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Preparation and study of some mechanical properties of Epoxy and Novolac composites

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Abstract

The research involves using Epoxy and Novolac resins; they were needed to prepare ternary polymer blends, Impact resistance, hardness, and compressive strength, using these resins with ratios as (4%, 6%, 8%, 10%, and 11%). Polymeric compositions were compared before and after reinforcement. Novolac has increased the values of all mechanical properties (Impact resistance, hardness, compressive strength). The values (compressive strength, hardness) are reduced by increasing the temperature.

Introduction

The industrial and scientific importance of the science of polymers has increased significantly in the late last century, where global statistics estimated that more than 20% of engineers and 40% of scientists work in the field of plastic industries and its technologies [1], and that polymers are chemicals substances that are characterized by With specifications superior to metals and ceramics in light of their weight, easey of production, cheapness, low density and high durability, and they do not rust and do not corrode and have low thermal and electrical conductivity, so they are used as electrical and thermal insulators [2]. As a result of scientific progress, the need for polymeric materials with certain specifications that cannot be obtained from a polymer of one type has emerged. For this reason, attempts have appeared in mixing two or more types of polymers and obtaining a polymeric mixture with the desired industrial specifications. Physically, the resulting mixture possesses common properties between the basic compounds, which depends on the quality of the polymers and the method of mixing [3].

The term “Advanced Composites” has appeared to design specific multifunctional composite materials with unprecedented mechanical and physical properties that can be tuned to meet the requirements of special applications[4].

Polymeric composite materials are made of two materials, the base material (polymer), which is characterized by its light weight and high flexibility [5], and the reinforcing material, the aim of which is to obtain properties that enhance the properties of the base material [6],[7],[8]. There are several methods of strengthening, including micro substance strengthening and fiber strengthening [9],[10].

This encouraged researchers to work in this field, so the researcher [11], studied the shock resistance at temperatures (20, 40, 60°C) of a polymeric mixture consisting of (90%) epoxy resin and (10%) polyurethane Reinforced with (PVC) and aluminum fibers with a volume fraction (15%), and the results showed that the reinforcement of the base material with fibers increased the values of shock resistance, as well as the increase in temperature led to an increase in the values of shock resistance, and the researcher [12], prepared A composite material of unsaturated polyester resin (UPE) and nitrile-butadiene rubber (NBR) was reinforced with glass powder, which was added with different volume fractions (10, 15, 20%) and it was found that adding glass powder to the polymer mixture leads to an increase in thermal conductivity And as a diffusion coefficient was calculated for all models in solutions (C_3H_6O, H_2O) at a concentration of 0.5N, it was found that the highest value of the diffusivity coefficient appeared in the acetone solution and that the lowest value of the diffusivity coefficient appeared in water.

The researcher[8], studied the mechanical behavior of epoxy resin by using nanoparticles of alumina (10 nm) and fine grains of alumina (10 µm) with a weight fraction (40%). These properties include: compressive strength, flexural strength, and modulus of Flexibility The results showed an improvement in the mechanical properties of epoxy after reinforcement with alumina (nano and micro), where these properties increase with an increase in the percentage of reinforcement. The researcher[13], also studied the mechanical properties as well as the physical properties of a polymeric mixture of epoxy resin with polyurethane rubber by weight (wt 15%), and the results showed that there is a direct relationship between tensile strength, shock resistance and thermal conductivity with increasing immersion to (28) days In contrast, the hardness decreases with increasing immersion time, and the bending resistance increases when immersion increases to 14 days and then decreases with increasing immersion to 28 days, and the percentage of water absorption increases with increasing immersion to (50) days and that the durability of the dry mixture is higher than the durability The mixture immersed in distilled water.

The aim of the research

This study aims to prepare composite materials that show good resistance to shock loads and high compressive strength, to identify the behavior of polymeric mixtures under standard conditions and to compare them with the polymeric material before adding Novolac, and then study the mechanical properties (shock resistance, hardness, compressive strength) for all models before and after adding Novolac.

