International Journal of Engineering & Applied Sciences (IJEAS)
Vol.15, Issue 4 (2023) 144-149
http://dx.doi.org/10.24107/ijeas.1326042
Int J Eng Appl Sci 15(4) (2023) 144-149

Investigation of Effect of W-Zn-Co Alloy on Microstructure And Hardness of The Epoxy Composites

Mikail Aslan

Gaziantep University, Faculty of Engineering, Department of Metallurgical and Material Science Engineering, Gaziantep, 27310, Turkey

E-mail: mikailsln@gmail.com , ORCID: *0000-0003-2235-5104-0000*

Received:12.07.2023, Revised: 28.09.2023, Accepted: 28.10.2023

Abstract

This research investigates the production of epoxy resin composites reinforced by the synthesized heavy tungsten alloys (W-7Zn-3Co-Y_2O_3). Y_2O_3 is used for dispersion of the compound during the ball milling process. Laminating resin component A and hardened component B were used to produce polymer epoxy matrix. The tungsten heavy alloys reinforced epoxy composites were examined in terms of Vickers hardness, density measurement and microstructural characterization . The results indicate that the 16 hour-milled reinforced epoxy composites have the highest hardness value.

Keywords: Tungsten alloys, mechanical alloying, and polymer epoxy composites

1. Introduction

With extensive applications of polymer and its composites, epoxy resin polymer composites are extensively prefered in national economic construction and national defense construction works[1-3] due to their high specific strength-weight ratio, chemical, wear and corrosion resistance. Forexample; epoxy resins can be employed as insulating systems in high-voltage applications, including cables, generators, motors, and cast resin dry-type transformers, among others [4]. Fiori et al. [5] conducted an assessment of how the inclusion of uniaxial basalt fabric layers impacts the mechanical properties of a glass mat/epoxy composite specifically designed for marine applications. Baig et al. focused on the hybrid epoxy composite coatings for tribological applications [6]. Also, epoxy composites can be alternative for aleminium, steel and titanium [7-9]. On the other hand, the application of pure epoxy resin is limited by its brittleness, small elongation and poor mechanical impact resistance [10, 11].

Many researchers found that the addition of nanoparticles into adhesives like epoxies improved the adhesive characteristics [12-14]. Conradi et al.[15] studied the dispersed silica nanoparticles into the epoxy matrix to produce a coating with a better hardness of 50% when compared with coatings of pure epoxy. Karippal et al.[16] used multi-walled carbon nanotubes (MWCNT) and carbon black (CB) as reinforcements with different fractions into the epoxy matrix and determine the change in hardness of the composite. Radwan et al.[17] studied the effect of reinforced epoxy risen by aluminum particles with variation in weight percentage and evaluated the change in vickers hardness, density, and the compression stress of the composites. Al fillers with higher percentages tend to increase the hardness of resulting composites when compared with pure epoxy resin. The study conducted by Halder et al.[18] demonstrated significant improvements in various mechanical properties of the epoxy system. The maximum enhancements observed were approximately 24% in tensile strength, 47% in tensile modulus, 48% in compressive strength, 44% in flexural strength, and an impressive 77% in flexural modulus compared to the neat epoxy system. In another study[19], researchers aimed to enhance the coating properties of epoxy resin by incorporating Ni–La–Fe–O nanoparticles in the form of $NiLa_xFe_{2-x}O_4$/epoxy nanocomposites. To achieve this, they synthesized new composites with varying x compositions (x = 0.00, 0.50, 1.00, 1.50, and 2.00) in situ, while the epoxy resin was prepared using a straightforward solution method with ultrasonic assistance. The inclusion of Ni–Fe formulations demonstrated considerable potential in improving epoxy coatings.

In this paper, W-Zn7-3Co + %0.5 Y_2O_3 reinforcement particles were synthesized with different milling times and techniques before adding them into the epoxy resin matrix. Different samples were produced to investigate the effect of milling time on the hardness and density of epoxy matrix composites.

