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USE OF THERMO VISION RESEARCH TO ANALYZE THE THERMAL STABILITY OF MICROCELLULAR EXTRUSION PROCESS OF POLY(VINYL CHLORIDE)

WYKORZYSTANIE BADAŃ TERMOWIZYJNYCH DO ANALIZY STABILNOŚCI PROCESU WYTŁACZANIA MIKROPORUJĄCEGO POLI(CHLORKU WINYLU)*

Essential role in polymer processing takes processing conditions i.e. temperature, pressure, screw rotational speed and time. During the polymer modification in cellular and microcellular extrusion process significant changes in the process ensue. Influence of this two factors caused also another changes in properties and physical structure of obtained extruded products. Because of that, proper selection of processing conditions, specially temperature, machines and equipment parameters is necessary. Is such a case, process will be effective and stable.

***Keywords**: Microcellular extrusion process, blowing agent, microspheres, polymer materials, thermovision.*

Znaczącą rolę w procesach przetwórstwa tworzyw odgrywają warunki procesu takie jak temperatura, ciśnienie, szybkość obrotowa ślimaka, czas. Podczas modyfikacji tworzywa polimerowego w procesie wytłaczania porującego oraz mikroporującego na skutek działania podwyższonej temperatury oraz jednocześnie działania poroforu następują istotne zmiany w przebiegu procesu wytłaczania. Kolejną zmianą, jaką niesie za sobą wpływ obu czynników jest zmiana właściwości oraz struktury fizycznej otrzymanych wytworów. Z tego względu konieczny staje się taki dobór poszczególnych warunków przetwórstwa, w tym szczególnie temperatury oraz parametrów maszyn i urządzeń przetwórczych, aby proces mógł być prowadzony efektywnie i stabilnie.

***Słowa kluczowe**: Wytłaczanie mikroporujące, środek mikroporujący, mikrosfery, tworzywo polimerowe, termowizja.*

1. Introduction

The course of each of the processes of polymer processing, both thermoplastic and thermosets depends on several factors, including selection of appropriate processing methods. Each method is characterized by significant conditions that must be satisfied that the process could not only exist, but above all to be effective, stable and efficient [6, 7, 13, 15]. Among the popular methods of processing such as injection molding, conventional extrusion or extrusion coating noteworthy is microcellular extrusion process [2, 12, 16]. It allows to receive the products of the altered physical mechanical and utility properties with different physical structure. Items that have been modified polymer material by means microcellular blowing agents characterized by a greatly reduced density, stiffness and hardness. Also exhibit less processing shrinkage and good damping properties. This creates new fields of applications of polymers, wherever it is important to weight, flexibility and hardness of the products [3].

Modification of the extrusion process, caused by microporosity of polymer material, takes place at the end of the extruder plasticizing system and must be carried out in order to use microcellular agent (blowing agent) spread in the right place [9]. The satisfactory operation of the process of microcellular extrusion processing ensure proper selection of polymeric material and blowing agent, processing conditions and the design of individual processing machines and tools placed at the production line [1].

Microcellular extrusion depends on inserting microcellular blowing agent into the material being processed under appropriate distributed processing conditions, changing the structure of materials into microporous. It is possible to obtain microporous products of the entire cross-section or having a solid outer layer and a microporous core of extrudate. This involves using a suitably embossed intensive cooling element, preventing the initiation process in the surface layer [2, 4].

The microporous structure of the extrudate obtained by the microcellular extrusion process primarily affected by such factors as the quantity dispensed and the temperature of the blowing agent in the subsequent processing zones of the extruder plasticizing and extrusion head. The values of these factors should be coordinated, and controlled the conduct of the process to obtain a uniform structure throughout the cross section of the profile generated. The most important is to establish and stabilize the selected temperature range, so it seems reasonable to thermal imaging of the process by thermal testing [15].

Currently, thermal tests are widely used in various fields of science and life, such as energy, construction, machinery diagnostics, electronics, environmental protection, medicine, marine salvage industry [10, 14]. Infrared, also known as thermography, deals with the detection, recording, processing and visualization of invisible infrared radiation emitted by objects. Obtained by measurements of infrared image (thermometer) is a mapping of temperature distribution on the surface of the observed object. The research intensity of the thermal phenomena are a rich source of information about the technical condition of machines, operation, and of the changes that occur during their operation [8, 9]. Allows to customize the functional characteristics of individual elements of technological line for a particular process and selection of processing conditions such that the process was carried out properly, and the resulting product was characterized by high quality [11, 16].

