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INFLUENCE OF PROCESSING MULTIPLICITY ON VALUES OF MASS FLOW RATE AND MELT VOLUME RATE OF POLYCARBONATE

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A b s t r a c t

Both the mass flow rate and melt volume rate are the basic technological indictors of the polymers injection moulding. During material recycling, which is the injection moulding of recyclates, awareness of the values of the above mentioned indicators is crucial. It enables setting up the optimal values of an injection moulding machine and if necessary suggests using other type of recycling.

WPŁYW KROTNOŚCI PRZETWÓRSTWA NA WARTOŚĆ MASOWEGO I OBJĘTOŚCIOWEGO WSKAŹNIKA SZYBKOŚCI PŁYNIĘCIA POLIWĘGLANU

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S ł o w a k l u c z o w e: polimery, masowy i objętościowy wskaźnik szybkości płynięcia, recykling.

A b s t r a k t

Masowy i objętościowy wskaźnik szybkości płynięcia to podstawowe wskaźniki technologiczne wtryskowego przetwórstwa tworzyw polimerowych. W czasie recyklingu materiałowego polegającego na wtryskiwaniu recyklatów istotna jest znajomość wartości tych wskaźników. Umożliwia to optymalne ustawienie parametrów pracy wtryskarki, a w skrajnych przypadkach należy zastosować inny rodzaj recyklingu.

Introduction

Both the mass flow rate and melt volume rate are the basic technological indictors of the polymers injection moulding. Their values are directly connected with the viscosity of plastics, whereas the viscosity is dependent on the length of a polymer chain and its branching. During material recycling, which is the injection moulding of recyclates, awareness of the values of the above mentioned indicators is crucial. It enables setting up the optimal values of an injection moulding machine and if necessary suggests using other type of recycling.

Obtaining Polycarbonate

Polycarbonates are received in the polycondensation reaction of alcohols or phenols with phosgene or esters of the carbonic acid. The reaction can proceed on the phase boundary or in a solver (PIELICHOWSKI, PUSZYŃSKI 1998).

Polycarbonate Properties

The polycarbonate is received by phosgening of the dian (just that was used in the research). It is a thermoplastic polymer of the very high softening temperature, linear constitution, with no branches. The polycarbonate macromolecules characterize with the high rigidity, which is limited by the rotation of the aromatic rings, and relatively long segments having no polar units. It results from the constitution that polycarbonate has small tendency to crystallization, relatively high vitrification temperature, high melting temperature and high viscosity in the melted state. Clean polycarbonate products are colorless and transparent because of the low crystallization ability. The light transmittance is comparable with that of glass. The polymer characterizes with the smooth glossy surface. It can be easily colored (PIELICHOWSKI, PUSZYŃSKI 1998, SEACHTLING 1999, ŻUCHOWSKA 2000).

Polycarbonate belongs to not numerous polymers which join good mechanical and thermal properties with electric and optic ones. It is distinguished by the high rigidity, strength, and particularly the impact strength in the range of 150°C to 135°C. The maximal short-term use temperature is 150°C. The range of long-term use is 40°C do 130°C. The range qualifies polycarbonate to the thermal resistant materials. Polycarbonate is one of not numerous thermoplastic polymers of the high resistance to the impact fatigue (with no notch). However, it is fragile for a notch, which is obviously visible at the long-term

fatigue strength. There is a risk of the strain cracking. In the abrasion activity conditions its application is limited. Polycarbonate characterizes with the creep resistance and the small water absorbing capacity. Humidity has no influence on the dielectric properties of that polymer. The chemical resistance of polycarbonate is limited, especially in case of the organic solvents, as: chloroform and dichloromethane. CO_2 permeability is relatively high. That is why in the production of bottles for the carbonated drinks the protective layers of PET or PBT should be applied. Polycarbonate does not show neither the poisonous properties nor harmful influence on the human body. It is hydrolysis resistant. It can be sterilized and used in medicine (it is physiologically neutral). It is a self-extinguishing polymer after removal of the source of fire (PIELICHOWSKI, PUSZYŃSKI 1998, SEACHTLING 1999, ŻUCHOWSKA 2000).

Polycarbonate Processing

Polycarbonate is processed by all the methods typical for the thermoplastics, e.g. injection, drawing, etc. It is a polymer difficult in processing. In spite of that its flow temperature is 220°C, its processing temperature (because of the low heat conduction) is high and it is equal to 280–320°C at injection, and while drawing – 240–280°C. In the melted state polycarbonate has big adhesion to a metal what considerably makes the processing more difficult. High viscosity of the polymer requires much injection power or small ratio between the flow distance and wall thickness. The preliminary drying at the temperature of 120°C of the polymer prior to processing is necessary within 4 to 24 hours to decrease the humidity under 0.01–0.02%. The processing shrinkage is 0.6–0.8%, the after – shrinkage is not crucial (SEACHTLING 1999, ŻUCHOWSKA 2000, SZLEZYNGIER 1998).

