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Experimental Study on Effect of Recycled Epoxy Powder Reinforcement on Tensile Behavior of Acrylonitrile Butadiene Styrene

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Abstract

Thermosetting plastic found wider application in the field of Aerospace, Aircraft, Wind Turbines, Marine and construction due to their long life, light weight and high strength. Among thermosets, epoxy is the major contributor. The world epoxy resin usage is almost 3.6 million tons in the year 2022 and it may cross 5.91 million tons by 2029. At their end of life most of it goes to land filling which leads to major soil pollution and degradation of soil fertility. It is essential and need of the hour to recycle the cross linked epoxy for the sustainability of the same. This study investigates how incorporating cross-linked epoxy microparticles influences the tensile properties of ABS polymer. Cross-linked epoxy, processed to micro powder form is used as a reinforcement to recycle along with virgin Acrylonitrile Butadiene Styrene. Prepared cross linked epoxy micro powder were used in various proportions of 5%, 10%, 15% and 20%, finally compared with tensile behavior of neat ABS. Specimens are fabricated using micro compounder injection molding machine. Evaluated mechanical characteristics including tensile strength, tensile modulus, and elongation percentage. The tensile modulus and tensile strength reaches the value of neat ABS for composite with 80:20 ABS and Epoxy proportion. The change in percentage elongation is negligible.

Keywords: ABS, Epoxy, Tensile strength, Tensile modulus, Percentage elongation

INTRODUCTION

Polymers are composed of monomers which are repeating structural units, linked one to another through chemical bonds. Polymers can be classified in to natural and synthetic polymers in general. Natural polymers are found in nature whereas synthetic polymers are made by humans. Polymers are light in weight, resistant to corrosion, low thermal and electrical conductivity, flexible and rigid based on type of structure. Among synthetic polymers plastic finds wider applications.

Based on thermal behavior plastics can be classified in to Thermoplastic and Thermosetting plastic. In thermoplastics, molecules are arranged in linear chains and can be used again and again several times as they soften on heating and harden on cooling. Thermoplastics are recyclable and soluble in certain solvents. Thermoplastics finds application in households, automobiles, medical, electrical and construction etc. In thermosetting polymers, molecules are cross linked to form a strong bond and cannot be used again and again several times as they harden permanently when heated. Thermosetting polymers are cannot be recycled and are hard, rigid, chemical and heat resistant.

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Among synthetic polymers ABS is one of the widely used thermoplastic polymer. ABS polymer is made from three monomers such as Styrene, Butadiene, and Acrylonitrile. ABS becoming popular among polymers as copolymers proportion can be varied according to the requirement. Styrene gives the property of machinability and glossy, butadiene enhances impact resistance and ductility, Acrylonitrile provides chemical and thermal resistance [1]. The ratio of these monomers can be varied to get different properties of the resulted polymer. ABS is a durable and strong polymer; the natural material color is an opaque ivory but dyes can be used to get different colors. It has excellent mechanical properties such as hardness and toughness thus delivers good impact strength and also have high degree of surface quality, low water absorption due to good weathering characteristics and good dimensional stability [1, 4]. Apart from these characteristics, Acrylonitrile Butadiene Styrene is a chemically resistant resin and exhibits good electrical insulating properties. ABS has wide range of applications in the field of automobile parts such as instrument panel, radiator grill, fenders, door panels, mirror housing, head light housing, seat belt components, door liners, handles, bumpers etc. ABS also finds its application in electronic housings such as Television, Computer, Printer etc., domestic appliances such as vacuum cleaner, refrigerator etc, gardening tools, medical devices, protective housings etc. [2]. In order to further increase / enhance mechanical, electrical, chemical and thermal properties, various additives, fillers and reinforcements can be added to ABS polymer. The filler materials such as CF, CNT, MWCNT, SiC, Basalt, Glass fibre, Graphene etc. are commonly added to polymers to improve mechanical, electrical, thermal and morphological properties [3, 15, 18].

