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STUDIES AND RESEARCH ON GLASS THERMOFORMING

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ABSTRACT

The paper presents a study on the properties that can influence the glass thermoforming process, and an experimental research on glass plate samples, with the aim of observing how glass deforms through thermoforming, using concave and convex support shapes and exposure to temperature, in different areas inside the oven.

KEYWORDS: glass, thermoforming, viscosity

1. Introduction

Glass is one of the oldest materials used by man. Having become an indispensable material in human life, glass is currently produced in large quantities. In general, thermoforming is the technique of obtaining a piece from a thermo formable material, using heat to make it take the desired configuration, using for this purpose a form appropriates to the intended purpose.

Thermoforming is the name of the operation of hot forming glass, which is generally flat. The process consists of placing glass sheets, in a certain position, with or without a support, in an oven.

Thermoforming consists of shaping a piece of glass, solid and flat, placed on a support, usually around its perimeter, in an oven, initially cold, and heating it until it becomes viscous. Near temperatures of 700 °C, under the action of weight, the plate deforms and stretches until the desired shape is obtained, in contact with the walls of the model. The piece can also be shaped by blowing. suction, or by some mechanical action [2, 4, 8].

Thermoforming steps: The steps of thermoforming glass are shown in Figure 1.

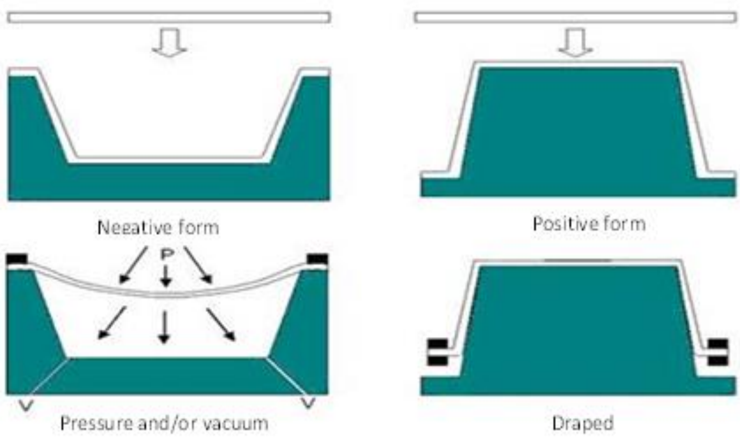

Fig. 1. *Stages of glass thermoforming*

In addition to creating artistic pieces, this process is used industrially, in the case of flat glass, in the manufacture of windshields and other components for motor vehicles, lenses, television screens, and glass containers.

The main difficulty lies in achieving uniform thickness of the formed piece, which can lead to additional costs. Artisans, in turn, face the same difficulties in obtaining the desired configuration when shaping glass by thermoforming.

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In the case of large-scale production by thermoforming, a correction/improvement process can be easily developed industrially to remedy deficiencies and obtain the desired object. However, for artisanal or one-off manufacturing, it is difficult to apply without wasting money and time.

Thermal regime: Thermoforming is, in practice, a heating process, using, to obtain the desired effect, refractory moulds so as to give the piece a certain, particular, desired, imagined configuration (most often, concave). The glass, under the effect of heat, softens, "sinks" (sags) and faithfully copies the configuration of the form.

The shaping of the glass is determined by its viscosity, which is temperature-dependent.

The glass, placed above the mould, is heated to a high temperature (approximately 800 °C). The temperature is increased progressively, with the glass taking, under the action of gravity, the configuration of the 3D relief of the mould.

The thermal regime of the furnace, can be broken down into four basic stages (Figure 2).