2. Materials and Methods

To produce W-Zr-Co-Y_2O_3 reinforced epoxy polymer composites, W, Zr, Co, and Y_2O_3 particles and laminating resin component A and component B were supplied from Nanografi, EGE nano A.Ş and ADS Chemistry, respectively. The heavy tungsten alloys were synthesized by mechanical alloy routine. There are two kinds of strategy were used to produce the heavy tungsten alloys, which are called the classic and alternative methods respectively. In the classical method, all raw materials are milled for 24 hours. In the second technique, initially, the Zn-Co compounds were milled for 24 hours. The W and Y_2O_3 and the milled Zn-Co compounds were then milled for 8, 16, and 24 hours. The detailed information is given in previous study [20]. In the second technique, sample 1,2,3 and 4 are called according to their milling times of 0,8, 16 and 24 hours, respectively while the sample 5 is produced by classical method. To form heavy tungsten reinforced epoxy composites, the heavy tungsten alloy (0.5 g) and the epoxy (10 g) were weighted. The powder compounds and resin were placed in a beaker and the mixing was carried out by utilizing a mechanical stirrer for half-hour. The hardener is then poured into the beaker as the weight ratio between the resin and hardener of 2. The resulting suspension was mixed for 2 hours by a magnetic stirrer with a speed of 800 rpm. To ensure homogenous distribution, the compound was again mechanically mixed for 5 minutes and the compound was dried at room temperature.

3. Results and Discussion

Figure 1 shows the Vickers hardness of the pure epoxy and the heavy tungsten reinforced epoxy polymer composites with the force load of 0.3 kgf and the dwell time of 20 sec. Five measurements were applied for each sample to calculate the average value of the measurements. The addition of the tungsten metal powder as reinforcement material to the epoxy matrix leads to a noticeable increase in the microhardness value. Furthermore, the ball milling time of tungsten powder has a significant effect on the microhardness. The composite having 16-hour milled tungsten heavy alloy shows the best hardness value of 22.6 HV.

On the other hand, the effect of the second milling method was determined by comparing the two samples fabricated by using these two different strategies. The composites produced by the second one have approximately 25 % higher microhardness values when compared with the first one.

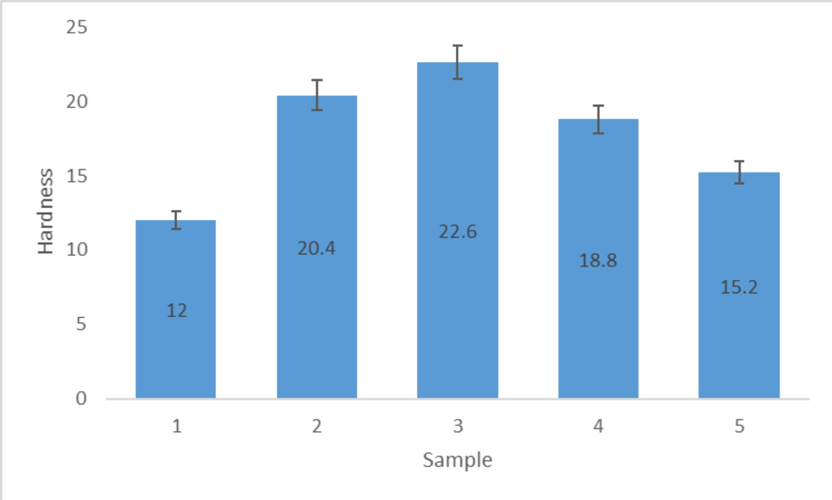


Fig. 1. The Vickers hardness values of the given epoxy composites

The density measurements are based on Archimedes' principle. The measured density of pure epoxy and the reinforced epoxy composites are shown in Figure 2. As expected, due to the nature of the high density of tungsten alloy, the addition of the synthesized tungsten alloy to the epoxy matrix increases the density of the composites since the density of the pure epoxy is the smallest value among them with a value of 1.146 g/cm^3 When regarding the polymer composites produced by the second method, the composite with the 8 hours milled alloy indicates the highest measured density value having value of 1.198 g/cm^3. This can be because pure tungstens powders are higher density values than the synthesized alloys, which means the 8-hour milled alloy may include the highest pure tungsten ratio when comparing the other milled alloys. On the other hand, In the classical method, as expected, the measured density is a slightly higher value than pure, and 16 and 24 hour milled alloyed reinforced epoxy composites.

