Al-Khwarizmi Engineering Journal,Vol. 11, No. 3, P.P. 96-101 (2015)

Al-Khwarizmi Engineering Journal

Tensile and Compressive Properties of Kaolin Rienforced Epoxy

Jabbar Hussein Mohmmed

Department of Material Engineering/ University of Technology

Email: jabbaraljanaby@yahoo.com

(Received 2 September 2014; accepted 23 March 2015)

Abstract

The toughening of epoxy resins with the addition of organic or inorganic compounds is of great interest nowadays, considering their large scale of applications. In the present work, composites of epoxy are synthesized with kaolin particles having different particle sizes as reinforcement. Composites of epoxy with varying concentration (0 to 40 weight %) of kaolin was prepared by using hand lay method. The variation of mechanical properties such as modulus of elasticity, yield, tensile, and compressive strength with filler content was evaluated. The composite showed improved modulus of elasticity and compressive properties on addition of filler. In contrast, the tensile and yield strength of the composites decreases with rising kaolin content. It is also observed that mechanical properties increase with decrease in particle size in all cases.

Keywords: *mechanical properties, composite materials, epoxy risen, and kaolin.*

1. Introduction

Particles filled polymer composites have become attractive because of their wide applications and low cost. Incorporating inorganic mineral fillers into plastic resin improves various mechanical and physical properties of the materials such as mechanical strength, modulus and heat deflection temperature. In general the mechanical properties of particulate filled polymer composites depend strongly on size, shape and distribution of filler particles in the matrix polymer and good adhesion at the interface surface.

Epoxy resin is widely used as a substrate material in electronic packaging industry. As one of the most widely used thermosetting resin, epoxy resin possess special chemical characteristics such as little or no by-products or volatiles formation upon curing, low shrinkage, can be cured over a wide range of curing temperatures and control-able degree of cross-linking [1]. However, it is reported that the epoxy resin without mineral filler cannot meet the requirement for its thermo-mechanical properties. Hence, Many investigators have used various toughening filler with epoxy, such as alumina [1], silica powder and aramid fiber [2, 3], Granite [4], and glass-fiber [5] in order to improve specific properties or reduce cost. In this investigation kaolin of variable particle size was added to epoxy. Influences of the addition of these fillers on the mechanical properties (Young's modulus, yield, tensile, and compressive strength) were examined.

2. Experimental Procedure

2.1. Materials System

The matrix material used for the present study was epoxy (type:CY233 supplied by Ciba-Geigy. Co.-German) having density in range of (1.1-1.2 g/cm^3) at 25˚C and hardener (HY956). The properties and chemical structure of uncured epoxy are presented in Fig.1 and Table 1.

Kaolin clay has a density of 2.64 g/cm^3 with a general chemical formulation $Al_2Si_2O_5(OH)_4$ supplied by Iraqi National Company for

Geological Survey and Refinery was used in this study. This clay was milled by using a ball mill instrument, and it was sieved by using a sieve analyzer to obtain different particle size for kaolin (d<8, 18<d<25, 33<d<45, and 50<d<62 μm). The chemical composition and general properties of kaolin are presented in Tables (2, and 3)

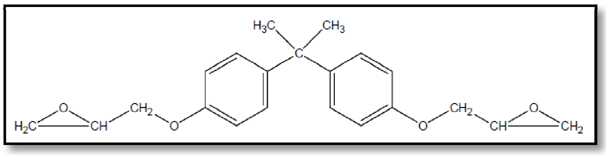

Fig. 1. Chemical Structure of uncured epoxy [12].

Table 1,
Properties of epoxy.

Properties	Quantity
Density, g/cm^3	1.1-1.2
Modulus of elasticity, GPa	1.5
Tensile strength, MPa	40.5
Yield strength, MPa	66.22
Compressive strength, MPa	82.3

Table 2,
Chemical composition of kaolin.

SiO_2%	**Al_2O_3%**	**Fe_2O_3%**	**TiO_2%**
52.48	31.31	2.094	1.43
MgO%	**Na_2O%**	**CaO%**	**L.O.I%**
0.33	0.28	0.462	10.93

Table 3,
General properties of kaolin.

Properties	Quantity
Density, g/cm^3	2.64
Powder color	white
Melting point °C	1755
Fracture resistance	Higher 225
Thermal properties	Endothermic at 260°C Exothermic at 980°C

2.2. Mold Preparation

A standard steel sample for each type of tests was manufactured for the purpose of making the final mold. The molds were manufactured from the white cement material. Manufacturing mold process can be summarized in the following steps:

1. Forming a rectangular frame of wood for each mold and then put them on glass bases.
2. Poured the mixture of white cement into the wooden structures.
3. Put the standard steel samples in own mold and kept for one hour.
4. Take out the standard samples from molds. The cement material will take the form of standard samples.
5. Take out the molds from the wooden frames.

