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Correlation Between Composition and Properties of Composite Material Based on Scrap Tires

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Abstract: **Purpose of present work is to investigate mechanical and insulation properties of the composite material based on scrap tires and polyurethane-type binder in correlation with composition of composite material. The studies of material's hardness must be considered as an express-method for estimation of the selected mechanical properties (E and ccompressive stress) of the composite material without direct experimental testing of given parameters. It was shown that composite material must be recommended as insulation material for practical application.**

Keywords: **composite, polyurethane, scrap tires, insulation, properties**

I INTRODUCTION

The utilization of scrap tires still obtains a remarkable importance from the aspect of unloading the environment from non-degradable waste [1]. One of the most perspective ways for scrap tires reuse is a production of composite materials (floor mats, tiles, insulation materials etc.) [2, 3]. The present work must be considered as an extension of previous investigations [4]. It is dedicated to the clarification of possible correlation between composition and definite properties of the composite material based on scrap tires and polyurethane-type binder. Therefore correlation between polymer binder content, some technological parameters and selected properties of the material was clarified. Hereby apparent density, compressive stress at 10% deformation, compression modulus of elasticity in statistic and cyclic mode of loading, Shore hardness and sound insulation properties were the parameters of the special interest of present investigation. It was cleared up that purposeful variation of material composition lead to predictable mechanical and insulation properties of the composite material.

II MATERIALS AND METHODS

Scrap tires, mechanically grinded at room temperature (particle size from 0.2 till 8.0 mm) and in the liquid nitrogen (particle size from 0.25 till 3.0 mm), and polyurethane – type binder were used. Uniform samples of the composite material were prepared by mechanical mixing of above mentioned components under defined conditions such as temperature T (C^0), relative humidity RH (%), molding pressure P (MPa) and time t (hours). The following characteristics of the composite material were investigated for selected samples in correlation with apparent density AD (kg/cm^3) (prEN1602): compressive stress $\sigma_{10\%}$, compressive modulus E (EN 826) under specified statistic and cyclic deformation condition, stroke and sound absorption (respectively EN ISO 140-7 and "Brüel & Kjær" method) and hardness (Shore scale, according to ISO 7619 and ISO 868).

III RESULTS AND DISCUSSIONS

The direct influence of polymer binder content BC (wt. %) on the investigated parameters was observed as it can be seen in Fig. 1. Non-fractionated rubber fines with different particle size were used for manufacturing of test samples. The higher value of apparent density AD was observed in the case when cryogenically grinded rubber particles were used in the preparation of composite material samples. This relationship can be explained with differences in the shape of grinded rubber particles likely because of in liquid nitrogen grinded rubber particles have more regular (close to spherical) shape which leads to higher packing degree of composite material samples.

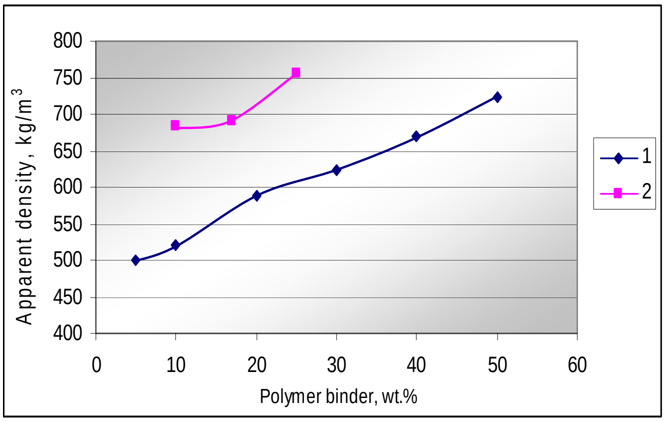

Fig. 1. Correlation between composition and AD of composite material (1-rubber grinded at room temperature, 2- in liquid nitrogen).