Materials :used:

1- Epoxy Resin

An epoxy resin type (MasterBrace ADH 1420) with a density of 1.55 kg/liter was used, while the hardener is (Phenol, 4-nonyl) and two supplied by BASF Company, where the hardener is added to the epoxy in a ratio of 3:1 so that suitable samples can be obtained. For molding at room temperature.

2- Novolac

Where it is in the form of thermoplastic blocks, transparent in color and with a distinctive odor, it turns into a cross-linked polymer in addition to it a hardener which is Hexa methylene tetra amine (HMTA) in the form of a white powder. The percentage of hardener added to Novolac is (10 gm) for every (30 gm) of novolac .

Preparation of samples

Three types of models were prepared for mechanical testing :

1- Impact Testsamples

The shock test models were prepared according to the American Standard (ASTM-D256-87) with dimensions (10×10×55 mm3) and suitable for examination. The grooving depth in the models (2 mm) and the grooving angle of (45°) was obtained directly from the Charpy Impact Instrument supplied by Tokyo Koki

Seizosho, LTD.) figure 1 shows the shape and dimensions of the sample prepared for the shock resistance test.

Figure 1: The shape and dimensions of the sample prepared for the shock resistance test

2- Hardness Testing Samples

Non-standard models were used, so which model of the composite material is suitable for this test. The Shore Durometer, a type (Shore-D) supplied by the company (WOLPERT - Germany) was used to measure the hardness of thermosetting polymeric materials, which is a device similar to a compass that contains a needle in the middle. Perpendicular to the sample whose hardness is to be measured so that it is tangent to the surface of the sample whose hardness is to be measured in order to insert the needle into the surface of the material and then wait for three seconds after which the hardness value is taken from the device, and no less than three readings were taken in different places of the sample and then take the average.

3- Compressive Resistance Test samples

Compressive strength test models were prepared according to the specification (ASTM-D618), which is in a cylindrical shape. A hydraulic piston was used (Testing Machine Co.LTD) supplied by WOLPERT - Germany company to determine the maximum compressive load that the model can bear and by dividing this load by the cross-sectional area of the model before deformation was calculated. The compressive strength of all models, and Figure (2) shows the shape of the sample prepared for the compressive strength test.

Figure 2: The shape of the sample prepared for the compressive strength test

Preparation Method

An epoxy resin was used and a hardener (Phenol,4-nonyl) was added in a ratio of 3:1 to turn it into a gelatinous substance that hardened at room temperature. Then the Novolac was added by weight (4%, 6%, 8%, 10%, 11%), where the hand-lay up molding technique was followed in the process of preparing the samples before and after adding the Novolac. Where an epoxy polymer was prepared by adding a hardener to it in a ratio of 3:1 and mixing the mixture with a glass rod to obtain a homogeneous mixture, then mixing the novolak and its hardener, which are in lumps, and turned into a fine powder by grinding it by means of the mill. Hexamethylenetetramine (HMTA) is converted into a viscous liquid by mixing (30 g) of novolac and (10 g) of its hardener and dissolving the mixture in 15 ml of ethanol alcohol and mixing well until we obtain a viscous liquid of novolac and its hardener and thus a homogeneous mixture was prepared of binary components, then the mixture is placed in the molds designated for measurements, which are according to the standard specifications specific to each examination. After the casting process is completed, it is left for 24 hours at a temperature of (25°C) and (55°C) to complete the process of solidification (curing), overlapping and complete homogeneity between the molecules and reduce the internal stresses formed during the casting process, Figure 3 shows a schematic diagram of the templates used in preparing the samples.

