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# Overall Effect of Nano Clay on the Physical Mechanical Properties of Epoxy Resin

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***Abstract*—**In this paper, the effect of modified clay on the mechanical efficiency of epoxy resin is examined. Studies by X ray diffraction and microscopic transient electron method show that modified clay distribution in polymer area is intercalated kind. Examination the results of mechanical tests shows that existence of modified clay in epoxy area increases pressure yield strength, tension module and nano composite fracture toughness in relate of pure epoxy. By microscopic examinations it is recognized too that the action of toughness growth of this kind of nano composite is due to crack deflection, formation of new surfaces and fracture of clay piles.

***Keywords*—**Nano clay, Epoxy, Toughness, Composite

## I. Introduction

WITH entrance to nano era in material science area, reinforced polymers to nano phase are emphasized by industrial and scientific societies. In aspect of science, a new position in researches in middle-scale of molecular and micro scales is opened and knowledge of behavior and interaction of materials in nano area is categorized in medical primacies. From industrial view point what is caused that many industrials pay attention to this subject is appreciable improvement of polymer characteristics in insulation discussion, covering and protection of vessels and pipes in oil, gas and petrochemical industries[1]-[3]. It is seems that these systems represent new collection of materials in comparison of common polymer composites. Therefore, in recent years many researches for knowing nano composite polymer characteristics and development of this kind of materials are formed and clay is used as a nano filler in making polymer nano composites in a notable content. About polymer nano composites it is reported notable improvement of mechanical characteristics such as strength, solidness and thermal characteristics without negative effect to density and process ability[4]-[7]. Reinforced polymers with modified clay plus of mentioned advantages have not porosity against transient of water and gas. These materials have acceptable transparency against ultraviolet ray too. In amount of all kinds of polymers, epoxy resins have used in many applications such as making composites, packaging of electronic components and making of industrial coverings, color and adhesive industry because of mechanical strength, good thermal resistance and great stickiness to most of materials. But in spite of having numerous advantages this materials are fragile and many efforts for resistance improvement against crack development in this kind of materials is done that among of them can be recited the use of lactic powder and wood and clay as filler in nano scale[5],[7]-[9].tauphness improvement of this materials is usually accompaniments with solidness reduction. In previous years some researches about nano composites are done, but fracture mechanism of this kind of materials is still unknown. Therefore according to importance of subject and world approach towards nano composites and unknowing fracture mechanism of this materials, the purpose of this article is determined to study the mechanical behavior and knowing fracture mechanism of clay-epoxy resin nano composite[4],[10]-[12].

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## II. Experimental

*Materials*

Used material in this research are included epoxy resin and modified clay(organ clay) in dimensions 25-35 nm. Components of used epoxy are epoxy resin liquid(diglycidyl ether of bisphenol A, DGEBA) with trade name Epian 06 from Khuzestan petrochemical company and solidifier tri-ethylene thetra amine (TETA) from china country. Used clay is with epoxy grade and from products ATP Company. It is quotable that intended clay is purchased in modified form respective company and no treatment is done during production on it.

*Machines*

Used machines in this project are Ultra sonic mixture, X ray diffraction made in Philips company, tension and adhesion of Elcometer.

## III. Methods

*Samples preparation*

Epoxy resin and clay with defined weight ratio(2,3 and 5 weight percent) for 8 hour with Ultra sonic mixture are mixed and after adding solidifier the mixing is continued. In the end of mixture process the materials are transferred into the cast and for 16 hours in 120 $°C$ are cocked. Making of pure epoxy samples is done with mechanical mixture.

*Samples recognition*

Clay distribution in epoxy with X ray diffraction and microscopic transient electron method is investigated. Pressure and tension behavior of epoxy-clay nano composites are respectively according to standard D638 and ASTM D695 and velocity of applied force are 1.5 and 5 mm/min and average results are reported for at least four measurements. Examination of fracture behavior and fracture toughness( $K_{IC}$ ) of prepared formula is measured with one-slot samples by 3 point-bending method according to standard ASTM D5045. to be assured from correctness of results, in each item 3samples are examined. Also in this research, a microscopic study of dynamism electron is done to recognize the mechanism of epoxy-clay nano composite fracture.

## IV. RESULTS AND DISCUSSION

As discussed in section methods, X ray diffraction prepares the possibility of knowing the kind of made nano composites shape and provides how distributes clay in the epoxy. Figure 1 shows the X ray diffraction results of modified powder clay and epoxy nano composite 3 weight percent clay. Due to similarity of X ray diffraction graphs for nano composites 2,3 and 5 weight percent clay, in figure 1 only epoxy nano composite diffraction for 3 weight percent clay is showed and avoided from repeating similar graphs. X ray diffraction studies show that the distance between clay layers is increased and clay distribution to epoxy is intercalated shape. As is observed, X ray diffraction angle and distance between layers of powder clay is respectively received from 4.2 and 21.2 $A^{\circ}$ to 2.5 and 35.3 $A^{\circ}$ in epoxy-clay nano composite.

