Chemistry and Materials Research www.iiste.org
ISSN 2224- 3224 (Print) ISSN 2225- 0956 (Online)
Vol.7 No.7, 2015

Utilization of PVC Particles to Improve the Bending Properties of Epoxy and Unsaturated Polyester

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Abstract

Two sets of polymeric composites were formed. The first set included epoxy as matrix ,while the second set included unsaturated polyester (UP) as matrix. The two sets were reinforced with Polyvinyl Chloride (PVC) at different volume fractions. Each set was formed into two groups: one was allowed to cure at room temperature and the other was post cured at 40°C for 4hr .

The percent of reinforcing and the curing temperature can affect the behavior of composites. The epoxy composites is the highest in flexural properties than unsaturated polyester composites after reinforcing with thermoplastic material (PVC) .

Keywords: epoxy, unsaturated polyester, polyvinyl chloride (PVC), bending.

1. Introduction

Many of our technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloy, ceramics and polymeric materials. A composite is a multiphase material that is artificially made and chemically dissimilar and separated by distinct interface. One of these phases is termed the matrix which is the primary phase having a continuous character. The matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it. Dispersed (reinforcing) phase is embedded in the matrix in a discontinuous form. This secondary phase is called the reinforcing phase. The reinforcing phase consists of three main divisions: particles, fibers and structure, so it is usually stronger and stiffer than the matrix [1].

Polymeric composite is considered the earliest type of composite that is used in the greatest diversity of composite applications as well as in the largest quantities in the light of suitable ambient temperature properties, ease of fabrication, low density, good ductility and low cost. Polymeric materials could be classified according to behavior with rising temperature in to (Thermoplastics ,Thermosets) [2, 3, and 4].

Upon heating thermoplastic materials soften and melt, removal of the heat results in hardening, while with a thermosets, heat causes the material to char and decompose with no softening. thermosetting polymers are stronger and stiffer than thermoplastics. Thermoplastics offer the possibility of being heated and then pressed into to the required shapes, an example of thermoset polymers is epoxy and unsaturated polyester [5, 6].

An example of thermoplastic materials is Polyvinyl chloride (PVC) which is one of the most widely used plastics in the vinyl family. PVC is a very durable and long last construction material, which can be used in a variety of applications, either rigid or flexible. Its good impact strength and weatherproof attributes make it ideal for construction products [7, 8].

2. Aims

Study the effect of PVC particles addition in different percentages to the epoxy and unsaturated polyester as matrices on the Flexural properties, also find out the effect of post curing on the properties of composites.

3. Experimental work

3.1Materials

1. matrix I

The Unsaturated polyester (UP) was chosen to be the resin of matrix I which was transparent liquid .The accelerator and the hardener of the Unsaturated polyester were Cobalt Naphthalate and Methyl Ethyl Keton Peroxide (MEKP) respectively in a liquid state.

2. matrix II

Quickmast epoxy 105 (DCP) Company /Jordan. was chosen to be the resin of matrix II . Specific gravity and viscosity of this epoxy resin were 1.04 and 1 poise respectively. The ratio between resin and hardener for this epoxy is 1:3 by weight .

3. Reinforcement

PVC polymer (polyvinyl chloride) which was in a solid state as fine powder (75-300µ). The density of PVC is 1.3 (g/cm^3).

4. Experimental Procedure

The basic processing procedure was started by preparing the materials that are necessary to form composites (resin, reinforcement, mold, mold release agent…etc.). The materials were weighed by a sensitive balance to weigh the proper quantities that are needed to produce the specimens.

A rectangular metal mold (100mm length,13 mm width , 6 mm thickness) which has a removable base to facilitate the demolding of the specimen after having sufficient rigidity beside a release agent is applied to the mold surface after it cleaned, was prepared.

A hand lay-up process was chosen to form two sets of composite's specimens ; the first one included unsaturated polyester (UP) as matrix and the second one included epoxy as matrix, each set was reinforced with polyvinyl chloride (PVC).

In the first set the unsaturated polyester was mixed with the accelerator (Cobalt Naphthalate) at 0.5% which give it a pink colour after it was transparent ,then the hardener(MEKP) was mixed with them at 2%; while in the second set the epoxy was only mixed with the hardener (Quickmast 105 hardener) at 1:3 by weight .

Careful should be made in adding the hardener at specific percentage to keep the reaction under control because it's an exothermic reaction and to prevent any internal stresses or bubbles can occur.

After the homogeneity is achieved in the polymer, the reinforcement is added at different weight to obtain different volume fractions to the both sets.

