Temperature Effect on physical and Mechanical Properties of epoxy Composite Specimens

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Abstract. The aim of this study is to temperature effect on the mechanical properties of Epoxy DGEBA, with adding zirconium oxide (ZrO₂) nanostructures. At different ratios (0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7) wt% of zirconium oxide (ZrO₂) nanostructures, which are prepared by hand lay-up method, and then the samples are exposed to different temperatures (40, 50, 60, and 70 °C) for 16 hr.. The results showed that, the compressive strength, impact strength and hardness decreases increasing the temperature of the curing. The damping properties percentages of these properties are (3.74%, 79.61% and 23.33%) for compressive, respectively; for adding 0.4% wt. from zirconium oxide (ZrO₂) nanostructures. The reduction in strength of epoxy - nanomaterialos is attributed to oxidation at the near-surface. The increasing of the temperatures have the opposite effect on the mechanical properties of the epoxy up to 0.3 addition of the nano materials. the increasing of the addition of the nano material led to decrease the effect of temperature on the mechanical properties. The water absorption decreasing with increase the percentage of the addition of nano materials at different temperature.

1. Introduction

Polymer-matrix composite s are very popular between the different industrial application such as mechanical, electrical, automotive, semiconductor, and aerospace. This state is because of the cause that the compound materials show a considerable enhancement in the properties such as chemical, electrical, mechanical, and thermal coefficient of expansion as compare to their original phase. Additives and fillers are commonly used in the synthesize process to enhanced the mechanical and thermal properties of polymers [1] Nanomaterials consists of more components, one of them being matrix or continuous phase in which nano sized particles are dispersed. These nanoparticles, or nano fillers, constitute the second phase [2].Thermosetting of the epoxy are commonly used as adhesives, they are amorphous and very highly cross linked, and the micro structure of these materials has many interesting properties for engineering application such as light weight, high failure strength, low creep, and interesting adhesive properties[3].

There are studies have been conduct on behavior of fiber reinforcement polymer composite in high and high temperatures. However, reinforcement materials composite laminates showed poor mechanical behavior in high and elevated temperatures and it may lower the lifespan of structures designed using this materials [4-7]. When the working temperatures of the structures are higher than the glass transition temperatures (Tg) of polymeric matrix, the materials gets softer and it may collapse [8]. High
temperature may have attributed to the chemical and/or physical damages caused in the polymer matrix, loss of adhesion at the fiber/matrix interface, and/or reduction of fiber strength and stiffness [9]

2. Experimental work

2.1 The materials of this work
The resin of the epoxy is (diglycidylether of bisphenol A – DGEBA) viscosity 9200 to 13500 cps which can be used as basic epoxy and the hardner is Triethylenetetramine [CH₂NHCH₂CH₂NH₂]₂ from Parikh Chemicals, Ltd. Kanpur, India. zinc and zirconium Oxide powder purity (99 -99.7%) with (20-50 nm) from TMMINDIA, Jaipur, India. / Egypt.

2.1.1 Sample Preparation
The epoxy (DGEBA) resin and the TETA hardener should be mixed gradually together by using a disposable stirrer at room temperature in order to avoid making air bubbles. The blend of the epoxy with nano- (zirconium Oxide) was lefted for 20 minutes to get a homogeneous mixture and the concentration of the prepared samples have the same in all its part. Then the mixture which contain the nano materials was poured into the mould and left for 24 hours at room temperature, then all samples exposed to different temperature (40, 50, 60, and 70 °C).

2.2 Test of the Mechanical

2.2.1 Test of the Tensile
The samples for each mix methods and for each percentage of nanoparticles (ZnO and ZrO₂) and DGEBA fiber were tested. This test was performing according to ASTM D638- TYPEI standard [10].

2.2.2 Compression Test
The samples for each mix methods and for each percentage of nanoparticles (ZnO and ZrO₂) were tested. This analysis was performing according to ASTM D-695 [11].

2.2.3 Bending Test (Strength of the Flexural)
This analysis was performing according to ASTM D-790 [12] with a speed rate of about 1.5 mm/min at ambient temperature.

2.2.4 Test of the Impact
It was considered one of the most important properties of the mechanical tests that give the energy absorption that is necessary for fracture of the sample which is given directly from the device. This analysis was carried out in accordance to ISO-179TYPE-D [13] at ambient temperature using charpy machine HSM41Pendulum impact tester.

