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[1.] Jozef DOBRÁNSKY, [2.] Juraj RUŽBARSKÝ

IMPACT OF MOISTURE ON RHEOLOGICAL PROPERTIES OF PROCESSED MATERIALS

[1-2.] Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Manufacturing Processes Operation, Štúrova 31, 080 01 Prešov, SLOVAKIA

Abstract: Paper deals with assessing the impact of moisture content in thermoplastic material on rheological properties of processed material. The measurements were carried out on samples of hygroscopic plastics, i.e. plastics that tend to absorb moisture from the surrounding environment. Moisture in plastic material before its processing can have negative influence on physical or thermal properties of a product and can devalue visual aspect of the end product, thus these plastics have to be dried before their processing. Observed samples of materials were placed in three different rooms and measurements of Melt Volume-Flow Rate of thermoplastics were carried out at precisely determined intervals.
Keywords: moisture, granulate, drying, rheology

INTRODUCTION

Rheology is the study of flow and deformation of materials under applied forces which is routinely measured using a rheometer. [1] The measurement of rheological properties is applicable to all materials – from fluids such as dilute solutions of polymers and surfactants through to concentrated protein formulations, to semi-solids such as pastes and creams, to molten or solid polymers as well as asphalt. Rheological properties can be measured from bulk sample deformation using a mechanical rheometer, or on a micro-scale by using a microcapillary viscometer or an optical technique such as Microrheology.

Many commonly-used materials and formulations exhibit complex rheological properties, whose viscosity and viscoelasticity can vary depending upon the external conditions applied, such as stress, strain, timescale and temperature. Rheological properties impact at all stages of material use across multiple industries – from formulation development and stability to processing and product performance. The type of rheometer required for measuring these properties is often dependent on the relevant shear rates and timescales as well as sample size and viscosity. [2]

It is well known that materials of the same grade, but from different batches, may process quite differently. The transformation process reacts very sensitively to small variations of the material, i.e. the rheology of the polymer melt is very sensitive to small changes of the polymer structure. Because of the sensitivity of rheology of the condensed phase to structure, rheology is a most convenient method to characterize polymers. A small amount of a high molecular weight polymer can change the processing behaviour dramatically and so does the melt rheology. [3,4]

EXPERIMENTAL PROCEDURE / TESTED MATERIALS

Four kinds of polymers from different groups of thermoplastics were used for the measurement. Before rheological testing, all four kinds of polymers were pre-dried in drying rooms. Chosen materials belong to a group of hygroscopic materials, i.e. it is necessary to dry them and to remove moisture from them before they are processed. The material was provided in the form of granulate, as is also used for processing by injection molding technology.

- **Makrolon AL 2647** - this PC (polycarbonate), together with other polycarbonates, presents specific group of thermoplastic polymers, which are easily worked, moulded, and thermoformed. Because of these properties, it finds many applications. Polycarbonates are highly molecular amorphous technical thermoplastics. They are characterized by a combination of excellent mechanical resistance, glasslike transparency, excellent dimensional stability, thermal resistance and good electrical properties.
- **Durethan BKV 30 H2** – PA6 (polyamide) Durethan BKV 30 H2 is characterized by high yield stress (70 – 110 MPa), high resilience and strength (up to M98). Its density ranges from 1.15 to 1.16 kg/dm3. This material is well workable, has a wide range of working temperatures and attenuates shocks. Basic areas of its use are bearing liners, conveyor chain lines, cogwheels and gear bars, foam blocks, insulating elements, sealing rings etc. It is a highly absorbent material (up to 3 % vol.) and due to this fact, it is important to dry it up before processing. Storage in humid places and subsequent processing may result in changes of dimensions and properties.
- **Plexiglas Formmasse 8N** - this material belongs to PMMA (Polymethyl Methacrylate) group and it is a transparent thermoplastic, commonly known as acrylic glass or acrylate. It is often used as an alternative to glass because it is light and shatter-resistant. Density of PMMA ranges from 1.17 to 1.20 g/cm3, which is less than half of glass density. PMMA's permeability of light is 92%. Its surface can be washed off and dissolved in various organic solvents. Regarding its hydrolyzed ester group, it has poor resistance to many other chemicals.
- **Lustran H802** - material with this trade name belongs to a family of ABS (Acrylonitrile Butadiene Styrene). It is an amorphous polymer which is resistant to mechanical damage. Its main properties include: strength, resilience, resistance to high temperatures, low absorbency and harmlessness to health. It is also resistant to acids, alcohols, oils and fats. Before processing, it is mostly used in the form of granulate and it has a wide use in production of furniture, household equipment or car parts (bumpers, back parts of lights etc.).

EXPERIMENTAL EQUIPMENTS

Determination of moisture content in thermoplastic granulate

Moisture content was determined by Mettler Toledo HB43-S moisture analyzer (Fig. 1). This tool is suitable for use in almost every substance. This tool works on thermo gravimetric principle: At the beginning of the measurement, the analyser determines sample's start weight, then the sample is quickly heated by a halogen radiator and the moisture evaporates. While drying, the analyser continually records weight of the sample and loss in weight is displayed. When drying is finished, the final result is interpreted as moisture content or the content of dry substance of our sample. [5]