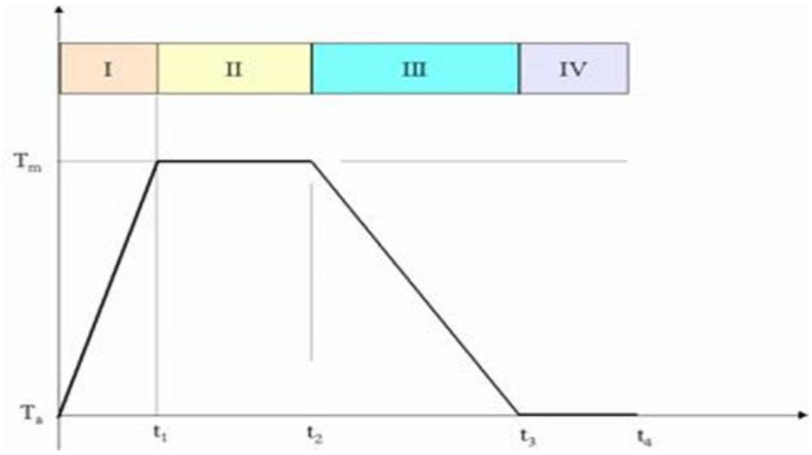

***Fig. 2.** Thermal regime during thermoforming*

Heating: The glass sheet (S), placed on the mould (M) (Figure 3), inside the oven, initially at ambient temperature, is heated in stages.

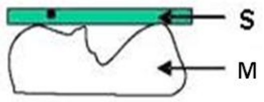

***Fig. 3.** The mold-glass plate assembly used in thermoforming*

The purpose of heating is to quickly obtain a well-defined temperature, as homogeneous as possible in the surface plane and in the thickness of the plate. It is advisable to ensure a temperature increase on the platforms so as to completely avoid the risk of thermal cracking.

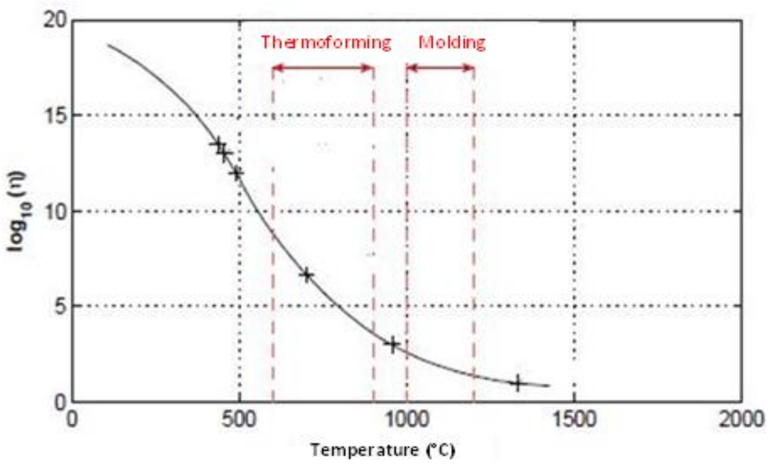

***Fig. 4.** Variation of glass viscosity with temperature*

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There are three possible methods:

- by contact with a heating body, a method based on thermal conductivity: the main disadvantage is that it induces a very high temperature heterogeneity across the thickness of the glass plate;

- by convection, which leads to good temperature homogeneity across the thickness of the glass plate, but has the disadvantage of a long process duration.

-by radiation, the most common method which has the advantage of rapid heating but which can induce a certain heterogeneity across the thickness of the glass plate when it is thicker [1, 3].

Forming stage: Temperature is kept constant inside the oven, to allow the glass to soften. Under the action of weight, the plate deforms, and stretches/adheres until it covers the mould, faithfully reproducing its deformations, in contact with the soft glass plate (Figure 5).

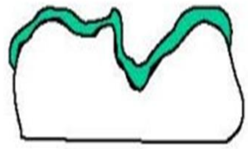

Fig. 5. *Thermoformed part, at the end of the heating process*

Cooling stage: Cooling is carried out in the third stage, and is characterized by controlled cooling, at ambient temperature, which allows the glass to resolidify, while preserving the configuration of the part, obtained at the moment of part-shell contact, and avoiding the appearance of significant residual stresses [5].

Separation of the profiled part: This separation takes place at ambient temperature, and represents the last step of the thermoforming process (Figure 6).

