Determination of Rheological Behaviour of Polymer/Gas Solution using Rheometer Equipped with a Pressure Cell

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ABSTRACT

Rheological characterization of polymer/gas solution is not well defined even though understanding of the rheological properties of these systems could provide easier process optimization. In this work, extrusion experiments on polyethylene matrix with isobutane as a physical blowing agent were carried out utilizing the industrial polymer foam production line including online rheometer under different mass flow rates and gas amount injected into the polymer melt. Shear viscosity experimental data were determined from the pressure drop measured inside of the online rheometer over a straight rectangular channel of defined dimensions. The rheological data were completed with rheological data evaluated using high pressure capillary rheometer.

INTRODUCTION

Extrusion of polymer/gas solution is a very complex process. The continuous foam production can be done utilizing physical or chemical blowing agent. Generally, in both cases, the process consists in creating bubbles and their stabilization within a polymer matrix. In more detail, defined concentrated gas (for example under pressure) is incorporated to polymer melt where it expands at a given temperature and pressure with subsequent stabilization of this foaming process.[1,2]

In foam extrusion, occurrence of the gas in the polymer melt is usually ensured by a physical blowing agent (e.g. pressurized carbon dioxide, isobutane or nitrogen) followed by temperature reduction necessary to facilitate the process stabilization. Then, final products of this technology reach good properties for example in area of cushioning, insulation or protection which leads to increasing interest about this technology.[1,2]

The efficiency of polymer foam preparation is influenced by optimized processing parameters, such as extrusion temperature and pressure or physical blowing agent concentration. For this reason, rheological characterization of this system is very important. It should be noted that rheology of polymer/gas solution is still not well defined, mainly due to lack of quality experimental data.[1,2]

Rheological characterization techniques of polymer/gas solution can be performed utilizing capillary rheometer where stationary melt viscosity is taken as a function of blowing agent concentration.[3,4] Several studies were focused on shear flows and a large pressure in order to dissolve the blowing agent within the polymer melt[5]. In recent years, a rotational rheometer equipped with a pressure cell has been used for characterization of pressure dependence of the viscosity. Only few works have been published yet on this topic.[6,7]

The main objective of this work is to compare difficult to obtain rheological data from industrial polymer foam production line with measured rheological data using high pressure capillary rheometer.

EXPERIMENTAL

Extrusion experiments were carried out with a commercial low density polyethylene (LDPE) and isobutane on the industrial polymer foam production line including Promix static mixer and online rheometer as a pressure cell with a straight rectangular channel of defined dimensions, 2 mm thick and 25 mm wide (see Fig. 1). The pressure drop was measured between three pressure sensors 40 mm apart. Experimental data were obtained for five mass flow rates (5, 8, 15, 22, 26 kg/h) and four values of gas amount (0, 6, 8, 12 %). When the certain gas amount was injected under constant pressure (150 bar) into the polymer melt, temperature of the online rheometer was set to 105 °C. On the other hand, in the case of 0 % of gas, online rheometer was heated to 150 °C and 190 °C.

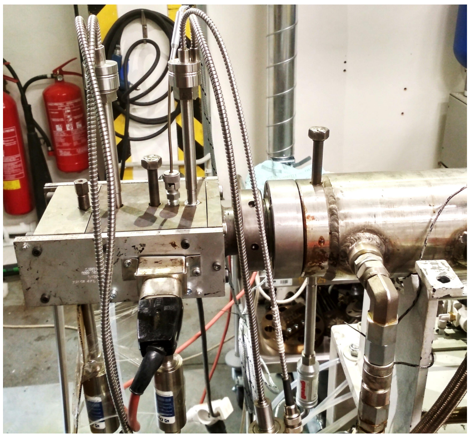

Figure 1. The online rheometer installed on the industrial polymer foam production line.