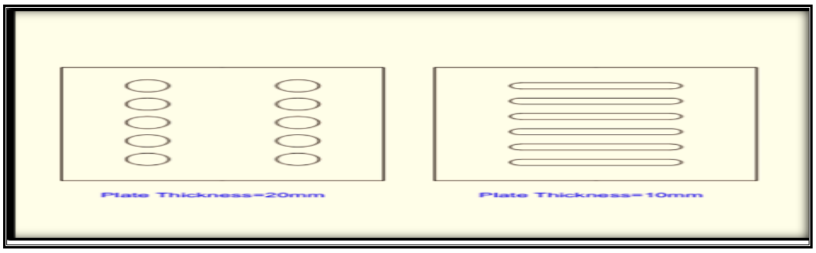

Figure 3: Schematic diagram of the molds used for sample preparation

Results and discussion

1- Impact Strength (I.S)

Examination of shock resistance is one of the practical methods that give a correct descriptive indication of the strength of materials and their resistance to fracture under the influence of stress at high speeds[14],[15], and the shock strength was calculated using the relationship:

$$I \cdot S = \frac{energy\ of\ \ fracture\ (J)}{area\ of\ cross\ \ section\ (m^2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The shock resistance in general is low for epoxy due to its fragility, but after mixing it with novolac, we notice that the shock resistance values have increased significantly than in the case of epoxy alone, and this can be seen in Figure (4), and the reason for this is that novolac will bear the bulk of the shock energy applied to the composite material which improves this resistance. Thus, the shock resistance increases with increasing the proportion of novolac to (10%) and (11%), which is consistent with the results reached by the researcher [16],[9].

From (Table 1) and (Figure 5), we note that the values of shock resistance increase with the increase in temperature as a result of loosening the bonds between the particles of the material and their sliding movement, which gives them the possibility of absorbing part of the energy, which leads to an increase in the energy needed to break [17],[5].

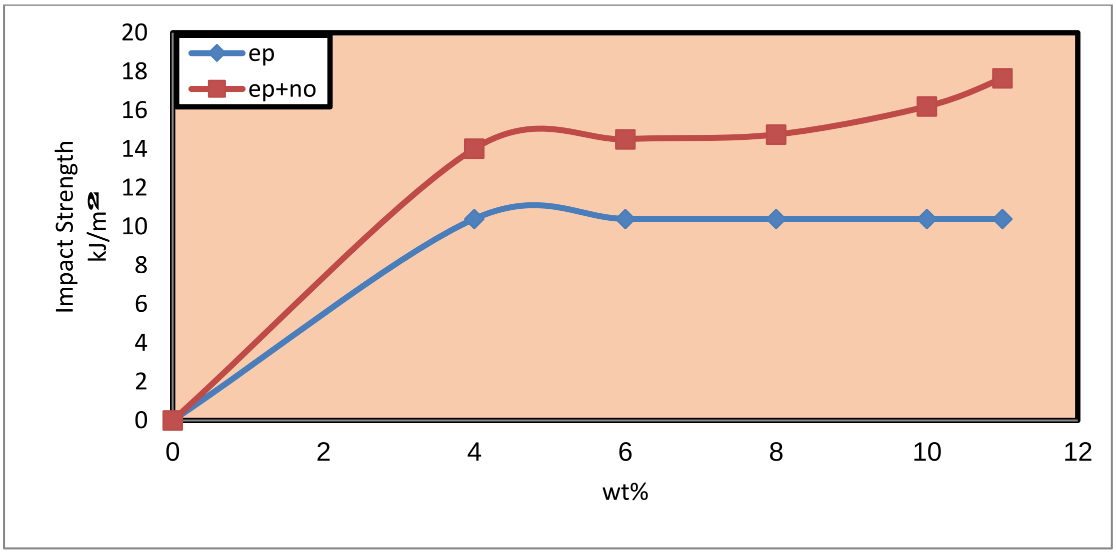

Figure 4: The relationship between the impact resistance (I.S) and the weight percentage of epoxy before and after mixing it with novolac at 25°C.