There are many thermosetting polymers such as Epoxy resins, Phenol formaldehyde resin, Bakelite and Urea formaldehyde resin etc., Epoxy is a thermosetting polymer that becomes permanently hard when cured is produced by the reaction between curing agent and epoxy resin. It has excellent mechanical and Thermal properties which makes it to find its applications in varies fields. It is strong, durable, has excellent adhesion property, good corrosion and chemical resistance. Among thermosets, epoxy is the major contributor as it is one of the widely used thermoset polymer in the field of aircraft, aerospace, marine, construction resin etc.[5-6] and finds application as Adhesives in structural and industrial field, Coatings in protective and decorative, as Composites in fiberglass and carbon fiber, in Electrical insulators and encapsulates, in Aerospace aircraft and spacecraft, Automotive as body parts and repair, Marine as boat building and repair, Construction as flooring and roofing[14, 15]. After usage and at their end of life most of it goes to land filling which leads to major soil pollution, environmental and economical concern. An attempt is made to recycle the cross linked epoxy / used epoxy through further processing to use it as a micro filler reinforcement material. Recycling of epoxy leads to sustainability, saving environment and material as well. In order to study the effect of filler material on the mechanical properties of the composite [19], micro powder epoxy size ranging below 50 microns is used as a reinforcing material to ABS polymer matrix in various proportions [8, 9, 10, 11,16].

MATERIALS AND METHODS

The purpose of this study is to recycle the cross linked epoxy [20] by using it as a micro filler reinforcement material with ABS polymer matrix and carry out Tensile testing to assess the effect of cross linked epoxy micro powder reinforcement on ABS polymer tensile properties. Epoxy raw material is supplied by a company called carbon black composites, Mumbai. Epoxy is available in two components such as resin and hardener are thoroughly mixed with a mix ratio of 3:1 as supplied and cured to get cross linked rectangular block. Cross linking of the epoxy is confirmed through FTIR (Fourier Transform Infrared Spectroscopy) test as shown in Figure 5(d). The block of cross linked epoxy is hammered into small fragments to grind the same in to small granules using industrial grinder in order to make the material suitable for ball milling machine processing. Ball milling machine further reduces the epoxy granules to micro scale level as shown in Figure 1(a) (b) & (c). The material is powdered to less than 50 microns, whose size is ensured using SEM imaging which ranges from 2.5 microns to 33.4 microns as shown in Figure 2(a) & (b). The Pellets form of ABS raw material is shown in the Figure 1(d), which is manufactured by STYROLUTION ABS (INDIA) LIMITED and the above prepared cross linked epoxy micro powder were used in the proportions of 5%, 10%, 15% and 20% to fabricate the test specimens. Micro–compounder Injection molding machine and other facilities available at Central Institute of Plastic Engineering and Technology (CIPET), Jala hobli, Bengaluru unit are used to fabricate and test the specimens. Tensile test specimens are fabricated and Tested according to ASTM D638 Type-V standards.

Test specimens detailed dimensions are given in the Table 1. During specimen fabrication temperature range of micro compounder machine is maintained between 230 to 270 degree and pressure is in the order of 500 to 600 bar. After fabrication, the specimens are kept in controlled atmosphere for a period of one week to relieve thermal stresses generated during molding process. Detailed discussion of the test results can be found in the below sections.

Table 1. Dimensions of Tensile Test Specimens as per ASTM D638 Type-V Standards.

Parameter	Dimension in mm
Overall length	(L) 63.75
Gauge Length	(G) 7.62
Width of narrow section	(W) 3.18
Length of narrow section	(D) 9.53
Thickness (t)	3.2
Width at ends (Wo)	9.53
Radius of fillet (R)	12.7

Figure 1. Production Process of Epoxy Micro Particles from Rectangular Blocks. **a** - Shows Epoxy Granules Obtained by Breaking Rectangular Blocks, **b** - Shows Ball Milling of Epoxy Granules, **c**– Shows Cross Linked Epoxy Micro Particles and **d**- Shows Natural ABS Polymer Pellets.