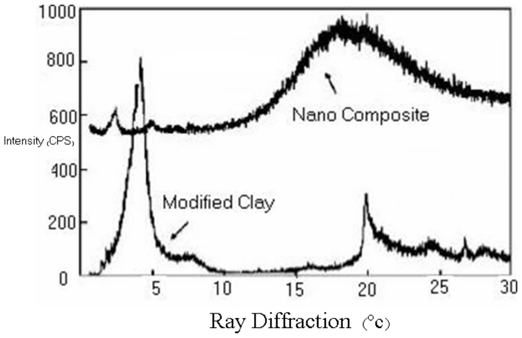



Fig.1-Ray diffraction of modified clay and epoxy nano composite with 3 weight percent clay

To be assured from decomposition results of X ray diffraction, the studies of microscopic transient electron is drone too.(Figure 2). The image of microscopic transient electron shows thatpolymer phase between clay layers is infiltrated. Whereas direction and regulation between layers is retained. In otherwise, like decomposition of X ray diffraction, studies of microscopic transient electron represents clay intercalation in epoxy and nano composite providing. Providing of nano composite with intercalation shape does not mean full separation of clay layers and ruining the clay piles, but clay piles are distended and in some cases primary piles are diminished that usually are observable with light microscopic. What is important in these systems locating polymer chains between clay layers and distance enhancement between these layers that provides possibility of more contact surface and using of nano phase advantages. In figure 3 effect of modified clay on pressure yield strength is shown. According to this figure, adding modified clay to epoxy resin increases the pressure yield strength and this quantity depends to clay amount in epoxy. Range of pressure yield strength changing is from 91.5 to 94.2 MPa. In otherwise, existence of nano filler in epoxy to some extent delays shear yield in pressure loading condition.

Figure 4 shows changes of tension module in nano composite epoxy-clay per amount of modified clay in. According to tension test results, yaunge module has linear dependence with nano filler amount in polymer. So module with 31 percent enhancement in pure system increases from 2.79 GPa to 3.66 GPA in epoxy nano composite with 5 percent clay where is a notable enhancement. According to that clay is a kind of mineral filler and is solid phase, it is predictable to nano composite module to be more than pure epoxy.

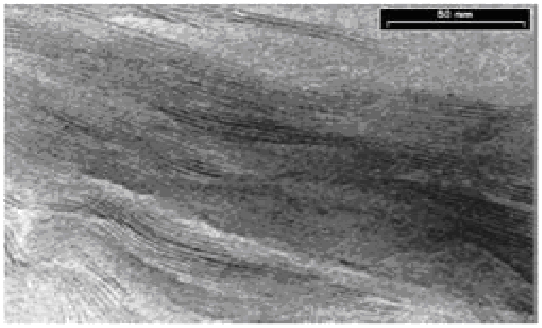


Fig. 2- The image of microscopic transient electron of epoxy nano composite 3 weight percent clay

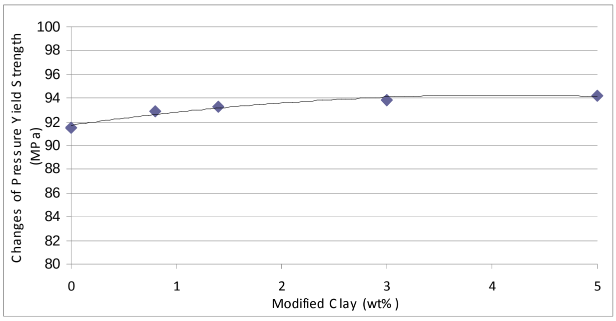



Fig. 3 changes of pressure yield strength a nano composite per modified clay

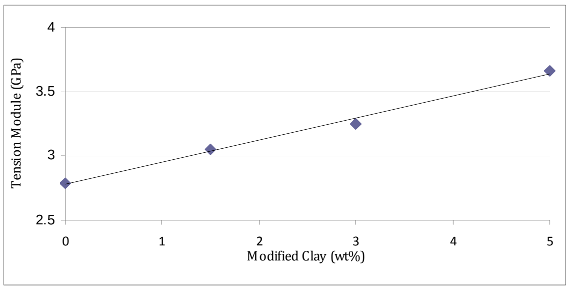



Fig. 4 changes of tension module for nano composite per amount of modified clay

Effect of adding nano filler to enlargement percent of relative length in epoxy is shown in figure 5. According to this figure there is not any notable difference between relavie enlargement of nano composite-1.5 weight percent clay and pure epoxy. Adding modified clay with more than 1.5 weight percent decreases epoxy enlargement and the lowest enlargement is related to nano epoxy composite-3 weight percent clay. Also tension experiment results shows that adding nano filler with more than 3 weight percent does not effect the relative enlargement of this nano composite kind.