Thoroughly mixing is recommended to achieve the best distribution in the formed composites.

The composite's specimens that are formed in both sets are allowed to cure at room temperature for 24 hr to reach complete hardening. After curing the specimens are demolded and weighed , then the same procedure are repeated again to produce a second group of composite's specimens; the only difference from the first group is that the specimens were post cured at 40° c for 4 hr.

5. Bending technique

Bending strength can be defined as the ability of material to bend under the applied load without fracture [9].
This test was performed according to ASTM-D790 at room temperature [10]. The specimen dimensions were 100 mm length, 13 mm width and 6 mm thickness.

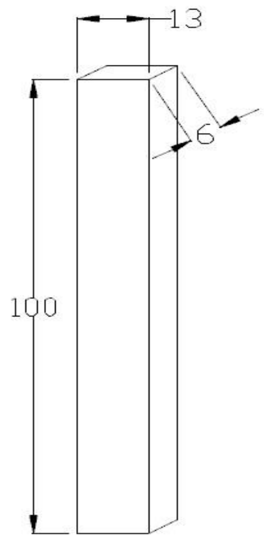

Figure (1): the standard specimen according to ASTM -D790 .

In engineering mechanics, flexure (or bending) characterizes the behavior of a structural element subjected to an external load applied perpendicular to the axis of the element .

Flexural strength represents the strength at the fracture of the beam section when tested. The flexural strength can be calculated by "Three- Point Test" or "Four- Point Test". Figure (2) shows three- point bending test (simple supported beam specimen). A flat rectangular specimen is simply supported close to its ends and either centrally loaded in three-point bending or by two loads placed symmetrically between the supports, giving four-point bending.

Clearly stress concentrations exist at the loading points but in four-point loading, between the inner loading points, there is a constant bending moment [11].

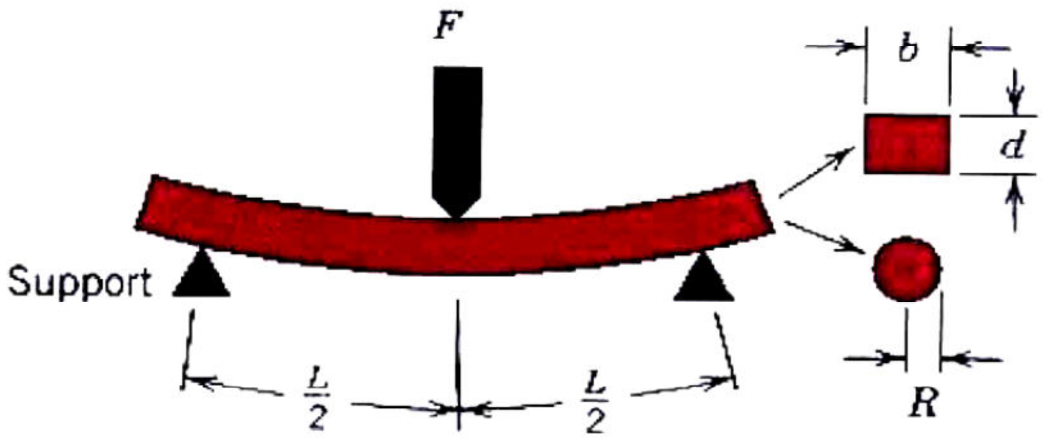

Figure (2): Three- point bending test (simple specimen) [12] .

At the point of loading the top surface of the specimen is placed in a state of compression, while the bottom surface is in tension
The maximum flexural strength in this test can be calculated by the following equation [13&14] **:-**

$$\mathbf{F.S} = \frac{3PL}{2bd^2} \quad \text{......................................(1)}$$

where:
P: load at fracture (N).
L: length of specimen (m).
d: thickness of specimen (m).
b: width of specimen (m).

The bending modulus (E_{Bend}) can be determined by using Equation**:-**

$$E_{Bend} = \frac{fl^3}{48Ib\delta} \quad \text{.................................(2)}$$

Where:
E_{Bend}: modulus of elasticity in bending (MPa).
f: applied forced (N).
l: length of specimen (support span) (m).
δ: specimen deflection (m).
I: moment of inertia of specimen (m4).

The moment of inertia of specimen is determined using Equation**:-**

$$I = \frac{bd^3}{12} \quad \text{.......................................(3)}$$

where:
b: width of beam tested (m).
d: thickness of beam tested (m).
Also the maximum load at failure, the max. shear stress is determined using Equation**:-**

$$\tau_{max} = \frac{3P}{4bd} \quad \text{..................................(4)}$$

where:
P: load at fracture (N).
d: thickness of specimen (m).
b: width of specimen (m).