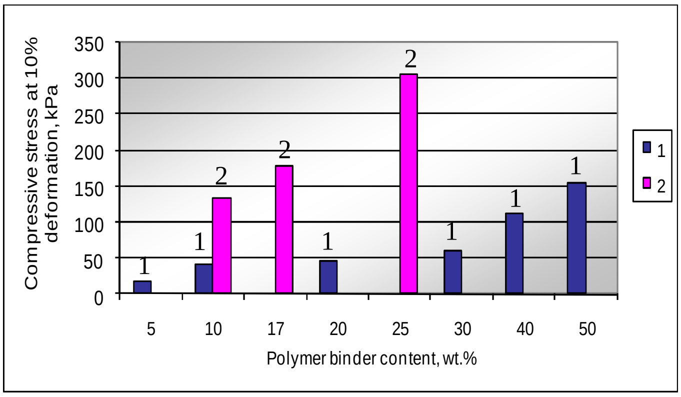

Fig. 2. Correlation between composition and compressive stress at 10% deformation (σ_{10}) of composite material (1-rubber grinded at room temperature, 2- in liquid nitrogen).

Strong influence of composite material composition on $\sigma_{10\%}$ and E was shown in selected interval of the polymer binder content. Gradual increase of the compressive stress values was observed for tested samples with changes in composition of the composite material (Fig. 2.) regardless to the type of the grinded rubber. However further increase of binder content (more than 50 wt. %) was not acceptable due to the fact that the material becomes less homogeneous.

The influence of the material composition to the compressive modulus of elasticity E (at 10% deformation) is represented in Fig. 3. A creation of material composition including cryogenically grinded rubber leads not only to higher values of AD as it was shown in Fig. 1., but also to relatively higher stiffness of material potentially due to specific shape of grinded rubber particles.

Strong influence of composite material composition on $\sigma_{10\%}$ was shown (at selected interval of polymer binder content) in the case if deformation of samples is carried out at the cyclic deformation mode (till 20 cycles of deformation) as it is demonstrated in the Fig. 4.

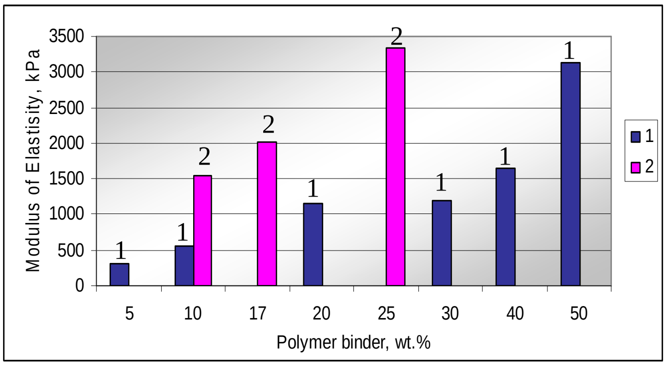

Fig. 3. Effect of material composition (binder content from 5 till 50 wt. %) to the compressive modulus of elasticity E (at 10% deformation; 1- rubber grinded at the room temperature, 2- in liquid nitrogen).

