

Specification

Method and Apparatus for Forming Optical Element

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Technical Field

The present invention relates to a method and an apparatus for forming an optical element such as a glass lens or a glass molded product by pressing in a set of molds.

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Background Art

A conventional process of forming an optical element made of a glass material includes detecting the temperature of a set of upper and lower molds, heating the molds to a glass formable temperature which exceeds the transition temperature but is not higher than the softening point temperature of the glass material, and forming the glass material to a desired shape by pressing or the like.

Such a conventional forming process has however a drawback that the dimensional accuracy of a finished optical element is not always favorable. The thermal expansion coefficient of glass in a temperature range higher than the transition point is several times as great as one in the lower temperature range. The thermal expansion coefficient of glass material in such a higher temperature range is also greater than that of ceramic or metal, e.g. super steel, which is generally used for fabricating the molds. When the glass material is press-formed

to a desired shape in the high temperature range, its shape remains at certain accuracy just after the forming process but may considerably be contracted as the temperature falls down to the transition temperature, and its dimensional accuracy is hardly maintained.

For solving the above drawback, the temperature of the glass material is preferably reduced to as close to the transition temperature as possible at a process of finally closing the mold during the forming process. It is however not easy to directly measure the temperature of the glass material. Also, since the temperature of the glass material may vary depending upon measuring locations, a technique of controlling the forming process with the use of temperature measurements of the molds is limited in the accuracy.

Disclosure of the Invention

According to a first aspect of the invention, there is provided a forming method of forming an optical element for placing a glass material between a pair of upper and lower molds, measuring and controlling a temperature of the molds to heat up the glass material together with the molds, and forming the glass material into an optical element, said forming method comprising the steps of:

(a) placing the glass material between the upper and lower molds heated and maintained at a pre-heating temperature;

(b) heating up the molds together with the glass material;

(c) when a temperature of the molds reaches a setting temperature which is higher than a transition temperature of the glass material, moving at least one of the upper and lower molds until the molds for making a direct contact between the glass material and the molds at a pressure P_1 at which the glass material deforms;

(d) measuring a displacement of the mold caused by softening and deforming of the glass material, applying a pressure P_2 which is greater than the pressure P_1 while measuring a speed of deforming the glass material, and confirming that a period of time when a viscosity of the glass material balances with the pressure P_2 has elapsed;

(e) shifting a pressure from the pressure P_2 to a pressure P_3 which is smaller than the pressure P_2 ;

(f) controlling a temperature of the molds in response to a temperature decreasing instruction to cool down the glass material, and when the temperature drops down to below the transition temperature, canceling to apply the forming pressure; and

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(g) moving at least one of the upper and lower molds, further cooling down the molds and the glass material to the pre-heating temperature.

According to this aspect of the present invention, the glass material remains not in direct contact with the molds before its temperature rises up to on higher than the transition

temperature T_3 . When the deforming of the glass material is detected from the movement of the mold, the forming pressure is shifted to P_2 for promoting the forming of the glass material into a desired shape. A difference in the contraction of the finished product and a difference in the contraction of the molds due to a change in the thermal expansion adjacent to the transition temperature T_3 of the glass material are forcefully offset by the pressure P_2 .

The glass material may be formed into a desired shape by e.g. pressing regardless of direct measurement of the temperature of the glass material and without injuring the glass material and the molds.

The accuracy of the forming process may be improved by the control to gradually increase or decrease the forming pressure in response to the speed of deforming the glass material.

The forming process may be made less expensive by controlling the forming pressure by an air cylinder and an electro-pneumatic regulator without using a servo mechanism.

The speed of deforming the glass material may be detected from the speed of movement of the mold.

It may be acknowledged that the viscosity of the glass material balances with the pressure P_2 when the speed of movement of the mold falls down to zero.

According to a second aspect of the invention, there is provided an optical element forming apparatus comprising a glass material between upper and lower molds, measuring and controlling the temperature of the molds to heat up the glass material together with the molds, and forming the glass material into an optical element, said apparatus comprising:

action instructing means for performing an action of controlling the forming process according to a setting temperature $T2$ which is higher than a transition temperature of the glass material, a movement $S1$ of the molds, and the speed of the movement of the molds

means for determining a forming pressure to at least a pressure $P2$ for loading to deform the glass material and a pressure $P1$ which is lower than the pressure $P2$;

calculating and controlling means for gradually increasing and decreasing the forming pressure depending on a speed of a movement of the molds;

means for measuring the movement of the molds while the forming pressure is maintained at the pressure $P1$;
and

means for calculating and controlling the speed of the movement of the molds while the forming pressure is maintained at the pressure $P2$.