(a) (b)

Figure (3): The preparations of bending specimens.
a-The bending specimen in the mold.
b- The bending specimens after demolding

(a) (b)

Figure (4): The bending test
a- The ends of the specimen is on the supports of the instruments.
b- Universal testing machine.

6.Results and discussion

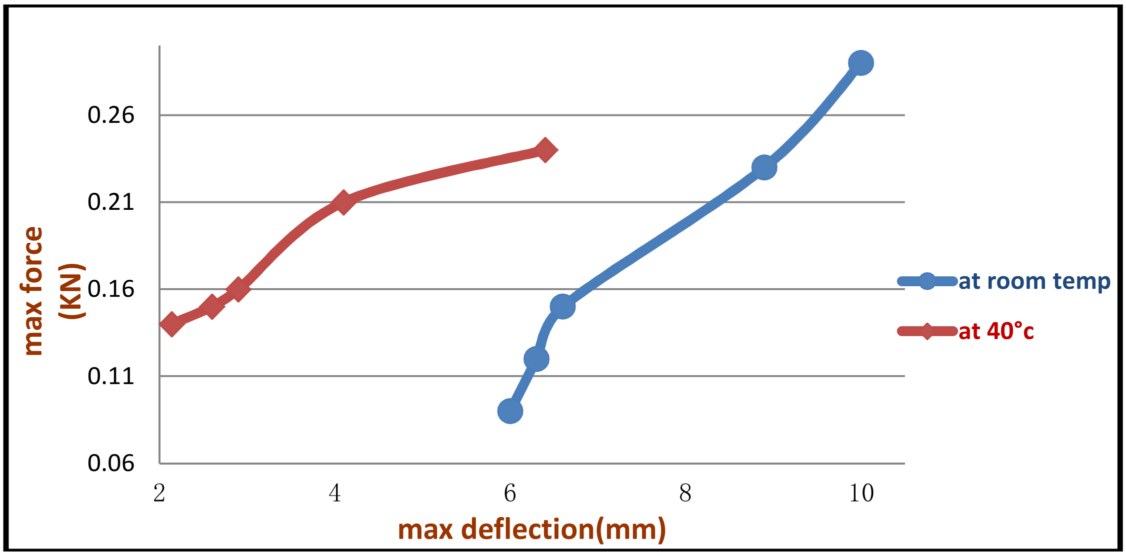

Figure (5): a relationship between max force & max deflection of UP composites before & after post curing .

From figure(5) it was noticed that the maximum deflection in the unsaturated polyester composites increased with increasing of force at room temperature , while the maximum deflection decreased with the decreasing of force after post cured (at 40°C) as the volume fraction increased .

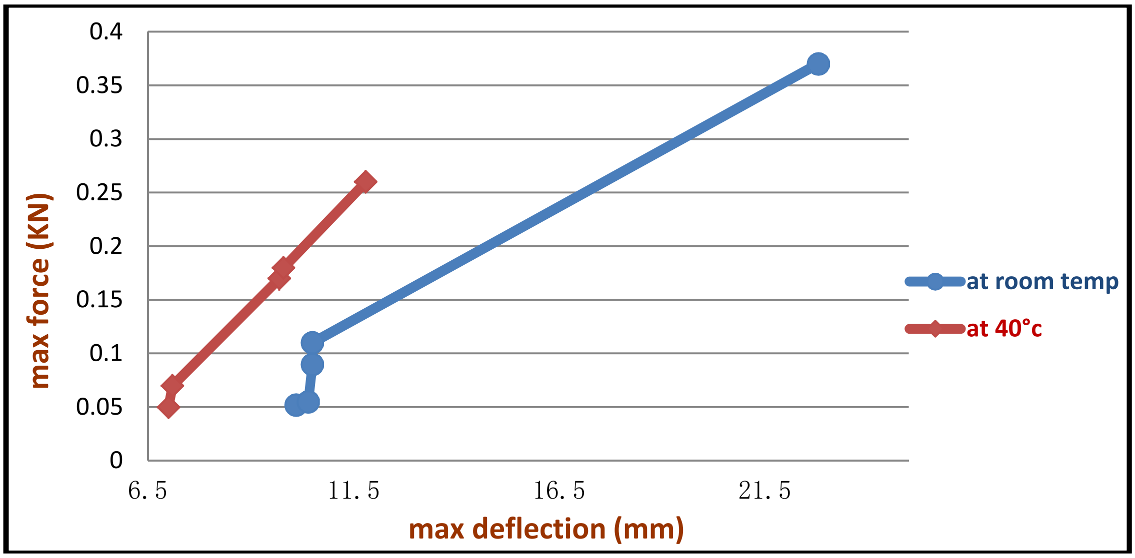

Figure (6): a relationship between max force and max deflection of Epoxy composites before & after post curing .

