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Research Article

MODERNIZATION OF TECHNOLOGICAL LINE FOR CELLULAR EXTRUSION PROCESS

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ABSTRACT
In recent years, cellular extrusion of polymers has been one of the fastest growing processing methods. It is used especially to obtain sections, bars, pipes and cellular coatings free from strains on the product surface, displaying reduced density and minimum shrinkage, at the same time maintaining similar properties of products extruded in a conventional way. In order to obtain cellular structure, product properties are modified by application of proper plastics or adding blowing agents. The article provides a description of manufacturing processes of cellular product. It gives characteristics of blowing agents used in the extrusion process and of processing conditions. Also, it discusses selected results of examined properties of the obtained cellular products. As part of the modernization of the cellular extrusion technology the extrusion head was designed and made. During the designing and modeling of the head the Auto CAD programe was used. After the prototyping the extrusion head was tested. In the article specification of cellular extrusion process of thermoplastics was presented. In the research, the endothermal chemical blowing agents in amount 1,0% by mass were used. The quantity of used blowing agent has a direct influence on density and structure of the extruded product of modified polymers. However, these properties have further influence on porosity, impact strength, hardness, tensile strength and another.

Keywords: cellular extrusion, extrusion head, simultaneous construction, CAD, blowing agents, physical properties.

INTRODUCTION

Extrusion of cellular plastics differs from extrusion of solid plastics in that the product obtained as a result of processing procedure is formed into a diphase structure plastic material-gas, with possibly smallest and evenly distributed gas bubbles. Cellular structure is obtained due to the insertion of the blowing agent (porophor) in the form of an inert gas, low-boiling liquid or a solid body into the input plastic which, when in liquid or solid state, transforms into gas under the determined conditions of extrusion process [1, 2, 3, 4, 5, 19, 20]. When in the proper temperature the process of gas emission is started, numerous microspheres which are then generated, dissolve in the ambient plastic material due to the operation of pressure and surface development. The emerging cells may be filled with air or with any other gases, for instance CO_2 and N_2, yet later they are replaced by air as a result of diffusion [6, 7].

The blowing agent (porophor) is selected so as to match the type of plastic material, and its decomposition temperature has to be higher than the melting point of the plastic material, yet lower than the temperature during plastic extrusion. Cellular plastic in a liquid form is not yet a stable system because as a result of interfacial tension at the material–gas contact point, and as a result of diffusion, the number of cells decreases, whereas their dimensions enlarge, which constitutes an undesirable effect. The obtained cells keep enlarging until gas pressure and interfacial tension are balanced. Favourable structure of a small-cell plastic can be maintained in the product by its immediate cooling and solidification. [2, 8, 9].

Currently, the most significant group of porophors used in extrusion and injection moulding of plastics are organic porophors. They belong to a number of groups having different chemical structures. Of those, the greatest significance is displayed by an azo compound; azo-formic acid diamide (azodicarbanamide). Blowing agents used in cellular extrusion of plastics may have exothermic or endothermic decomposition characteristics [1, 2, 8, 10, 11, 12]. Porophors that has been used so far usually have exothermic decomposition characteristics. This may be the cause of local overheatings and generation of irregular cellular structure of the product. When blowing agents have endothermic decomposition characteristics, generation of gas during processing is violently stopped when the energy flow is cut off. The application of such blowing agents considerably shortens the cooling time. Examples belonging to this group are among others bicarbonates e.g. sodium bicarbonate, ammonium bicarbonate.

The studies on cellular extrusion process conducted by authors of the articles [6, 7, 9, 10, 13] are focused, among others, on the generation of products from cellular plastics. This results in the reduction of purchase costs of the plastic material, of process energy costs and of transport costs. Study on cellular extrusion of thermoplastics regards the process in which the modification of product properties is done by alternating the extrusion conditions and design features of technological line elements. The extruded product obtained may have a fully solid or cellular structure, both cellular core and topcoat, or cellular core but solid topcoat [2, 7, 14]. Extrusion process which involves the application of blowing agents results in obtaining new, modified physical and technological properties of the extruded products.

