Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

MICROCELLULAR MONOLAYER EXTRUSION BLOW MOLDING FOR HOLLOW OBJECT

Karol Pepliński

Bydgoszcz University of Technology and Agriculture
ul. Aleja Prof. S. Kaliskiego 7, 85-789 Bydgoszcz, Poland
tel.: +48 52 3408224, fax: +48 52 3408222
e-mail: karolpep@utp.edu.pl

Abstract

Microcellular monolayer extrusion blow molding (MM-EBM) is a relatively new manufacturing process which can be used to produce thin thermoplastic hollow object with lower weight and new inside wall structure of container. This process can be realized on standard extrusion blow molding machine and tooling: extruder and blow mold. On the world are know other similar process like MuCell Foam for Blow-Molding [1], but this process required some modification of extrusion blow molding system: SCF injection system. Our considered process base on standard extrusion blow molding process and can give similar results with using expandable microspheres. In this article the main Author assumption is describe and show some results of realizing this MM-EBM process with using standard polymer (HDPE) and Expancel microspheres for blow molding. Also during manufacturing on mass scale can be seen that MM-EBM process is energy effective because can be realize at lower plastics processing temperature and blowing pressure.

Keywords: *microcellular extrusion blow molding, expandable microspheres, container weight, energy effectiveness*

1. Introduction

Blow molding covers three main thermoplastic processes: extrusion blow molding, stretch blow molding, and injection blow molding. Extrusion blow molding is the largest and most popular for other blowing process like injection blow molding and stretch blow molding. The whole blow molding industry is growing approximately in stabile rate 3÷5 % yearly. According to statistic data, in 2010, Europe processed 46,6 million tons of plastics. The demand of packaging producers accounted for 39 % of European market for plastics processing [8]. These data show that the manufacturing of packaging technology, in particular extrusion blow molding process, is a vital direction of progress of polymer processing. Blowing containers can be produce by popular following resins for container below and over five liters [3]: HDPE and PP. Nowadays it is very popular trend in plastics and design industry to minimize weight of the product and energy consumption during their manufacturing. Rise of energy, material and transport cost demand new approach to manufacturing process like it is extrusion blow molding. In order to comply with these requirements can apply specialized foam additives like available special blowing agents – Expancel [2], which mainly contribute to the reduction hollow container weight and help achieve other benefits such as reduced energy demand per blowing unit during realizations of the process and minimizing the consumption of plastics for an individual blowing product.

In the world literature on the realized subject in this article is contained only very sparse information of a vague and advertising on the MM-EBM process, especially HDPE modified special agent in the form of microspheres. Brand is the lack of research results to modify the impact of this material on the course and efficiency of MM-EBM, which raises the need for the implementation of the theme of this issue. In this article the Author presents selected the first stage of their research, which concerns selection of the ranges processing of MM-EBM conditions in terms of accepted criteria: minimize the weight of the product, reduce temperature profile on the plasticizing and extrusion head system and also to cut the demand for compressed air consumption during inflation and blowing parison. Like it is obviously known producing compressed air form most standard EBM systems which need value range about 4÷6 bars it is cost. It is well known that the loss in pressure of 1 bar results in a loss of energy equivalent to 7÷8 % of power consumed by air compressor manufacturers. Therefore, the lower blowing pressure value from 5 to 3 bar reduces the generation of compressed air at about 21÷26 %. Hence it is advisable to make attempts to blow molded parison at lower pressures. These requirements are very good for idea of material and energy-consuming systems [4]. The manufacturer's data Expancel that such blowing pressure reduction is possible, however, information on the MM-EBM is elementary (in a few sentences). Other general information is that Expacel in most plastics technology can be processed on the temperature range 140÷220 °C [2]. It should also be noted that for the standard process of extrusion blow molding HDPE extruded parison temperature is about 190 °C (similar to the plasticizing unit – 180÷190 °C) and the blowing pressure is 5 bar. These assumptions are by no means true for containers with an average thickness of the extruded parison wall thickness 2÷3 mm. For these assumptions can be realized first try of microcellular monolayer extrusion blow molding process which task range will be describe in process description.

