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Tensile and Morphological Properties of Waste Tire Rubber Granule/Polyester Polymer Matrix Composite

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Abstract

In this study, waste tire rubber granules were used as filler material for the fabrication of polymer matrix composite samples. The polyester resin which is one of the most preferred matrix materials and recycled waste tire rubber granules were combined at varying ratios with the open molding method. The samples were characterized experimentally by conducting tensile and hardness tests. The morphological properties of the specimens were examined with scanning electron microscope images. The study revealed that the addition of untreated waste tire rubber granules to polyester resin decreases the tensile and yield strength values, while it causes to increase in elongation and ductility of the material. The morphological examinations showed that waste rubber granules and polyester resin have poor interfacial adhesion and thus the waste rubber granules should be properly treated to be used as filler material. The study indicated that waste tire rubber granule/polyester composites can be used for non-structural applications with the benefits of using less fossil sourced raw materials and contributing to the decrement of environmental pollution.

Keywords: Composite material, Waste rubber, Mechanical properties, Polyester

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Atık Lastik Kauçuk Granül/Polyester Polimer Matris Kompozitinin Çekme ve Morfolojik Özellikleri

Öz

Bu çalışmada, polimer matrisli kompozit numunelerin üretimi için dolgu malzemesi olarak atık lastik kauçuk granülleri kullanılmıştır. En çok tercih edilen matris malzemelerinden biri olan polyester reçine ile geri dönüştürülmüş atık lastik kauçuk granülleri açık kalıplama yöntemi ile farklı oranlarda birleştirilmiştir. Numuneler, çekme ve sertlik testleri yapılarak deneysel olarak karakterize edilmiştir. Numunelerin morfolojik özellikleri taramalı elektron mikroskobu görüntüleri ile incelenmiştir. Çalışma, polyester reçineye işlenmemiş atık lastik kauçuk granüllerinin eklenmesinin çekme ve akma dayanımı değerlerini düşürürken, malzemenin uzama ve sünekliğinin artmasına neden olduğunu ortaya koymuştur. Morfolojik incelemeler, atık kauçuk granüllerin ve polyester reçinenin ara yüzey yapışmasının zayıf olduğunu ve bu nedenle atık kauçuk granüllerin dolgu malzemesi olarak kullanılmak üzere uygun şekilde işlenmesi gerektiğini göstermiştir. Çalışma, atık lastik kauçuk granül/polyester kompozitlerinin, daha az fosil kaynaklı hammadde kullanılması ve çevre kirliliğinin azalmasına katkıda bulunması gibi faydaları ile yapısal olmayan uygulamalarda kullanılabileceğini göstermiştir.

Anahtar Kelimeler: Kompozit malzemeler, Atık kauçuk, Mekanik özellikler, Polyester

1. INTRODUCTION

Today, it is a well-known fact that the population of the world is increasing and thus the consumption of goods and energy is increasing exponentially. The limited sources of raw materials and energy have been a major issue all over the world. Since the raw materials and energy sources are limited, it is very critical to employ sustainable production [1]. One of the most promising solutions for this problem is the recycling of waste materials which has many benefits both economically and environmentally [2]. The recycled materials can be directly used to produce new products or they can be employed as the raw material in composite materials with proper treatment. Composite materials have been one of the most important material categories in recent years. Composites have critical advantages in comparison with conventional engineering materials such as high specific strength and modulus, good corrosion resistance, material variety, and tailorable properties [3]. The variety of products has significantly increased in the last decades and parallel to this increment the demand and need for new materials with discrete properties have been inevitable. Composite materials can be a combination of any type of conventional material with the aim of providing required material specifications that are not possible with monolithic materials. Especially, the applications where good mechanical properties and low weight is needed, composite materials are mostly preferred in material selection processes. Polymer matrix composites (PMCs) have a wider application area - due to their relatively low cost and easier production methods- than metal or ceramic matrix composites. The most common matrix materials are polyesters, vinyl esters, epoxies while the most common reinforcement materials are glass, basalt, carbon, and aramid fibers. Each type of matrix material and reinforcement material has a particular application area which is determined by the product specifications.

Recently many researchers have been studied on the fabrication and characterization of composite materials with waste materials. There are many types of waste materials that are studied by researchers. The authors mostly focused on particular type of wastes that are abundant and have a high potential of environmental pollution such as plastic wastes [4], construction/demolition wastes [5], agricultural/food wastes [6], and industrial wastes [7]. Besides those waste types, tire wastes have started to get attention since every year tonnes of tire wastes which are one of the alternative waste materials [8]. Currently, there are some applications to reuse the tire wastes but the ratio of reuse is not high enough for a sustainable environment. Lately, many authors have studied on using tire wastes in composite material fabrication [9-14].