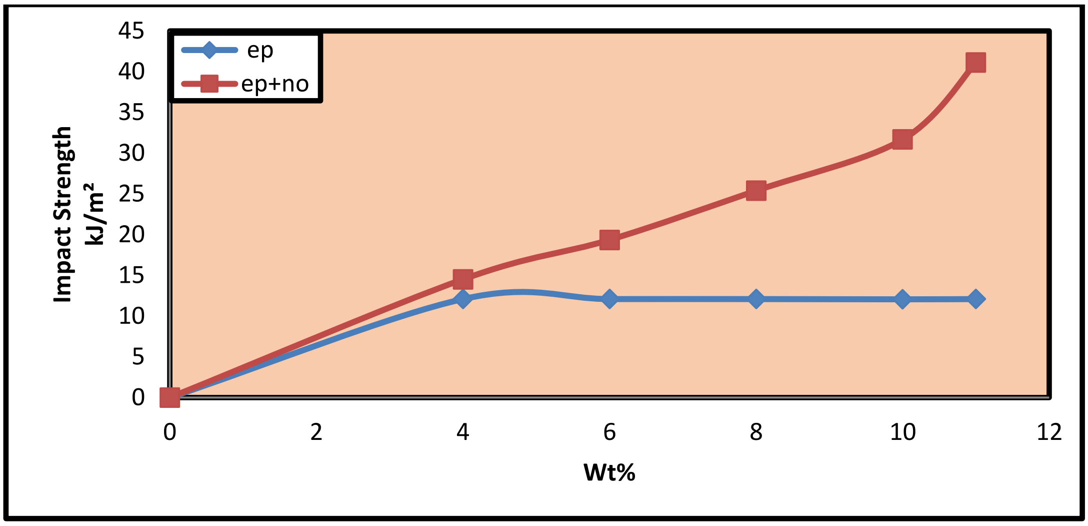

Figure 5: The relationship between the impact resistance (I.S) and the weight percentage of epoxy before and after mixing with novolac at 55°C.

Composite at 25°C	Impact Resistance (KJ/m^2)	Composite at 55°C	Impact Resitance (KJ/m^2)
EP	10.400	EP	12.09
EP+no 4%	14.02	EP+no 4%	14.51
EP+no 6%	14.51	EP+no 6%	19.35
EP+no 8%	14.75	EP+no 8%	25.39
EP+no 10%	16.20	EP+no 10%	31.68
EP+no 11%	17.65	EP+no 11%	41.11

Table 1: Values of the impact resistance of epoxy before and after mixing it with novolac in different weight ratios at 25°C and 55°C

2- Hardness Test (Shore-D test)

The hardness property is an important surface mechanical property, which can be defined as the measure of plastic destortion - which a material can suffer under the influence of external stress applied to it as a result of its exposure in general to scratching and penetration by equipment that is harder than it during its use in various applied fields [18],[19].

Through the research, we note that the hardness values have improved after mixing the epoxy with novolac due to the increase in crosslinking and agglutination resulting from the cross-linking between epoxy and novolac, so its hardness increases, which leads to an increase in its resistance to deformation [10],[20]. The hardness of the composite material increases with the increase in the percentage of the additive [21], as shown in Figures (7,6). The hardness values calculated at room temperature 25°C were improved after mixing the epoxy with Novolac, which has high hardness and its ability to withstand the largest part of the stresses [6]. But the hardness values decrease with the increase in temperature, and the reason for this is that the increase in temperature led to an increase in the ductility of the material due to the movement of the elementary units and the loosening of the bonds between them, and this leads to a weakening of its resistance to scratching and stitches [17],[22], as shown in (Table 2).