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl***

2. The test stand and conduct of the study

Thermal studies of microcellular extrusion were carried out in extrusion technological line for profiles. The line included: extruder T-32-25, mandrel extruder head with a nozzle diameter of 5 mm, cooling and the receiving units. In the process, was changed the course of the rotational speed of the extruder screw using the 0,75; 1,02; 1,30; 1,57; 1,85 s^{-1} and content of blowing agent in the input polymer material range of 0; 0,5; 1,0; 1,5; 2,0; 2,5 % mass with the reference to the mass of the plastic. Plasticized poly(vinyl chloride) Alfavinyl GFM-31-TR was modified by the means of microcellular blowing agent in the form of microspheres Expancel 930 MB 120 [5]. The temperature of particular plasticizing system zones of extruder was appropriately 100, 110, 120, 130 ºC, temperature of extruder head was 140 ºC and temperature of cooling factor was 17 ºC.

The thermal study of microcellular extrusion process uses infrared camera V-20, ER005-25 model. It allows to remote non-contact recording of the temperature distribution on the surface of the examined objects. The camera is equipped with a photovoltaic detector PDI-2TE-5 with high sensitivity. Image created by a mechanical scan system using mirrors and precision powertrain. Image was created point by point, line by line. With the help of the lens assembly, infrared radiation is focused onto a detector. Voltage generated by the detector is dependent on the radiation power. Through precise control of mirror motion is possible to measure the radiation point by point. Infrared detection system in the camera V-20 is based on a thermoelectrically cooled HgCdTe detector, which allows to perform temperature measurement from -10 to 500 ° C, the temperature resolution NEDT from 0.05 to 5°C, corresponding to the recorded temperature. Scanning angle is 30°, while creating thermogram consists of 57 600 points (240 points in 240 lines), with a line scan time of 7,2 ms. This camera allows the remote measurement, recording and visualization of infrared radiation emitted by machinery, tools, processing equipment and parts made of plastic, corresponding to the temperature of the surface [11, 13].

Stimulus objects during the ongoing process of microcellular extrusion were nozzle of extruder head and the microporous residue leaving the nozzle head. Recorded the infrared radiation emitted by the surface of the examined objects, which after processing has enabled the visualization in the form of thermal images. A detailed analysis of temperature measurement was carried out on the section of extrudate, which includes 29 points. We analyzed the change in temperature during the extrusion process of the selected point on the surface of the nozzle of extruder head and the surface of the extrudate at a distance of 40 mm from the nozzle.

3. Results

As a result of measurements of thermal infrared images were obtained (Fig. 1) together with the values of the examined surface temperature and its distribution facilities. Then the images were analyzed using specialized computer program Therm V20 ver. 2.2.2. On the basis of the results of micro-brewing temperature measurements directly after leaving the nozzle of extruder head in different measuring points drawn graphs of the measured temperature dependence of microporous extrudate, containing a microcellular blowing agent in

a) b)

