THE BLOWING PROCESS OF A PET BOTTLES

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Abstract: The article presents the process of blowing out PET bottles. PET is processed for various applications due to its very good physical properties. In the packaging industry it is used for the production of PET bottles. The concepts of Blow molding is a process used to produce hollow objects from thermoplastic. The basic blow molding process has two fundamental phases. The first phase of the device’s operation consists in heating preforms. The second phase consists in the mechanical extension of the preforms on the axes and on the extension by means of pre-blowing and then blowing the preforms. The discussion was prepared on the basis of the collected literature data.

Keywords: INDUSTRIAL COMMODITIES, WASTES, PLASTICS, PET PACKAGING, WASTE MANAGEMENT

1. Introduction

Plastics are an inseparable element of modern human life.

In 2014, 311 million tons of plastics were produced in the world, which is twenty times more than in 1964. The forecast of plastics production assumes that this number will double by 2036 and will increase fourfold by 2050. Demand for plastics in Europe in 2015 amounted to 49 million tons, of which almost 40% was the raw material used for packaging production. Currently, we distinguish over 1,000 types of plastics, 90% of which comes from primary fossil fuels. In Europe, post-production waste plastics are developed by incineration with energy recovery at 39%, they are deposited in landfills in an amount of 31% or derived from recycling of 30%.

The potential and benefits of plastic products refer to low manufacturing costs, high durability and versatility in use. A large number of positive features also reflects the broadly understood production problems that have a negative impact on the natural environment, climate and human life and health [3].

In 2015, the European Union Commission recognized plastics as one of the priority areas for economic activities. It assumes that the production of plastics takes place in a closed circuit, by reusing the packaging waste, which gives the possibility to reduce the amount of waste to a minimum. The change of the plastics strategy in the presented chain would improve the recycling process, promote re-use and redesign the product in terms of the whole life cycle.

The presented changes give the opportunity to increase the security of supply, simulate the growth of economic benefits and reduce the pressure associated with care for the protection of the natural environment. Before implementing the changes, the challenge for entrepreneurs is the lack of adequate economic support, technical and financial constraints [3,10].

2. Characteristics of the PET bottle production process

Po Polyethylene terephthalate in short PET is a thermoplastic polymer from the group of polyesters. Used for the production of synthetic fibers and bottles for non-alcoholic beverages with structural structure [5].

![Fig. 1. Polyethylene terephthalate](image1)

The PET bottle is made using a semi-finished product preform. PET preforms are produced in various variants, colors and types. Parameters such as the type of thread, weight, wall thickness and length define the PET preform. It is thanks to them that you can determine what capacity the preform bottle can be blown. A view of an exemplary PET preform is shown in Figure 2 [2,4].

![Fig. 2. PET bottle preforms](image2)

The blasting machine is designed for the production of PET bottles, stretched in two axes. The principle of operation of the device consists in heating preforms, removing the preforms on the axes mechanically and pulling them out by pre-blowing and then blowing the preforms.

The initial dimensions of the preform depend on the expected stretch ratio to obtain the characteristics of the finished bottle. The degree of stretching is determined by the stretching factor on the two axes, which takes into account the orthotropic development of the preform and, consequently, preferential stretching of the material.

Depending on the capacity and use of the bottle, different stretching factors are defined after two axes [4,7].
### Table 1: Stretching factor

<table>
<thead>
<tr>
<th></th>
<th>Carbonated drinks / still drinks</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal stretching factor</td>
<td>2.8 ÷ 3.1</td>
<td>2.6 ÷ 23.9</td>
</tr>
<tr>
<td>Diameter stretching factor</td>
<td>3.5 ÷ 4.2</td>
<td>3.3 ÷ 3.6</td>
</tr>
<tr>
<td>Stretching on two axes</td>
<td>9.8 ÷ 13.5</td>
<td>8.6 ÷ 10.5</td>
</tr>
</tbody>
</table>

**The stretching process of the PET preform**

The greater the order in the material structure, the better the mechanical properties of the processed object. In the process of stretching during the production of the bodies, the preforms are reduced by cold blowing with a reduced size in relation to the final shape of the finished product. The stretching takes place along the axes and radially leading to stretching the material along two axes in parallel, so-called two-dimensional pulling.

Figure 2 presents a two-stage process of blowing out a PET bottle [4,10].

**Stage 1**

![Material](image1)

- Receiving preform by means of injection
- Heating the preform

**Stage 2**

![Introducing the preform to the mold](image2)

- Blowing on two axes
- Bottle

![Fig. 3. A two-stage process of blowing out PET bottles](image3)

A two-stage stretching process means an internal change in the structure of the material. After completion of the heating process used preform it takes the form of a rubber in the form of liquid rubber.