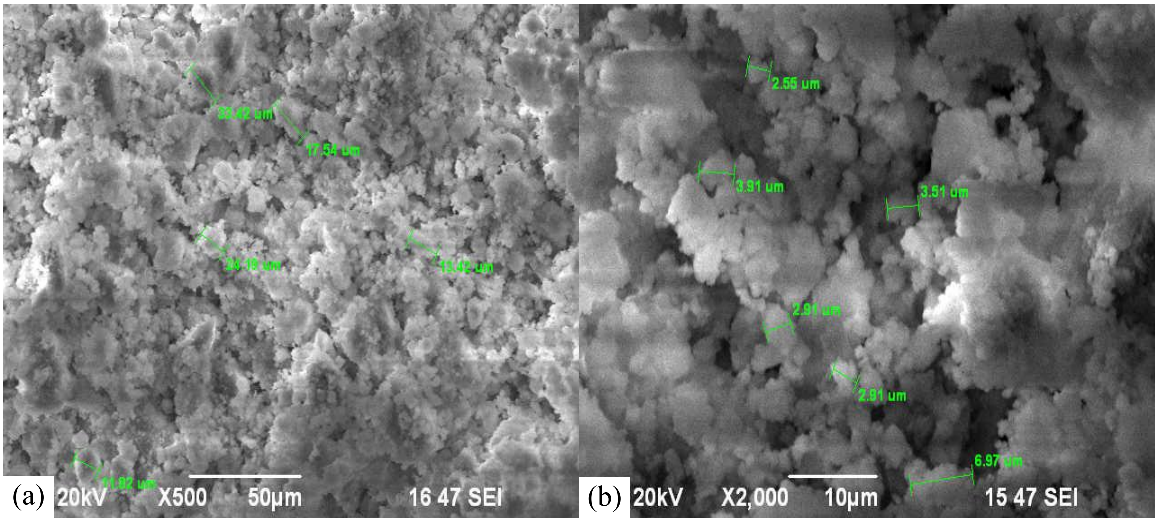
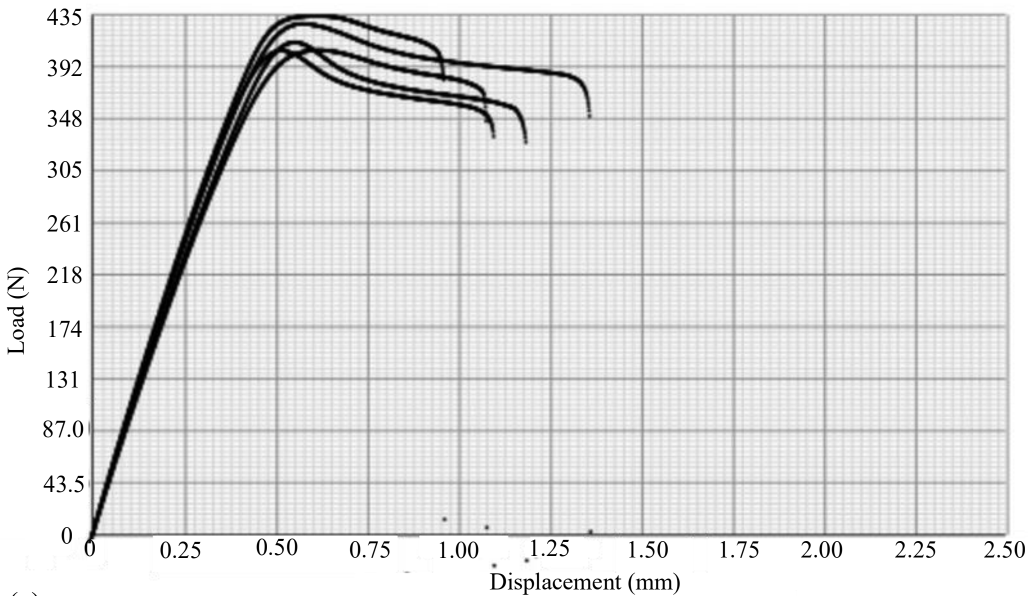


Figure 2: SEM Images Showing Particle Size Range of Cross Linked Epoxy Powder Sample. (a) – at 500X and (b) – at 2000X.

Figure 3: Tensile Testing Specimens A1 (100%ABS + 0%E), A2 (95%ABS + 5%E), A3 (90%ABS + 10%E), A4 (85%ABS +15%E) and A5 (80%ABS + 20%E) Before and After Testing.