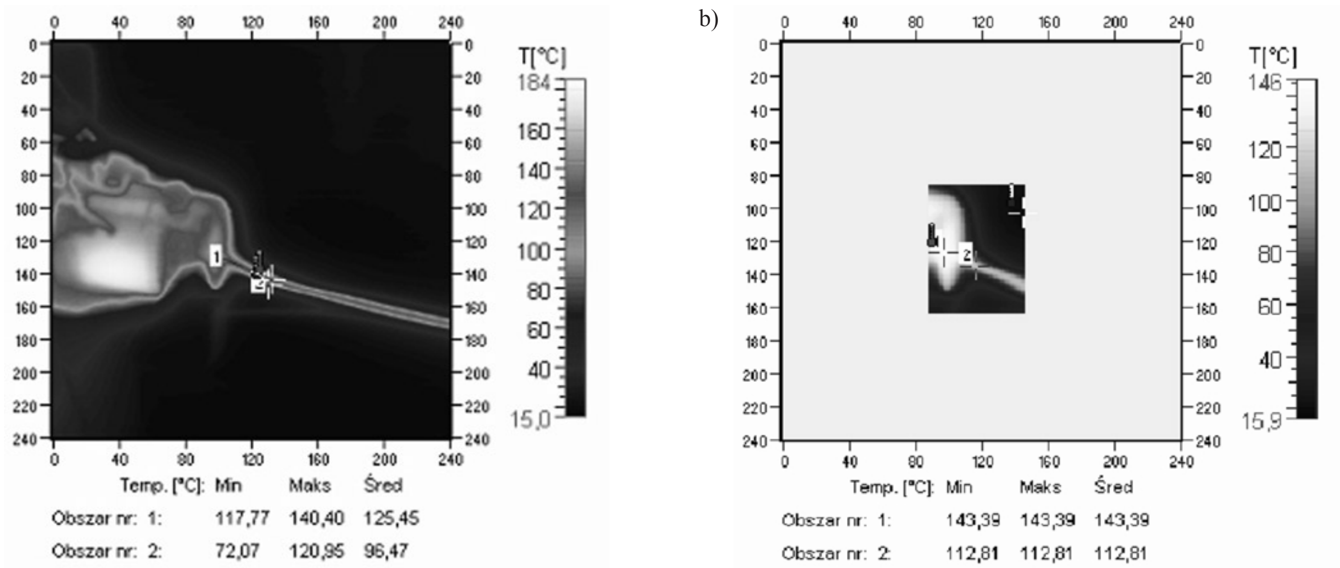

Fig. 1. Examples of thermal images extrusion head and micro brewing: a) with the selected section of the extrudate surface measurement, b) with the selected measurement points on the surface of the nozzle head, and extrudate.

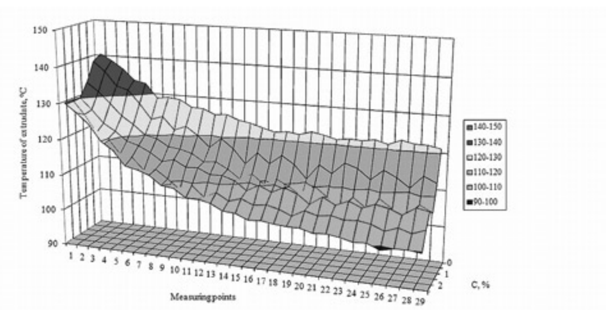

Fig. 2. Dependence of the extrudate temperature in individual measuring points at a rate of screw rotation $\upsilon^1 = 0.75\ s^{-1}$ and the content of microspheres from 0 to 2.5% of the masses.

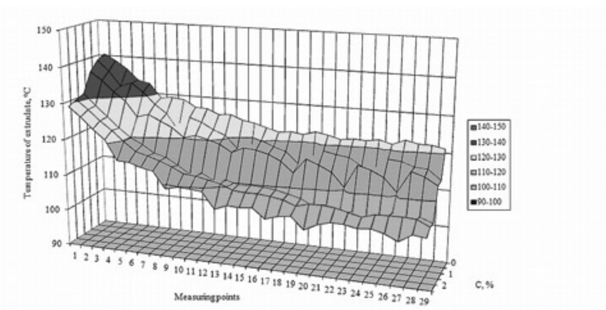

Fig. 3. Dependence of the extrudate temperature in individual measuring points at a rate of screw rotation $\upsilon^2 = 1.02\ s^{-1}$ and the content of microspheres from 0 to 2.5% of the masses.

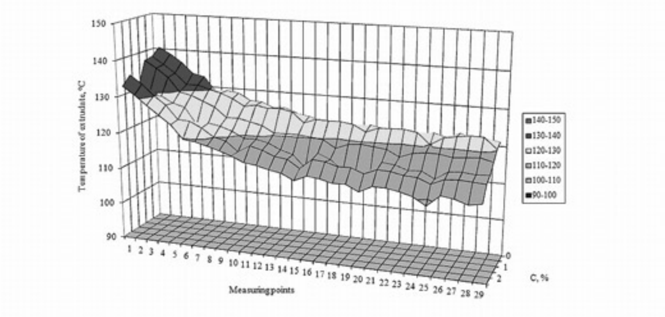

Fig. 4. Dependence of the extrudate temperature in individual measuring points at a rate of screw rotation $\upsilon^3 = 1.30\ s^{-1}$ and the content of microspheres from 0 to 2.5% of the masses.

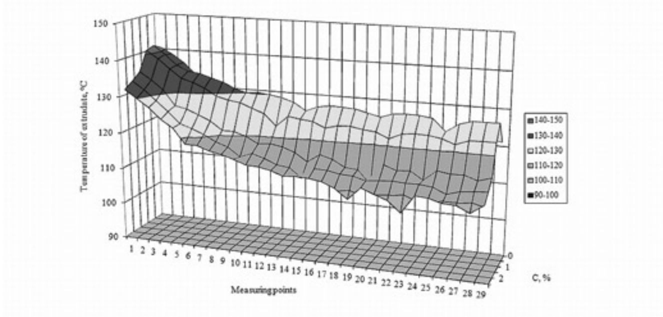

Fig. 5. Dependence of the extrudate temperature in individual measuring points at a rate of screw rotation $\upsilon^4 = 1.57\ s^{-1}$ and the content of microspheres from 0 to 2.5% of the masses.