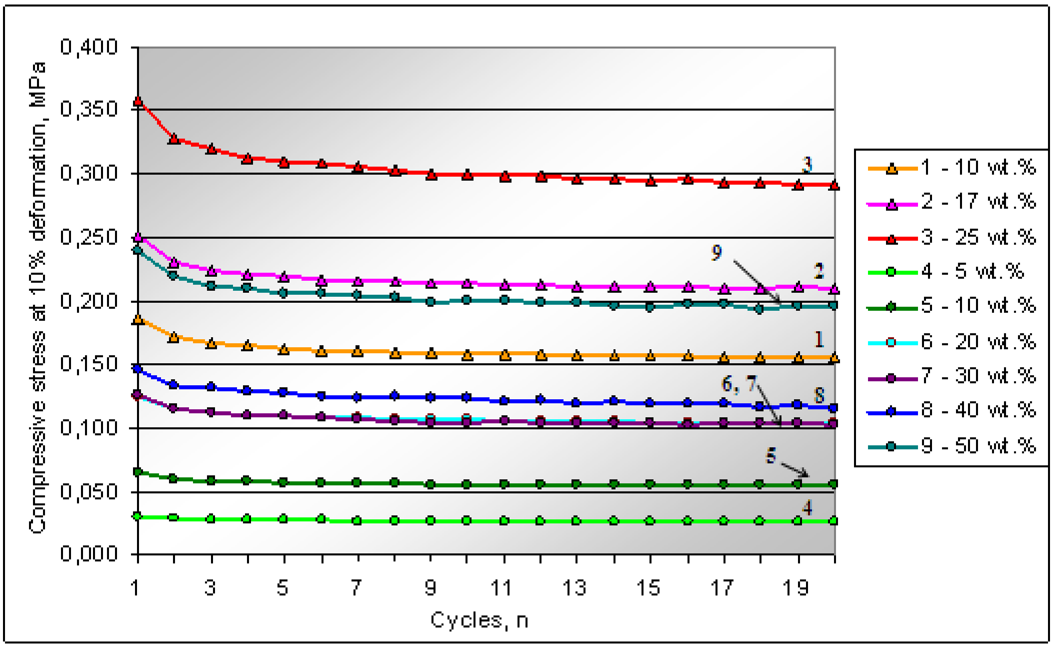

Fig. 4. Effect of loading time (cycles) on compressive stress σ_{10} of composite material at different polymer binder contents: rubber grinded at room temperature (No. 4 - 9), rubber grinded in liquid nitrogen (No. 1 – 3).

According to Fig. 4. it is important to note that σ_{10} does not keep constant values if number of deformation cycles increase. It seems that observed slight decrease of σ_{10} is connected with some irreclaimable structural changes of material under mechanical load – occurring mostly in the first 10 cycles.

As it was cleared up a remarkable increase of the compressive stress at 10% deformation as well as compression modulus of elasticity with variation of the material composition can be explained by growth of the composite material integral stiffness if the content of the polymer binder has been increased. It was confirmed also by investigation of the Shore hardness (HD) of the prepared samples of the composite material (Fig. 5.).

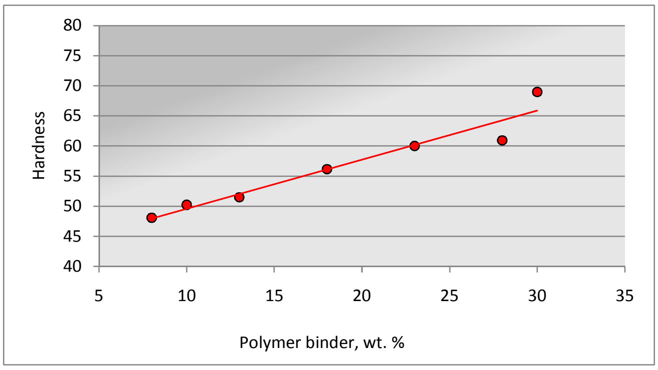

Fig. 5. Effect of material composition on the Shore hardness (rubber mechanically grinded at the room temperature).

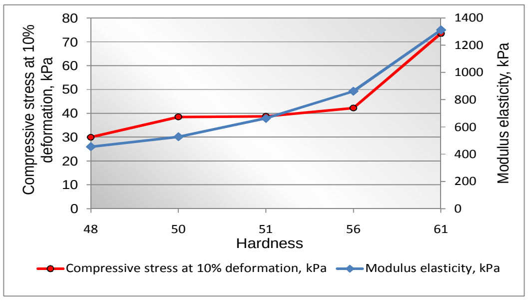

Fig. 6. Correlation between hardness and E or $\sigma_{10\%}$ (rubber grinded at the room temperature)

Correlation between hardness and the compressive stress at 10% as well as the compressive modulus of the composite material is demonstrated in Fig. 6. Thereby hardness of samples should be considered as an express-method for estimation of the selected mechanical properties ($\sigma_{10\%}$, E) of the composite material without direct experimental testing of given parameters.

Stroke and sound absorption properties of selected material samples were estimated for better understanding potential field of practical application of the designed composites. It was shown that composite material demonstrates a significant stroke-sound absorption possibility and sound transmission loss effect for selected samples in a wide range of frequencies and can be used as an insulation material for practical application at definite circumstances. The results obtained are demonstrated in Fig. 7 and Fig. 8.

