Rheological Behavior Modelling of Composite Materials used in Engineering Industry

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Abstract **– The paper deals with modelling of rheological behavior of composite materials reinforced with fabric from used tires. By this method was analyzed the melt flow rate (MFR) and melt volume rate (MVR) for composite material with 10% fabrics by modeling of rheology system, using statistics concepts and language. The matrix of composite material is thermoplastic, namely polyvinyl butyral (PVB), which is a component in safety car glass. The results help for determination of the quality testing of materials and quality of the manufacturing processes used in engineering industry.**

Keyword **– rheology, modelling, MFR, MVR, composite**

1. Introduction

Saving natural resources and development of new materials is the first and essential step. The use of secondary raw materials saves the primary raw materials. One of the commodities are used tires, therefore tires, which do not meet the requirements specified parameters of the relevant regulations on road safety [1]. The used tires are gaining valuable raw material, which is the rubber crumb. Separate steel parts are also used in the engineering and the metallurgical industries [2]. The last component of used tires is fabric. The important properties are sound absorption, the absorption capacity, thermal properties, flexibility and elasticity. From the present situation it is clear that research and testing of this material are more focused on the rubber compound which is widely used as an ingredient in asphalt, concrete filler, base layers of roads, railway crossings, coatings, paints, running tracks, playgrounds etc.. The components of the recovered tires are still defined as a valuable source of raw materials, as well as viable means to achieve sustainable growth and development. [2]. Actually, recycling plays in European Union an important role.[2],[3] Existing and potential users are inclined to use secondary materials in comparison to the traditional, often find that it is much more economical and environmental advantageously[3]. Understanding of recirculation vortices in flows of polymer modelling solutions and melts through contraction geometries have been the subjects of many scientific papers, over the last 50 years. By this process technology, we detected the rheological properties of this material, specifically the MFR (Melt Flow Rate) and the MVR (Melt Volume Rate) [4]. In the theoretical field rheology is a science that deals with the flow properties of materials under the influence of deformation. Deformation is defined as relative shift points in the body under load. Rheology is an useful technique of measuring the viscoelastic materials using oscillating properties of procedures, the dynamic and the mechanical analysis [5],[6]. Readings indicate the difference between the viscous component (referred to as piston) and the elastic component (referred to as spring) at a shear load of material. Generally, rheology is the branch of physics and deals with material flow deformation under the external forces [4], [5].

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2. Input material and measurement process

During the testing of the rheological properties were used the following materials and equipment:

- Fabrics from used tires (Fig.1)
- Polyvinyl butyral (PVB) in granulated form (Fig.2)
- Zwick / Roell Mflow (Fig.4)

Fabric from used tires, was achieved by cleaning process on the vibrating screen. The analysis of the vibration screen is known in the following results, which are shown in Table 1. The analysis was performed by vibrating screen. [1] Another important material in our research is polyvinyl butyral (PVB) (Fig.2). The homogenization was prepared by the kneading equipment Brabender. We achieved the desired mix needed to create a composite (Fig.3). [1] Homogenization of mixtures was conducted at 150°C, duration 30 min, torsion moment 18 1/min and the machine temperature is 200°C.

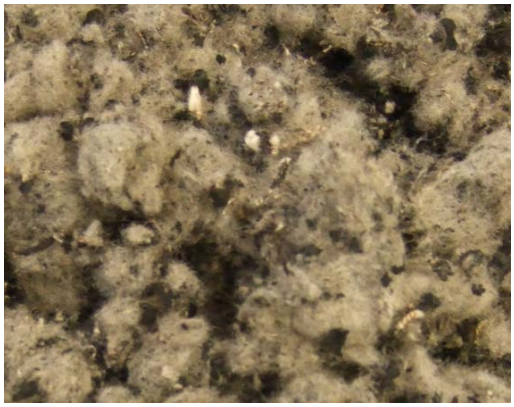

Figure 1. Fabrics from used tires

Figure 2. Granulated polyvinyl butyral

Figure 3. Composite material PVB and fabrics from used tires after homogenization

Figure 4. Zwick / Roell Mflow (Germany)

The following Table 1. describes the measurement characteristics.