In this study, the effects of the matrix/filler ratio of polyester/waste tire granule composites were investigated experimentally. Polyester/waste tire granule specimens were fabricated with 3 different matrix/filler ratios and the specimens were mechanically characterized.

2. MATERIAL AND METHODS

2.1. Materials

In this study, polyester resin and recycled waste tire granules were used as matrix material and filler material, respectively. In Table 1, the technical properties of the polyester are given. Methyl ethyl ketone peroxide (AKPEROX A60) was used as a curing agent and Cobalt(II) 2-Ethyl Hexanoate (AKCOBALT KXC6) was used as an accelerator. The recycled waste tire granules were obtained from a local supplier and they were used with no modification.

Table 1. Technical properties of the polyester resin (supplier data)

Type	Polyester	
Viscosity (cps)	350-450	Liquid Resin
Monomer content (%)	38-42	
Density (gr/cm^3)	1.1	
Tensile strength (MPa)	65	Cured Resin
Elongation at break (%)	2	

2.2. Fabrication of the Samples

The specimens were fabricated with the open molding method. To fabricate samples, firstly accelerator (0.2% wt.) and polyester resin were mixed and stirred to obtain a homogenous mixture. Afterward, the recycled waste tire granules were added to the mixture and stirred mechanically for 10 minutes. The hardener chemical (2% wt.) was added and 10 more minutes stirring was applied. After the homogeneous mixture is obtained, the mixture was poured into the open mold at room temperature. The specimens were cured at room temperature for 24 hours and after that, the specimens were removed from the molds. The specimen fabrication procedure was applied for each specimen and the schematic of the fabrication processes and testing is illustrated in Figure 1.

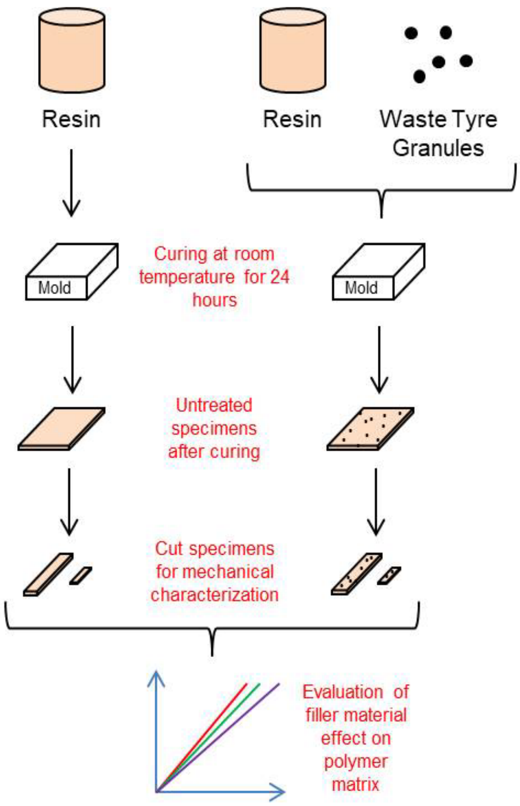


Figure 1. Schematic of the experimental fabrication and test procedure

4 different specimen types were prepared for the experimental studies. The material ratios of the specimens were given in Table 2. After the fabrication processes, the tensile, impact and hardness specimens were cut out from the samples.

2.3. Characterization of the Samples

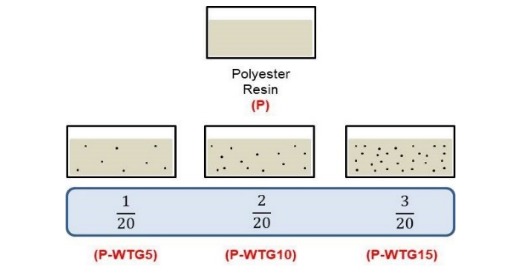
The prepared specimens were experimentally characterized to determine the effects of the filler ratios. Tensile tests were conducted with ALŞA Hydraulic (60 ton) mechanical testing device. The dimensions of the tensile specimens were 250 mm x 25 mm x 2.5 mm. The hardness values of the specimens were determined with Vickers Micro-Hardness test. 10 seconds dwell time and 0.3 kgf of the load were used for the hardness tests. The microstructures of the samples were examined with the scanning electron microscope (FEI Quante 650 FEG scanning electron microscope).

