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Renate Plesuma and Laimonis Malers*

Correlation between some technological parameters and properties of composite material based on recycled tires and polymer binder

Abstract: The present article is dedicated to the determination of a possible connection between the composition, specific properties of the composite material and molding pressure as an important technological parameter. Apparent density, Shore C hardness, compressive modulus of elasticity and compressive stress at 10% deformation was determined for composite material samples. Definite formation conditions – varying molding pressure conditions at ambient temperature and corresponding relative air humidity were realized. The results obtained showed a significant effect of molding pressure on the apparent density, mechanical properties of composite material as well as on the compressive stress change at a cyclic mode of loading. Some general regularities were determined - mechanical properties of the composite material, as well as values of Shore C hardness increases with an increase of molding pressure.

Keywords: recycled tires; polymer binder; composite material; properties; molding pressure

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1 Introduction

The utilization of scrap tires still is remarkably important from the viewpoint of relieving the environment of non-degradable waste [1]. It is a common knowledge that the most promising way of scrap tires reuse is in combination with polymer binder and production of composite material [2–4]. The authors have previously conducted studies of composition and technology of manufacturing composite material using mechanically grinded scrap tires and polyurethane type binder [5, 6]. It was elucidated that the mechanical properties of the composite material are highly dependent not only on the composition of material and the type of polymer binder used, but also on specific technological parameters such as, formation time, temperature etc. [7, 8].

The objective of this paper is to present additional research and it is devoted to estimation of a possible connection between the composition, certain mechanical properties of the composite material and the molding pressure as an important technological parameter. The authors of the article do not have information at their disposal to confirm, that a special evaluation has been carried out as regards the significance of the molding pressure as technological parameter and influence of this parameter on the properties of the similar composite material based on scrap tires.

2 Materials and investigation methods

Apparent density AD (LVS EN 1602), Shore C hardness (ISO 7619, ISO 868), compressive modulus of elasticity (E_c) and compressive stress at 10% deformation ($\sigma_{10\%}$) were determined according to LVS EN 826. Six parallel composite material samples were tested for each test parameter. Mechanically grinded scrap tires and polyurethane – type binder with isocyanate group content of 2,42%. were used. Uniform samples of the composite material were prepared by mechanical mixing of the above mentioned components. Uniform samples of the composite material were prepared under defined conditions: formation temperature (18-22°C) and corresponding relative air humidity, at four molding pressure P values ranging from 0.004 to 0.02 MPa and permanent molding time (24 h.). Content of polymer binder $C_{pol.}$: 8, 13, 18 and 23 wt.%.

***Corresponding Author: Laimonis Malers:** Department of Polymer Materials Technology, Riga Technical University, P.Valdena Street 3, LV 1048, Riga, Latvia, E-mail: laimis@ktf.rtu.lv
Renate Plesuma: Department of Polymer Materials Technology, Riga Technical University, P.Valdena Street 3, LV 1048, Riga, Latvia

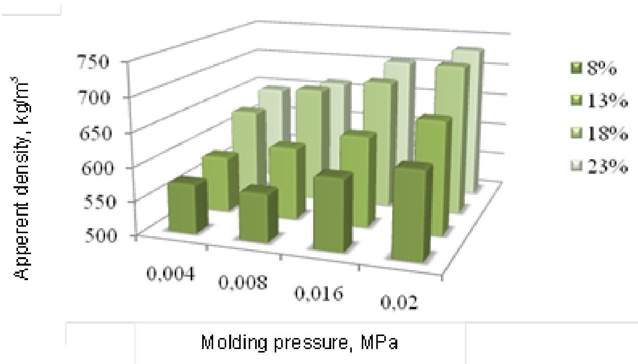

Figure 1: Variation in apparent density with molding pressure and content of polymer binder (8, 13, 18 and 23 wt.%).

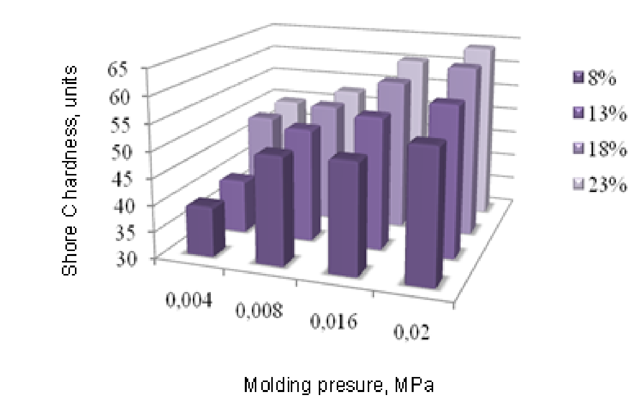

Figure 2: Shore C hardness dependence on molding pressure and content of polymer binder (8, 13, 18 and 23 wt.%).

3 Results and discussion

The authors have previously conducted studies of composition and technology of manufacturing composite material using mechanicaly grinded scrap tires and polyurethane type binder [5–7]. According to these studies it was declared, that composite material from rubber crumb and polymer binder in general must be considered as heterogeneous system due to polydisperity of used non-fractioned rubber particles. Therefore, more compact arrangement of structures must be expected if molding pressure of the samples arrises. In this connection increase of mechanical properties like compressive stress, hardness and also apparent density (AD) of the composite material also must be expected. The influence of certain technological parameters (molding temperature and time, relative air humidity etc.) during the preparation of composite material samples (based on polymer binder and grinded scrap tires) on the properties of composite material was demonstrated also by investigators in [9–11]. It was declared that the above mentioned technological parameters have a direct influence on the mixing time of components as well as on the formation time of samples and mechanical properties of material.