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The forming apparatus according to the present invention may include a nozzle and a rotary table for holding and conveying

the glass material and the optical element, hence allowing both of them to be conveyed by a single mechanism.

The forming apparatus of the present invention may further employ a cylinder for driving the mold, hence making its structural arrangement simpler.

Brief Description of the Drawings

Fig. 1 is a cross sectional front view of a primary part of an apparatus for forming an optical element showing an embodiment of the present invention; and

Figs. 2 (a) through 2 (c) are characteristic diagrams showing a temperature, a displacement, and a pressure respectively in a forming process.

Detailed Description of the Preferred Embodiment

An embodiment of the present invention will be described referring to the relevant drawings. Fig. 1 is a cross sectional front view of a primary part of an apparatus for forming an optical element showing the embodiment of the present invention. Figs. 2 (a) through 2 (c) are characteristic diagram showing a temperature, a displacement, and a pressure respectively in a forming process.

An optical element forming apparatus of the embodiment of the present invention comprises, as shown in Fig. 1, upper mold 2 made of super steel, lower mold 3 made of the same and arranged corresponding to upper mold 2 for forming glass material 1 to an optical element, upper holder 4 for securely holding the upper

mold 2 made of metal, and lower holder 5 securely holding the lower mold 3. Heating member 15 having upper holder 4 mounted to one side thereof are provided with built-in heaters 6a and joined to the inner side of main frame 14 by upper shaft 7 made
5 of heat-resistant metal or ceramic.

Lower shaft 8 is driven by cylinder 9, which has very small frictional resistance, for upward and downward movements closely through one side of main frame 14. Also, another heating member 16 is provided with built-in heaters 6b and is joined at one
10 side to the bottom of lower holder 5 and at another side to the distal end of lower shaft 8.

The apparatus also comprises rotary table 11 which can rotate to carry glass material 1 and its finished optical element between the outside and inside of the apparatus defined by main
15 frame 14. It also comprises nozzle 13 arranged movable for suctioning and gripping glass material 1 or the optical element to transfer them between lower mold 3 and one of pockets 12. It further comprises sensor 10 mounted to one side of rotary table 11 for detecting the displacement of lower shaft 8 or lower
20 mold 3 and plural pockets 12 on rotary table 11 for accepting and carrying glass material 1 or its finished optical element.

The action of the foregoing apparatus will now be described referring to Figs. 1 and 2. Pocket 12 provided on rotary table 11 located on one side of the forming apparatus is filled with
25 glass material 1. Then, rotary table 11 is turned to convey glass material 1 into the inside of main frame 14 at an atmosphere of inert gas in the forming apparatus.

In the forming apparatus, glass material 1 is picked up and transferred by nozzle 13, of which the driving mechanism is not shown. Meanwhile, lower mold 3 remains at pre-heating temperature T1 which is lower than transition temperature T3 for minimizing the duration of the temperature of glass material 1 rising up to its setting temperature T2 higher than transition temperature T3. Glass material 1 is then loaded into lower mold 3.

After it is confirmed that lower mold 3 is filled with glass material 1, upper mold 2 and lower mold 3 are heated by heaters 6a and 6b of heating members 15 and 16 according to receiving a heating and controlling instruction, of which the system and mechanism is not shown.

As the temperature of upper mold 2 and lower mold 3 reach at setting temperature T2, lower mold 3 is lifted up by the action of low-friction cylinder 9 with an electro-pneumatic regulator (not shown) to hold glass material 1 between upper mold 2 and lower mold 3. Pressure P1 for loading to deform is high enough to form glass material 1 to a desired shape at temperature T2.

Glass material 1 is rigid, fragile, and susceptible to fracture at a normal temperature and may injure the molds. However, as its temperature rises up, glass material 1 is declined in the viscosity. Once its temperature exceeds transition temperature T3, glass material 1 becomes soft and deformable.

The forming apparatus confirms the start of abrupt displacement S1 of glass material 1 maintained in its softened state at setting temperature T2 between upper mold 2 and lower

mold 3. In turn, the forming apparatus shifts the load for deforming from pressure P1 to higher pressure P2 to shape glass material 1 in a short period while the temperature is kept at setting temperature T2. Pressure P2 and setting temperature T2 are maintained until the force of viscosity of glass material 1 becomes balanced with pressure P2.

At the time, it is preferable to calculate and control the pressure by steps of increase or decrease (with the use of an unshown system and mechanism) for forming glass material 1 to a desired shape as quick as possible based on the characteristic of glass material 1.