3. RESULT AND DISCUSSION

In Table 3, the tensile and hardness test results of the specimens are given. The results revealed that the addition of waste tires to polyester resin decreased the tensile and yield strength of the polyester resin while addition increased the elongation. With the increment of the waste tire granule amount, the strength values were further decreased. Tensile strength of the polyester resin was decreased 8.85%, 13.51%, and 16.19% for 100:5, 100:10, and 100:15 resin:waste tire granule ratios, respectively.

Table 2. Material ratios of the experimental composite samples

Specimen designation	Resin	Resin:waste tire granule
P	Polyester	100:0
P-WTG5		100:5
P-WTG10		100:10
P-WTG15		100:15

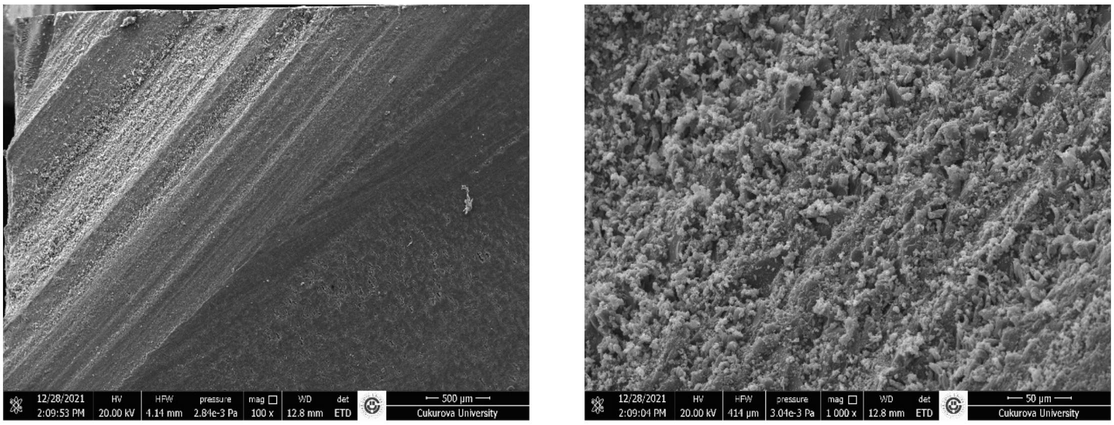


The decrement of the strength may be due to poor interfacial interphase between the rubber granules and the polyester matrix [15, 16]. The decrement of the strength values is a critical disadvantage for the application of these combination for a product. But also, it should be emphasized that using waste tire granule as a filler material for composite material decreases the usage of polymeric resins which are mainly fossil sourced raw materials. The results show a decrement in strength values and this indicates that these combinations are not feasible for structural applications where good mechanical properties are required. In addition to this fact, this combination can be utilized in applications where low cost and environmental issues are the primary considerations.

Table 3. Tensile test results

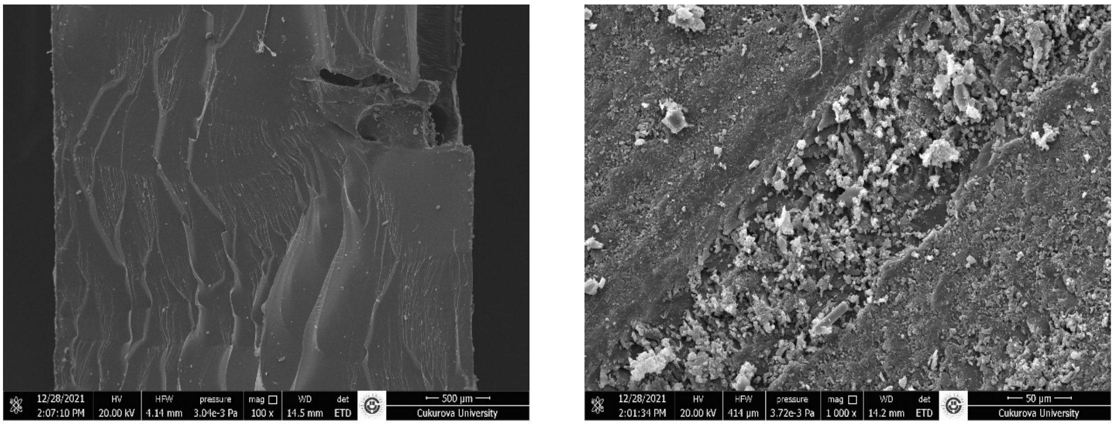
Specimen	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Tensile modulus (MPa)
P	51.46	62	1.95	3335
P-WTG5	45.20	56.51	2.15	3210
P-WTG10	43.96	53.62	2.28	3250
P-WTG15	41.82	51.96	2.35	3270

The SEM images (Figures 2 – 5) of the specimens after the tensile test were taken from the breaking points. The SEM images provide insights into the microstructures and the breaking mechanisms of the specimens. From Figure 2, it can be seen that the polyester resin has brittle nature and its breakage created significantly sharp faces. However, from Figures 3 – 4, it can be seen that the sharpness has been reduced with the addition of the rubber granules. These images also explain the increment of the elongation values with additional rubber granules.