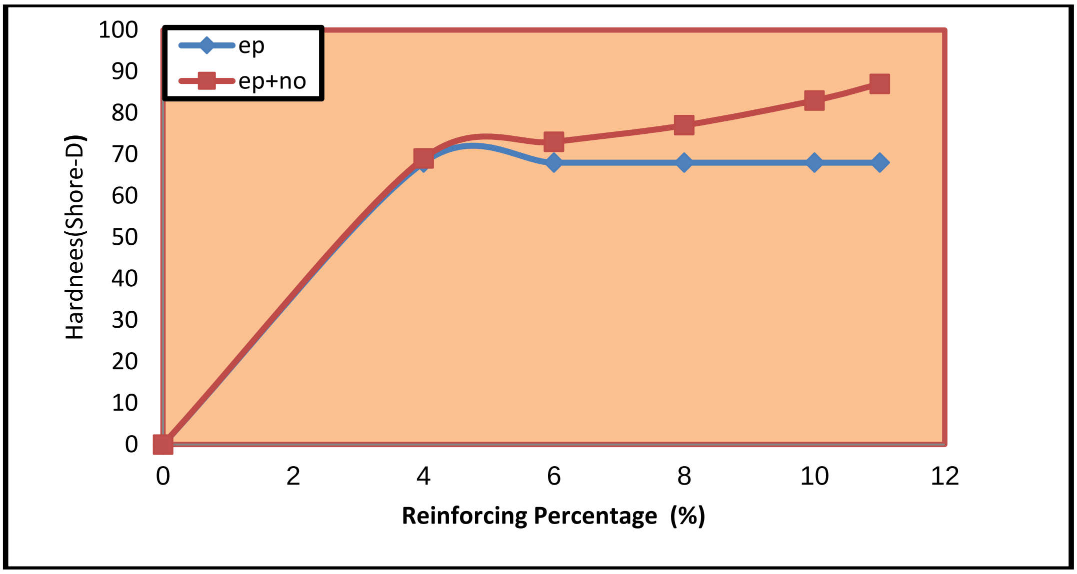

Figure 6: The relationship between the hardness values (Shore-D) and the weight percentage of epoxy before and after mixing it with Novolac at 25°C.

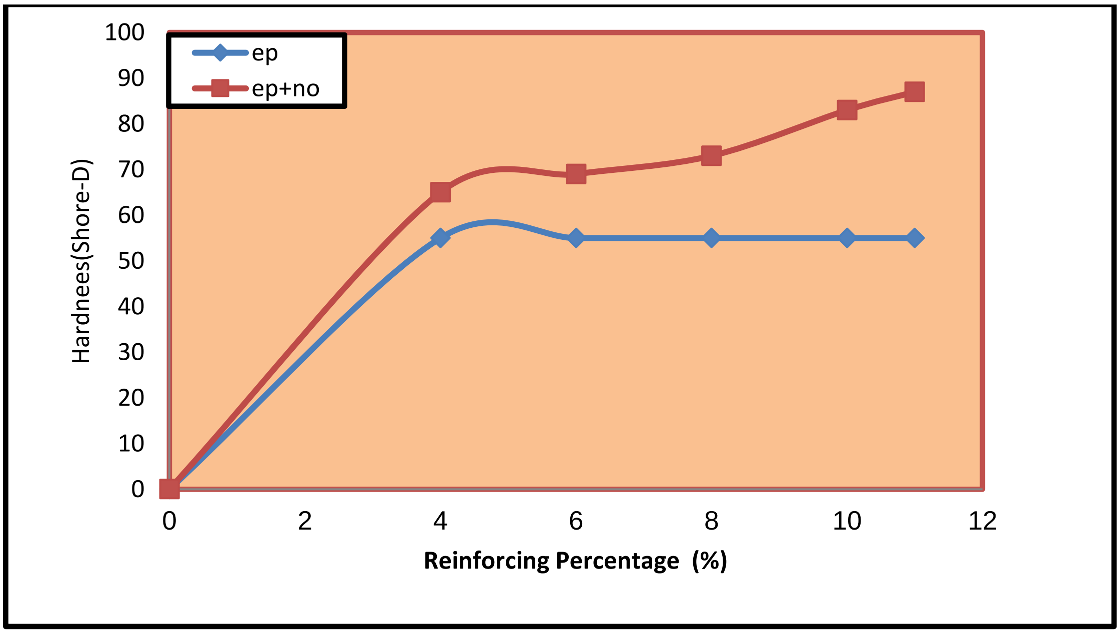

Figure 7: The relationship between the (Shore-D) hardness values and the weight percentage of epoxy before and after mixing with novolac at 55°C**.**

