is necessary to use as parameters the specific gravity, and the thermal properties such as the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin. When heat conduction analysis is performed, these parameters are input.

Next, a mold in which a heat-insulating layer is formed on the cavity surface will be explained. It is necessary to

perform heat conduction analysis after determining how the heat-insulating layer is provided within the mold. This is because the degree of heat transfer varies depending on how the heat-insulating layer is provided. However, the degree of specificity to which how the heat-insulating layer is provided within the mold can be appropriately changed according to a required degree of accuracy.

Hereinafter, placement and the like of the heat-insulating layer will be more specifically explained.

Examples include a mold in which a heat-insulating layer is formed on the entire surface of a cavity, and FIG. 1A shows a schematic view of the cross section of a divided mold in which a heat-insulating layer is formed on the entire surface of a cavity. By thus providing a heat-insulating layer on the entire surface of a cavity, molding can be performed such that no surface layer is formed on the entire surface of a molded article. As shown in FIG. 1, the divided mold consists of a front mold and a rear mold.

If it is determined that heat conduction analysis is performed using a mold as in FIG. 1A, the thickness L_s of the heat-insulating layer (in a direction perpendicular to a parting surface of the divided mold), the thickness L_M of the mold in the thickness direction of the heat-insulating layer and the thickness L_p of the cavity in the thickness direction of the heat-insulating layer will be determined. These values are also input when heat conduction analysis is performed. The positions of L_s , L_M and L_p are shown in FIG. 2.

In FIG. 1A, the heat-insulating layer is formed on the entire surface of the cavity, but the heat-insulating layer may be formed on a part of the cavity surface as shown in FIG. 1B.

Other examples include a mold in which a metal layer is formed on a heat-insulating layer of the mold in which the heat-insulating layer is formed on the entire surface of a cavity, and FIG. 1C shows a schematic view of the cross section of a divided mold in which a metal layer is formed on the heat-insulating layer.

By forming a metal layer on the heat-insulating layer, the wear resistance of the cavity surface is improved. Particularly, when an inorganic filler such as glass fibers is blended, the cavity surface is easily worn. Therefore, when a resin composition in which glass fibers or the like are blended is used, it is preferable to use a mold as shown in FIG. 1C.

When a metal layer is present on the entire surface of the cavity, it becomes necessary to increase the thickness of the heat-insulating layer, or the like, because the thermal conductivity of the metal layer is high.

If it is determined that heat conduction analysis is performed using a mold as shown in FIG. 1C, the thickness L_s of the heat-insulating layer (in a direction perpendicular to a parting surface of the divided mold), the thickness L_m of the mold in the thickness direction of the heat-insulating layer, the thickness L_p of the cavity in the thickness direction of

the heat-insulating layer and the thickness L_{HI} of the metal layer in the thickness direction of the heat-insulating layer will be determined. These values are input when heat conduction analysis is performed.

Heat conduction analysis is performed using input conditions such as parameters determined in the manner described above. The relationship between the temperature near the cavity surface and the retention time is derived for each molding condition while changing molding conditions such as the mold temperature. Then, molding is actually carried out for each molding condition, and whether or not a surface layer is formed on a skin layer is checked. For example, the relationship for each molding condition is derived by a graph shown in FIG. 3 (P_1 to P_4 in FIG. 3). Then, heat conduction analysis is performed under such a condition that the mold temperature is about 200°C and the heat-insulating layer is absent, i.e. a condition such that no surface layer is formed on the surface of a molded article, so that the relationship between the temperature near the surface of the mold and the retention time is derived (line Q in FIG. 3). Here, assume that no surface layer is formed on the surface of a molded article at P_2 , and a surface layer is formed on the surface of a molded article at P_3 . A threshold as to whether or not a surface layer is formed on the surface of a molded article exists between intersection point α_2 of solid lines P_2 and Q and intersection point α_2 of solid lines P_3 and Q. For example, it can be determined that the threshold exists at α between α_2

and α_3 .

If the position of α corresponds to the threshold, a temperature range of the temperature near the surface of the mold such that no surface layer is formed on a skin layer of a molded article is not less than $T^\circ\text{C}$ and a retention-time range of the retention time is not less than t seconds as shown in FIG. 3.