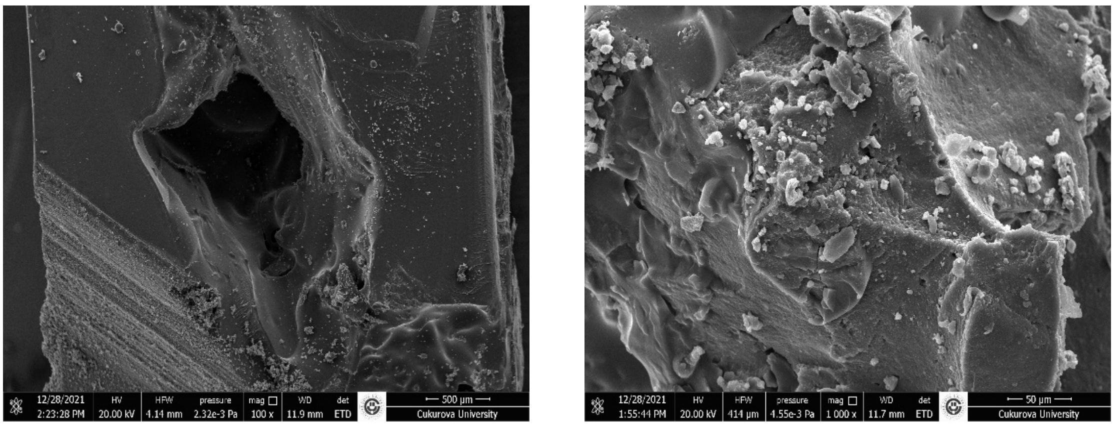
(a) (b)

Figure 2. SEM image of P a-100 X, b-1000 X



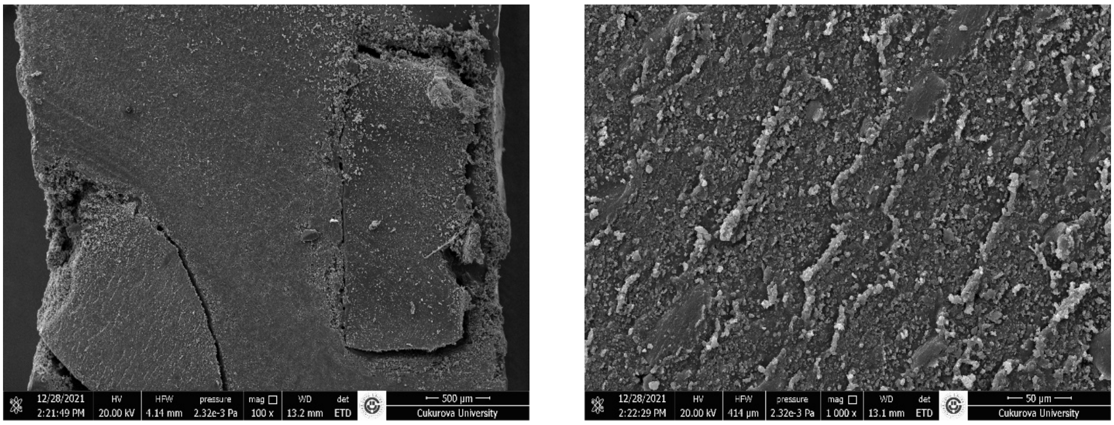
(a) (b)

Figure 3. SEM image of P-WTG5 a-100 X, b-1000 X



(a) (b)

Figure 4. SEM image of P-WTG10 a-100 X, b-1000 X



(a) (b)

Figure 5. SEM image of P-WTG15 a-100 X, b-1000 X

4. CONCLUSIONS

In this study, waste tire rubber granules were used as filler material to produce polymer matrix composite samples. The polyester resin was used as matrix material and three different ratios of waste tire rubber granules were employed to fabricate the experimental samples. The specimens were fabricated with the open molding method. Tensile and hardness tests were conducted to determine the mechanical properties of the specimens and SEM images were taken to examine the microstructures of the specimens. From the study, the following statements are concluded;

- Waste tire rubber granules can be used as filler material especially for non-structural applications since rubber granule addition to polyester matrix decreases the strength of the structure.
- Even the addition of waste tire rubber granules to the structure weakens the structure, but also it increases the ductility of the material.
- Untreated waste tire rubber granules and polyester matrix combination create poor interfacial adhesion which should be improved with proper treatment.
- Using waste tire rubber granules for composite material fabrication is a promising alternative solution for sustainable and environmental-friendly production by employing recycling and decreasing usage amount of the fossil sourced raw materials.