2. Extrusion blow molding process

Extrusion blow molding is a manufacturing technique used to quickly form hollow object like blown bottles and containers of different geometry and volume. It has alternative glass and metal containers. The fast developments in BM polymers, additives and EBM equipment technology give whole spectrum to blowing product like: multilayered fuel tanks, spoilers, and drums. It does mean that consumer product industries (beverage, cosmetics) are the prime users of blow molding. Diagram of an extrusion blow molding process is visible on Fig. 1. Blow molding involves a tube of hot thermoplastic being extruded continuously downward from the die. When the extruded parison is of the accurate length, the mold is closed, squeeze and pinching off the top and bottom ends (sometimes in a different place or in each place) and a cutoff knife cuts the parison at the near die face [3]. Next the blow mold is going to the blow pin station. Compressed air is injected into the molten parison and then expands to contact with mold cavity and starts cooling cycle to moment when hollow object solidifies. The cooling action is realized by water mold cooling and dry purge of compressed air. Subsequently article is then ejected. The excessive amount of plastics material ("tail") created in the pinch off section is automatically trimmed. For bigger parts this operations are made manual by an operator.

Machines with programming head can extrude a controlled variable-wall-thickness parison using the moveable core which is inside die head. In place where container will be have higher blow ratio parison should be thicker then other place. For complex geometry it is not to easy predict the parison profile thickness distribution. The programmable parison extrusion program for thickness utilizes just the correct amount of material for the container. Wall thickness can be controlled in almost all sections of the container [3]. In this place can be very helpful CAE programs like Ansys-Polyflow [6], which assist to obtain proper parison shape to final blowing hollow object.

Blow molded parts are made with undercuts and are easily removed from the mold, eliminating the need for expensive in-mold cams and slides. Blow molds are also less expensive and need not have in-mold cams and slides (they are cost) [5] because containers are easily removed from the mold. In extrusion blowing molds forces and pressures are much more smaller then the high injection and packing pressures of injection moldings. Therefore, cast aluminum, steel alloys plus beryllium copper molds are used [7].

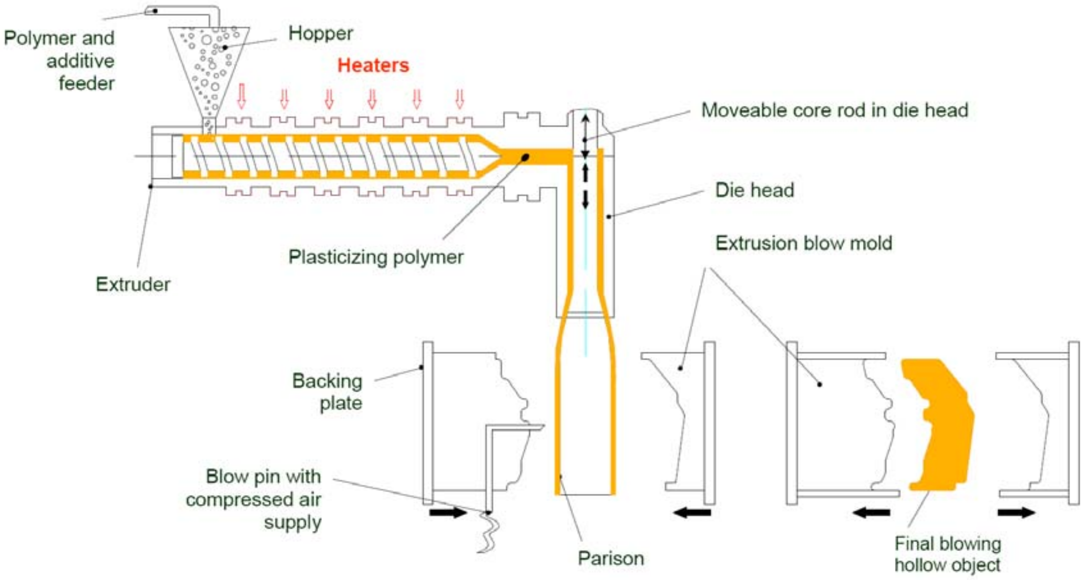

Fig. 1. Idea of extrusion blow molding proces

3. MM-EBM process description

MM-EBM process consists in adding microspheres granules to the plastics material, also known as the blowing agent which include a gas, which under appropriate conditions of extrusion blow molding process is expanded, and the microspheres increasing its size several times. As a result of MM-EBM a received hollow container suitable two-phase structure, changing it structure from solid to the microporous.