When a condition such that no surface layer is formed on the surface of a molded article cannot be obtained through heat conduction analysis, input conditions are changed such that the thickness of the heat-insulating layer is increased, the material is changed, or the like. When only a condition such that no surface layer is formed on the surface of a molded article can be obtained, a threshold can be arbitrarily determined from the condition.

Second step

In the second step, a heat-insulating layer is provided on a mold so that no surface layer is formed on a skin layer of a molded article. The material, the shape, the placement position and the like of the heat-insulating layer may be those used in heat conduction analysis in the first step, but molding conditions may be examined so that the temperature range and the retention-time range are satisfied using the heat conduction analysis for different heat-insulating layers. For examination, as described above, the material, the position and the like of the heat-insulating layer are input, parameters of the specific gravity, the specific heat, the

thermal conductivity and the thermal diffusivity of a material constituting the mold, and the like are input, and the relationship between the temperature of a resin near the cavity surface and the retention time is derived per a plurality of molding conditions.

As long as molding conditions allowing the temperature range and retention-time range to be satisfied are used, no surface layer is formed on the surface of a molded article. Namely, a heat-insulating layer consistent with the input heat-insulating layer information may be formed on the mold.

Heat-insulating layer

A heat-insulating layer or the like that allows the temperature range and retention-time range to be easily satisfied will now be briefly described before explaining a method for forming a heat-insulating layer.

The heat-insulating layers preferably have a thermal conductivity of 0.3 W/m·K or less and a thickness of 60 μm or more. A heat-insulating layer satisfying these conditions tends to provide sufficient thermal insulation, and allows the temperature range and retention-time range to be easily satisfied.

Examples of the material having a thermal conductivity of 0.3 W/m·K or less and such a heat resistance that a high temperature during molding can be endured include epoxy, polyimide, polybenzimidazole, polyimide and polyether ether ketone.

As described above, a metal layer can be placed on the

heat-insulating layer. As the metal layer, a plate of aluminum, SUS or the like is preferably used. As a method for forming a metal layer on a heat-insulating layer, a conventionally known lamination method or the like can be employed. The thickness of the metal layer depends on the type of a metal contained in the metal layer, but is preferably 0.1 mm or less. When a metal plate is used as described above, the thickness of the heat-insulating layer is required to be increased as described above, and is set to, for example, 10 mm or more, more preferably 20 mm or more.

A thin film-shaped metal layer can be formed on the heat-insulating layer using a conventionally known method for forming a plated film, such as a sputtering method or an ion plating method. Since the plated film is very thin, the thickness of the heat-insulating layer is preferably 60 μm or more unlike the case of using a metal plate.

The method for forming a heat-insulating layer on the inner surface of a metal portion of a mold is not particularly limited. It is preferable to form a heat-insulating layer on the inner surface of a mold by, for example, the following method.

The methods include a method in which a solution of a polymer precursor such as a polyimide precursor, which can form a polymer heat-insulating layer, is applied to the inner surface of a metal portion of a mold, heated to evaporate a solvent, and overheated to be formed into a polymer, whereby a heat-insulating layer such as a polyimide film is formed, a

method in which a monomer of a heat-resistant polymer, for example pyromellitic anhydride and 4,4-diaminodiphenyl ether, are subjected to vapor deposition polymerization, and a method in which a piece mold, in which a portion corresponding to the cavity surface is made of a heat-insulating plate, is prepared, and the piece mold is mounted on a main mold. Alternatively, concerning a plane mold, mention is made of a method in which a polymer heat-insulating film is attached to a desired portion of a mold by an appropriate bonding process or with an adhesive tape-like polymer thermo-insulation film to form a heat-insulating layer. Formation of a heat-insulating layer may be performed by a method in which a resin forming a heat-insulating layer is electro-deposited on a mold. A metal layer can be formed on the heat-insulating layer or the surface of the heat-insulating plate for the purpose of imparting durability for prevention of flawing.