5. ACKNOWLEDGEMENT

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6. REFERENCES

1. Berger, C., Mattos, D.B., Amico, S.C., Farias, S., Coldebella, R., Gatto, D.A., Missio, A.L., 2020. Production of Sustainable Polymeric Composites Using Grape Pomace Biomass. Biomass Conversion and Biorefinery.
2. Taurino, R., Pozzi, P., Lucchetti, G., Paterlini, L., 2013. New Composite Materials Based on Glass Waste. Composites Part B-Engineering,. 45(1), 497-503.
3. Serin, H., Yildizhan, S., 2021. Tensile Properties and Cost-property Efficiency Analyses of Expanded Polystyrene/chopped Glass Fiber/epoxy Novel Composite. Journal of Mechanical Science and Technology, 35(1), 145-151.
4. Shahani, S., Zhongquan, G., Qaisrani, M.A., Ahmed, N., Yaqoob, H., Khoshnaw, F., Sher, F., 2021. Preparation and Characterisation of

Sustainable Wood Plastic Composites Extracted from Municipal Solid Waste. Polymers, 13(21).

5. Lahtela, V., Karki, T., 2021. A Study on the Effect of Construction and Demolition Waste (CDW) Plastic Fractions on the Moisture and Resistance to Indentation of Wood-polymer Composites (WPC). Journal of Composites Science, 5(8).

6. Vaisanen, T., Haapala, A., Lappalainen, R., Tomppo, L., 2016. Utilization of Agricultural and Forest Industry Waste and Residues in Natural Fiber-polymer Composites: A Review. Waste Management, 54, 62-73.

7. Gangwar, S., Pathak, V.K., 2021. A Critical Review on Tribological Properties, Thermal Behavior, and Different Applications of Industrial Waste Reinforcement for Composites. Proceedings of the Institution of Mechanical Engineers Part L-Journal of Materials-design and Applications, 235(3), 684-706.

8. Dwivedi, R.K., Bhaskar, J., Pandey, P., Kumar., S., 2017. Characterization of Non-metallic Waste Material Reinforced Polymer Composites. Materials Today-proceedings, 4(4), 5361-5369.

9. Yogeshwaran, S., Natrayan, L., Udhayakumar, L., Godwin, G., Yuvaraj, L., 2021. Effect of Waste Tyre Particles Reinforcement on Mechanical Properties of Jute and Abaca Fiber-Epoxy Hybrid Composites with Pre-Treatment. Materials Today-Proceedings, 37, 1377-1380

10. Revelo, C.F., Correa, M., Aguilar, C., Colorado, H.A., 2021. Composite Materials Made of Waste Tires and Polyurethane Resin: A Case Study of Flexible Tiles Successfully Applied in Industry. Case Studies in Construction Materials, 15(5).

11. Mousa, B.H., Azab, N.A, Bassioni, G., Abdellatif, M.H., 2021. Assessment of the Damage Resulting from Drilling Holes in Waste Tire Rubber Polyester Composite Laminates. Waste and Biomass Valorization, 12(7), 4069-4080.

12. Kosmela, P., Olszewski, A., Zedler, L., Burger, P., Piasecki, A., Formela, K., Hejna, A., 2021. Ground Tire Rubber Filled Flexible Polyurethane Foam-effect of Waste Rubber Treatment on Composite Performance. Materials, 14(14).

13. Hittini, W., Mourad, A.H.I., Abu-Jdayil, B., 2021. Utilization of Devulcanized Waste Rubber Tire in Development of Heat Insulation Composite. Journal of Cleaner Production, 280.

14. Hamdi, A., Abdelaziz, G., Farhan, K.Z., 2021. Scope of Reusing Waste Shredded Tires in Concrete and Cementitious Composite Materials: A Review. Journal of Building Engineering, 35.

15. Adesina, A.Y., Zainelabdeen, I.H., Dalhat, M.A., Mohammed, A.S., Sorour, A.A., Al-Badour, F.A., 2020. Influence of Micronized Waste Tire Rubber on the Mechanical and Tribological Properties of Epoxy Composite Coatings. Tribology International, 146.

16. Xu, X.W., Tian, F.Y., Li, X.K., 2020. Regenerated Waste Tire Powders as Fillers for Wood Fiber Composites. Bioresources, 15(2), 3029-3040.