MONITORING OF RHEOLOGICAL PROPERTIES OF POLYPROPYLENE

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Abstract: The article deals with the evaluation of the impact of the addition of recycled material in the pure material in the processing of thermoplastic injection molding technology.The experiment was determined what proportion of recycled material in the pure material is acceptable to secure the required rheological properties of processed material injection molding technology. To assess the rheological properties was used melt volume rate index MVR of thermoplastic materials. The experiment was conducted in specialized laboratory support equipment according to STN EN ISO 1133.
Key words: rheology, recycled material, polypropylene, plastic

1. INTRODUCTION

Rheology describes the deformation of a body under the influence of stresses. "Bodies" in this context can be solids, liquids, or gases. Ideal solids deform elastically. The energy required for the deformation is fully recovered when the stresses are removed. Ideal fluids such as liquids and gases deform irreversibly - they flow. The energy required for the deformation is dissipated within the fluid in the form of heat and cannot be recovered simply by removing the stresses.

Measurement of rheological properties of polymers is important for several reasons. Their knowledge helps us to formulate a polymeric system that would best meet the individual requirements of the physical properties of finished plastic products. This fact shows that the rheological properties directly affect the processing conditions, eg. injection temperature and pressure during extrusion.

2. DESCRIPTION OF WORK METHODOLOGY, MATERIALS AND EXPERIMENTS

Tested material was polypropylene Hostacom M2 N01 what is a 20% mineral filled PP homopolymer, with low flow, good stiffness. It is not intended for medical, pharmaceutical or drinking water applications. Melt volume-flow rate (**MVR**) was measured by Thermo Scientific HAAKE MeltFlow MT indexer. The test sample of 5 g was mixed from granulate and recycled polypropylene where the proportion of recycled material for each additional measurement increases by 5%.

The area of the cylinder is inserted and secured on the underside of the capillary. After the stabilizing the temperature at the top and bottom of the cylinder measurement starts. A sample weighing 5 g is weighed on a digital weight METTLER TOLEDO PL-303 IC. With hopper sample is dropped into the cylinder cavity. After filling the sample is inserted piston without additional weight and gently pushed. The program is set preheat time of four minutes, during which the sample reaches the plastic state. After the sample is transformed into the plastic state program issues an instruction to load the piston weight (5 kg). The measurement starts by visiting the bottom of the reference marks of the reading device. Program notes, displayed in real time precisely the values which are stored and

displayed after the measurement. Measurement stops scanned the top of the reference marks of the piston.

3. EVALUATION OF THE MEASUREMENT

Average MVR is calculated from the results of individual 6 measurements (Fig. 1).

No. of measurement	Percentage of net Polypropylene	Percentage of recycled material	Average value of MVR
1	100%	0%	11,0676 cm³/10 min
2	95%	5%	11,4175 cm³/10 min
3	90%	10%	11,5429 cm³/10 min
4	85%	15%	11,8436 cm³/10 min
5	80%	20%	12,1334 cm³/10 min
6	75%	25%	12,2088 cm³/10 min
7	70%	30%	12,5307 cm³/10 min
8	65%	35%	12,9547 cm³/10 min
9	60%	40%	13,2110 cm³/10 min
10	55%	45%	13,2777 cm³/10 min
11	50%	50%	13,6323 cm³/10 min
12	45%	55%	13,9530 cm³/10 min
13	40%	60%	14,3784 cm³/10 min
14	35%	65%	14,3050 cm³/10 min
15	30%	70%	14,7167 cm³/10 min
16	25%	75%	15,0546 cm³/10 min
17	20%	80%	15,3162 cm³/10 min
18	15%	85%	15,6732 cm³/10 min
19	10%	90%	15,7689 cm³/10 min
20	5%	95%	16,2549 cm³/10 min
21	0%	100%	16,7929 cm³/10 min

Fig. 1. Table of MVR values obtained by measuring

From the results it is clear that a gradual increase in representation of recycled material in the sample also increases the value of melt volume-flow rate. Since the material has a value of MVR sheet of material bounded by the values of 7-13 cm³/10 min recycled material can add up to a maximum 35% share in the material. After crossing the 35% value share of recycled MVR value is above the range of material form and it can affect change in the quality of the product. Some correction process of processing parameters may be modified final product quality. Opaque mixture of recycled material and granulate may be non-homogeneous material (different fluidity) and the injection process may arise cold joints. Standard deviation from the average (mean) of all measurements has the value 1.6815 cm³/10 min, and the average measured value is 1.6986 cm³/10 min.