From figure(6) it was noticed that the maximum deflection in epoxy composites increased with increasing of force before & after post curing. The highest value was reached at room temperature.

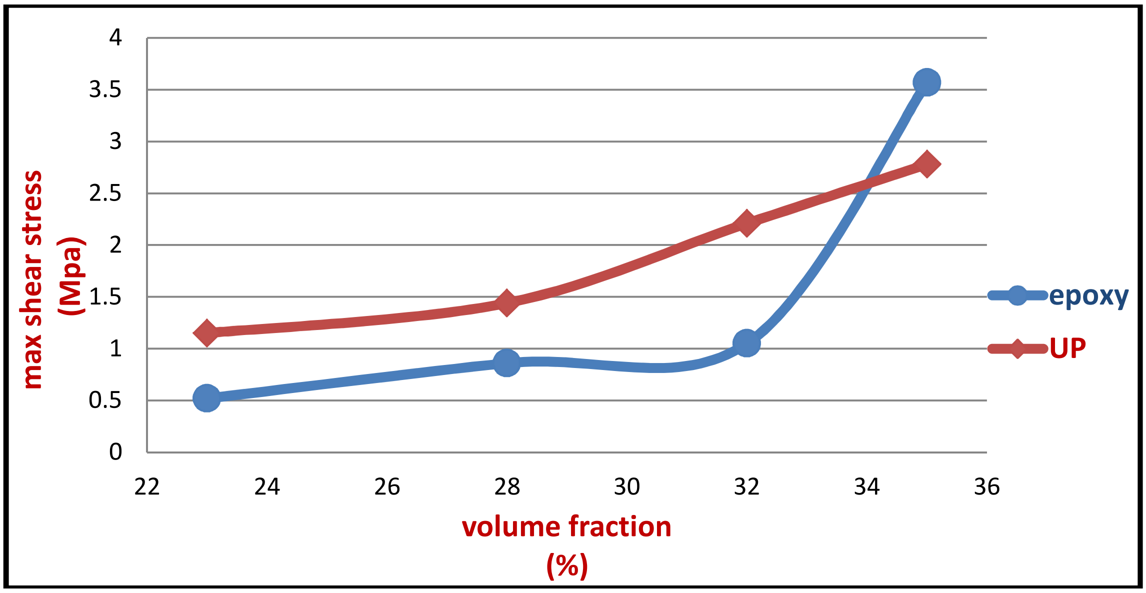

Figure (7): comparison of max shear stress between Epoxy and UP composites at room temperature.

From figure(7) it can be seen that the max shear stress had been improved by the PVC reinforcing for both composites.
The max shear stress of epoxy and unsaturated polyester composites increased with increasing of volume fraction at room temperature. The highest value of shear stress was reached in epoxy composites .