In order to describe valuable experimental data in the area of processing shear rates, rheological experiments using high pressure capillary rheometer have been done. The rheological characterization was performed using high pressure capillary rheometer Göttfert RG50 equipped with two barrels with diameter of 15 mm. During the experiments, two types of capillaries (long die and orifice die) with the same diameter were used. The ratio of the length to the diameter of the long capillary die was equal to 20, while in the case of the orifice capillary die, the ratio was less than 1. Experiments were carried out for temperatures 130 °C, 150 °C and 190 °C. For each test, 10 values of the apparent shear rates were measured over the range of 35 s^{-1} to 2000 s^{-1} until the stable pressure was reached. Consequently, Bagley and Rabinowitch corrections were applied.

RESULTS AND DISCUSSION

Experimental data obtained from industrial polymer foam production line were completed and compared with high pressure capillary rheometer data.

As can be seen in Fig. 2, the experimental data from the industrial line and rheometer are in very good agreement. That means the online rheometer can be applied to investigate the isobutane effect injected into the polymer mixture on viscosity of the polymer/gas solution.

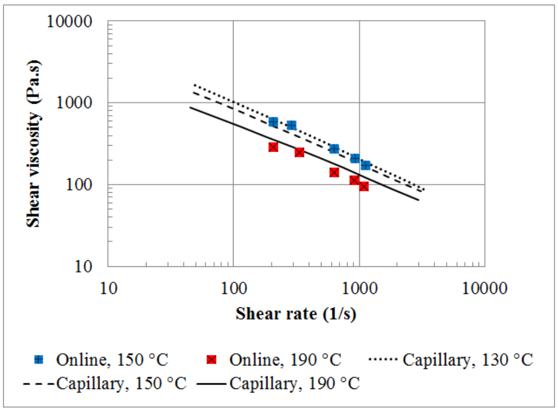

Figure 2. Comparison between experimental data without gas addition obtained utilizing online rheometer installed on industrial line and high pressure capillary rheometer.

As can be seen in Fig. 3, addition of an isobutane into the polymer melt leads to reduction of the polymer/gas solution viscosity. It is important to note that experimental data with gas addition are obtained at online rheometer temperature of 105 °C while data without gas addition at 150 °C, in order to overcome viscosity fall due to gas presence.

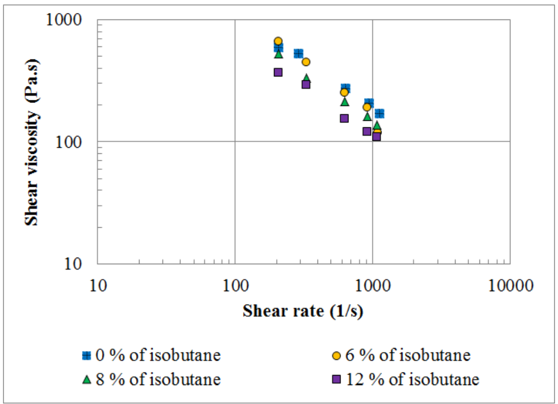

Figure 3. Influence of isobutane addition to the polymer mixture viscosity.

CONCLUSION

It is clear that in case of polymer melt extrusion without gas, the corresponding experimental data obtained using online rheometer installed on the industrial polymer foam production line are in very good agreement with the experimental data evaluated using high pressure capillary rheometer in case of both investigated temperatures.

It has been experimentally demonstrated that addition of isobutane significantly reduces the polymer melt viscosity. This effect is emphasized by the fact that foaming process occurs at a significantly reduced temperature of extrusion die to ensure stable process.

It was revealed that the online rheometer is a suitable tool for measuring the viscosity on an industrial scale in order to obtain optimized processing conditions for stable polymer foam preparation.

ACKNOWLEDGMENTS

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic – Program NPU I (LO1504).

Further, the authors thank SPUR a.s. and Ing. Ondřej Krátký for the opportunity to obtain experimental data on the SPUR a.s. industrial polymer foam production line.

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