The microcellular monolayer extrusion blow molding process was carried out using an industrial blow molding machine Battenfel Fischer (Fig. 2). To the realizing of MM-EBM was used the following initial conditions:

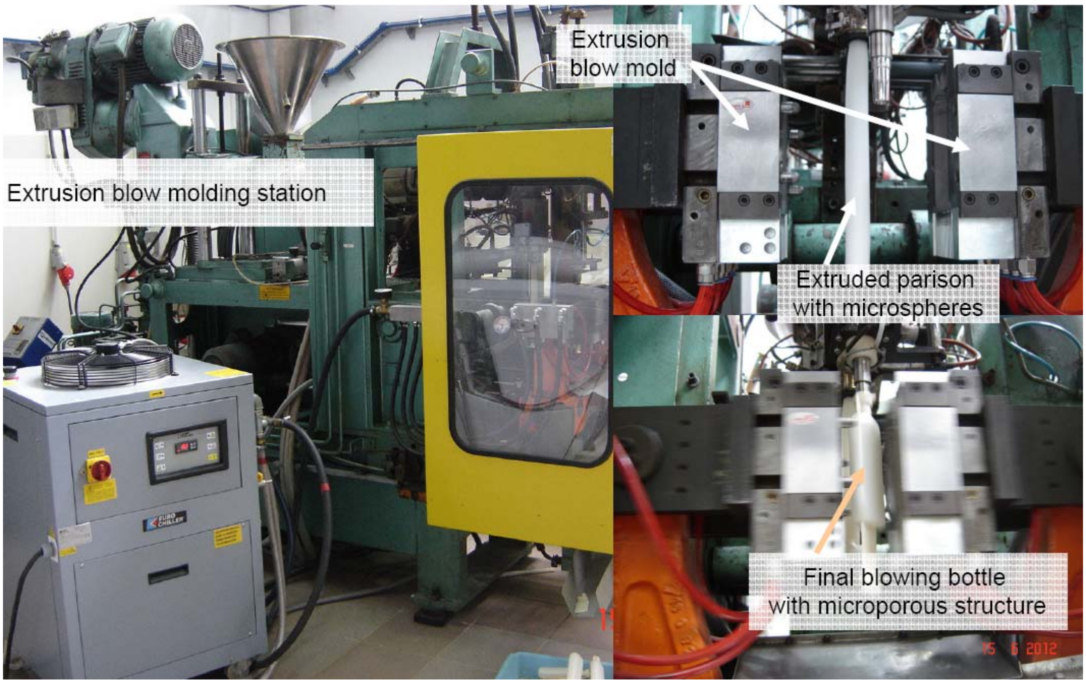

Fig. 2. Extrusion blow molding machine to realizing MM-EBM process

- the temperature in each heating zones: (plasticizing unit) T_1= 170 °C, T_2= 175 °C, T_3= 175 °C, T_4= 175 °C, (die head) T_5= 180 °C, T_6= 175 °C,
- screw speed during extrusion blow molding n_s = 1.8 min^{-1}
- two different percentage value of blowing agent in the material (e_1=0,5 % end e_2=1,2 %) at constant blowing pressure p_{b1} = 4 bar.
- overall blow molding cycle time t_c = 15,46 s,
- mold temperature during cooling T_c = 15 °C

Also began to produce bottles in the MM-EBM at a reduced blowing pressure p_{b2} = 2 bar. It should be mentioned that the process of extrusion blow molding has also been made for standard processing conditions without blowing agent (standard profile temperature in plasticizing and die head unit for PE-HD processing is 20 °C higher, and blowing pressure is 5 bar). After the MM-EBM processes began to assess the weight and inside structure of blowing container, using a laboratory microscope MN800 EPI/DIA. Results is presented in the next chapter.