(a)

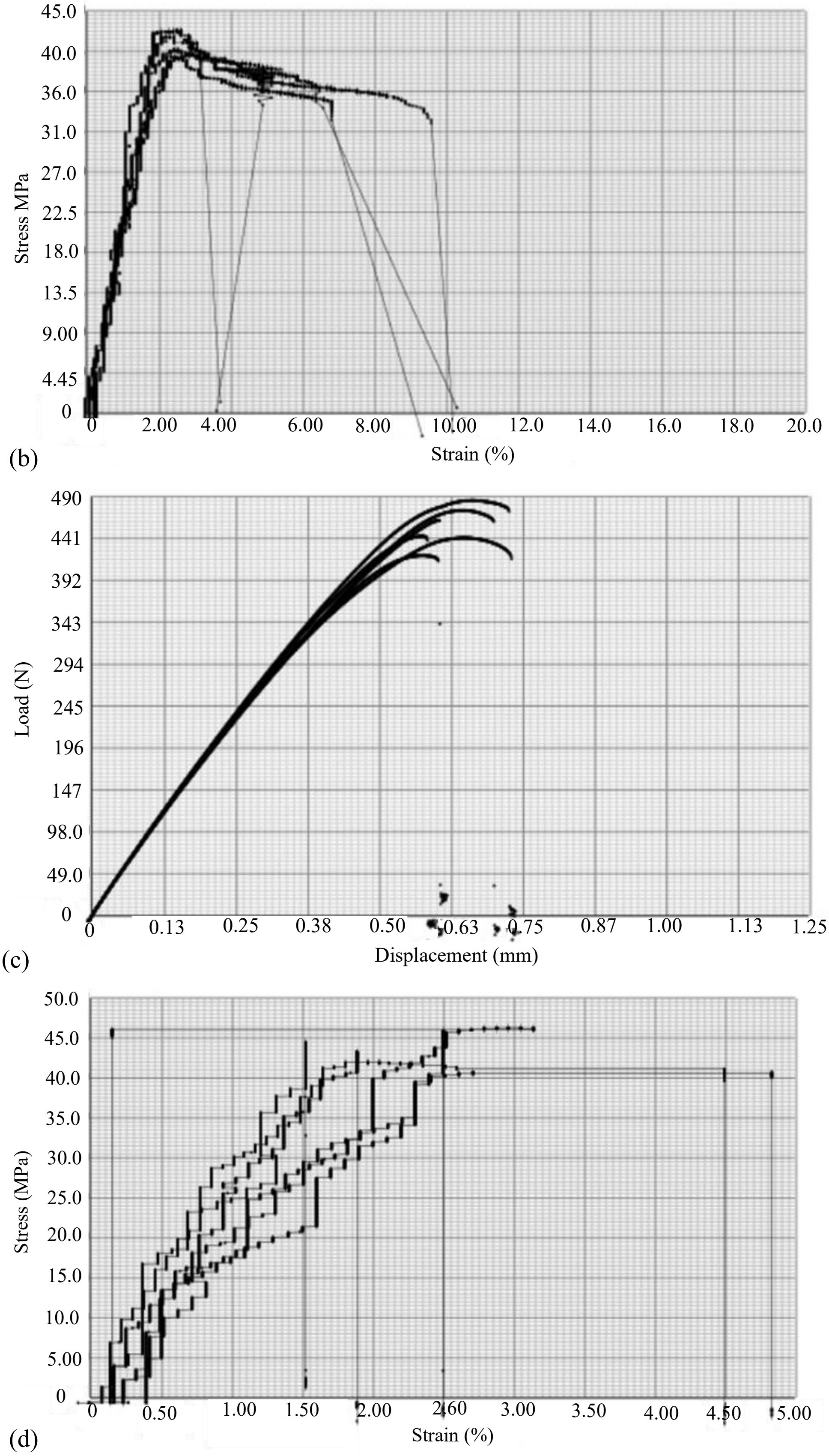
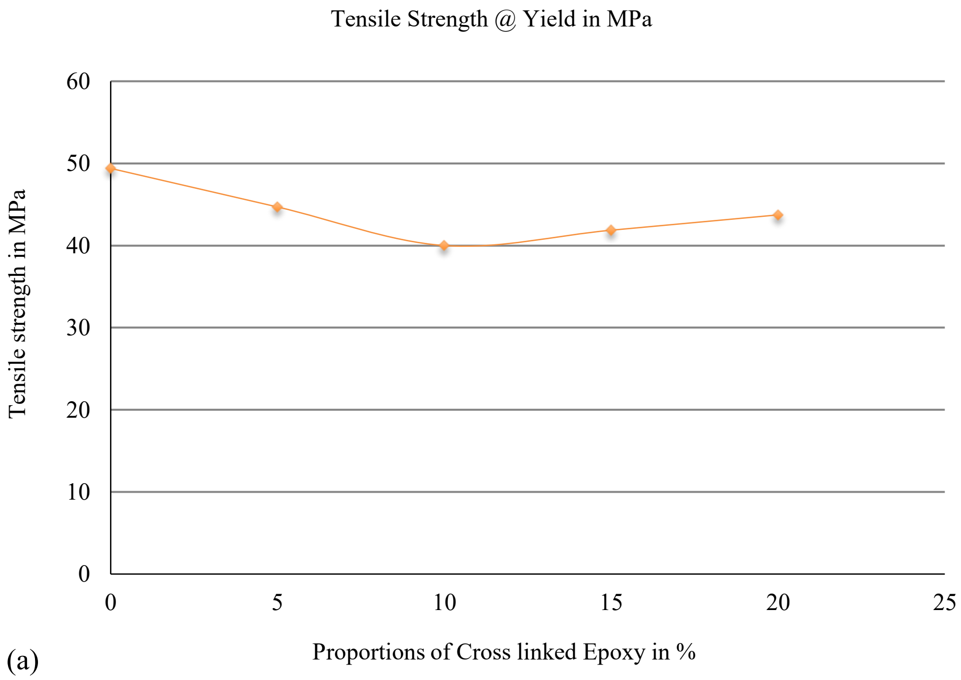