EXPERIMENTAL PROCEDURE AND RESULTS

As a part of the modernization of the cellular extrusion technology the extrusion head was designed, with the using Auto CAD program. Next, the extrusion head was made according to the prepared design solution. After the prototyping the extrusion head was testing in order to apply in technological line of cellular extrusion. Figure 1 shows the schemes of the designed extrusion head, while in Figure 2 and 3 the actual appearance of the designed extrusion head is presented.

The body (2) of extrusion head consists of two parts, one of which allows the connection of head to the extruder plasticizing system, the second part of the body enables the assembly of the extruder die (1). Between the two parts of body the distributive mandrel (4) is mounted. Extrusion die is a replaceable item, which allows the extrusion of profiles with different shapes and sizes, both symmetrical and asymmetrical.

The extrusion head has two heating zones and two corresponding annular heaters mounted on the body of the head and the die body, and two temperature sensors (thermocouples) installed in two heating zones of the head. Interchangeable dies allow the production of symmetrical shapes.

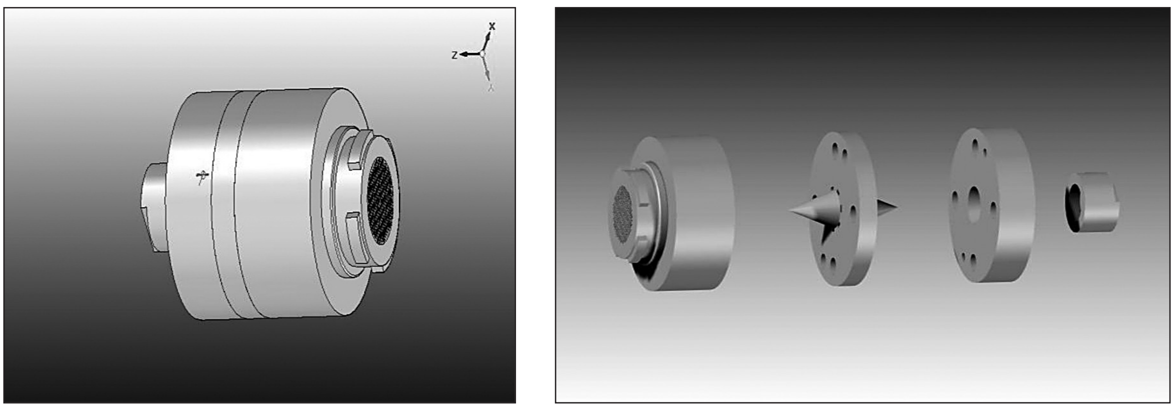

Fig. 1. Examples of the designed schemes of extrusion head for profiles

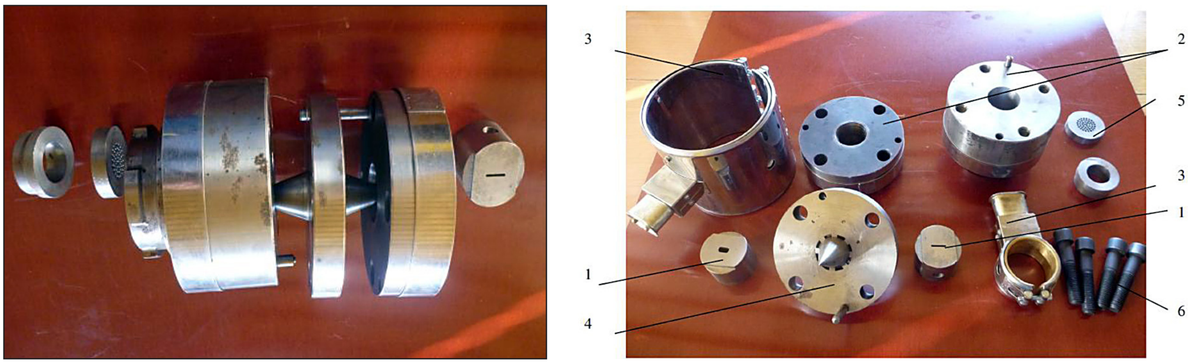

Fig. 2. View of the parts of extrusion head for profiles: 1 – die, 2 – body parts, 3 – annular heaters, 4 – distributive mandrel, 5 – filter of polymer