Composite at 25°C	Hardness Shore-D (Hd)	composite at 25°C	HardnessShore-D (Hd)
EP 25C°	68	EP 55C°	55
EP+no 4%	69	EP+no 4%	65
EP+no 6%	73	EP+no 6%	69
EP+no 8%	77	EP+no 8%	73
EP+no 10%	85	EP+no10%	83
EP+no 11%	91	EP+no11%	87

Table 2: Hardness values of epoxy before and after mixing with novolac in different weight ratios at 25°C and 55°C

3- Compressive Resistance Test

Testing the compressive strength of the material is an important test for the strength and durability of the polymer. Many materials may be brittle when tensed but appear ductile when compressed. So we find that the compression test is used to determine the yield strength in addition to the compressive strength[23],[24].

In general, compressive strength is defined as the maximum stress that a solid can withstand under perpendicular pressure:

$$C.S\ (MPa) = \frac{Force\ (N)}{area\ (m^2)} ------(2)$$

The results of the values of compressive strength at a temperature of 25°C and based on equation (2) showed that polymeric mixtures have a higher compressive strength than epoxy alone, because it bears most of the effort applied to the material, as the composite material's resistance to compression increases with the increase in the percentage of novolac added due to the distribution of the load on it. As well as the efficiency of their linkage, which raises the values of compressive strength [25],[4],[27], and this can be seen in Figures (9,8).

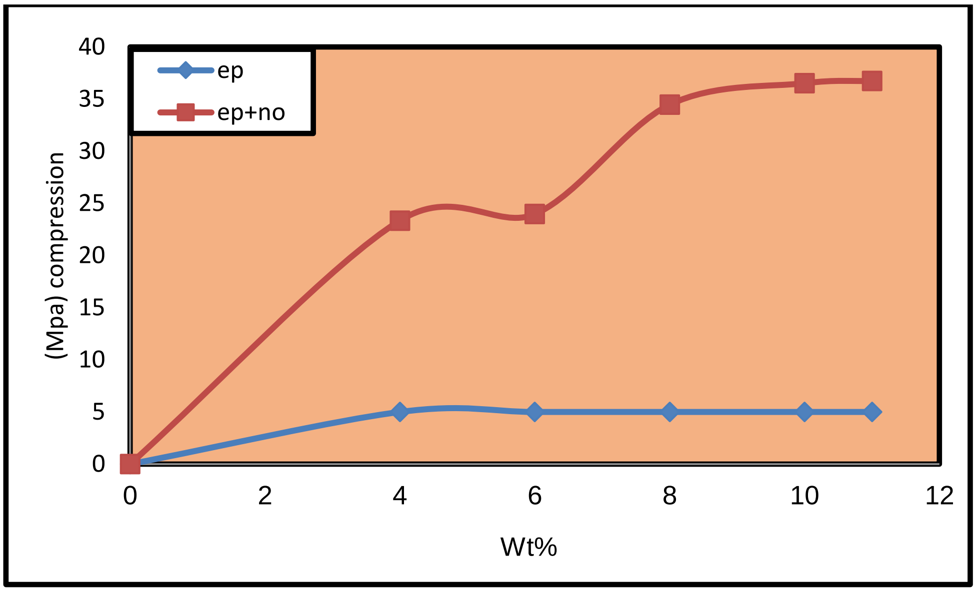

Figure 8: Relationship between compression (S.C) and percentages weight of epoxy before and after mixing with novolac at 25°C.