4. Research results and their analyses

After completing the extrusion blow molding process, for standard EBM terms and terms for MM-EBM, began to assess the weight of blowing products. This assessment was realized according to accepted criteria (% amount of the special blowing agent – microspheres and blowing pressure). Normally, in the standard extrusion blow molding condition, the average weight of the bottle was 16,2 ± 0,25 g. The addition of special blowing agent in the amount of e_1=0,5 % end e_2=1,2 % leads to a successive reduction of the bottle weight: respectivelly value of 14,4 ± 0,16 g and 11,8 ± 0,14 g. Also should be noted that the use of higher content of blowing agent, for example, in an amount of 1.5 % did not bring positive results in the considered MM-EBM process conditions. These dependencies can be clearly seen in Fig. 3. In conclusion, the uses of special blowing agent in an amount of 1,2 %, to significant reduce (27 %) the weight of the bottle.

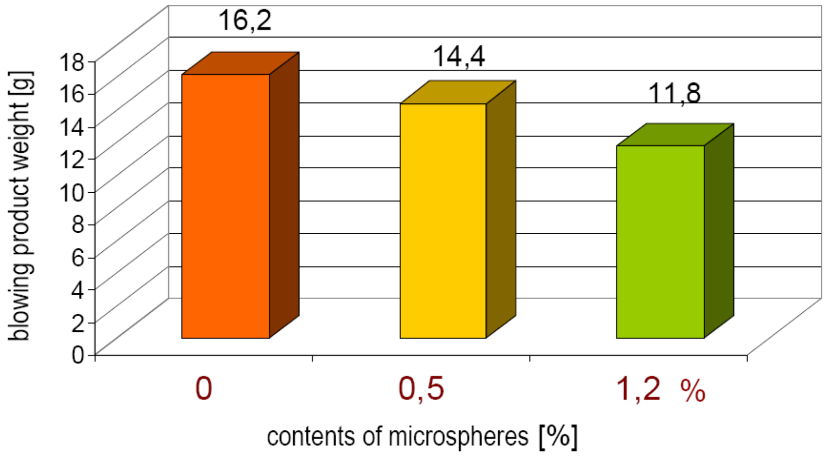

Fig. 3. Blowing product weight reduction as a effect of using microspheres

The next step concerned the evaluation of the bottle wall microstructure in the accepted convention area, as indicated in Fig. 4. As a result of forty times magnification were assessed an average microsphere size. The average pore size determined based connected twenty measurements on samples taken from bottles, where in each sample was measured most visible microspheres. With the Expancel blowing agent in the number of e_1 = 0,5 %, average microsphere size of about $L_{\mu p}$ = 80 μm, and in turn for e_2 = 1,2 % of the value of $L_{\mu p}$ = 120 μm (see Fig. 4). The study was conducted for blowing pressure of 4 bar. Also clearly shows that the higher the content of the Expancel the denser pore distribution in the structure of the bottle wall, which also determines a significant reduction in the bottle weight. In each case under consideration, it is noted that the lower blowing pressure p_2 = 2 bar generates about 10% lower value of microspheres size $L_{\mu p}$. For lower blow pressures notes are visually much denser distribution (in each 1 cm^2) of microspheres in the inside of bottle wall.