Fig. 3. View of the extrusion head for profiles

In the study presented in the article, the used blowing agent was Hydrocerol BIH 70. It has endothermic decomposition characteristics and it assumes the form of granules with diameter of 1.2 to 1.8 mm. Hydrocerol BIH 70 contains 70% of the blowing agent mass having the initial decomposition temperature of 140°C. The blowing agent is a mixture of sodium bicarbonate and 2-hydroxypropane- 1,2,3-tricarboxylic acid (citric acid). In the presented study, Hydrocerol BIH 70 was dispensed as 0.2% to 1.0% of the mass.

The investigation of the extrusion process was carried out in the processing line for extrusion .The extruder plasticizing unit was equipped with four heating zones. The screw had an L/D ratio of 24 and external diameter D of 45 mm (Figure 4). The line also contained the extruder head for moulding rods with external extrusion die diameter equal 8.00 mm, cooling device (cooling bath) and collection device. Extrusion was carried out under the following parameters: temperature of the heating zones 150, 160, 160 and 165°C respectively; extruder head temperature within two heating zones 155°C.

As a result of the carried out process of extruding modified polyethylene with blowing agents, the extruder product was obtained in a form of a rod of 8.00 ± 0.01 mm in diameter. Extrusion and cooling conditions were properly selected, which allowed to obtain a product having a solid topcoat and a cellular core.

The specimens of of the extruded product were then examined in structural properties in compliance with relevant recommendations and norms [15–18]. Their density and porosity were investigated. In addition to that, their

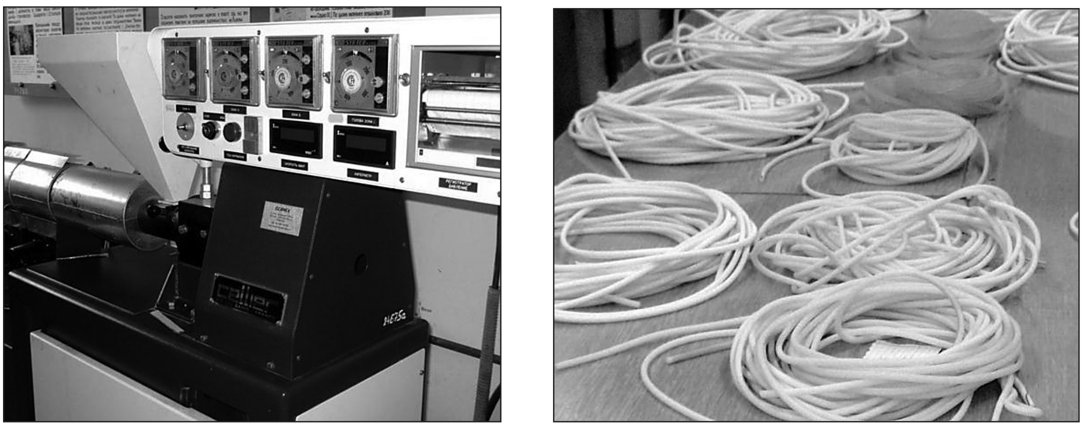

Fig. 4. View of the technological line section for extrusion process and extruded product

surface structure was analyzed based on digital images made.

The method of standard density determination of plastic materials was applied during studies on density of sample products from cellular plastics. Measurements were taken in accordance with recommendations of a relevant standard. Refined particles of sample, whose mass ranged from 1 to 5 g, were the object of the study.

The hardness tests by Shore's method were conducted using an Affri-manufactured hardness tester, type ART13 – Shore's method D. Such a choice was due to the method employed for determining solid polymers hardness.

Water and oil absorptivity examination was carried out in accordance with PN-EN ISO 62:2000: Plastic materials. Determination of water absorptivity standards and with PN-EN ISO 175: 2002: Determination methods of effects of immersion in liquid chemicals.

The investigation and analysis of the porous structure of the produced extruded parts were conducted using an confocal microscope, type Olympus FluoView FV1000 and copyright position of image analysis of porous structure and the author's stand for porous structure image analysis. Microscope FV1000 was equipped with 1.3 Mpix camera, enabling direct viewing of microscaning image on computer screen. Observation of specimens structure and its recording was made in reflected light with suitable magnification.