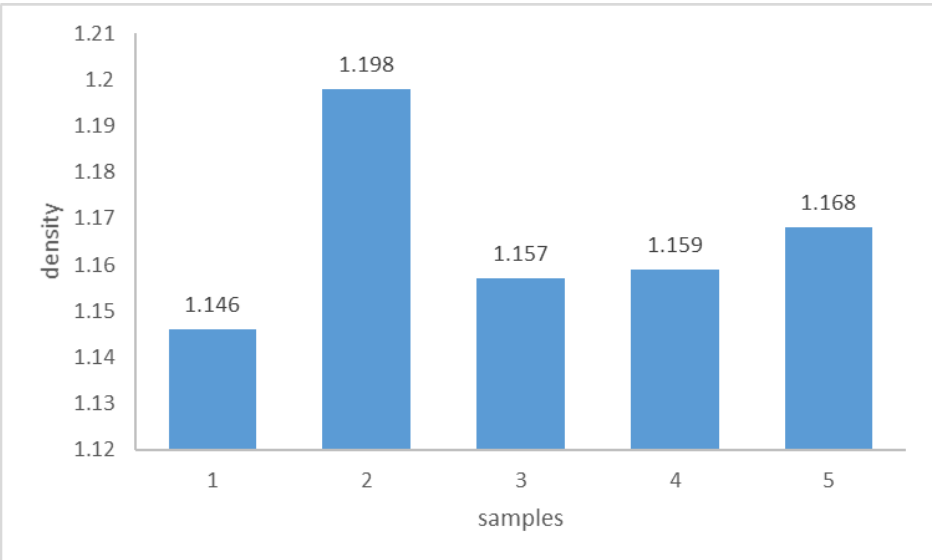
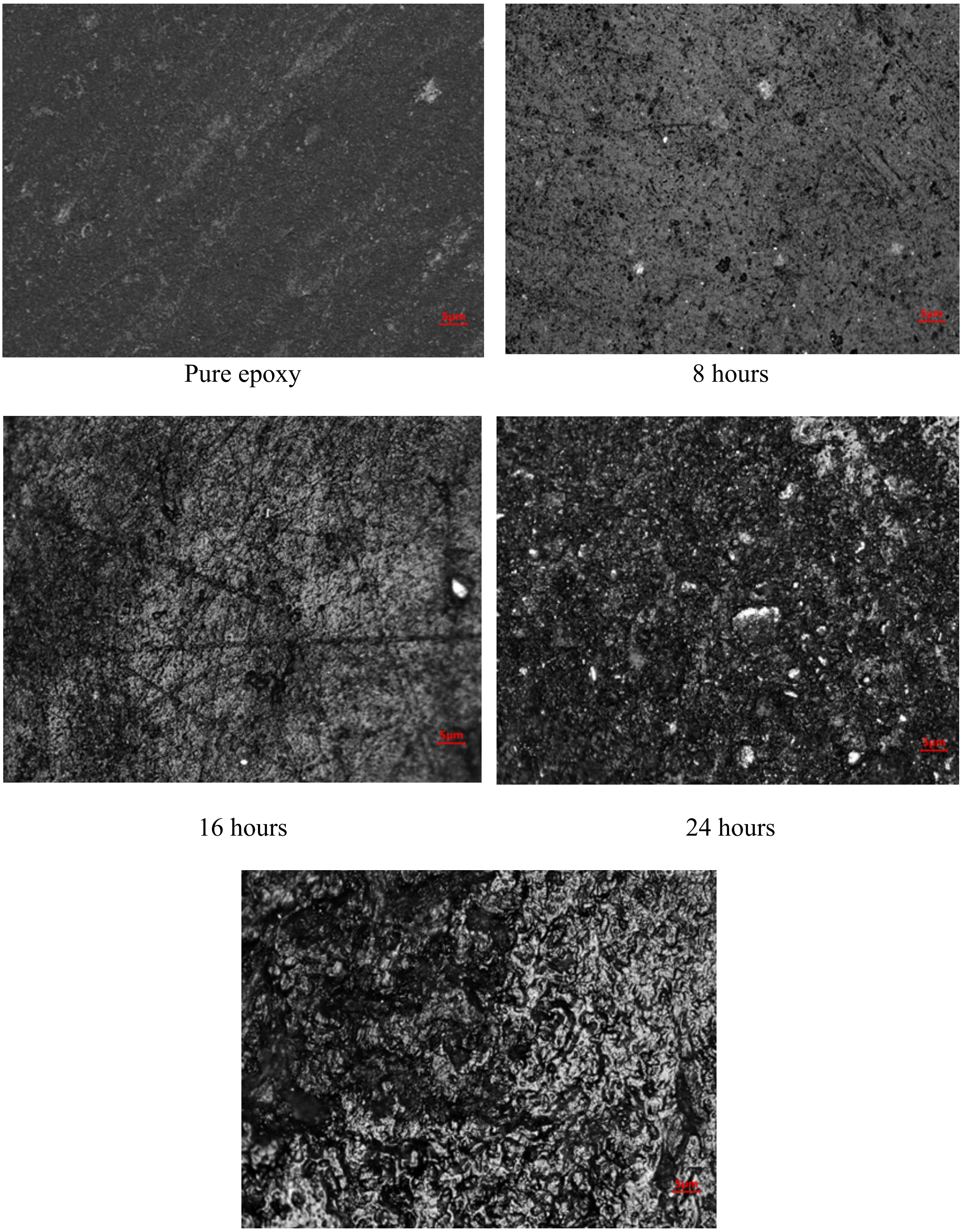