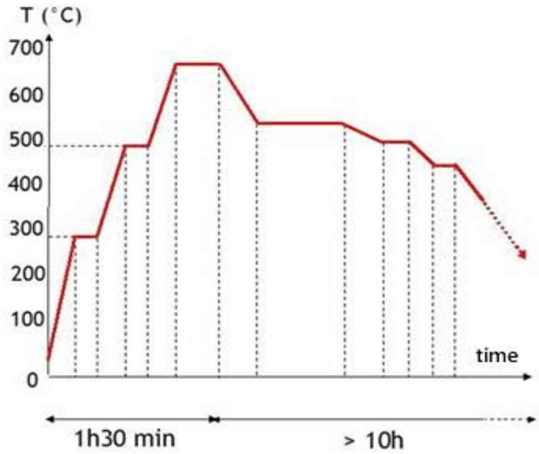

Fig. 6. *Diagram of the glass thermoforming cycle*

The heating process is divided into three main stages:

- heating to a temperature of approximately 700 °C;

- processing or forming stage: the minimum temperature reached corresponds to the softening point at which the glass deforms under the action of its own weight in a visible way; at this temperature, a stage long enough to allow the piece to take the configuration of the shape under the effect of gravity is carried out;

- cooling: the glass piece is cooled to ambient temperature; this cycle is carried out slowly (approximately 10 hours) so as not to damage the piece produced under the effect of too rapid cooling.

As a result of this process, the flat shape of the glass acquires a different configuration, a new relief or a new texture. The softening of the glass, under the action of heat, allows the glass sheet to stretch, practically bend under its own weight, and take the configuration of a support form or a support material. The thickness of the glass determines the heating time and the fineness of the texture [6, 7].

The shaping depends on the imposed thermal regime, the geometry of the part and its properties. In the case of thermoforming, the most important characteristic of glass is viscosity. It is the one that controls the deformation rate, and it is dependent on temperature.

2. Experimental research on the glass thermoforming process

For the study of thermoforming, 2 moulds with a simple configuration were used, namely, two semi-cylinders with a diameter of 50 mm and a length of 60 mm. (Figure 7).

When thermoforming the concave glass plate, it was chosen to fix the plate to the edges of the mould,

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and not to support it, in order to observe how the glass deforms, and how the thickness of the glass varies, during thermoforming, in free fall, in a cavity.

In the case of the convex shape, a glass plate was used, with a length equal to the unfolded length of the outer surface of the shape, and a width equal to that of the shape.

To avoid the glass sticking to the shape, and its subsequent breakage, a ceramic separator was used, mandatory, especially at thermoforming temperatures.

Figure 8 shows the two samples, prepared for insertion into the oven.

The samples were obtained in a silica bar furnace, from the faculty laboratories, based on an adopted cycle for thermoforming the two glass plates.

The obtained samples are presented in Figure 9.

Fig. 7. *Shapes used in the study of thermoforming: a-concave; b-convex*

Fig. 8. *Glass samples prepared for thermoforming*

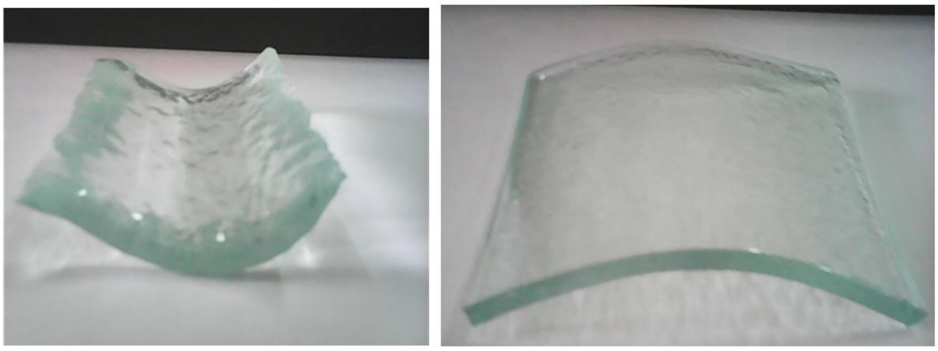

Fig. 9. *Thermoforming glass samples: a-concave; b-convex*

It is observed that the glass sample obtained on the concave mould took the configuration of its shape. The size of the glass was adapted to the mould opening, and not to its full length, which did not ensure complete coverage of the mould.

We found that the thickness of the glass plate did not change significantly, and the softening did not lead to a symmetrical "covering" of the metal mould.

It can be seen that in one of the areas, the glass sheet remained fixed to the edge of one of the mould walls, taking on a concave shape and reproducing its shape in its entirety, while reproducing less so that of the shape of the second wall (Figure 10).