Figure 2 shows the time of measurement with respect to individual measurements. Shortening the time trials in the difference between the first and the last measurement is

approximately 50 seconds. Shortening the time would help reduce the time of injection and thus shorten the period of filling mold cavity. Acceptable value of adding recycled material is 65% granules to 35% of recycled material.
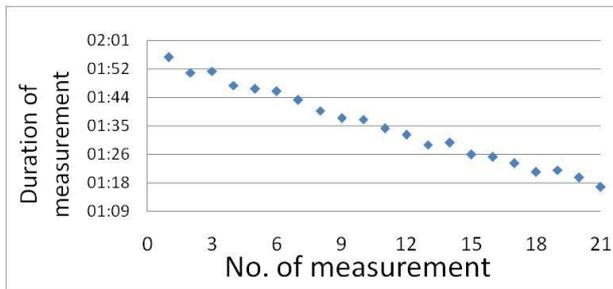

Fig. 2. The average measurement time in each measurement

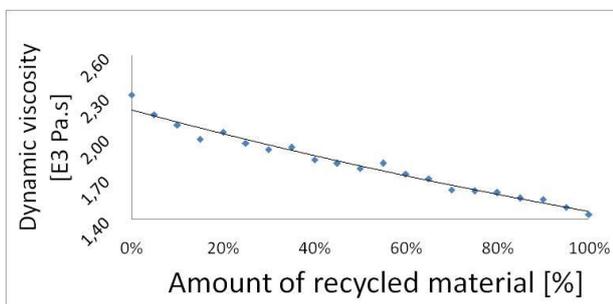As we can see on Figure 3 with the increasing amount of recycled material viscosity decreases rapidly.

Fig. 3. Dependence of dynamic viscosity on the addition of recycled material

With the increasing of melt volume-flow index, according to the chart in Fig. 4 value of viscosity decreased $[\eta]$. Lower viscosity can cause rejects and overflow. The low value of viscosity can occur in some places the product burns. This product defects can be removed using a small proportion of granules and recycled, thereby reducing the melt flow index. Otherwise, if the value is too high viscosity may give rise to incomplete products; this means that the low melt flow index did not fill the whole mold cavity. The high viscosity may also give rise to depression, withdrawal and ripple the surface location.
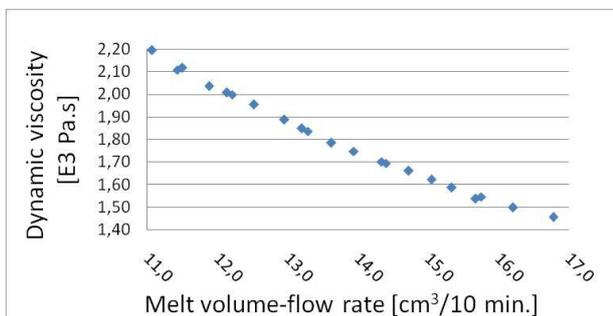

Fig. 4. Dependence of dynamic viscosity and MVR

The shear stress τ causes the liquid to flow in a special pattern. A maximum flow speed v_{max} is found at the upper boundary. The speed drops across the gap size y down to $v_{min} = 0$ at the lower boundary contacting the stationary plate. Laminar flow means that infinitesimally thin liquid layers slide on top of each other, similar to the cards in a deck of cards. One laminar layer is then displaced with respect to the adjacent ones by a fraction of the total displacement encountered in the liquid between both plates.
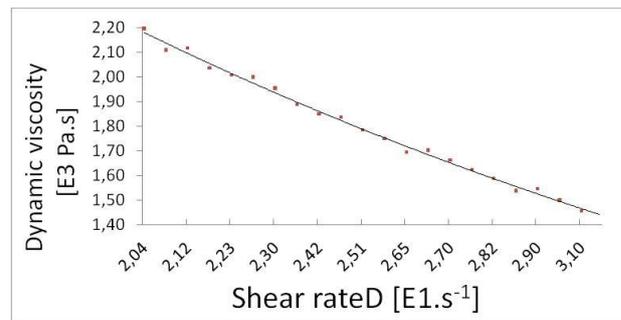

Fig. 5. Dependence of dynamic viscosity on shear rate

The chart shows that increasing the shear rate there is a reduction of viscosity. The cause of decline in viscosity, more or less developed macromolecules move easier. By reducing the temperature the melt viscosity increases. In practice, this means that the higher the value of the melt flow index, melt better then flows to all parts of the mold, especially in smaller and narrower parts.

4. CONCLUSION

As we can see on the charts of the different dependencies the addition of recycled material greatly influenced different material properties. All of these material properties are an important indicator in the processing of plastics injection molding technology. Based on determination of the addition of recycled material in pure material and its impact on the MVR we can say that the maximum limit of added recycled material is 30 to 35%. This article originated as a result of the cooperation of our department and company dealing in plastics processing technology.

5. ACKNOWLEDGEMENTS

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