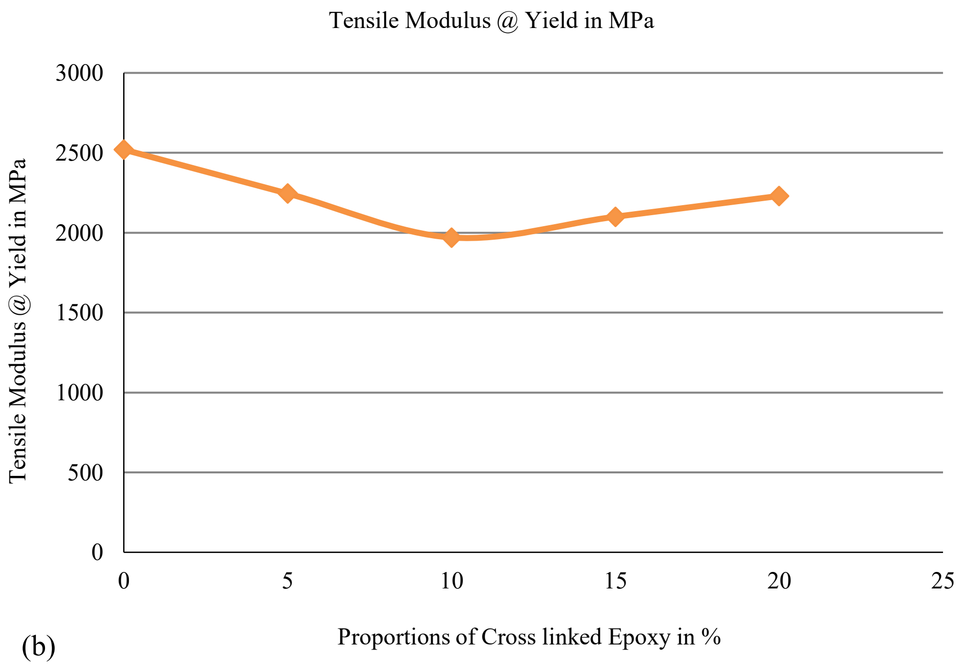
Figure 4. Load vs Displacement and Stress vs Strain Graphs. (a) and (b) – for 90% ABS and 10% Epoxy, (c) and (d) – for 80% ABS and 20% Epoxy