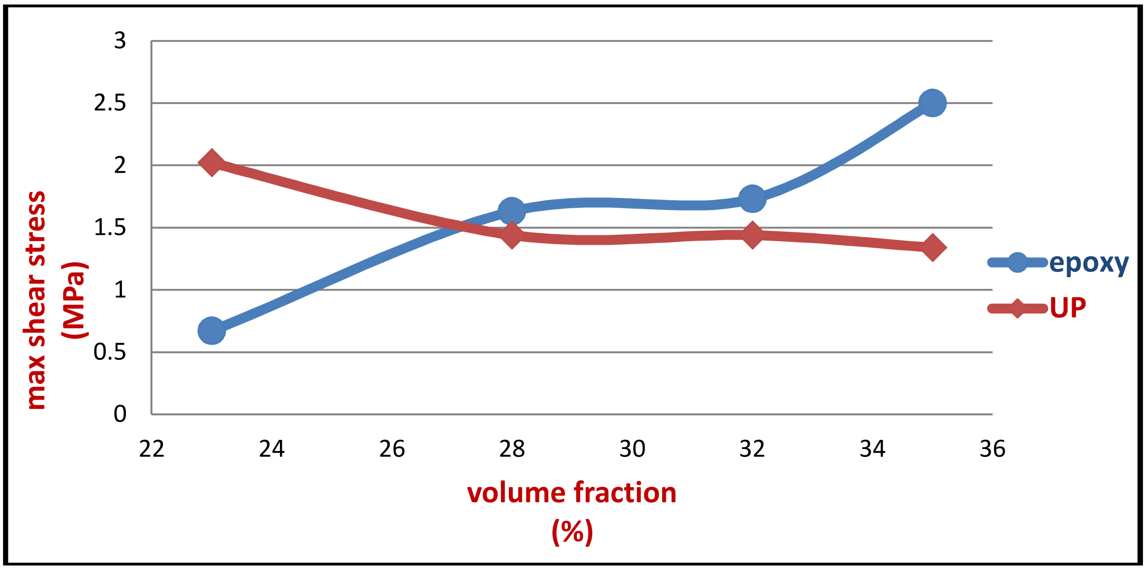

Figure (8): comparison of max shear stress between Epoxy and UP composites after post cured (40°C) .

From figure(8) it can be seen that the max shear stress of epoxy composites increased with increasing of volume fraction after post cured (at 40°C) , while the max shear stress of unsaturated polyester composites decreased with increasing of volume fraction.

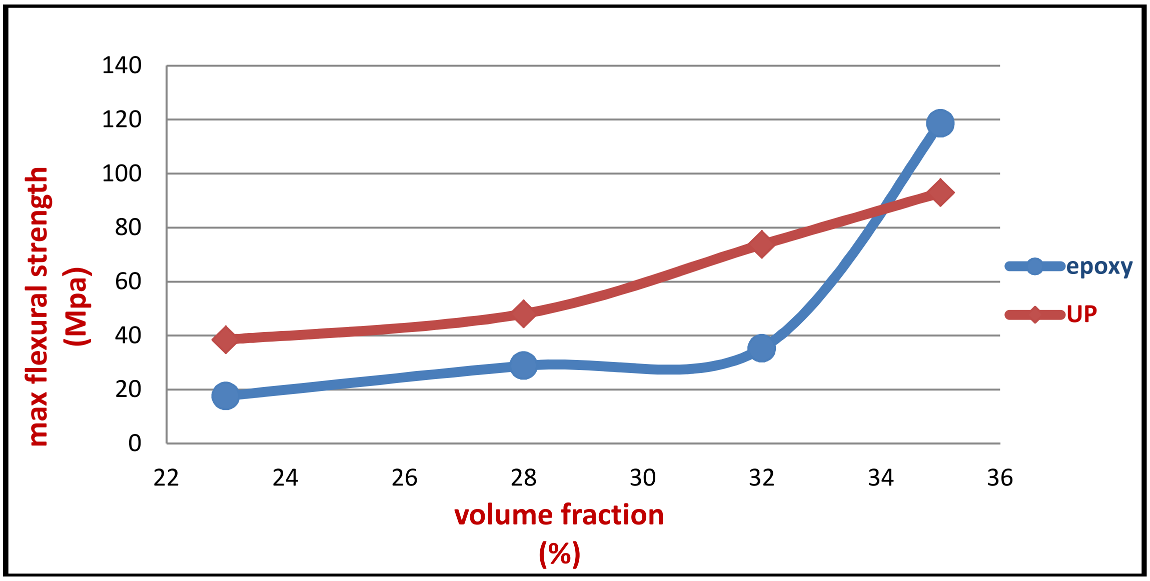

Figure (9): comparison of max flexural strength between Epoxy and UP composites at room temperature.

From figure(9) it could be observed that the max flexural strength of epoxy and unsaturated polyester composites increased with increasing of volume fraction of reinforcing PVC at room temperature. The highest value of the max flexural strength was reached in epoxy composites .