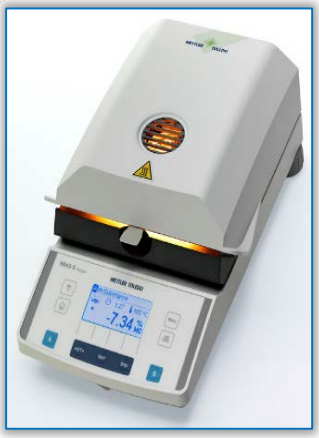

Figure 1: Halogen moisture analyser METTLER TOLEDO HB43-S

Determination of melt volume-flow rate of thermoplastics

Melt Volume-Flow Rate (MVR) is defined as speed of melt extrusion through the capillary of defined length and diameter under determined conditions of temperature, load and position of the piston in cylinder of melt indexer. The speed is determined as substance volume pushed out in particular time and is stated in $cm^3/10$ min. Determination of Melt Volume-Flow Rate is based on international STN EN ISO 1133 standard which specifies particular procedures. A method for weight determination and a method of pushed volume measurement are used. Melt Volume-Flow Rate is used for comparison of materials with different content of filler and for comparison of filled and unfilled thermoplastics. These methods can also be used for thermoplastics which rheological behaviour during measurement is influenced by phenomena such as hydrolysis, condensation or reticulation, however only up to limited extent and provided that repeatability and reproducibility of results are in acceptable extent. Melt Volume-Flow Rate was determined by TermoHaakeMeltflow MT melt indexer (Fig. 2). [6,7]

Figure 2: Melt indexer HAAKE MELTFLOW MT

RESULTS AND DISCUSSION

Moisture of each material was measured immediately after being removed from drying room, and subsequently it was divided into three rooms with different air temperatures.

- room no. 1 – production hall with injection molding machines, air temperature 22°C.
- room no. 2 – company's laboratory, air-conditioned room, air temperature 19°C.
- room no. 3 – company's storeroom of raw materials, air temperature about 10°C.

A sample of granulate was placed in each room for 15, 30 and 60 minutes, and subsequently its moisture was measured and Melt Volume-Flow Rate of thermoplastics measurement was carried out. Testing of materials was carried out in accordance with prearranged procedure. As was already mentioned, moisture of each material was measured immediately after being removed from drying room, and subsequently it was divided into three rooms with different air temperatures. Measurement of Melt Volume-Flow Rate of thermoplastics was carried out in each material immediately after being removed from drying room, and subsequently in each testing room in accordance with precisely determined intervals schedule of conditioning.

Measurement of Melt Volume-Flow Rate of thermoplastics was performed in six repetitions of which average values are stated in tables and assessments. In table 1 to 4, there are recorded values of relative moisture and average MVR values in each testing room for different intervals of conditionation for tested materials.

Table 1: Recorded results for material Makrolon AL 2647

Observed parameters		Room no. 1			Room no. 2			Room no. 3		
Standing time [min]	0	15	30	60	15	30	60	15	30	60
Relative moisture [%]	0.02	0.03	0.05	0.05	0.04	0.05	0.04	0.05	0.05	0.09
MVR [cm³/10 min]	12.5	11.8	12.3	12.3	12.6	13.2	12.6	12.0	12.3	12.6

Table 2: Recorded results for material Durethan BKV 30 H2

Observed parameters		Room no. 1			Room no. 2			Room no. 3		
Standing time [min]	0	15	30	60	15	30	60	15	30	60
Relative moisture [%]	0.04	0.07	0.13	0.14	0.09	0.11	0.13	0.11	0.11	0.15
MVR [cm³/10 min]	21.52	25.62	29.8	30.4	28.6	29.4	29.5	29.5	29.6	30.5

Table 3: Recorded results for material Plexiglas Formmasse 8N

Observed parameters		Room no. 1			Room no. 2			Room no. 3		
Standing time [min]	0	15	30	60	15	30	60	15	30	60
Relative moisture [%]	0	0.01	0.01	0.02	0.06	0.08	0.08	0.10	0.11	0.13
MVR [cm³/10 min]	2.86	2.91	2.95	3.01	2.88	2.91	2.92	2.91	2.92	3.02

Table 4: Recorded results for material Lustran H802

Observed parameters		Room no. 1			Room no. 2			Room no. 3		
Standing time [min]	0	15	30	60	15	30	60	15	30	60
Relative moisture [%]	0	0.01	0.01	0.03	0.02	0.03	0.03	0.06	0.08	0.09
MVR [cm³/10 min]	8.12	8.18	8.21	8.28	7.57	7.77	8.26	8.26	8.26	8.39

As can be seen in tables, polyamide Durethan BKV 30 H2 absorbed the highest percentage of moisture at shortest time. Moisture in polyamide Durethan BKV 30 H2 has influenced the most the rheological properties and recorded MVR values 21.4 – 29.6 cm³/10min highly exceed allowed values specified in producer's material sheet. When working with this material, it is necessary to ensure suitable storage area, or rather place the dryers directly to injection equipment. Due to quick absorption of moisture, location of the dryers far from injection equipment and subsequent transport might cause defects of products.

CONCLUSION

The rheology-polymer structure relation makes rheology the ideal tool to design materials with specific processing and end-use performance. Whereas the rheology of the melt provides direct information on the processability, the rheology of the solid and melt phase can be related to the performance of the end product. Also, due to the viscoelastic nature of the melt which may cause wanted and unwanted anisotropy during flow, the final product also depends on how the material is being processed.

Note

This paper is based on the paper presented at The 10th International Conference for Young Researchers and PhD Students – ERIN 2016, organized by University of Zilina, Faculty of Mechanical Engineering, in Liptovský Ján, SLOVAKIA, May 10–12, 2016, referred here as [8].

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