For the heat-insulating layer, a ceramic material can also be used. Since the surface of the ceramic material is excellent in wear resistance, it is not necessary to place a metal layer as described above on a heat-insulating layer constituted by a ceramic material. For the ceramic material, porous zirconia containing air bubbles therein, silicon dioxide or the like is preferably used. Among them, a heat-insulating layer constituted by porous zirconia is formed mainly of zirconia, and is therefore highly durable to a pressure applied on the heat-insulating layer during injection molding. Therefore, defects of the heat-insulating layer

caused by the pressure are hard to occur. Thus, the number of interruptions of molding in the course of injection molding decreases, so that productivity of injection-molded articles is improved.

The zirconia is not particularly limited, and may be any of stabilized zirconia, partially stabilized zirconia and unstabilized zirconia. The stabilized zirconia is such that cubic-crystal zirconia is kept stable even at room temperature, and is excellent in mechanical properties such as strength and toughness and wear resistance. The partially stabilized zirconia refers to a state in which tetragonal-crystal zirconia partly remains even at room temperature, wherein martensitic transformation occurs from the tetragonal crystal to the monoclinic crystal upon reception of external stress, growth of cracks spread by an action particularly of tensile stress is suppressed, and toughness to breakage is high. The unstabilized zirconia refers to zirconia that is not stabilized by a stabilizer. At least two types selected from stabilized zirconia, partially stabilized zirconia and unstabilized zirconia may be combined and used.

As a stabilizer contained in stabilized zirconia and partially stabilized zirconia, a conventionally known general stabilizer can be employed. Examples thereof include yttria, ceria and magnesia. The used amount of the stabilizer is not particularly limited, and can be appropriately determined according to the intended use, the material used and the like.

Besides the above-mentioned zirconia and stabilizer,

conventionally known additives and the like may be further contained within the bounds of not impairing the effect of the present invention.

The method for forming a heat-insulating layer using the above-mentioned raw materials is not particularly limited, but a spraying method is preferably employed. By employing the spraying method, the thermal conductivity of porous zirconia is easily adjusted to a desired range. Such a problem does not occur that air bubbles are excessively formed within porous zirconia, resulting in a considerable reduction in mechanical strength of the heat-insulating layer. Thus, by forming a heat-insulating layer by spraying, the structure of the heat-insulating layer becomes suitable for the intended use of the present invention.

For example, formation of a heat-insulating layer by spraying can be carried out in the manner described below. First, a raw material of the heat-insulating layer is melted into a liquid. The liquid is accelerated to collide against the inner surface of a cavity. Finally, the raw material that has collided against the inner surface of the cavity and deposited thereon is solidified. In this way, a very thin heat-insulating layer is formed on the inner surface of the mold. By further colliding the melted raw material onto the very thin heat-insulating layer and solidifying the same, the thickness of the heat-insulating layer can be adjusted. As a method for solidifying the raw material, conventionally known cooling means may be used, or the raw material may be merely

left standing to be solidified. The spraying method is not particularly limited, and a preferred method can be appropriately selected from conventionally known methods such as arc spraying, plasma spraying and flame spraying.

The heat-insulating layer having a multilayered structure can be produced by adjusting production conditions for the heat-insulating layer. For example, when the heat-insulating layer is formed by the spraying method, the heat-insulating layer can be produced by adjusting a condition for depositing a melted raw material on the inner surface of the mold.

EXAMPLES

Hereinafter, the present invention will be explained in further detail based on Examples; however, the present invention is not to be limited by these Examples.

Example 1

In Example 1, the following materials were used.

Resin: liquid-crystalline resin ("VECTRA E463i" manufactured by Polyplastics Co., Ltd.)

Heat-insulating layer: a polyimide resin (polyimide resin varnish (manufactured by Fine Chemical Japan Co., Ltd.) having a thermal conductivity of 0.2 W/m·K was sprayed onto the inner surface of a mold, and baked at 250°C for an hour, followed by polishing the polyimide surface.)

A mold as shown in FIG. 4 was used. The thickness of the heat-insulating layer and the like was as follows: $L_M = 10$ mm, $L_P = 0.7$ mm and $L_S = 0.06$ mm.

The specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin were as shown in Table 1 below. The thermal conductivity was calculated by measuring the thermal diffusivity by a laser flash method. The specific gravity was measured by an Archimedes method, and the specific heat was measured by DSC.

