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

Piotr Mazur, Piotr Smoleński

Chair of Materials and Machines Technology
University of Warmia and Mazury in Olsztyn

Key words: polymers, mass flow rate, volume rate, recycling.

Abstract

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 PPS

Piotr Mazur, Piotr Smoleński

Katedra Technologii Materiałów i Maszyn
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: polimery, masowy i objętościowy wskaźnik szybkości płynięcia, recykling.

Abstrakt

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 wymienionych 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 it suggests using other type of recycling.

Obtaining PPS

Production of polyphenylene sulfide for needs of plastics processing is based mainly on two technological processes. Polycondensation of dichlorobenzene with sodium sulfide is first of them. Thermal modification of PPS is the second one.

Properties of PPS

At present the most familiar form of polyphenylene sulfide is a polymer known in the market as Ryton, which is manufactured by the Phillips Petroleum Company in the USA. Also German and Japan companies manufacture the chemical compound. PPS is produced in several varieties, which differ in the degree of the physical modification and types of the fillers (JURGA 1994). The characteristic feature of PPS is change of the properties during heating in the presence of oxygen. Polyphenylene sulfide heated to the temperature of over 320°C behaves as a thermohardening polymer. However, the hardening process proceeds very slowly and does not make difficult processing by the injection moulding (HAŁASA, HENECZKOWSKI 2007).

The perfect utility properties of PPS, and especially PPS hardened by the glass fiber (HAŁASA, HENECZKOWSKI 2007), are:

– High rigidity and hardness,

– High mechanical strength, thanks to the huge adhesion of PPS to the glass fiber,

– Dimension stability,

– Low creep,

– High resistance to chemicals and solvents,

– Self-extinguishing properties,

– Very good dielectric properties, practically independent neither on the humidity rate of environment nor frequency.

PPS is a fragile thermoplastic and in the not-filled form it is seldom used in the injection moulding processing. However, PPS can be used for the production of foils and fibers. The injection moulding method is applied to manufacture mixtures hardened by the fibers, the mineral fillers or their combinations. For the purposes there are used the glass fibers, carbon fibers, aramid fibers and as a filler is used calcium carbonate, calcium sulfate, kaolin, mica, talc and quartz. The mechanical properties are mostly dependent on kinds and quantity of additives (SZLEZYNGIER 1998). Polyphenylene sulfide, except for the good thermal resistance, characterizes with very satisfactory chemical resistance. It is also resistant to the hydrolysis. PPS is not UV resistant. This feature might be improved by adding some dark pigment (HAŁASA, HENECZKOWSKI 2007).

PPS processing

PPS and its composites processing is carried out by the ordinary machines used for processing of the typical thermoplastics but after the necessary modifications. The basic differences concern higher limitation temperature of a cylinder, nozzle and mould (HAŁASA, HENECZKOWSKI 2007).

The main parameters of the injection moulding process are as follows (HAŁASA, HENECZKOWSKI 2007):

– mould temperature – 130–160°C – it decides on crystallization degree, which means it decides on the polymer properties,

– injection temperature – recommended in the range of 305–345°C.

Polyphenylene sulfide is not hygroscopic but the fillers are. This is why the filled polymer prior to processing has to be dried to the humidity level of 0.03%. The granulated PPS is dried in the temperature of 150–160°C over 2–3 hours. PPS can be processed by injection moulding, pressing or sintering.

Research Methodology of Processing Properties

Precise determining of the viscosity curves for plastics, that is the dependence of the viscosity on the shear rate, is expensive and time consuming. That is why the MFR and MVR indexes characterize polymers flow in 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 measurement of the mean flow rate of a plastic at the specified basic parameters of 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 an 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 to a type of the examined plastic, and to be precise, they are conditional on the properties of a 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 the 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 measurements were carried out using the REO-100 plastometer characterizing the following parameters:
- 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 literature does not present the influence of the processing multiplicity on values of the MFR and MVR. In the paper there was made an effort to determine the above mentioned dependence. The granulated PPS was the initial material and each processing was followed by the mechanical shredding to the form of regralulate.

The process temperature was equal to 300°C and the load equaled 5000 g.

Research Results and their Analysis

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

$$y = 0.0002x_3 - 0.0142x_2 - 0.5386x + 47.838 \quad (1)$$

where $R^2 = 0.8747$.

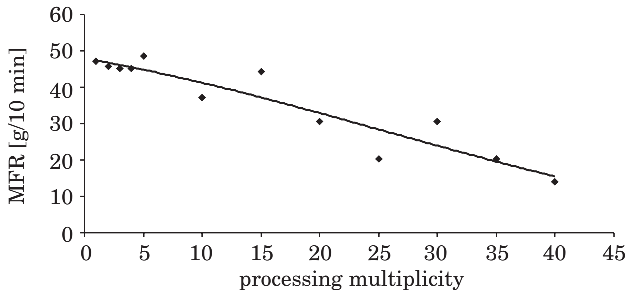

Fig. 1. Changes of Mass Flow Rate in dependence on processing multiplicity

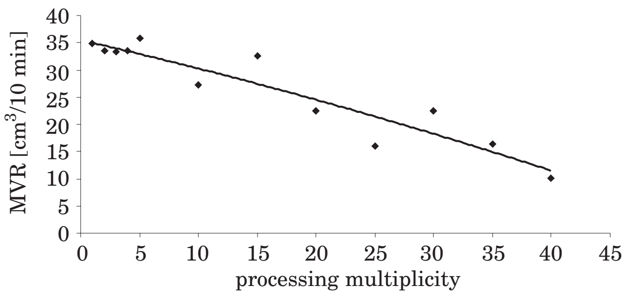

Fig. 2. Changes of Melt Volume Rate in dependence on processing multiplicity

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

$$y = -0.0026x_2 - 0.4968x + 35.477 \quad (2)$$

where $R^2 = 0.8801$.

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 the increase of the polymer viscosity which is connected with either elongation of the chain or its branches growth (flanks).

It is caused by the temperature during the following processing multiplicities (KOSZKUL, MAZUR 2003). It creates huge possibilities for material recycling of the polymer.

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