Fig. 2. The measured density of the given epoxy composites

Figure 3 illustrates optical microscope images of reinforced epoxy composites with varying milling times, showcasing different types of agglomerations across all structures. This is due to the differences between dimensions, interactions, and volume fractions of the neat epoxy and tungsten alloy. In contrast to the Vicker's results, the distribution of tungsten alloys in the 24-hour milled structures is superior to that of the 16-hour milled structures.



Pure epoxy

8 hours

16 hours

24 hours

24 hours-classical methods

Fig. 3. Optical images of the given materials

4. Conclusion

This study examines the W-Zn-Co-Y_2O_3 alloy reinforced epoxy polymer composites in terms of Vicker hardness and density measurements. Component A and B were chosen as epoxy elements. The study indicates the second method may be chosen due to the highest Vicker hardness value and lower measured density values as compared to the reinforced composites. Furthermore, the

16 hours milled heavy tungsten alloy reinforced epoxy composites have the highest mechanical value. The utilization of the tungsten alloy as a reinforcement within the epoxy composites significantly enhanced their mechanical properties, thereby expanding the potential applications of composites in diverse industries, including aerospace, automotive, marine, and military sectors.

References

[1] Lu, Song, Jin-Yu Xu, Er-Lei Bai, Xin Luo., Effect of Particles with different Mechanical Properties on the Energy Dissipation Properties of Concrete. *Construction and Building Materials,* 144, 502-515, 2017.

[2] Sakthivel, S.N., Kathuria, A., Singh, B., Utilization of Inferior Quality Aggregates in Asphalt Mixes: A Systematic Review. *Journal of Traffic and Transportation Engineering*, 9(5), 864-879, 2022.

[3] Shahedan, Noor Fifinatasha, Mohd Mustafa., Potential of Geopolymer Coating for Lightweight Aggregate via Milling and Dipping Method: A Review. *European Journal of Materials Science and Engineering,* 7(2), 094–105, 2022.

[4] Lim, T., Lee, J.H., Mun, J.H., Yang, K.H., Ju, S., Jeong, S.M., Enhancing Functionality of Epoxy–TiO_2-Embedded High-Strength Lightweight Aggregates. *Polymers,* 12(10), 1-11, 2020.

[5] Abutaha, F., Abdul Razak, H., Ibrahim, H.A., Effect of Coating Palm Oil Clinker Aggregate on the Engineering Properties of Normal Grade Concrete. *Coatings*, 7(10), 1-26, 2017.