EXPERIMENT RESULTS AND DISCUSSION

The test specimens made of Acrylonitrile Butadiene Styrene (ABS) Epoxy (ABSE) composite were fabricated by reinforcing cross linked micro epoxy at a proportion of 0%, 5%, 10%, 15% and 20%, it is designated as A1, A2, A3, A4 and A5 respectively in Acrylonitrile Butadiene Styrene matrix using micro compounder (screw extruder) injection molding machine [7, 13, 17]. In this experimental study the tensile test is carried out on the specimens of Acrylonitrile Butadiene Styrene Epoxy (ABSE) composites according to ASTM D638 standards. Figure 3 shows images of tensile test specimens before and after testing respectively. Figure 4 (a) shows load vs displacement diagram and (b) shows stress vs strain diagram for 90%ABS and 10% Epoxy proportion. Figure 4 (c) shows load vs displacement diagram and (d) shows stress vs strain diagram for 80%ABS and 20% Epoxy proportion The test results are compared with the neat Acrylonitrile Butadiene Styrene [7,12,13].



(a)



(b)

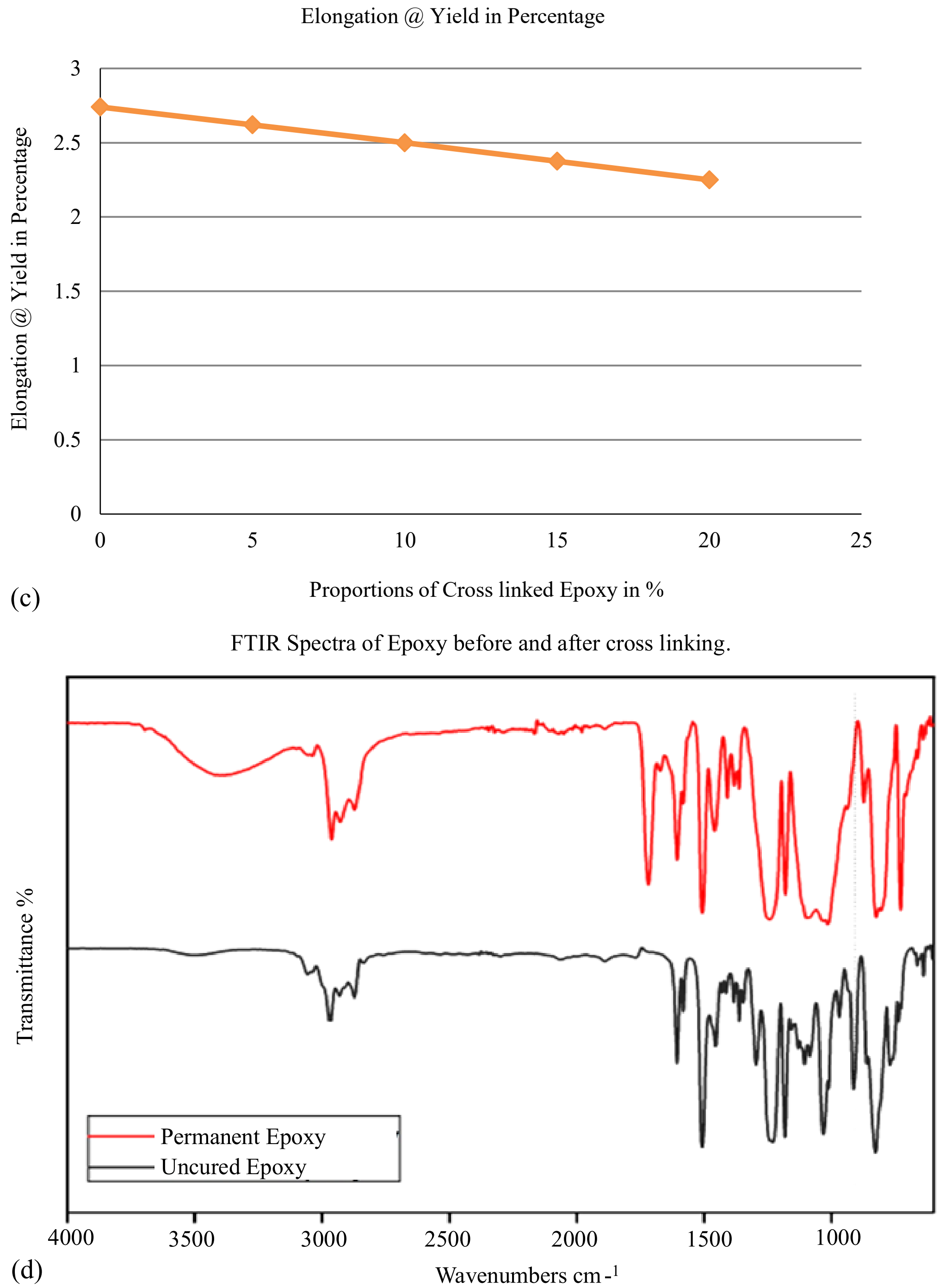


Figure 5. Mechanical Properties Versus % of Cross Linked Epoxy, **a**-Tensile Strength, **b**- Percentage Elongation, **c**-Tensile Modulus and **d**- FTIR Spectra of Epoxy Before and After Cross Linking.

When Figure 5(a) is observed, epoxy micro particles reinforcement have impact on tensile strength of ABSE (Acrylonitrile Butadiene Styrene Epoxy) composite. The tensile strength of composite reduces slightly with increasing epoxy percentage and then increases. Tensile strength of neat Acrylonitrile Butadiene Styrene is 45 MPa reduced to 39.02 MPa for composite with 95% of ABS and 5% of cross linked epoxy and then increases to 40 MPa, 41.86 MPa and then to 43.73 MPa for composite with 90% ABS: 10% Epoxy, 85% ABS: 15% Epoxy, 80% ABS: 20% Epoxy respectively. The Tensile strength of composite with 80% ABS and 20% Epoxy almost reaches the value of neat ABS. Figure 5(b) depicted that, cross linked epoxy micro particles have slight impact on Percentage elongation of ABSE composite. The Percentage elongation of composite decreases slightly with increasing epoxy percentage. Percentage elongation of neat ABS is 2.74 % reduced to 2.62, 2.5, 2.38, 2.25 for composite with 95% ABS: 