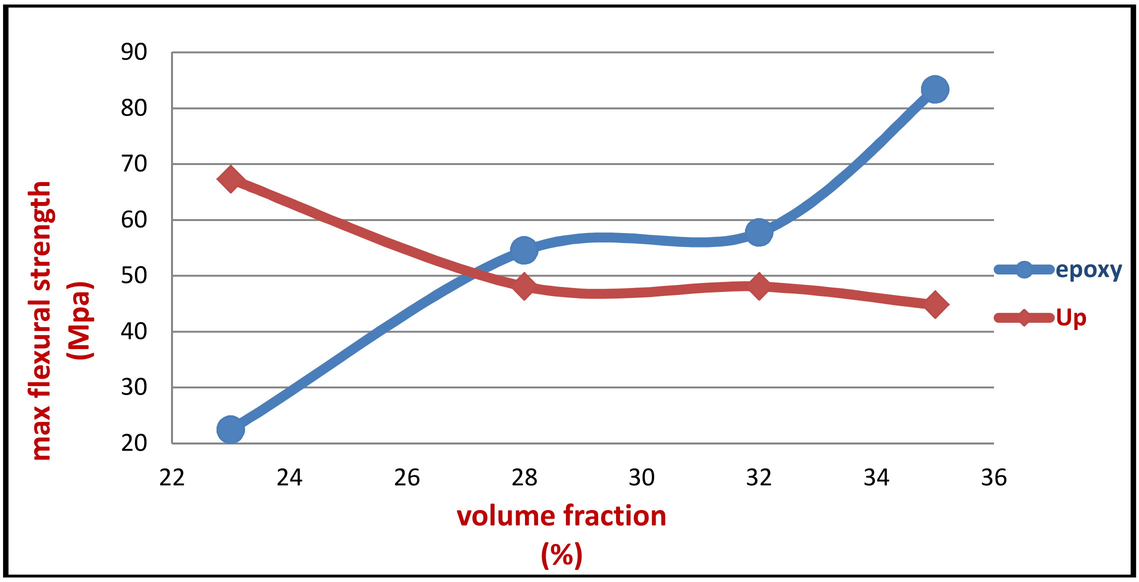

Figure (10): comparison of max flexural strength between Epoxy and UP composites after post cured (40°C) .

From figure(10) it could be observed that the max flexural strength of epoxy composites increased with increasing of volume fraction of reinforcing PVC after post cured (at 40°C), while the max flexural strength of unsaturated polyester composites decreased with increasing of volume fraction.

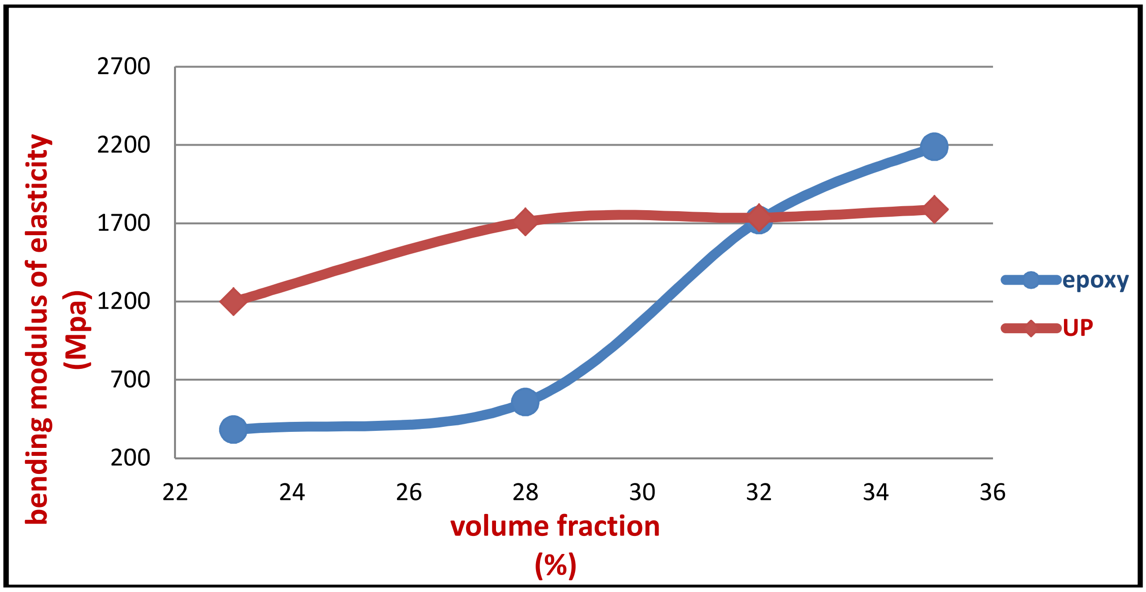

Figure (11): comparison of bending modulus of elasticity between Epoxy and UP composites at room temperature.

Figure (11) illustrates that the bending modulus of elasticity of epoxy and unsaturated polyester composites increased with increasing of volume fraction at room temperature. The highest value bending modulus of elasticity was reached in epoxy composites .