The results show that the values of apparent density (AD) really increase upon increasing the molding pressure (Figure 1).

This can possibly be explained by the reduction of voids and therefore the formation of a more compact structure of the composite material.

The correlation between the characteristics and properties of the composite material with the binder content, used in the production of the samples, has been investigated and demonstrated in several previous investigations [5, 6, 8]. It was noted, that not only the reactivity of selected polymer binder, but also the potential of obtaining a more compact structure with increasing of the binder content in the material is responsible for the suggested correlations. The obtained AD values with the increase of binder content at a constant molding pressure at all selected levels confirms this conclusion in all range of the polymer binder content (Figure 1). The results obtained showed a significant effect of molding pressure not only on the apparent density, but also on selected mechanical properties of composite material and compressive stress change at cyclic mode of loading. Some general regularity was determined - values of Shore C hardness increases with an increase of the molding pressure independently of the polymer binder content probably due to the formation of a more compact structure of the material and reducing voids (Figure 2).

Taking into account increase of the apparent density with rising of molding pressure, also increase of compressive modulus of elasticity and compressive stress at 10% deformation were anticipated. Samples of composite material for testing were prepared as mentioned above. It was demonstrated (Table 1), that similar regularities are taking place - mechanical properties of the material increase at higher molding pressure values and with the increase of content of the polymer binder.

It can be explained with the formation of a more denser structure and thereby higher stiffness of the composite material as a consequence of the decreasing of incorporated air in the material by applying higher molding pressure and concentration of the polymer binder. At the same time it must be also underlined, that the detected regularity can be explained by the fact, that with an increase of the polymer binder content thereby a higher crosslinking degree of the composite material was ensured. Influ-

Table 1: Variation in compressive modulus of elasticity (E_c) and compressive stress at 10% deformation ($\sigma_{10\%}$) with molding pressure (P) and polymer binder content (C_{pol}).

P, MPa	$C_{pol.}$, wt.%	E_c, kPa	$\sigma_{10\%}$, kPa
	8	176.74	10.55
	13	239.33	14.64
0.004	18	359.38	19.65
	23	440.78	34.74
	8	219.1	15.94
	13	344.66	20.65
0.008	18	411.89	24.83
	23	461.64	26,00
	8	321.47	19.03
	13	498.83	23.96
0.016	18	729.54	33.50
	23	821.45	40.14
	8	353.11	21.40
	13	55.27	34.62
0.02	18	721.19	35.49
	23	1014.23	48.80

ence of the material crosslinking degree on mechanical properties of the composite material by changing reactivity and quantity of selected polymer binder was demonstrated in our previous study [12].

After testing the samples in the cyclic mode of loading (at 10% deformation) it was found, that better results can be achieved from the point of mechanical resistance of the material when formation of samples is carried out at elevated molding pressure values (Figure 3).

The results presented in Figure 3 showed, that a more essential decrease of compressive stress is ascertained during the first cycles of deformation. It can be explained with the degradation of the weaker intermolecular bonds

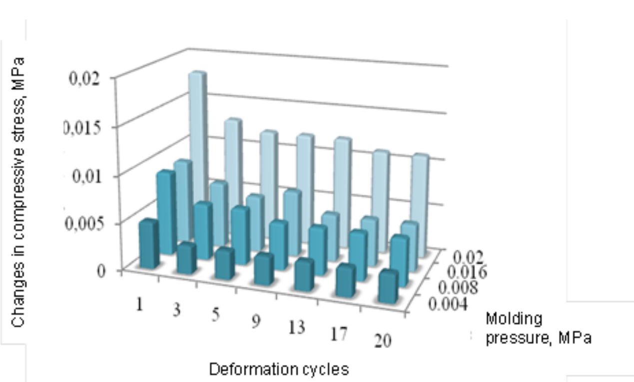

Figure 3: Changes in compressive stress at 10% deformation with number of deformation cycles of composite material and molding pressure. Polymer binder content 18 wt.%

between the rubber particles and polymer binder in the material during the first cycles of deformation. It is probably linked to the presence of more sensitive intermolecular bonds to compressive loading in the material and accumulation of defects during the cyclical mode of deformation leading to the same decrease of mechanical resistance. After the first three deformation cycles changes in compressive stress are less intrinsic and the material remains practically with similar compressive strength values if the moulding pressure of the composite material is constant. As it was shown in Figure 3, higher compressive stress values after an initial loss of strength during the first cycles of deformation presented material samples obtained at higher applied moulding pressure during the formation of the composite material.

4 Conclusion

It is possible to improve the mechanical properties of the composite material not only by altering the composition of the composite material, but also by changing such a technological parameter as the formation molding pressure.

The test results of samples in the cyclical mode of loading demonstrated a regularity, namely that higher values of residual mechanical resistance of the material achieved when the formation of samples is carried out at elevated molding pressure.

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