2.2.5 Hardness Test
The hardness (Shore D) test for control, PNCs and hybrid composites were carried out in accordance to (ASTM D2240) [14]

2.2.6 Water Absorption analysis
This analysis was performing according to ASTM D-2240 standard [14]

3. Results And Discussion
The results of the tests which have been studied in this paper under different conditions including, different temperature to invistigate the physical and mechanical properties of the epoxy with nanomaterials after exposed the samples to the temperature. Figure 1 is showing Compressive Strength of ZrO₂ and reinforced epoxy DGEBA at different temperature. The compressive strength calculated by adding ZrO₂ with different percentage of weight fraction (0.0,0.1,0.2,0.3,0.4,0.5 and 0.6)% for nano ZrO₂. The compressive strength decreased with increasing the percentage of additive up to 0.3% wt
for ZrO$_2$ at different temperature, the compressive strength increased with increasing the percentage of the nanomaterial for all the temperature. Highest damped in the compressive strength for ZrO$_2$ was obtained for samples with the percent 0.3 wt %. In this test had chosen the best percentage that has achieved the best values for the compressive strength at greater than or equal 0.4 wt% of the zirconium oxide. It is seen that from the result the use of the materials which contain on the nanoparticle has a surface morphology which lead to both single and dispersal packing of nano zinc oxide and nano zirconium oxide and the high interaction among the matrix of the epoxy and nano materials which point out the high strong adhesion among the organic and inorganic phases and the interaction cause to very good wetting and a high strong interface as a result of homogeneous dispersal and increase the resistance to the exposed for the temperature. The materials which contain on the nanoparticle have a rougher fracture surface demonstrating increasing in the roughness of the surface as a result of the addition of zirconium oxide. These nanomaterials are it seems that dispersal by homogenously in the matrix and they are prevented from the agglomeration cause to the high viscosity of the epoxy matrix.

Figure 1 the relationship between the compressive strength and the percentage of the nanomaterials at different temperature.

Figure 2 is showing Compressive modulus of ZrO$_2$ and reinforced epoxy DGEBA at different temperature. The compressive modulus calculated by adding ZrO$_2$ with different percentage of weight fraction (0.1, 0.2, 0.3, 0.4, 0.5 and 0.6) % for nano ZrO$_2$. The compressive modulus decreased with increasing the percentage of additive up to 0.3% wt for ZrO$_2$ at different temperature, the compressive modulus increased with increasing the percentage of the nanomaterial for all the temperature. Highest damped in the compressive modulus for ZrO$_2$ was obtained for samples with the percent 0.3 wt %. In this test had chosen the best percentage that has achieved the best values for the compressive modulus at greater than or equal 0.4 wt% of the zirconium oxide. It is seen that from the result the use of the materials which contain on the nanoparticle has a surface morphology which lead to both single and dispersal packing of nano zinc oxide and nano zirconium oxide and the high interaction among the matrix of the epoxy and nano materials which point out the high strong adhesion among the organic and inorganic phases and the interaction cause to very good wetting and a high strong interface as a result of homogeneous dispersal and increase the resistance to the exposed for the temperature. The materials which contain on the nanoparticle have a rougher fracture surface demonstrating increasing in the roughness of the surface as a result of the addition of zirconium oxide. These nanomaterials are it seems that dispersal by homogenously in the matrix and they are prevented from the agglomeration cause to the high viscosity of the epoxy matrix.
Figure 2 shows the relationship between the compressive modulus and the percentage of the nanomaterials at different temperatures.

Figure 3 shows the ultimate tensile strength of ZrO$_2$ reinforced epoxy DGEBA. Ultimate tensile strength decreased with increasing the percentage of additive up to 0.3% wt for ZrO$_2$ at different temperature, then the ultimate tensile strength increased with increasing the percentage of the nanomaterial for all the temperature. Highest damped in the compressive modulus for ZrO$_2$ was obtained for samples with the percent 0.3 wt %. In this test had chosen the best percentage that has achieved the best values for the compressive modulus at greater than or equal 0.4 wt% of the zirconium oxide increase with increasing the percentage of the additive up to 0.3% for ZrO$_2$ at different temperature. These increasing of the Ultimate tensile strength leading to rich load transfer ability and the strong interaction between nanomaterials and epoxy. The properties of the mechanical of the modified epoxy depending on the nanomaterials which reinforced epoxy which lead to improve the adhesion and increase the resistance to the temperature that is responsible for the efficiency of load transfer in the epoxy, and the nature of the nanomaterials.

Figure 3 shows the relationship between the ultimate tensile strength and the percentage of the nanomaterials at different temperatures.
Figure 4 shows that the impact strength of ZrO$_2$ when added to epoxy at different temperature. There was a decrease with increasing of weight fraction of ZrO$_2$ and reached a maximum decreasing when ZrO$_2$ content was 0.3% wt and the impact strength is increasing with increase the percentage of the nanomaterials. This is due to the fact that ZrO$_2$ have strong interaction between nanomaterials and epoxy, which will bear the bulk of the energy shock inflicted on composite materials and increase the resistance to the temperature.

![Impact strength graph](image1)

Figure 4 the relationship between the impact strength and the percentage of the nanomaterials at different temperature

The flexural strength of nano ZrO$_2$ reinforced epoxy, which it is shown in figure 5. The lower flexural strength at weight fraction 0.3% wt. and then the flexural strength increase with increasing the percentage of nanomaterials. This may be lead to the improve the interfacial interaction existed among the nanomaterials and epoxy, which can be allowable the transfer the stress from epoxy to the nanomaterials thereby enhancement the stiffness of the epoxy which reinforced by the nanomaterials.