[Table 1]

	Specific gravity (kg/m^3)	Specific heat ($\text{J}/(\text{kg} \cdot \text{K})$)	Thermal conductivity ($\text{W}/(\text{m} \cdot \text{K})$)	Thermal diffusivity ($\text{m}^2 \cdot \text{s}$)
Metal material of mold	7800	461	33.1	9.21×10^{-6}
Polyimide resin	1270	1130	0.22	1.53×10^{-7}
Liquid-crystalline resin	1640	1730	0.79	2.78×10^{-7}

Therm 1 (one-dimensional heat conduction analysis software) was used to derive the relationship between the temperature of the resin at a depth of 7 μm from the cavity surface and the retention time of the resin within the mold under molding conditions of the mold temperature and the like shown in Table 2. The derived relationship is graphically shown in FIG. 5. Results of heat conduction analysis performed in the same manner as in Example 1 except that no heat-insulating layer was provided, and performed under a condition of mold temperature: 200°C are also shown in FIG. 5.

Furthermore, a molded article was prepared under molding conditions shown in table 2, and presence/absence of a surface layer was checked by attaching Sellotape (registered trademark) to the molded article and peeling off the Sellotape (registered trademark). Presence/absence of a surface layer is

also shown in Table 2.

[Table 2]

	Resin temperature (°C)	Mold temperature (°C)	Presence/absence of surface layer
Molding condition 1	350	100	Present
Molding condition 2		120	Slight
Molding condition 3		140	Absent

A threshold as to whether a surface layer is formed or not exists between the intersection point of a graph representing the above-mentioned relationship under such a condition that the heat-insulating layer is absent and the mold temperature is 200°C and a graph representing the above-mentioned relationship under conditions 2 and 3. It can be estimated from FIG. 5 that if a resin which has flowed into the mold is retained at 230°C or higher for 0.3 seconds or more, no surface layer is formed on a skin layer.

Namely, a heat-insulating layer that allows the resin to be retained at 230°C or higher for 0.3 seconds or more is determined through heat conduction analysis, and the heat-insulating layer is provided on a mold to produce a mold for molding. When a mold is produced in this way, and molding is performed under specific molding conditions (for example molding condition 3 described above), a molded article with no surface layer formed on a skin layer can be injection-molded.

Example 2

In Example 2, the following materials were used.

Resin: liquid-crystalline resin ("VECTRA E4631" manufactured by Polyplastics Co., Ltd.)

Heat-insulating layer: heat-insulating plate made of glass fibers and a silicic acid-based binder

Metal layer 1: SUS plate

Metal layer 2: aluminum plate

A mold as shown in FIG. 6 was used. The thickness of the heat-insulating layer and the like was set to $L_M = 10$ mm, $L_P = 0.7$ mm, $L_S = 10$ mm, 20 mm or 30 mm, and $L_{HI} = 0.05$ mm, 0.10 mm, 0.15 mm, 0.20 mm or 0.25 mm.

The specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin were as shown in Table 3 below.

[Table 3]

	Specific gravity (kg / m^3)	Specific heat ($\text{J} / (\text{kg} \cdot \text{K})$)	Thermal conductivity ($\text{W} / (\text{m} \cdot \text{K})$)	Thermal diffusivity ($\text{m}^2 \cdot \text{s}$)
Metal material of mold	7 8 0 0	4 6 1	3 3 . 1	9.21×10^{-6}
Heat-insulating plate	2 0 0 0	9 9 0	0 . 2 4	1.21×10^{-7}
Liquid-crystalline resin	1 6 4 0	1 7 3 0	0 . 7 9	2.78×10^{-7}
SUS plate	7 9 3 0	5 9 0	1 6 . 7	3.57×10^{-6}
Aluminum plate	2 7 0 0	9 0 0	2 3 7	9.75×10^{-5}

Heat conduction analysis was performed in the same manner as in molding condition 3 of Example 1 to derive the relationship between the temperature of a resin at the depth of 7 μm from the cavity surface and the retention time of the resin within the mold. Those in which a resin which had flowed into a mold was retained at 230°C or higher for 0.3 seconds or more were rated as "o", and others were rated as "x". The evaluation result is shown in Tables 4 and 5 for each of conditions for the thickness of the heat-insulating layer and

the thickness of the metal layer.