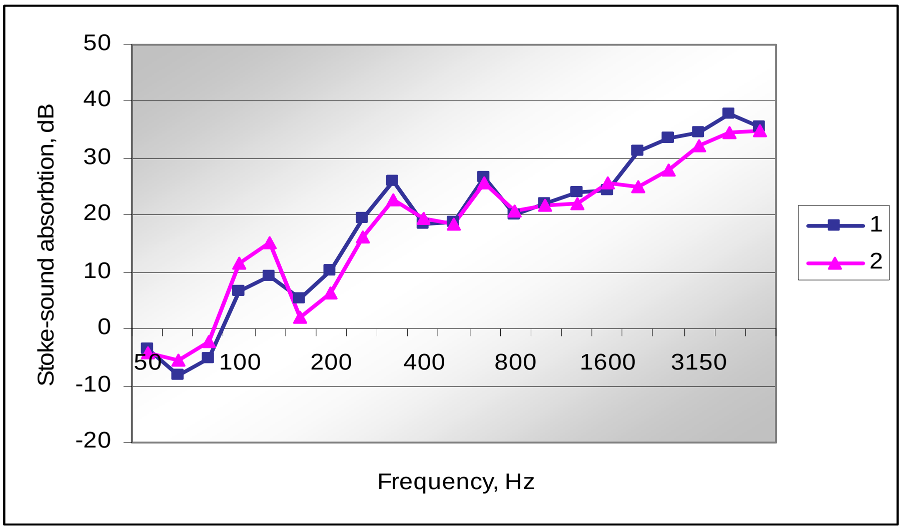

Fig. 7. Variations of composite material relative stroke-sound absorption with frequency (Hz) (1- rubber grinded at room temperature, polymer binder 10 wt.%; 2- rubber grinded in liquid nitrogen, polymer binder 17 wt.%).

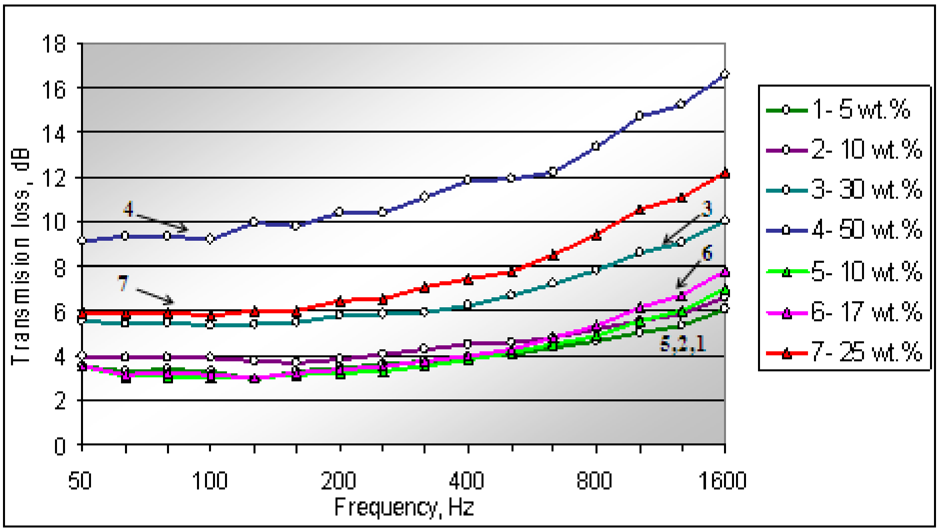

Fig. 8. Variations of composite material sound transmission loss with frequency (Hz). Samples: rubber grinded at room temperature, polymer binder content from 5 till 50 wt.%.; in liquid nitrogen, polymer binder content from 10 till 25 wt.% ; No. 1- 4 and 5- 7 correspondingly.

IV CONCLUSIONS

It was demonstrated how to produce composite material from mechanically grinded (at room temperature and in liquid nitrogen) scrap tires and polyurethane-type binder with defined mechanical and insulating properties.

Close correlation between composition of material and selected properties of composite material was demonstrated. All tested samples possessed remarkable insulating properties in all selected range of frequencies (independently from the material composition and used rubber scrap).