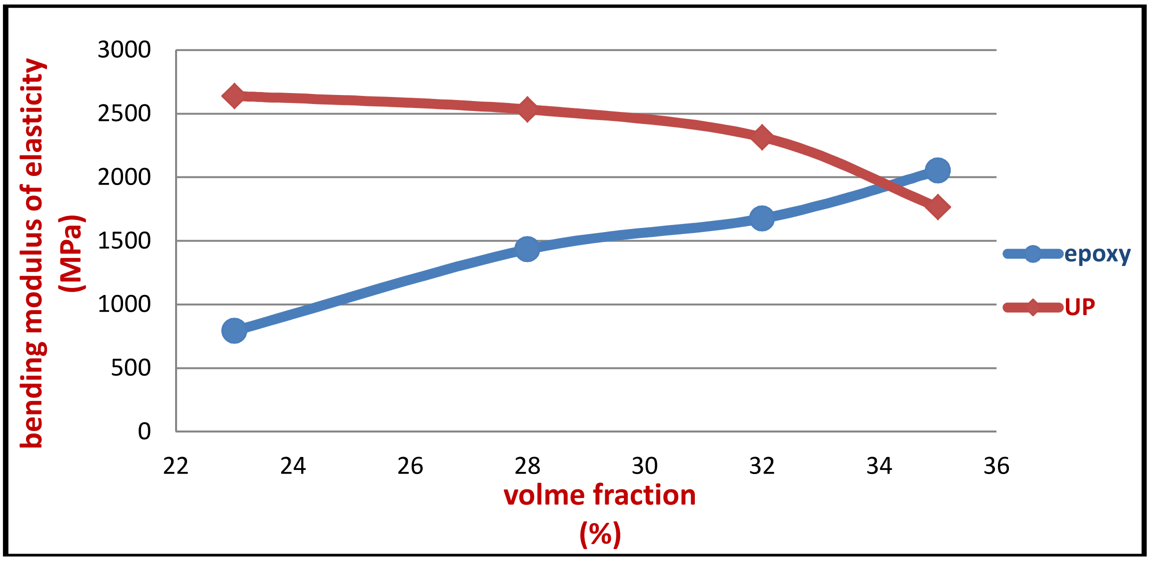

Figure (12): comparison of bending modulus of elasticity between Epoxy and UP composites after post cured (40°C) .

Figure (12) illustrates that the bending modulus of elasticity of epoxy composites increased with increasing of volume fraction after post cured (at 40°C), while the bending modulus of elasticity of unsaturated polyester composites decreased with increasing of volume fraction.

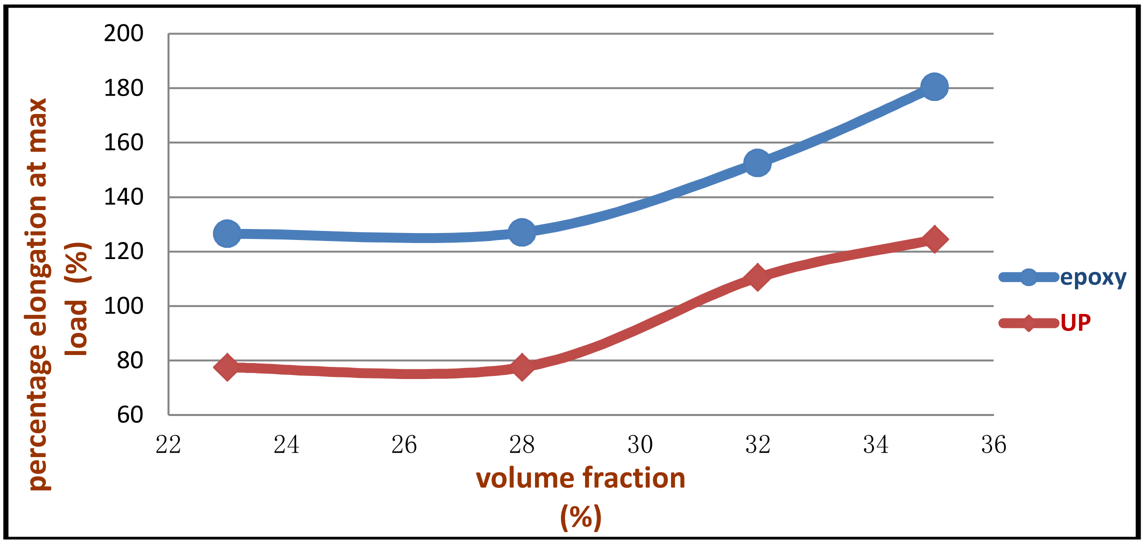

Figure (13): comparison of percentage elongation at max load between Epoxy and UP composites at room temperature.

figure(13) shows that the percentage elongation at max load of epoxy and unsaturated polyester composites increased with increasing of volume fraction of reinforcing PVC particles at room temperature. The highest value of the percentage elongation at max load was reached in epoxy composites .