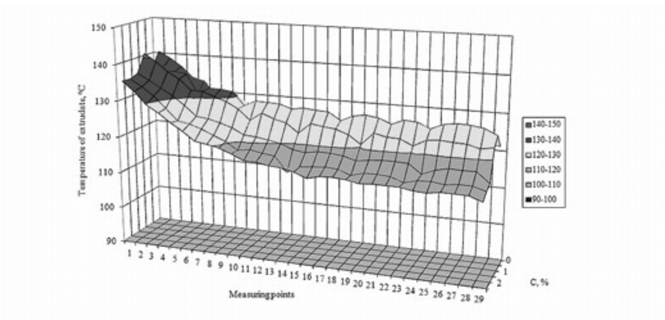

Fig. 6. Dependence of the extrudate temperature in individual measuring points at a rate of screw rotation $\upsilon^5 = 1.85\ s^{-1}$ and the content of microspheres from 0 to 2.5% of the masses.

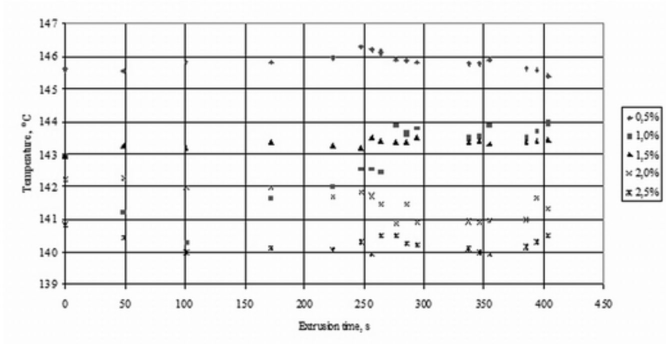

Fig. 7. Dependence temperature of nozzle head on extrusion time with screw rotational speed $\upsilon^1 = 0.75\ s^{-1}$ and content of microspheres range 0÷2,5% mass.

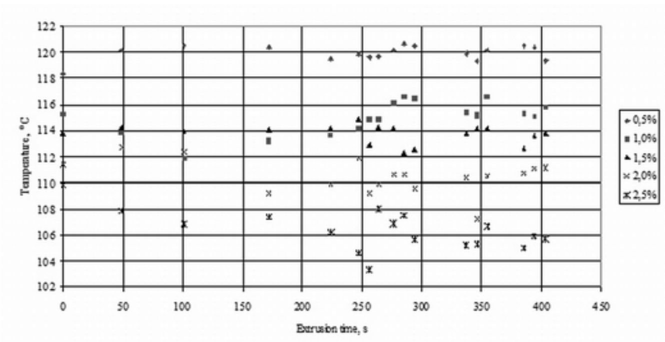

Fig. 8. Dependence temperature of nozzle head on extrusion time with screw rotational speed $\upsilon^3 = 1.30\ s^{-1}$ and content of microspheres range 0÷2,5% mass.

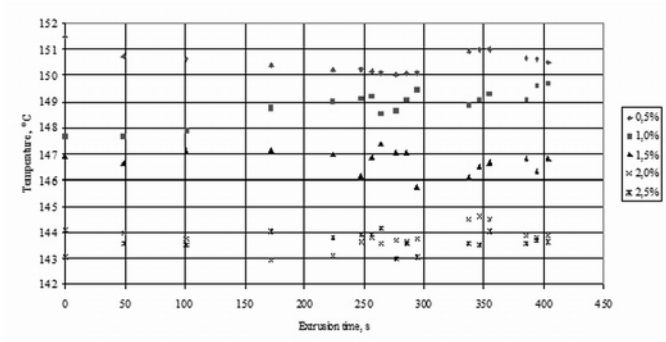

Fig. 9. Dependence temperature of nozzle head on extrusion time with screw rotational speed $\upsilon^4 = 1.57\ s^{-1}$ and content of microspheres range 0÷2,5% mass.