Table 1. Measurement parameters for composite materials

Measurement parameters	Value
Conditions according to standard	D (190°C ; 2,16kg)
Measurement temperature	190°C
Maximum load	2,16kg
Tolerance	2,5 %
Standard	DIN ISO 1133

By the rheological modeling analysis we determined the melt flow index. We needed PVB samples weighing approx. 4g. According to the standard we set the temperature to 190°C and the piston load weighing was 2,16kg. Before filling the cylinder material, we set the playing field, where we set the number of relevant cuttings into 3 pieces, the time difference between cuttings was 30s. Cylinder apparatus was filled with materials weighing 4g, and during the performance a parting rod was constantly used, whereby there was a better homogenization of the material and prevention of the presence of air, which could cause the presence of air bubbles in the sample. The temperature during the addition of the material fell a few °C, therefore it was necessary to wait until the temperature again reached the required 190 °C. During the work temperature is material lowered into the cylinder piston, which in our case was charged 2,16kg weight according to the standards [7]. During the measurements was used the software, that is part of the apparatus, separated cuttings that meet the required properties [8], [9]. After the time required for analysis of our samples, the individual cuts that comply with the conditions weighed to the nearest 1 mg. After measurements was determined MFR (Melt Flow Rate) and MVR (Melt Volume Rate) determination.

3. Results and discussion

After the rheological testing we achieved the next statistical results for the PVB material and for the composite reinforced by 10% of fabric mass. The following Table 2. shows the measurement results for PVB material.

Table 2. Measurement results for PVB

No.	Sample	Segment	MFR [g.10min^{-1}]	$\overline{MFR}$ [g.10min^{-1}]	MVR [cm^3.10min^{-1}]	$\overline{MVR}$ [cm^3.10min^{-1}]	Material Mass [g]
1	2	1	1,51		2,14		
	3	2	1,47	1,48	2,08	2,10	0,2962
	4	3	1,45		2,06		
2	1	1	1,84		1,99		
	3	2	1,88	1,85	2,04	2,01	0,2842
	4	3	1,85		2,00		
3	3	1	1,88		2,18		
	4	2	1,82	1,84	2,11	2,14	0,3017
	5	3	1,83		2,12		

The following Table 3. describes the results for composite materials reinforced with 10% fabrics from used tires. Melt flow rate for these materials is 0,67g.10min^{-1}for first measurement; next measurement for composite material is 0,63g. 10min^{-1}. MVR for 10% fabrics in composite materials is 0,75cm^3. 10min^{-1} , the second measurement is 0,68 cm3.10min^{-1} .

Table 3. Measurement results for composite materials

No.	Sample	Segment	MFR [g.10min^{-1}]	$\overline{MFR}$ [g.10min^{-1}]	MVR [cm^3.10min^{-1}]	$\overline{MVR}$ [cm^3.10min^{-1}]	Material Mass [g]
1.	2	1	0,66		0,74		
	4	2	0,66	0,67	0,74	0,75	0,104
	5	3	0,69		0,76		
2.	4	1	0,62		0,68		
	7	2	0,62	0,63	0,68	0,68	0,0976
	8	3	0,63		0,68		

In general we can say, the flow curves and rheological properties of processed thermoplastic constants allow reliable comparison of flow properties of different types of plastic. Since this is a test of technology designed primarily to assess the suitability of using polymeric materials to manufacture parts of the design.

4. Conclusion

Determination of melt flow index is practically important and generally suitable for materials quality and quality of the manufacturing process [7]. MFR and MVR depend on shear rate. Shear rate in this test is much lower than normal production conditions. The aim of our measurements was to determine the flow index for polyvinyl butyral and compare it with a Melt Flow with materials manufactured with polyvinyl butyral homogenization with 10% of fabrics from used tires. Knowledge of MFR index will serve for further studies regarding the evaluation of composite materials based on fabrics. From this measurement it is to show recycled PVB material without filler. Material has MFR value 0,65g. 10 min^{-1}, MVR value is 0,72 cm3.10min-1 and for the blend are the values of MFR 1,72 g.10min-1 and MVR 2,08cm3.10min-1. The filler in our composite material- fabric from waste tires has a compact function in this blend. The main benefit is the use of two secondary raw materials and creating a new material with a diversity of applications and usability. Processed results help to further investigate

this issue in terms of knowledge about the composites. After the testing is clearly, this material is possible to use for the molding technology. The testing of these composites is more important for the future using of this product in the different areas, mainly in the engineering industry, esp. in the automotive industry.

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