In line with recommendations and in accordance with proper standards, density, porosity, hardness, water and oil absorptivity in relation to the extruded product obtained from cellular polyethylene were examined. Exemplary results are demonstrated in Tables 1 and 2.

The macroscopic structure of the produced cellular products was examined at the stand for polymer cellular structure image analysis. The examples of the cellular structure of coatings produced are shown in Figures 5 and 6.

Extrusion products made of PE with 0.4% blowing agent content do not have sufficiently cellular structure (Figure 5). The cell dispersion patterns in the structure could be attributed to

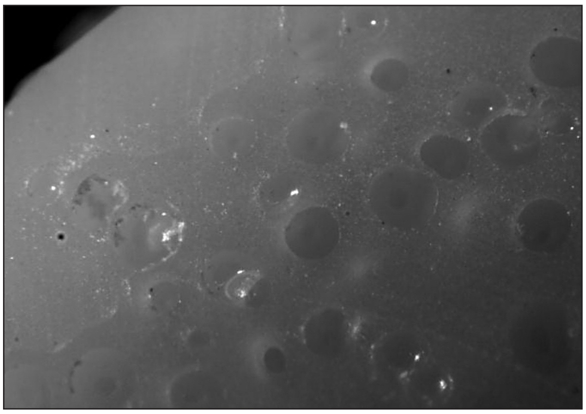

Fig. 5. Cross-sectional view of a cellular polyethylene product, with 0.4% content of the blowing agent Hydrocerol BIH 70

Table 1. Results of the studies of the apparent density, porosity and hardness of product modified by the blowing agent

Sample No.	Content of blowing agent, %	Porosity, %	Density, kg/m^3	Hardness, °Sh D
1	0	0	940	65
2	0,2	19	762	60
3	0,4	22	733	60
4	0,6	36	602	55
5	0,8	40	564	50
6	1,0	42	545	51

Table 2. Results of studies on water absorptivity and oil absorptivity of cellular polyethylene

Sample No.	Content of blowing agent, %	Water absorptivity, %	Change in mass following immersion in oil, %	Change in mass following desiccation, %
1	0	0,25	0,15	0,08
2	0,2	0,22	0,20	0,07
3	0,4	0,20	0,19	0,08
4	0,6	0,30	0,15	0,06
5	0,8	0,30	0,20	0,06
6	1,0	0,30	0,20	0,06

the non-uniform dosing of a very small blowing agent amount into the polymer and the characteristics of the applied blowing agent with the endothermic decomposition behavior.

Based on the analysis of the photographs taken, it can be seen that the coating with the 0.6 and 0.8% blowing agent contents has a visible solid surface and most uniform distribution of similarly sized pores (Figure 6).

The number of pores increases proportionately to the increase in the blowing agent content in the polymer being extruded. The number of pores also depends on their position and distance from the surface.

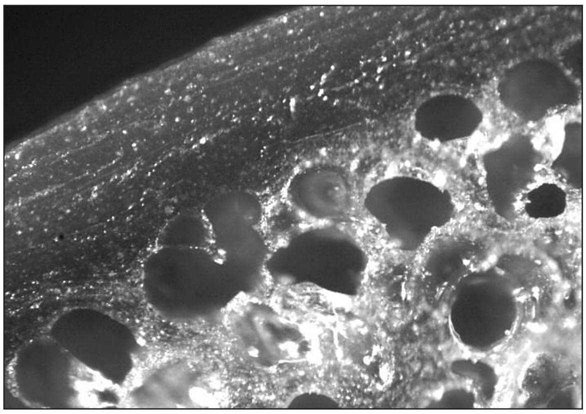

Fig. 6. Cross-sectional view of a cellular polyethylene product, with 0,8% content of the blowing agent