Figure 6 shows the toughness test results. As observed, epoxy nano composites have more toughness than pure epoxy and toughness of this kind of nano composite depends on nano filler amount in polymer. Range of fracture toughness changes is from 0.7 to $1.15 MPa.m^{0.5}$ that represents improvement of clay-epoxy nano composite toughness equivalent 64% accorded to failure toughness of pure epoxy.

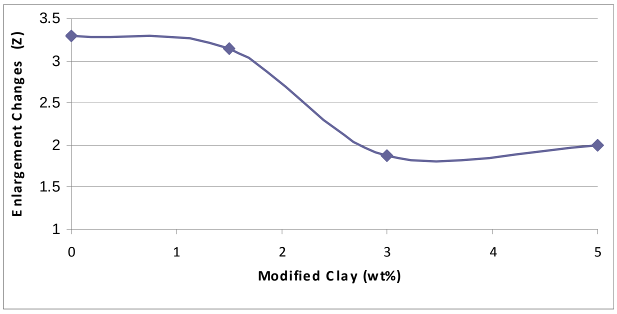



Fig. 5 enlargement changes of nano composite per amount of modified clay

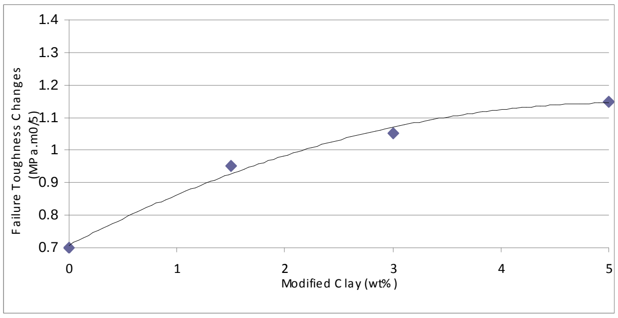
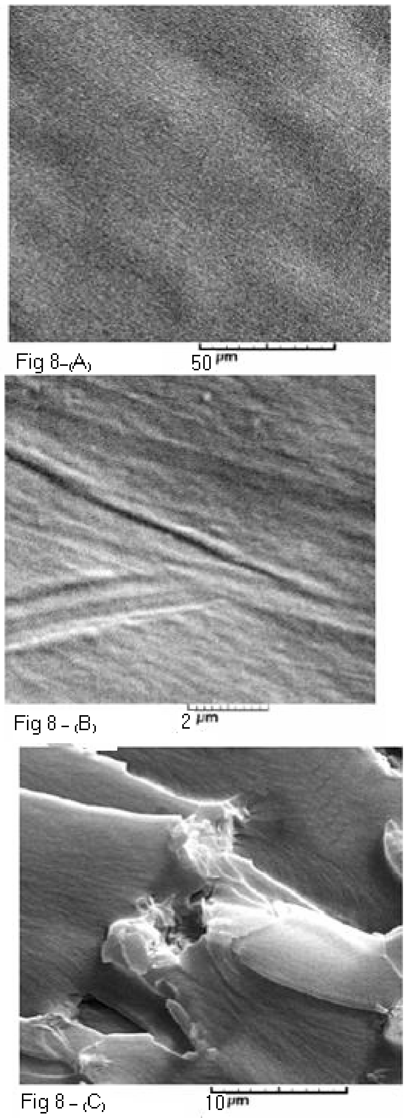



Fig. 6 failure toughness changes of nano composite per modified clay

Fig. 7 shows microscope images of dynamism electron in the failure surface of pure epoxy and epoxy nano composite-3 weight percent clay. According to microscopic studies, a notable difference between failure surface of pure epoxy and epoxy-clay system is observed. Failure surface of pure epoxy is completely smooth and is similar to failure surface of fragile polymers. That represents too much resistance against crack development. In spite of pure epoxy, failure surface of epoxy nano composite is too rough.. In some areas it seems that there is an aggregation of clay layers. Crack transits among them and at process zone in failure surface lines similar continuation after agglomeration areas of clay is observed. In this figure image of failure surface for nano composite 3 weight percent clay as a sample is shown. Failure surface of other compounds are like 3 weight percent clay compounds. With this different that roughness of failure surface depends on clay amount in it. So if the amount of nano filler is increased the failure surface of nano composites are become rougher. Improvement of failure behavior in epoxy-clay nano composites rather to pure epoxy is related to crack deflection, formation of new surfaces in front and also failure of clay piles. According to results of mechanical experiments plastic deformation in mentioned nano composites is delayed. With considering microscopic observations choice of shear yield mechanism as improving mechanism of failure behavior in this nano composites are almost impossible. According to attained results with adding modified clay to resin epoxy and making nano composite we can use coincident advantages the improvement of yield strength, yaung module, and adhesion and failure toughness. Where flexibility and toughness of materials usually improve with common methods and coincident solidness reduction.