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a. b. c.

Fig. 10. *Thermoformed, concave glass piece: a-side-top view; b-top view; c-texture of the sample*

On the opposite side, the edge of the glass piece descended onto the mould wall, acquiring a rounded shape, but the lack of material did not allow its full reproduction. The sample retained its thickness (Figure 10a), and the inner surface remained smooth and glossy (Figure 10b).

The outer surface of the sample acquired the texture of the ceramic separator (Figure 10c).

With glass samples cast on convex supports, two issues were encountered.

a. b.

Fig. 11. *Thermoformed part on convex mould: a-front view; b-top view*

In the case of samples (Figure 11.), maintained at the thermoforming temperature for a short period of time, the glass sample did not take the shape of the mould, but acquired only a small, non-uniform curvature along its length. It can be seen from Figure 12 that the sample was in the furnace within its loading zone, where the temperature is lower than in the area where the thermocouple is mounted.

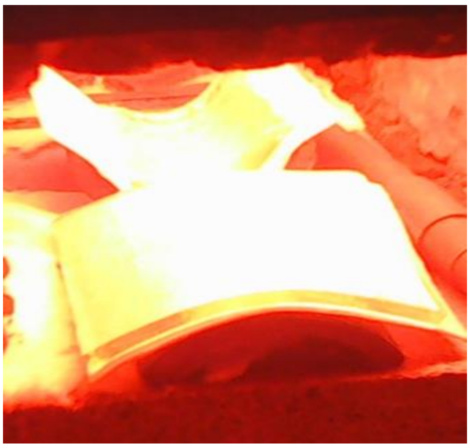

Fig. 12. *The furnace chamber, with the samples inside*

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In the case of the sample maintained for a longer period at the working temperature, a convex piece was obtained, cast on the same model.

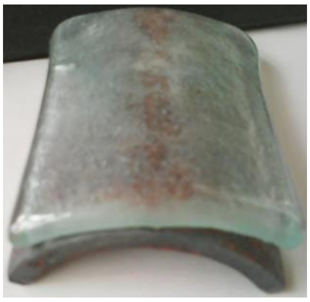

Fig. 13. *Second sample of convex shape*

The surface quality and edge shape of the sample are approximately the same as those of the concave sample. The edges have the same shape on both sides, determined by the softening of the glass, and its shaping, under the effect of its own weight on the mould.

The outer surface remained smooth and glossy, while the texture of the ceramic support used to avoid the imprint of the mould on the sheet appeared on the inner side.

3. Conclusions

Researchers are continuing their studies to ensure the best configuration for glass moulding. The goal is to reduce costs and simplify the manufacturing process for parts with complex geometry, made in small or medium series.

It is also aimed at avoiding possible defects that may occur due to the temperature and geometry of the parts, which greatly influence the viscosity of the glass during the thermoforming process.

The obtained samples show that it is possible to obtain the proposed deformations in the glass plates, using for this purpose different moulds, appropriate for the intended purpose, without the parts suffering damage.

References

[1]. James L., *Throne-Understanding Thermoforming 2E*, 2nd Edition - Hanser Publications, May 8, ISBN-10:1569904286, ISBN-13:978-1569904282, 2008.

[2]. Florea Gh., Chiriac Al., Mărginean I., *Procedee performante de punere în formă*, partea I, Editura Europlus, Galați, 2008.

[3]. Florea Gh., Chiriac Al., Marginean I., Croitoru Gh., *Turnatoria de Arta Foundry*, Materiale metalice, Partea I si II: Editura Europlus, Galati, 2008.

[4]. Simionescu Gh., *et al.*, *Ingineria proceselor de formare*, Editura Alvarom, Bucuresti, 2000.

[5]. Carcea I., Matei Gh., *Aliaje neferoase de turnatorie*, Editura Performantica, Iasi, 2000.

[6]. James L., *Throne-Technology of Thermoforming*, James L. Throne, Hanser Publications ISBN-10:1569901988, ISBN-13:978-1569901984, July 18, 1996.

[7]. Adriana Botez-Crainic, *Arta formei*, Editura Orator, București, 1993.

[8]. Buzilă S., *Procedee speciale de formare*, Editura didactică și Pedagogică, București, 1978.