CONCLUSIONS

1. As part of the modernization of the cellular extrusion technology the extrusion head was designed, with the using Auto CAD program. Next, the extrusion head was made according to prepared design solution. This extrusion head was used in the presented studies of cellular extrusion.
2. Type and quantity of the blowing agent applied in the study was matched in such a way that under assumed conditions of the extrusion process an extrudedr product having a solid topcoat and cellular core was obtained.
3. Quality of the obtained product, including features such as external look, degree of porosity and density should be evaluated as very good. The obtained product was a rod having degree of porosity of 19–42%, density ranging from 762 to 545 kg/m^3 respectively and hardness ranging from 50 to 65 Sh D.
4. As a result of the conducted measurements, values for amounts of water absorbed by a sample ranging from 0.25 to 0.30% were obtained. Quantity of absorbed water by sample surface does not change significantly along with the increase in blowing agent content. Values for sample mass gain after immersion in oil ranging from 0.15 to 0.20% were obtained. Neither water absorptivity nor mass gain after immersion in oil do not change along with the increase in blowing agent content in the processed plastic material. This may show that cells generated in the cellular extrusion process are closed and prevent penetration of water and oil into the interior of the cellular extrusion product.

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REFERENCES

1. Garbacz T.: Properties of triple-layered PVC coatings synthesized in the micropore coextrusion method. Polimery 56, 7-8, 2011, 129-134.
2. Dulebová Ľ., Greškovič F.: Influence of regrind on properties of plastics processing by injection moulding. Materials Engineering – Materiálové inžinierstvo 18, 2011, 44-48.
3. Samujło, B., Sikora, J.W.: The impact of selected granulometric properties of poly(vinyl chloride) on the effectiveness of the extrusion process. Journal of Polymer Engineering 33, 1, 2013, 77-85.
4. Ľ. Dulebová (et al.): The impact of the amount of filler on the properties of polymer materials. Kovárenství 44, 2012, 33-36.
5. Garbacz T., Krasinskyy V.: Title evaluate the effectivesness of the extrusion process. Progresivne Strojarske Technologie a Materialy. PRO-TECH-MA 2012, ÚVZ Herľany - TU Košice, Slovakia, 2012 (in CD).
6. Sikora J.W., Samujło B., Dzwonkowski J.: Influence of a feed-opening section on the output and selected mechanical properties of a poly(vinyl

chloride) extrudate. Advances in Polymer Technology 33, 1, 2014 (published online).

7. Bociąga E., Palutkiewicz P.: The influence of injection moulding parameters and blowing agent addition on selected properties, surface state and structure of HDPE parts. Polymer Engineering and Science 53, 4, 2013, 679-704.
8. Matuana L.M., Park C.B., Balatinecz J.J.: Structures and mechanical properties of microcellular foamed polyvinyl chloride. Cellular Polymers, 17, 1998, 1-16.
9. Tor-Świątek A., Samujło B.: Use of thermovision research to analyze the thermal stability of microcellular extrusion process of poly(vinyl chloride). Maintenance and Reliability 15, 2013, 58-61.
10. Garbacz T., Dulebova L.: Porophors during the extrusion process. Chemistry and Chemical Technology 7, 1, 2013, 113-118.
11. Tejeda E.H., Sahagún C.Z., González-Núñez R., Rodrigue D.: Morphology and mechanical properties of foamed polyethylene–polypropylene blends. Journal of Cellular Plastics 41, 2005, 417-435.
12. Dulebova L., Garbacz T.: Thermal analyzes of polymer composites. Transfer innovacii 26, 2013, 130-134.
13. Bociąga E., Palutkiewicz P.: The Impact of Mould Temperature and Blowing Agent Content on Structure and Properties of Injection Moulded Parts. Cellular Polymers, 2013, 32(5), 257-277.
14. Garbacz T., Dulebova L., Krasinsky V.: Effectiveness of cellular injection molding process. Advances in Science and Technology Research Journal 8(18), 2013, 74-80.
15. PN-EN ISO 1183-1 (2006): Methods for determining the density of plastics.
16. PN-EN ISO 868 (2003): Plastics and ebonite. Determination of indentation hardness by means of a durometer (Shore hardness).
17. PN-EN ISO 62 (2000): Plastics. Determination of water absorption.
18. PN-EN ISO 175 (2002): Plastics. Methods of test for the determination of the effects of immersion in liquid chemicals.