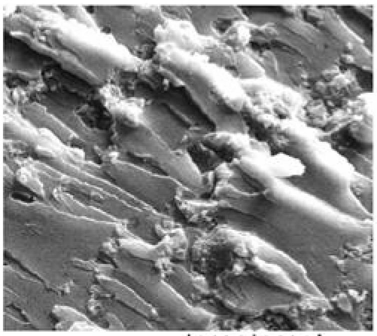



Fig. 7 Microscope image of dynamism electron in the failure surface:(A)(B) pure epoxy (C)(D) nano composite

## V. Conclusions

Examination of mechanical behaviour and failure in epoxy-clay nano composite is shown that existence of modified clay in epoxy increases the adhesive yield of this material in high tension condition. Enlargement percent to failure of epoxy nano composite-1.5% clay with 0.047 differences is almost similar to pure epoxy. Tension strength and failure toughness of epoxy-clay nano composite depends on amount of nano filler in epoxy and improvement of mentioned quantities in epoxy-clay nano composite rather to pure epoxy is completely observable. In otherwise, adding modified clay to resin epoxy improves coincidently solidness and toughness of this material. Microscopic considerations are shown that crack angle, formation of new surfaces and failure of new piles are some of the effective mechanisms to increase the toughness of epoxy-clay nano composite with intercalation shape.

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## References

[1] D. Bhattacharjee, Syed Arshad Hussain, S. Chakraborty, R.A. Schoonheyd," Effect of nano-clay platelets on the J-aggregation of thiacyanine dye organized in Langmuir–Blodgett films: A spectroscopic investigation",*J . Spectrochimica Acta*, Part A 77, 232–237 ,2010.
[2] Yang-Su Han, Shoji Yamanaka,- Jin-Ho Choy," Acidic and Hydrophobic Microporous Clays Pillared with Mixed Metal Oxide Nano-Sols",*Journal of Solid State Chemistry* 144, 45Đ52 ,1999.
[3] Haraguchi K, Takehisa T.," Nanocomposite hydrogels: a unique organic–inorganic network structure with extraordinary mechanical, optical, and swelling/de-swelling properties",Adv Mater;14(16):1120–4, 2002.
[4] Haraguchi K, Takehisa T, Fan S." Effects of clay content on the properties of nanocomposite hydrogels composed of poly(N-isopropylacrylamide) and clay", Macromolecules ;35(27):10162–71, 2002.
[5] Haraguchi K, Farnworth R, Ohbayashi A, Takehisa T.,"Compositional effects on mechanical properties of nanocomposite hydrogels composed of poly(N,N-dimethylacrylamide) and clay" Macromolecules;36(15):5732–41, 2003.
[6] Maser WK, Benito AM, Martinez MT.," Production of carbon nanotubes the light Approach", Carbon;40(10):1685–95,2002.
[7] Oncel C, Yurum Y. ,"Carbon nanotube synthesis via the catalytic CVD method, a review on the effect of reaction parameters", Fullerene, Nanotubes, Carbon Nanostruct;14:17–37,2006.
[8] Makar JM, Beaudoin JJ. ,"Carbon nanotubes and their applications in the construction industry. In: Proceedings of the first international symposium on nanotechnology in construction", Paisley, Scotland; June 23–25. p. 331– 41,2003.
[9] Hammel E, Tang X, Trampert M, Schmitt T, Mauthner K,," Eder A. Carbon nanofibers for composite applications", Carbon;42(5–6):1153–8,2004.
[10] Kumar S, Rath T, Mahaling RN," Reddy CS, Das CK, Pandey KN. Study on mechanical, morphological and electrical properties of carbon nanofiber/polyetherimide composites", Mater Sci Eng B;141(1–2):61–70,2007.
[11] Makar JM, Margeson J, Luh J.," Carbon nanotube/cement composites – early results and potential applications. In: The third international conference on construction materials: performance, innovations and structural implications",Vancouver, BC; August 22–24. p. 1–10,2005.
[12] Chung DDL. Comparison of submicron-diameter carbon filaments and conventional carbon.