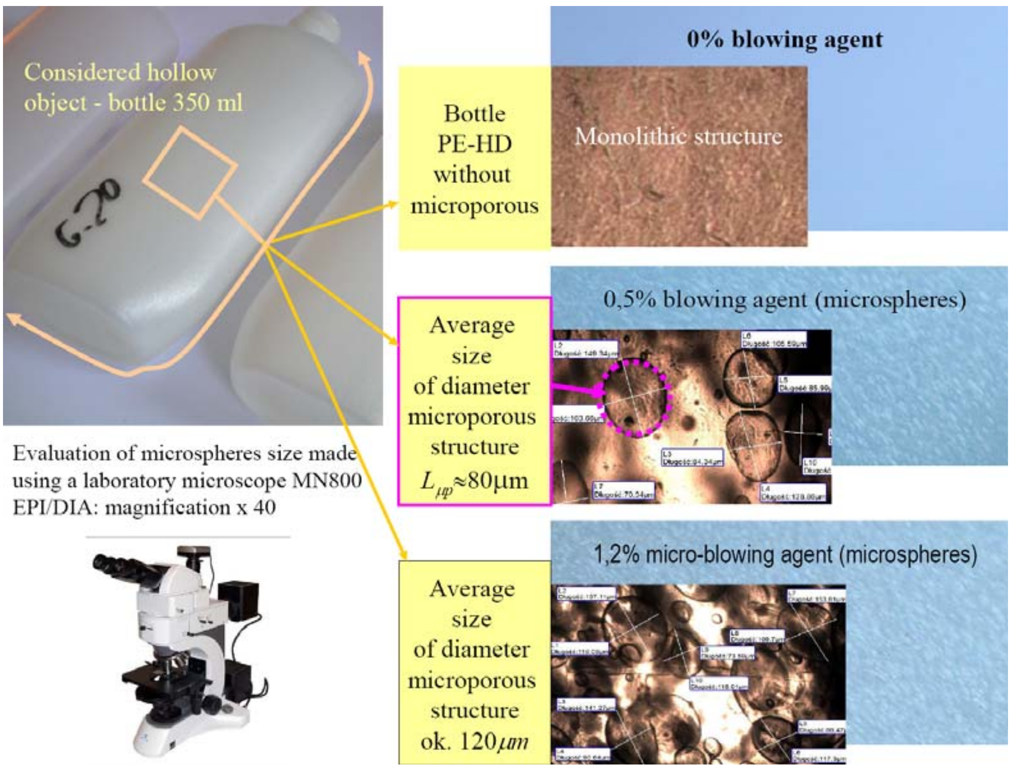

Fig. 4. The evaluation of the bottle wall microstructure in the accepted convention area: (on the left) considered and anlysed area, (on the right) microstructure of bottle wall with visible microspheres

4. Final consideration and summary

The use of special blowing agent – microspheres, called Expancel, allows to the production of hollow object with reduced weight. This can be extremely promising in the case of the measure used to produce object of a much larger size, even drums (200 liters) or canisters (20÷40 liters). However, in this case would include a separate practical study in industrial conditions. Assuming that the average drums weight is 5 kg, object is theoretically able to reduce its weight by up to about 1300 grams, which can be extremely important for the unit consumption of plastics materials for a given product, and also as well as reducing transport costs.

With regard to the management of energy resources should be noted that use of a special blowing agent – microspheres allows you to significantly reduce energy demand for the plasticizing material – on average by reduced processing temperature about 20 °C. Also reduced the demand for compressed blowing air by lowering the pressure with value 4 bar to 2 bar. As a result of the calculations, the author has noted, that despite the relatively high price of Expancel is possible to reduce material consumption at the global scale and doesn’t increase the global cost of processing materials. All the more should be considered highly advantageous, that the microcellular monolayer extrusion blow molding process can be implemented on standard extrusion blow molding machines.

References

[1] Anderson J.: *MuCell Foam for Blow-Molding*, Trexel Inc.
[2] *Expancel microspheres in thermoplastics*, Technical bulletin no 24, 2005.
[3] Kutz M.: *Applied plastics engineering handbook*, 1st ed., pp. 280 – 284, Elsevier 2011
[4] Michael F. Ashby: *Materials Selection in Mechanical Design*, 4th ed., Elsevier 2011
[5] Norman, C. L., *Practical guide to blow moulding*, Smithers Rapra Technology, 2006.
[6] Pepliński K., Mozer A.: *Ansys-Polyflow software use to select the parison diameter and its thickness distribution in blowing extrusion*, Journal of Polish CIMAC, 5, Gdańsk 2010.
[7] Pepliński K., Ohla A., Bieliński M.: *Design and manufacturing mold for extrusion blow molding* (part 1), Przetwórstwo Tworzyw, 2006, 1–2, p. 12–19
[8] www.plasticseurope.org, *The Compelling Facts About Plastics 2010*, Plastics Europe, Brussels – Belgium 2011.