![Flexural strength graph](image2)

Figure 5 the relationship between the flexural strength and the percentage of the nanomaterials at the different temperature

Figure 6. presents the hardness (shore D) for ZrO$_2$ reinforced epoxy matrix. There was an decreasing in the hardness of nano ZrO$_2$, and reached a minimum when nano ZrO$_2$ content was 0.3% wt. for And
then increases after 0.3% wt. ZrO$_2$. There was might be the nano ZrO$_2$ is too much which causes many bubbles on the surface of the samples and increases the resistance to the effecting of the temperature.

Figure 6 the relationship between the hardness (shore D) and the percentage of the nanomaterials at different temperature

It can be noted from figure 7 that the water absorption percentage for epoxy with adding 0.1 to 0.7% wt from nano ZrO$_2$ decreases with increasing the percentage of the addition. It is well known that the water absorption is the physical property dependent upon apparent porosity where the water enters the open pore channel. There was immersed into water for (1, 2, 3, 4, 5, 6, and 7) days. It is seen that the water absorption decreases with increasing the percentage of the additive nano ZrO$_2$. This phenomenon can be attributed to the presence of nano ZrO$_2$ filled epoxy. This may be attributed to the high surface area of nanoparticles can create a tortuous pathway for water molecules to diffuse into the PNCs, and due to better dispersion when using SM mixing method.

Figure 7 the relationship between the water absorption and the durability at different temperature

### 4. Conclusion:
The conclusion of the compressive strength and flexural strength are decreasing with increasing the percentage of the additive up to 0.3% for ZrO$_2$. The lower value of the compressive modulus and ultimate
tensile strength at 0.3% wt. for ZrO$_2$ for all samples and the all the properties increasing with increase the percentage of the addition. The nanomaterials led to increase the resistance to the effect of the temperature. The water absorption for the epoxy with ZrO$_2$ increasing with increase the percentage of the addition at different temperature.

REFERENCES

[1] Mu Liang 2018 long term performance of nano composite in power transmission and distribution systems " thesis of phd , RMIT university , Australia .
[2] I.Seenaa Hussein,Alaa M. Abd-Elnaiem, Tesleem B. Asafa and Harith I. Jaafar 2018 Effect of incorporation of conductive filler so mechanical properties and thermal conductivity of epoxy resin composite", Applied Physics A 124:475
[3] Lara J J, Rodriguez M T, Arzaluz M G , and Romo M R 2017effect of zirconia nano particles in epoxy – silica hybrids adhesive to join aluminum substrates , materials , 10, 1135, 1-20 .
[4] Coronado P, Arguelles A, J. Vina, V. Mollon, I. Vina, 2012 Influence of temperature on a carbon-fibre epoxy composite subjected to static and fatigue loading under mode-I delamination, International Journal of Solids and Structures, 49 , 2934-2940.
[5] Rami A. Hawileh, Adi Abu-Obeidah, Jamel A. Abdalla, Adil Al-Tamimi, 2015 Temperature effect on mechanical properties of carbon, glass and carbon-glass FRP laminates, Construction and Building Materials, 75 342-34, 8.
[6] Zhongyu Lu, Guijun Xian, Hui Li, Effects of elevated temperatures on the mechanical properties of basalt fibers and BFRP plates,2016 , Construction and Building materials, 127 , 1029-1036.
[7] Andrew Makeev, Yihong He, Nonlinear shear behavior and interlaminar shear strength of unidirectional polymer matrix composites:2014 A numerical study, International Journal of Solids and Structures, 51 ,1263-1273.
[8] Yu Bai, Thomas keller, Pultruded GFRP tubes with liquid-cooling system under combined temperature and compressive loading 2009, Composite structures, 90 ,115- 121.
[9] Botelho E C, L.C. Pardini, M.C. Rezende, Hygrothermal 2006 effects on the shear properties of carbon fiber/epoxy composites, J. Mater Sci , 41 , 7111-7118.
[10]"Standard Test Method for Tensile Properties of Plastics", 2003 , ASTM (D 638-00), An American National Standard ,14.02.
[11]"Standard Test Method for Compressive Properties of Rigid Plastics 1985 D695- 85", Annual Book of ASTM Standard, 10.01.
[12] Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials D 790- 03", 08.01, Annual Book of ASTM Standard, USA, 2003.
[13] Crawford R J 2000" Plastics Engineering", 2nd edition, Pergamon Press, New York.ASM Handbook, 8.
[14] Hardness Book of Standards 2010 "ASTM D2240-05 Standard Test Method for Rubber Property Durometer", 09.01, , USA.

Acknowledgments
The authors would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad-Iraq for its support in the present work