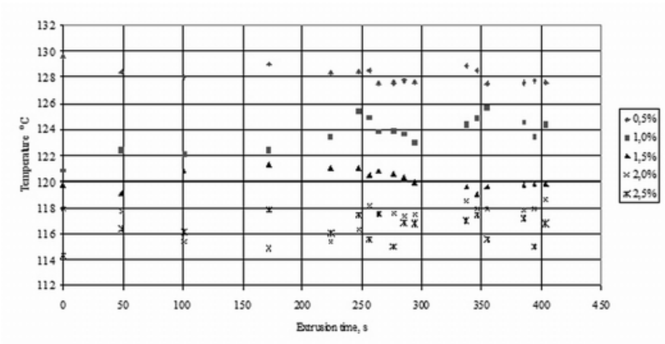

Fig. 10. Dependence temperature of nozzle head on extrusion time with screw rotational speed $\upsilon^5 = 1.85\ s^{-1}$ and content of microspheres range 0÷2,5% mass.

the amount of 0 to 2.5% of the masses., changed at different rotational speeds of the screw in the 0.75 ÷ 1.85 s^{-1}. The relevant diagrams are shown in Figures 2 to 6.

Along with increasing the content of the microspheres measure temperature of poly(vinyl chloride) leaving the nozzle of extruder head has decreased, and in that changes the dosage was a decrease of 10.04°C. It can also assume that for the content of microcellular blowing agent of 1.5% masses. temperature of the extrudate was some stabilization at around 120°C, especially at the measuring points 13 ÷ 29th. While increasing the screw rotation speed above the value of 1.30 s^{-1} there was a rise in temperature for the microcellular extrudate in the range of content of microspheres with 0.5% and 1% of the mass and its decline for content of microsphere above 1.5%.

In Figures 7 ÷ 10 shows examples of the ranges of temperature changes during the extrusion of poly(vinyl chloride) with different contents of the microspheres on the surface of the nozzle head, and microcellular extrudate with minimum and maximum rotational speed of the extruder screw.

Analysis of temperature changes during the extrusion process the various materials can to some extent, the assessment of thermal stability of the process, and therefore also during the process of maintaining a homogeneous physical structure and properties of micro-extrudate. With the increase of screw rotation speed of 0.75 s^{-1} to 1.30 s^{-1} decreases the stability of the process, as evidenced by the increasing spread of the measured values of both the surface temperature of the nozzle extrusion head (from 1.49 to 2.08ºC) as and microporous extrudate (from 4.32 to 5.31ºC) and maximum deviations from the mean. Further increasing the screw rotation speed to 1.85 s^{-1} stabilizes the process from the heat, since these reduce the size of its values corresponding to 1.61ºC and 3.27ºC.

In a similar way to change the maximum surface temperature deviations nozzle of extruder head and microporous extrudate than the average values. At least the screw rotation speed is equal to 0.96ºC for nozzle of extruder head and varies by 1.39ºC to a final value of 1.01ºC. Analogous changes in the surface microporous extrudate and reach higher values are respectively 2.58, 3.38 and 1.43ºC. Along with increasing the content of blowing agent in the plastic temperature stability of nozzle of extruder head increases, the microporous extrudate surface temperature decreases. Increasing the screw rotation speed increases the temperature stability of the microporous extrudate.

4. Summary

The research found that the inserting of blowing agent into poly(vinyl chloride) significantly affect the bottom-thermal phenomena in the microcellular extrusion process, especially during the flow in channels and extruder head for cooling the extrudate directly in the head. In the investigated range of content of microspheres measure the temperature drop extrudate leaving the extruder head is about 7%, which is likely to be attributed to endothermal effect accompanying widening of the microspheres during the microcellular process. Also increases the rate of cooling of the resulting extrudate with increasing microcellular blowing agent dosage. Decreasing the temperature difference between micro-extrudate, and the surrounding resort. This can have an impact on further steps in the process now taking place outside the extruder, especially in the calibration and the final cooling of the extrudate, thus in effect on the structure and properties of the resulting microporous creations.

The observed decrease in the microporous extrudate temperature increase the amount of blowing agent dosing may result from the characteristics of the microcellular agent used. Microspheres for the action of high temperature heat charge resulting in their expansion.

Stability of microcellular extrusion of poly(vinyl chloride) in the tested range of changes in the extruder screw rotation speed should be regarded as satisfactory, with the range of temperature-extrudate, forming element – nozzle of extruder head averaged only 1.7ºC with a maximum deviation from the value registered an average of at 3.6ºC. Micro brewing temperature variation during the process of the measured distance reached 4.3ºC.

The maximum difference in the microporous extrudate temperature during the process was just over 8ºC, which already may have a negative impact on the constitution of homogeneous structure and properties of the extrudate. Generally, obtaining a high thermal stability of the process favored the smallest and largest of the tested range, the extruder screw rotation speed, and low levels of blowing agents in the material to 1.5% by mass. In order to achieve high thermal stability of the process is preferred to use the minimum or maximum value of the extruder screw rotation speed and the content of micropsheres in amounts up to 1.5% of the masses., the weight of material processed.

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