5% Epoxy, 90% ABS: 10% Epoxy, 85% ABS: 15% Epoxy, 80% ABS: 20% Epoxy respectively. Figure 5(c) depicted that, epoxy micro particles have affected the tensile modulus of ABS. The tensile modulus of neat Acrylonitrile Butadiene Styrene is 2350 MPa reduced to 1890 MPa for composite with 95% of ABS and 5% of cross linked epoxy and then increases to 1970 MPa, 2100 MPa, 2230 MPa for composite with 90% ABS: 10% Epoxy, 85% ABS: 15% Epoxy, 80% ABS: 20% Epoxy respectively.

CONCLUSIONS

The ABS Epoxy Composite Tensile behavior is studied by varying the proportions of filler & matrix and the following conclusions can be drawn from the obtained result:

The ABS Epoxy Composite Tensile properties have strongly influenced by the cross linked epoxy fillers. The tensile strength and tensile modulus of ABSE composite reaches the values of neat ABS for 80:20 proportions of ABS and Epoxy. The maximum average tensile strength and tensile modulus obtained are 43.73 MPa and 2230 MPa respectively. The percentage elongation for neat ABS is 2.74 whereas for 80:20 ABSE composite is 2.25. The change in percentage elongation is negligible. The Tensile properties of the composite can be further enhanced by using suitable fillers, additives and compatibilizers. It can be concluded that, thermoset epoxy can be successfully recycled by using it as a reinforcement in ABS matrix material considering changes in other properties as well. Future plan of work is to carryout fabrication and testing of specimens to assess other mechanical properties such as flexural strength, Hardness, Impact strength and abrasion resistance etc. Use of suitable reinforcements / additives / fillers that enhances the mechanical, thermal, electrical and chemical properties depending upon specific applications.

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Declaration of conflict of Interest

The author hereby declares that there is no conflict of interest in research, authorship and publication of this article.

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Ethical considerations

I confirm that all the research meets ethical guidelines and adheres to the legal requirements of the study country.

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