[6] Muñoz Jose F., Expanded Study on the effects of Aggregate Coating and Films on Concrete Performance, *Wisconsin highway research program*, 2007.

[7] Muñoz, Jose F., M. Isabel Tejedor, Marc A. Anderson, and Steven M. Cramer., Detection of aggregate clay coatings and impacts on concrete. *ACI Materials Journal*, 107(4), 387-395, 2010.

[8] Rajasekaran, S., Vasudevan, R., Paulraj, S., Reuse of Waste Plastics Coated Aggregates-Bitumen Mix Composite for Road Application - Green Method. *American Journal of Engineering Research*, 2(11), 1-13, 2013.

[9] Alave, Y.B., Mahimkar, S.S., Patil, K.S., Gupta, J.J., Kazi, A., Experimental Investigation of Plastic Coated Aggregate. *International Journal of Engineering Research & Technology,* 9(3), 112-120, 2021.

[10] Sharma, S.D., Sharm, A., Utilization of Waste Plastic in Flexible Pavement. *International Journal of Science and Research*, 8(5), 1545-1549, 2019.

[11] Vasudevan, R.N.S.K., Nigam, S.K., Velkennedy, R., Sekar, A.R.C., Sundarakannan, B., Utilization of Waste Polymers for Flexible Pavement and Easy Disposal of Waste Polymers. *International Journal of Pavement Research and Technology,* 3, 34-42, 2010.

[12] Harnadh K.L., A. M. N. Kashyap, K. M. Gupta, Experimental Investigation on Coarse Aggregates by using Waste Plastics & Polymers. *International Journal of Innovative Resresach in Engineering and Management,* 2(3), 19-23, 2015.

[13] Dawale, S.A., Use of Waste Plastic Coated Aggregates in Bituminous Road Construction. *International Journal of Advancement in Engineering Technology, Management, and Applied Science,* 3(6), 118-126, 2016.

[14] Gebre, Y., Lahmer, T., Müller, M., Wiegand, T., Osburg, A., & Tarekegn, A. G., Properties of Concrete with Coated Aggregates under different Loading Conditions. *Journal of Research in Engineering and Applied Sciences*, 8(1), 449-459, 2023.

[15] Vahabi, Mir Yashar, Behzad Tahmouresi, Hossein Mosavi, and Siavash Fakhretaha Aval., Effect of pre-coating lightweight aggregates on the self-compacting concrete. *Structural Concrete*, 23(4), 2120-2131, 2023.

[16] Popovics, J.S., Zemajtis, J., Shkolnik, I., A Study of Static and Dynamic Modulus of Elasticity of Concrete, *American Concrete Institute - Concrete Research Council*, Report 16, 2008.

[17] Hansen, T. C., Recycled Aggregate and Recycled Aggregate Concrete. *Material and Structures,* 19, 201-246, 1986.

[18] ASTM C 136 - Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, *ASTM International*, 2014.

[19] Sikafloor®-161, Product Data Sheet, May 2019.

[20] Epoxy T 19-32/1000, Product Data Sheet, February 2019.

[21] BYK-C 8001, Polymeric Coupling Agent, Product Data Sheet, 2021.

[22] EN 12390-4:2019: Testing Hardened Concrete - Part 4: Compressive Strength of Test Specimens, 2019.

[23] ASTM C496-96: Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, *ASTM International*, 2017.

[24] EN 12390-6:2009: Testing Hardened Concrete - Part 6: Tensile Splitting Strength of Test Specimens, 2009.

[25] EN 12390-13:2021: Testing Hardened Concrete - Part 13: Determination of Secant Modulus of Elasticity in Compression, 2021.

[26] ASTM C215-08: Standard Test Method for Fundamental Transverse, Longitudinal and Torsional Resonant Frequencies of Concrete Specimens, *ASTM International*, 2009.

[27] Miura, T., Sato, K., Nakamura, H., The Role of Microcracking on the Compressive Strength and Stiffness of Cracked Concrete with different Crack Widths and Angles Evaluated by DIC. *Cement and Concrete Composites,* 114, 1-10, 2020.