[Table 4]

		Thickness of heat-insulating plate (mm)		
		10	20	30
Thickness of SUS plate (mm)	0.05	○	○	○
	0.10	×	○	○
	0.15	×	×	×
	0.20	×	×	×
	0.25	×	×	×

[Table 5]

		Thickness of heat-insulating plate (mm)		
		10	20	30
Thickness of aluminum plate (mm)	0.05	○	○	○
	0.10	○	○	○
	0.15	○	○	○
	0.20	×	○	○
	0.25	×	×	×

As is apparent from the results of Example 2, it has been confirmed that even when a metal layer is formed on the heat-insulating layer, a molded article with no surface layer formed on the surface can be produced. It has been confirmed that the acceptable thickness of the metal layer depends on the type of metal, but it has been confirmed that if the thickness is about 1 mm or less, a heat-insulating layer that allows no surface layer to be formed on the surface of a molded article is easily provided. If the thickness of the heat-insulating plate is 20 mm or more, a heat-insulating layer that allows no surface layer to be formed on the surface of a molded article is easily provided.

Thus, even when a metal layer is formed on the heat-insulating layer, a heat-insulating layer that allows a resin

to be retained at 230°C or higher for 0.3 seconds or more is determined through heat conduction analysis, and the heat-insulating layer is provided on a mold to produce a mold for molding as in Example 1. By performing molding using a mold produced in this way, a molded article with no surface layer formed on a skin layer can be injection-molded.

Example 3

In Example 3, the following materials were used.

Resin: liquid-crystalline resin ("VECTRA E463i" manufactured by Polyplastics Co., Ltd.)

Heat-insulating layer: porous zirconia layer prepared by spraying zirconia

It could be estimated from the results of Example 1 that in the case of molding condition 3 in Example 1, by ensuring that a resin which has flowed into a mold is retained at 230°C or higher for 0.3 seconds or more, no surface layer is formed on a skin layer.

In Example 3, the thickness of a heat-insulating layer that allows a resin, which flowed into a mold, to be retained at 230°C or higher for 0.3 seconds or more when the heat-insulating layer is a porous zirconia layer was derived using Therm 1 (one-dimensional heat conduction analysis software). For the mold, a mold as shown in FIG. 4 was contemplated as in Example 1. Namely, $L_M = 10$ mm and $L_P = 0.7$ mm. For the specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin, values shown in Table 6

below were used.

[Table 6]

	Specific gravity (kg/m^3)	Specific heat ($\text{J}/(\text{kg} \cdot \text{K})$)	Thermal conductivity ($\text{W}/(\text{m} \cdot \text{K})$)	Thermal diffusivity ($\text{m}^2 \cdot \text{s}$)
Metal material of mold	7 8 0 0	4 6 1	3 3. 1	$9. 2 1 \times 10^{-6}$
Zirconia layer	5 8 6 0	4 6 5	0. 9 6	$3. 5 2 \times 10^{-7}$
Liquid-crystalline resin	1 6 4 0	1 7 3 0	0. 7 9	$2. 7 8 \times 10^{-7}$

Using Therm 1 (one-dimensional heat conduction analysis software), the relationship between the temperature of a resin at a depth of 7 μm from the cavity surface and the retention time of the resin within a mold was derived as in Example 1 for each thickness with the thickness of the heat-insulating layer being changed, and resultantly it was estimated that by setting the thickness of the heat-insulating layer at 500 μm , the resin, which flowed into the mold, would be retained at 230°C or higher for 0.3 seconds or more in the case of molding condition 3 in Example 1. Then, a mold as shown in FIG. 4 with $L_M = 10 \text{ mm}$, $L_P = 0.7 \text{ mm}$ and $L_S = 500 \mu\text{m}$ was actually prepared. The method for forming a heat-insulating layer will be described later.