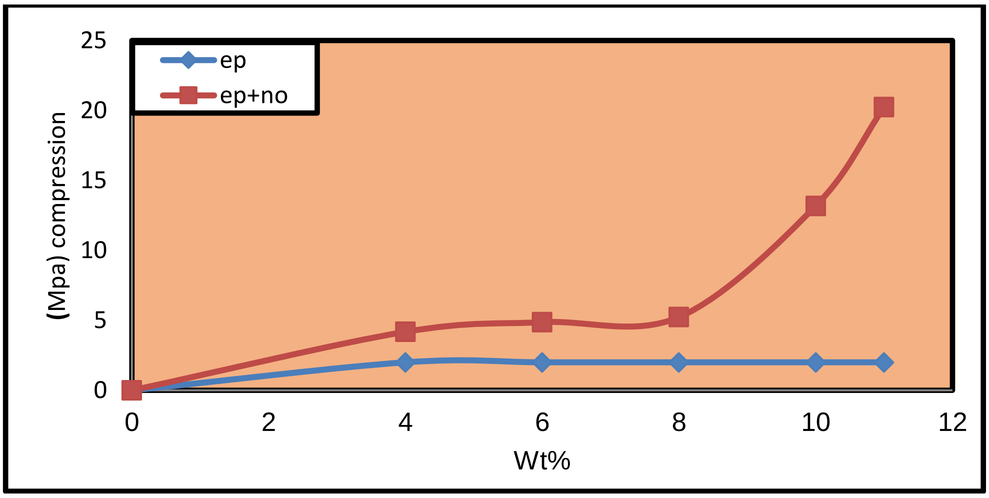

Figure 9: Relationship between compression (C.S) and weight percentages of epoxy before and after mixing with novolac at 55°C

Composite at 25°C	Compressive Strength MPa	Composite at 55°C	Compressive Strength Mpa
EP 25C°	5	EP 55C°	2
EP+no 4%	23.35	EP+no 4%	4.18
EP+no 6%	23.97	EP+no 6%	4.87

EP+no 8%	34.46	EP+no 8%	5.23
EP+no10%	36.52	EP+no10%	13.18
EP+no11%	36.75	EP+no11%	20.24

Table 3: The compressive strength of epoxy before and after mixing it with Novolac at (25°C and 55°C).

We note from (Table 3) that the compressive strength decreases with increasing temperature, due to the loosening of the bonds resulting from the increase in temperature.

Conclusions

The most important conclusions obtained during this research are summarized as follows:

1- The addition of Novolac to the epoxy led to an increase in the values of all the mechanical properties that were carried out in the research, which are the properties (shock resistance, hardness, compressive strength).

2- The values of all the mechanical properties mentioned above increase with the increase in the weight ratio of novolac.

3- The values of (compressive strength, hardness) decrease with increasing temperature.

References

1. Fred Plemer, translated by Dr. Salah Mohsen Alawi (1971). Basics of polymer science. College of Science, University of Mosul.

2. V.Raphanvan.(1979).Material Science Engineering A first Course. Prentice-Hall of India Private Limited New Delhi.

3. A.Leszek,Utracki, "polymer Alloys and Blends",New York,(1990).

4. Golestaneh, M.; Amini, G.; Najafpour, G.D.; Beygi, R.M.A. (2010). Evaluation of mechanical strength of epoxy polymer concrete. *World Applied Sci. J.*, **9**(2), 216-220.
5. Zuhair J. (2007). Addition natural pigments colorants and stabilizers materials polymers. Ph.D. Engineering Material, College of Engineering, Babylon University.