ACKNOWLEDGEMENTS

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REFERENCES

1. J.E.Mark, B.Erman, R.Erich. *The Science and Technology of Rubber. 3 d.;* Ed., Elsvier Inc., USA, 2006, 763 pp.
2. H.F.Lund. *McGraw – Hill recycling handbook;* R.R. Donelly & Sons Company, USA, 1993, 18.2-18.35 ch.
3. A.H.Hughes, S.Pennington. Precoated rubber crumb for composites. *Pat.* GB 2364708.
4. L.Malers, R.Plesuma and L.Locmele. Composite Material Based on Recycled Tires. *Mech. Compos. Mater.,* **2009**, 45(1), 1-6.

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Laimonis Mālers, Renāte Plēsuma, Liena Ločmele, Mārtiņš Kalniņš. Nolietotu riepu gumijas smalknes saturoša kompozītmateriāla sastāva un īpašību korelācija.
Nolietotu riepu utilizācija ieņem nozīmīgu vietu materiālu reciklēšanas tehnoloģijā un politikā, ņemot vērā to, ka riepas jāvērtē kā videi nedraudzīgs un sadalīties nespējīgs piesārņojums. Viens no perspektīviem nolietotu riepu utilizācijas virzieniem ir to sasmalcināšana un izmantošana kompozītmateriālu izgatavošanā. Pētījuma mērķis ir noskaidrot savstarpējo korelāciju starp kompozītmateriāla, kas sastāv no mehāniski istabas temperaturā sasmalcinātas nolietotu riepu gumijas smalknes un poliuretāna tipa saistvielas, sastāvu un tā mehāniskajām un akustiskajām īpašībām. Pastiprināta uzmanība tika pievērsta sekojošām kompozītmateriāla īpašībām - spiedes spriegumam un spiedes elastības modulim (EN826), cietībai (saskaņā ar Šora C klasifikāciju, ISO 7619), trokšņa un triecienvibrāciju absorbcijai (EN ISO 140-7). Tika novērtēts materiāla šķietamais blīvums (prEN1602) un šī parametra saistība ar kompozītmateriāla sastāvu. Noskaidrota visu izvēlēto parametru cieša saistība ar kompozītmateriāla sastāvu. Novērtēta materiāla spiedes pretestība cikliskos slogošanas apstākļos un konstatēts, ka materiāla spiedes pretestība samazinās tikai pirmo slogošanas ciklu ietvaros. Eksperimentāli noteiktās cietības vērtības var tikt izmntotas kā korelatīvi raksturojošs parametrs, ar iespēju novērtēt kompozītmateriāla mehāniskās īpašības (E un spiedes spriegumu), šos parametrus eksperimentāli paraugiem tieši netestējot. Tika noskaidrots, ka kompozītmateriāls var tikt izmantots kā izolācijas materiāls, jo uzrāda atzīstamu trokšņa un mehānisko triecienvibrāciju absorbcijas īpašības plašā frekvenču diapazonā.

Лаймонис Малерс, Ренате Плесума, Лиена Лочмеле, Мартинш Калниньш. Корреляция между свойствами и составом композиционного материала на базе измельченных шин.
Утилизация изношенных шин занимает значительное место среди технологий и политики рециклизации материалов, с учетом того, что шины должны расцениваться как недружелюбный природе и неспособный разлагаться материал.Одним из перспективных направлений утилизации изношенных шин является их дробление и использование для изготовления композиционных материалов.Цель исследования – выяснить взаимную корреляцию между составом композиционного материала, состоящего из механически измельченных шин и связующего полиуретанового типа, и механическими, а также акустическими свойствами материала.Усиленное внимание было уделено следующим свойствам композиционного материала: прочности и модулю упругости при сжатии (EN 826), твердости (ISO 7619), абсорбции звука и вибраций (EN ISO 140-7). Установлена кажущаяся плотность (prEN1602) и взаимосвязь этого параметра с составом композиционного материала. Оценено сопротивление к сжатию в условиях циклического нагружения материала и выяснено, что прочность понижается только при первых циклах испытания. Экспериментально установленные значения твердости материала могут быть использованы как коррелятивные параметры для оценки других механических свойств композиционного материала (модуля упругости и прочности при сжатии) без экспериментального тестирования этих параметров. Выяснено, что композиционный материал может быть использован с практической точки зрения в качестве изоляционного материала, так как показывает хорошие абсорбционные свойства звука и механических вибраций в широком диапазоне колебаний .