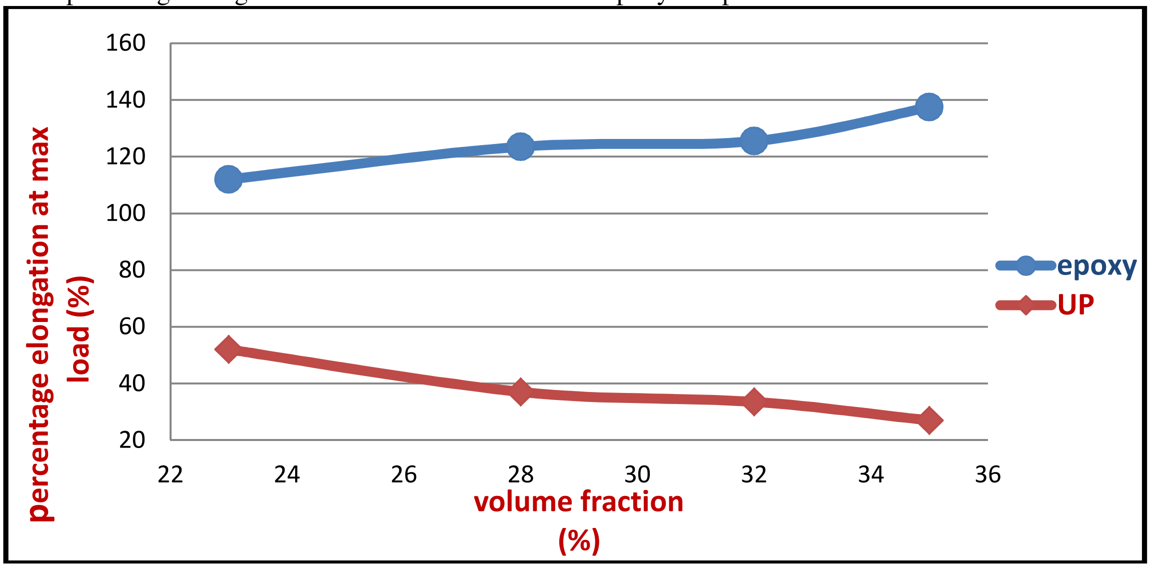

Figure (14): comparison of percentage elongation at max load between Epoxy and UP composites after post cured (40°C) .

figure(14) shows that the percentage elongation at max load of epoxy composites increased with increasing of volume fraction of reinforcing PVC particles after post cured (at 40°C), while the percentage elongation at max load of unsaturated polyester composites decreased with increasing of volume fraction.

7. conclusion

The percent of reinforcing and the curing temperature can affect the behavior of composites. The epoxy is the highest in flexural properties than unsaturated polyester composites after reinforcing with thermoplastic material

References

1.David Roylance,"INTRODUCTION TO COMPOSITE MATERIALS" Cambridge, MA 02139 ,March 24,(2000).
2. G. Lubin, "Handbook of Composite", Society of Plastic Engineering, SPE, Van Nostrand Reinhold VNR, New York, (1982).
3. W.D. Callister, "Materials Science and Engineering", 6th edition, University of Utah, John Wiley and sons. Inc., (2003).
4. J.W. Weeton, "Engineering's Guide to Composite Materials", published by American Society for Metals

ASM, U.S.A., (1987).
5. Autar K. Kaw., "Mechanics Of Composite Materials", Second edition, Taylor & Francis Group, LLC, Boca Raton London New York , (2006).
5. Joel R . Fried.," Polymer Science and Technology", Second Edition, PHI learning private limited, New Delhi, (2012).
7. Charles E. Wilkes, Charles A. Daniels and James W. Summers, "PVC Handbook" Hanser department, ISBN 3-446-22714-8,April (2005).
8. Arie Ram.,"Fundamentals of Polymer Engineering",© Plenum Press, New York, (1997).
9. D. R. Askeland and P.P. Phule,"The Science and Engineering of Materials", 4th Edition, Thomson Brook/Cole, (2003).
10. " Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials D 790- 03", Annual Book of ASTM Standard, Vol 08.01. (2003.).
11. J M Hodgkinson. , "Mechanical testing of advanced fibre composites", Cambridge England, Woodhead Publishing Limited and CRC Press LLC©, 2000.
12. W.D. Callister, "Materials Science and Engineering" 6th edition, University of Utah, John Wiley and sons. Inc., (2003).
13. G. C. Ives, G. A. Mead and M. M. Riley, "Handbook of Plastic Test Method" Fietcher and Son, (1971) .
14. B. R. Sanders and T. L. Weintraub, "Metal Handbook Mechanical Testing" Vol. 8, 9thed. USA, (1985) .