6. Mohammad, R.M.; Seiwench, N.R.; Rawabi, A.K. (2017). Evaluation of mechanical strength of epoxy polymer concrete reinforcement with different types of fibers. *Ibn Al-Haitham J. for Pure and Appl. Sci*., **30**(1),63-72.
7. Chianelli-Juniora, R.; Reisb, J.M.L.; Cardosoa, J.L.; Castroa, P.F. (2013). Mechanical characterization of sisal fiber-reinforced recycled hdpe composites. *Materials Research*, **16**(6), 1393-1397.
8. Al-Mosawi, A.I.; Abbas A.S.; Mustafa, A.R. (2015). Mechanical properties of epoxy nano composite. *International J. Advanced Research,* **3**(6), 1468-1472.
9. Cervenka, A.; Moore, D.R. (2002). Future requirements in the characterization of continuous fiber- reinforced polymeric composites. *IUPAC Technical Report, PureAppl. Chem.***4** , 601-628.
10. Xianming, S.; Tuan, A.N.; Zhiyong, S.; Yojun, L.; Recep, A. (2009). Effect of nanoparticles on the anticorrosion and mechanical properties of epoxy coating. *Surface and Coating Techn.*, **204**, 237-245.
11. Maki, S.A.; Ahmed, O.H.; Abdullah, M.Z.; Gheni, B.A. (2012). A study of reinforcing and temperature effect of impact strength for polymer blend. *Ibn Al-Haitham J. for Pure and Applied Sci.,* **3**(25),169-178.
12. Morsi, Bushra Hosni (2010). Study of the diffusive property and thermal conductivity of a mixture of UPE/NBR reinforced with ceramic powder. Diyala Journal of Pure Sciences. 6(4), 136-148.
13. Ahmed, Adnan Raad; Rahim, Saif Sabah; Abdul Majeed, Moayad Faik (2017). Practical study of some mechanical and physical properties of a binary polymer mixture of (epoxy-urethane resin). Tikrit Journal of Engineering Sciences, 24(2), 93-86.
14. Al Adam, Corgis Abd; Kashif Al-Ghada, Hussain Ali (1983). "Technology and Chemistry of Polymers". Basra University, p. 755.
15. William D. Callister, Jr., (2001). " Fundamentals of Materials Science and Engineering An Interactive ", John Wiley & Sons, Inc., 5th ed,, United States of America,250-254.
16. Al-Mosawi, A.I. (2009). Study of some mechanical properties for polymeric Composite , material reinforced by fibers. *AL-Qadisiyah J. for Engi. Sci.*,**2**(1), 14-24.
17. Crawford, R.J. (1987). "Plastic Engineering". 2nd ed, Pergamon Press, New York.
18. Muhammad, Akram Aziz (1993). "The Chemistry of Plastics". Mosul University, pp. 259-258.
19. Bolton, W. (1998). "Engineering Materials Technology". 3rd ed., Butter Worth-Heineman.193-200.

20. Al-Safi, Rola Abdel-Khader Abbas (2001). Study of the thermal and mechanical properties of Novolak and its compounds. Master's Thesis, University of Technology.
21. Florian, H.; Gojny, M.; Wichmann, H.G. (2005). Composites Part A: *Applied Sci. and Manufacturing.* **36**(11), 1525-1535.
22. Kenneth, H.G. (1993). "Fundamental Principles of Fiber Reinforced Composites". 2nd ed., CRC Press.
23. Derek Hull, (1981). "An Introduction to Composite Materials". Cambridge University Press, first Published,23-26.
24. Hibbeler, R.C. (2011). "Mechanics of Materials". 8th ed, Pearson prentice Hall, 81-83.
25. Al–Rawi Kh, R.; Yosif, R.H.; Najem, T.S. (2006). Mechanical properties of epoxy–polyurethane polymer blends. *Um–Salama Sci. J.,* **3**(4), 637–642.
26. Al-Bakri, Huda Abdel-Razzaq Younes (2012). Study of the mechanical properties of unsaturated polyester composite reinforced with randomly woven glass fibers and the effect of acidic solutions on some of its physical properties. Al-Rafidain Science Journal, (1)23, 129-114.

تحضير و دراسة بعض الخواص الميكانيكية لمتراكبات الايبوكسي والنوفولاك

الملخص

تم في هذا البحث دراسة خاصية مقاومة الانضغاط ومقاومة الصدمة والصلادة لنماذج محضرة من خليط بوليمري لراتنجات الايبوكسي والنوفولاك عند نسبة خلط مختلفة (4%, 6%, 8%, 10%, 11%) وقد تمت المقارنة بين المتراكبات البوليمرية قبل وبعد الخلط ووجد انه كلما زادت نسبة النوفولاك أدى ذلك الى زيادة في قيم كافة الخواص الميكانيكية (مقاومة الصدمة، الصلادة، مقاومة الانضغاط). وان قيم (مقاومة الانضغاط، الصلادة) تنخفض بزيادة درجة الحرارة.