Methodology of Processing Properties Research

The precise determination of the plastics viscosity curves, i.e. the dependence of the viscosity on the shear rate, is expensive and time consuming. That is why the MFR and MVR characterize polymers flow in the machines and devices canals during processing. These are the quantities defining mass or volume of a polymer drawn for 10 minutes through the nozzle with a specified diameter, under a specified load and at a specified temperature. The essence of determining the flow rate is the measurement of the mean flow rate of the plastic at the specified basic parameters of the processing. The flow rate is a measure of the liquidity of a material, therefore it is opposite to the viscosity.

It represents one point of the viscosity curve of the examined material, determined at the measurement temperature. It does not define unequivocally the examined material and it can be the same for plastics with different viscosity characteristics.

The standard measurement conditions (ISO 1133 norm) concern the capillary tube and piston geometry, load of a piston, time and temperature of the measurement. The load of the piston and measurement temperature are selected in dependence on a type of the examined plastic, and to be precise, they are conditional on the properties of the plastic. Results of the measurements are given either in g/10 min (MFR) or in cm^3/10 min (MVR). Evaluation of the Mass Flow Rate and Melt Volume Rate consists in the plasticization of a plastic sample in a heated cylinder, drawing of the plasticized material through the nozzle situated in the lower part of the cylinder and determining of the drawn mass or the cylinder displacement. Prior to the beginning of the research the cylinder and plastometer piston are heated to the proper temperature, which is maintained (±0.5°C) over 15 min before the measurement and during the measurement.

The research was carried out with the REO-100 plastometer, at the temperature of 280°C and under the load of 2160 g; the density of the investigated polycarbonate was $\rho = 1.20$ g cm^{-3}.

Basic technical parameters of the REO-100 plastometer:
- max. heating power of a heater – 1050 W,
- range of measured temperature – 30–300°C,
- temperature stabilization – ± 0.2°C,
- accuracy of time measurements – 10 μs,
- accuracy of distance measurements – 5 μm,
- range of measured distance – 100 mm.

The initial plastic had a form of granulate. After going through the plastometer the plastic was mechanically shredded (cut). The regranulate obtained that way was investigated in the plastometer.

Results

The research results of the Mass Flow Rate (Fig. 1) and Melt Volume Rate (Fig. 2) are presented in the diagrams. The curve presenting changes of the Mass Flow Rate can be circumscribed with the equation (1):

$$y = 14.587e^{0.6927x} \tag{1}$$

where $R^2 = 0.9589$.

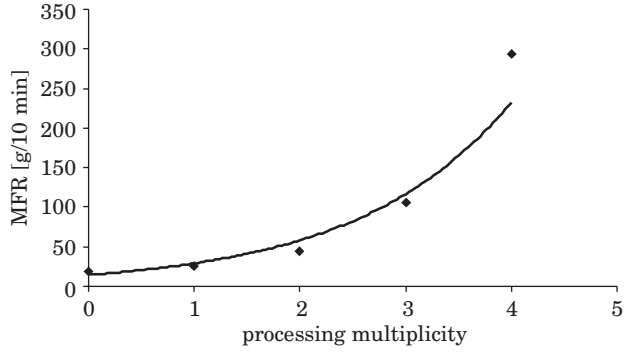

Fig. 1. Changes of Mass Flow Rate in dependence on processing multiplicity

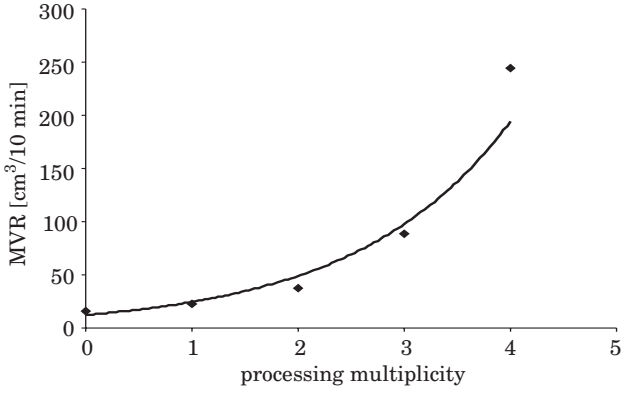

Fig. 2. Changes of Melt Volume Rate in dependence on processing multiplicity

The curve presenting changes of the Melt Volume Rate can be circumscribed with the equation (2):

$$y = 12.381e^{0.6883x} \tag{2}$$

where $R^2 = 0.9601$.

Conclusions

The MFR and MVR are closely related with each other. This fact is confirmed by the similarity of the regression curves and similarity of their equations. Their analysis shows degradation and destruction of the investigated polymer (shortening of chains) (KOSZKUL, MAZUR 2003). It is connected

with the influence of the temperature (processing) and mechanical shredding (recycling). The degradation proceeds so fast that it was impossible to carry out the measurements after the fourth processing, because the polymer was leaking through the not loaded nozzle. That limits using the material recycling (up to the fourth processing) in case of the polymer. On the other hand, that rather suggests application of the raw material recycling, which gives many more possibilities of reuse of the depolymerization products.

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