From measurements of sensor 10 indicating the displacement of lower mold 3 with time, the speed of deformation of glass material 1 is calculated and determined. Upon detecting that the force of viscosity of glass material 1 becomes balanced with pressure P2 or specifically the speed of the displacement is very close to zero, the forming apparatus shifts the load for forming from pressure P2 to lower pressure P3. After the pressure decreases, the temperature of glass material 1 with upper mold 2 and lower mold 3 is lowered down by a certain cooling control initiated according to a temperature decreasing instruction so as not to interrupt the surface of and the optical characteristics of a formed product. Pressure P3 may be equal to pressure P2.

The forming apparatus is responsive to the temperature decreasing instruction for performing the cooling control (of which the system and mechanism is not shown) for cooling down glass material 1 to pre-heating temperature T1, which is lower

than transition temperature T_3 , without injuring the same. Simultaneously, any difference in the contraction due to a change in the thermal expansion between the formed product and the upper and lower molds can forcefully be offset by applying pressure
5 P_3 which is slightly smaller than pressure P_2 . This allows the press forming action to be carried out at accuracy by the forming apparatus regardless of the precise measurement of the temperature of glass material 1 via the upper and lower molds.

As it is confirmed that the temperature of glass material
10 1 decreases to below transition temperature T_3 , lower mold 3 together with the form product or an optical element is lifted down by the action of the cylinder 9. After the optical element is further cooled down to pre-heating temperature T_1 , it is picked up by the suction and holding action of nozzle 13 and transferred
15 into pocket 12 of rotary table 11. When rotary table 11 is turned to convey the optical element to the outside of the apparatus, one cycle of the forming process is completed.

Industrial Applicability

20 The method and the apparatus for forming an optical element according to the present invention permit a glass material to be formed to a highly-accurate shape of the optical element without acquiring the temperature of the glass material during the forming process. Also, while the glass material is protected
25 from being injured as well as upper and lower molds, it can readily be formed to the optical element stably.

CLAIMS

1. A forming method of forming an optical element for placing
a glass material between a pair of upper and lower molds, measuring
and controlling a temperature of the molds to heat up the glass
5 material together with the molds, and forming the glass material
into an optical element, said forming method comprising the steps
of:

(a) placing the glass material between the upper and lower
molds heated and maintained at a pre-heating temperature;

10 (b) heating up the molds together with the glass material;

(c) when a temperature of the molds reaches a setting
temperature which is higher than a transition temperature of
the glass material, moving at least one of the upper and lower
molds until the molds for making a direct contact between the
15 glass material and the molds at a pressure P1 at which the glass
material deforms;

(d) measuring a displacement of the mold caused by softening
and deforming of the glass material, applying a pressure P2 which
is greater than the pressure P1 while measuring a speed of
20 deforming the glass material, and confirming that a period of
time when a viscosity of the glass material balances with the
pressure P2 has elapsed;

(e) shifting a pressure from the pressure P2 to a pressure
P3 which is smaller than the pressure P2;

25 (f) controlling a temperature of the molds in response to
a temperature decreasing instruction to cool down the glass
material, and when the temperature drops down to below the

transition temperature, canceling to apply the forming pressure;
and

(g) moving at least one of the upper and lower molds, further
cooling down the molds and the glass material to the pre-heating
5 temperature.

2. A forming method according to claim 1, wherein the forming
pressure is gradually increased or decreased at the steps (c),
(d), (e), and (f) depending on the speed of deforming the glass
10 material.

3. A forming method according to claim 1 or 2, wherein the
forming pressure is controlled by an action of an air cylinder
and an electro-pneumatic regulator.

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4. A forming method according to claim 1, wherein the speed
of deforming the glass material is measured from a speed of a
movement of the molds.

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5. A forming method according to claim 4, wherein it is
confirmed that the viscosity of the glass material balances with
the pressure P2 in accordance with that the speed of the movement
of the molds becomes zero.

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6. An optical element forming apparatus comprising a glass
material between upper and lower molds, measuring and controlling
the temperature of the molds to heat up the glass material together

with the molds, and forming the glass material into an optical element, said apparatus comprising:

action instructing means for performing an action of controlling the forming process according to a setting
5 temperature T2 which is higher than a transition temperature of the glass material, a movement S1 of the molds, and the speed of the movement of the molds

means for determining a forming pressure to at least a pressure P2 for loading to deform the glass material and a pressure
10 P1 which is lower than the pressure P2;

calculating and controlling means for gradually increasing and decreasing the forming pressure depending on a speed of a movement of the molds;

means for measuring the movement of the molds while the
15 forming pressure is maintained at the pressure P1; and

means for calculating and controlling the speed of the movement of the molds while the forming pressure is maintained at the pressure P2.

20 7. An optical element forming apparatus according to claim 6 further comprising a nozzle and a rotary table for holding and conveying the glass material and the optical element.

8. An optical element forming apparatus according to claim
25 6 or 7, wherein the movement of the molds is implemented by a cylinder.