Furthermore, a molded article was prepared under molding conditions shown in Table 7, and presence/absence of a surface layer was checked by attaching Sellotape (registered trademark) to the molded article and peeling off the Sellotape (registered trademark). Presence/absence of a surface layer is also shown in Table 7.

[Table 7]

	Resin temperature (°C)	Mold temperature (°C)	Presence/absence of surface layer
Molding condition 1	3 5 0	1 0 0	Present
Molding condition 2		1 2 0	Slight
Molding condition 3		1 4 0	Absent

Specific molding conditions are set, the thickness of the heat-insulating layer that allows a resin to be retained at 230°C or higher for 0.3 seconds or more is determined through heat conduction analysis, and a heat-insulating layer having the determined thickness is provided on a mold to produce a mold for molding. When a mold is produced in this way, and molding is performed under set molding conditions (for example molding condition 3 described above), a molded article with no surface layer formed on a skin layer can be injection-molded. Formation of heat-insulating layer and measurement of properties

A method for forming the heat-insulating layer and a method for measuring the properties of the heat-insulating layer shown in Table 1 will be explained. A raw material constituted mainly by zirconia was sprayed onto the inner surface of the mold by a spraying method. The surface of the heat-insulating layer was adjusted so as to have an increased density, and a heat-insulating layer having a multilayered structure was formed on the inner surface of the mold. Spraying was continued until the heat-insulating layer had a thickness of 500 μm .

The thermal conductivity was calculated by measuring the thermal diffusivity by a laser flash method. The specific

gravity was measured by an Archimedes method, and the specific heat was measured by DSC.

The thermal conductivity of the zirconia heat-insulating layer was calculated by measuring the thermal diffusivity by a laser flash method, measuring the specific heat by DSC, measuring the specific gravity by a method of collecting a gas over water (conforming to JIS Z8807 Solid Specific Gravity Measurement Method), and following the equation of [thermal conductivity] = [thermal diffusivity × specific heat × specific gravity]. The thermal conductivity (λ) of the heat-insulating layer having a multilayered structure was determined by determining the thermal conductivity of each of the low-density layer and the high-density layer, and conducting calculation using the equation of $[1/\lambda] = [t/\lambda_l] + [(1-t)/\lambda_h]$ where the thermal conductivity of the low-density layer is λ_l , the thermal conductivity of the high-density layer is λ_h and the ratio of the thickness of the low-density layer to the thickness of the entire heat-insulating layer is t .

As a result of actually performing measurements, the specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin were as shown in Table 6 above.

CLAIMS

1. A method for manufacturing a mold for producing a molded article made of a liquid-crystalline resin composition containing a liquid-crystalline resin,

wherein by deriving, through heat conduction analysis, the relationship between the temperature, near the surface of a mold, of a liquid-crystalline resin filled in the mold and the retention time of the liquid-crystalline resin within the mold, a temperature range of the temperature near the surface of the mold and a retention-time range of the retention time are derived such that no surface layer is formed on the skin layer of the molded article, a heat-insulating layer that allows the temperature range and the retention-time range to be satisfied is provided,

and the heat conduction analysis is performed using a mold, in which a heat-insulating layer is formed on the cavity surface, and using as parameters the specific gravity, the specific heat, the thermal conductivity and the thermal diffusivity of a material constituting the mold and the liquid-crystalline resin.

2. The method for manufacturing a mold according to claim 1,

wherein the temperature range is 230°C or higher and the retention-time range is 0.3 seconds or more.

3. The method for manufacturing a mold according to claim 1

or 2, wherein the heat conduction analysis determines the material, the placement position and the shape of the heat-insulating layer.

4. The method for manufacturing a mold according to any one of claims 1 to 3, wherein the heat-insulating layer has a thermal conductivity of 0.3 W/m·K or less and a thickness of 60 μm or more.

5. The method for manufacturing a mold according to any one of claims 1 to 4, wherein the heat-insulating layer contains at least one resin selected from polybenzimidazole, polyimide and polyether ether ketone.

6. The method for manufacturing a mold according to any one of claims 1 to 4, wherein the heat-insulating layer is a ceramic material constituted by porous zirconia.

7. The method for manufacturing a mold according to any one of claims 1 to 5, wherein the heat-insulating layer has a metal layer on the surface.