Then, during the stretching step after two axes, the material changes state, where at the end of the blowing process the material takes on a more stable state. Such a change in the state of aggregation is characterized by the "strain hardening" parameter, beyond which the solid state behavior is obtained.

Natural stretch ratio λN. It specifies that during the free blowing of preforms, the drawing coefficient decreases with the increase of temperature and increases with the decrease of the viscosities of the boundary lines 2 and 3.

![Fig. 4. Stresses depending on the stretching factor](image4)

The choice of intrinsic viscosity depends on the final use of the product. In order to obtain proper mechanical properties in the production of food packaging for carbonated drinks, strong degrees of intrinsic viscosity are assumed. In the case of still drinks in order to obtain the desired degree of mechanical strength, a weak degree of intrinsic viscosity is enough [10,11].

In the initial process of deformation under the influence of elongation of the tibia and blowing the preform mechanically weakest parts are deformed first.

The weakest parts are elements having a higher temperature obtained during the heating of the preform. If the mechanical properties of the deformed zone exceed the properties of non-deformed zones, then they deform and develop the bubble.

![Fig. 5. Stress depending on the stretching factor for different limiting viscosities (temperature 95 °C)](image5)

![Fig. 6. Blowing bottles](image6)
The process of molecular stretching after two axes is the result of double stretching of the plastic under specific conditions. Providing the appropriate thermal conditions allows to obtain the desired mechanical properties of the finished product. In the case of a PET bottle, the temperature of the double orientation is in the range of 90 °C to 120 °C.

According to the definition of the tensile factor up to two axes, the temperature of the double orientation depends on the product and the final application. In the case of hot filling, one should strive to achieve the natural draw ratio while maintaining the temperature range in the upper range between 110 °C and 120 °C. In the case of "soft drinks" increase the stresses induced in the lower temperature range from 90 °C to 100 °C.

After the blow-out process is completed, the process of stretching to the finished bottles forms. In order to prevent disorientation of the polymer that can cause product defects, an appropriate speed should be maintained for drawing ready bottles. Depending on the batch of bottles produced, the bottle withdrawal speed is from 500 to 1 500 mm / s.

After the bottle extrusion process is complete, the cooling process takes place. Cooling conditions vary with each other depending on the intended uses of the finished product. In the case of "soft drinks" applications, after cooling, the bottle is below the glass transition temperature (below 80°C). If the filling process was hot after taking out, the temperature should be maintained above 80°C. The behavior of the process conditions allows stabilizing the construction of the finished product [6, 9, 10].

The second type of maintaining the right conditions are the geometric features of the bottle. Geometric features are understood as a type of form, its dimensions and application. The kind of preform depends on the intrinsic viscosity. It is characterized by a stretching factor on two axes depending on the expected mechanical properties. Exceeding natural coefficients causes internal stresses that may hinder the extrusion process.

For products filled cold, to prevent swelling occurring as a result of the internal pressure must be increased. On the contrary, in the case of hot-filling of a non-carbonated beverage so as not to increase distortion due to the vacuum during cooling, the pressure should be reduced.

The concept and design of a PET bottle project depends primarily on the expectations of the manufacturer. Depending on the processing technology used, the product manufactured, or the type of conditioning, the obtained technical and mechanical conditions depend on the finished packaging [1,8].

3. Conclusions

Properly completed bottle blowing process allows further continuation of the manufacturing process of the finished product. The presented blowing technology positively influences the limitation of the type of bottle produced. Thus, it prevents the use of mold blanks or the need to locate the extraction process that may adversely affect the mechanical properties of the finished product.

The end of the blown bottles process includes the recoil phase of preforms and bottles. The occurrence of an incorrect preform or bottle is automatically signaled by the device.

The reasons for the defects of PET bottles are very diverse and depend on many factors. During the process of forming a PET bottle, defects are very often observed. Defects observed in the process could be in different forms. Types of Defects in PET bottle production processes: short shot, flash on thread, parting line flash, long gate, gate pin hole, gate stringing, gate crystallization, moisture marks, air bubbles, hazy preform, scratches [10].

Due to the dominant share of materials, the plastics industry aims to reduce the share of raw materials throughout the production cycle. An important factor related to the change in production parameters is the preservation of aesthetic values and the maintenance of an appropriate level of quality indicators. The basic condition for maintaining the correctness of the production process is the complete education of the PET preform to the required sizes [10,11].

References

[8] Poloczek P., Rak A., Żywiolek J., Analysis of the attractiveness of the PET bottle manufacturing sector, Polandm ARCHIVES OF ENGINEERING KNOWLEDGE VOL. 2 ISSUE 1, 2017
[9] Stachurek I., Problems with the biodegradation of plastics in the environment, ZESZYTY NAUKOWE WYŻSZEJ SZKOŁY ZARZĄDZANIA OCHRONĄ PRACY W KATOWICACH, Katowice, 2012