2.3. Preparation of Composites

For epoxy-kaolin composite, 17 samples containing varying sizes (d<8, 18<d<25, 33<d<45, and 50<d<62 μm) and weight percent (0, 10, 20, 30, 40 %wt) of kaolin in an epoxy matrix were prepared for each test by using hand lay method.

Prior the mixing, the kaolin powder was washed thoroughly with water then dried in an oven at 110˚C for 2 h to remove any moisture. Then, the required amounts of kaolin and epoxy were mixed mechanically. After 10 min of stirring, Hardener was added and gently mixed with the mixture in the ratio of 3:1 by weight of epoxy resin. Mixing was continued for another 15 min. The final mixture was poured into white cement molds and was allowed to cure at room temperature for 24 h. after this the composite was taken out the molds and post cured at 100˚C for 4 hr. The composite was allowed to cool to room temperature in the oven itself.

2.4. Measurement of Tensile and Compressive Strengths

Tensile tests were carried out according to ASTM D638 [6] on the Instron tensile testing machine 3710-016. The specimen type I with overall length 168 mm and width 29 mm was used in this test. A cross head speed of 10 mm/min was used and the test was performed at 25 ± 3^{o}C.
Compressive test was performed also by using a Instron tensile testing machine. For each weight fraction, 4 specimens have diameter of 12.7 mm and height of 25.4 mm with different particle size in addition to specimen for net epoxy were produced and tested according to ASTM D696 [6].

3. Results and Discussion

3.1. Modulus of Elasticity

Young's modulus is the stiffness (the ratio between stress and strain) of a material at the elastic stage of a tensile test. Figure 1 shows the effect of kaolin content (wt%) to the modulus of elasticity of the composites. As expected, the Young's modulus of the composite markedly improved with the addition of kaolin content. This improvement because of the kaolin particle is inherently stiff and thus influences the stiffness of the composite as a whole (bulk). A similar observation was made by H. salmah et.al [7] in the case of polypropylene/ kaolin composites. The rate of increase of Young's modulus was comparable to the increase in concentration of kaolin and the decrease in particle size. Thus it was confirmed that the total area available to deformation stress played an important role. These results are in good agreement with results obtained by S. Bose and P.A. Mahanwar [8], and Jawad Kadhim et al [9] in the case of Polymethyl methacrylate (PMMA)/ Silica composite.

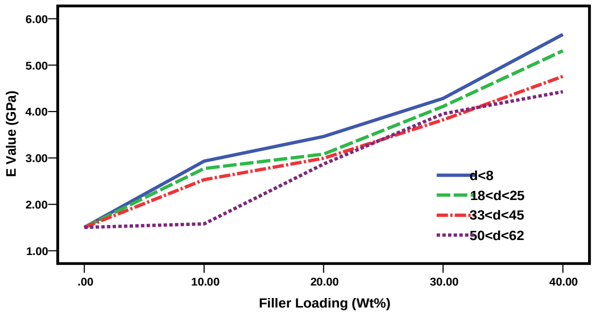

Fig. 1. Variation in Young's modulus of different particle size kaolin with varying concentration.

3.2. Tensile Strength

Figure 2 shows the effect of filler loading on tensile strength of epoxy/ kaolin composite with different particle size. It can be seen that the tensile strength decreases with increasing filler loading.

The decrease in tensile strength may be due to the non-uniform distribution of kaolin particles in the matrix. In addition to, brittleness of kaolin particles causes the concentration of local stresses at these particles and leads to the deterioration of tensile strength of the composite. These results are in agreement with those obtained by S. Bose and P.A. Mahanwar [10]. It was also observed that the rate of decrease of strength was higher when larger particle size was used. Smaller particles have a higher total surface area for a given particle loading. This indicates that the strength increases with increasing surface area of the filled particles through a more efficient stress transfer mechanism. Most investigators have enumerated that particle size is inversely related to reinforcing character and that an increase in surface area increases the composite mechanical properties [10, 11].

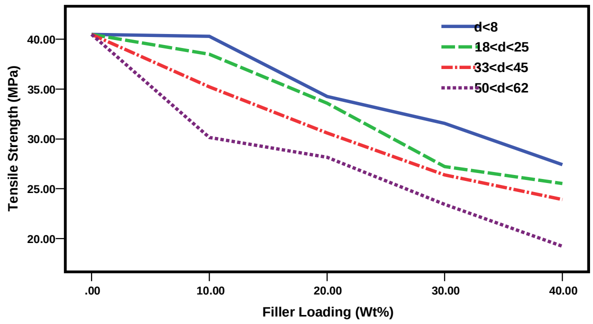

Fig. 2. Variation in tensile strength of different particle size kaolin with varying concentration

3.3. Yield Strength

The effect of filler loading on the yield strength of kaolin filled epoxy composites with different particle size is shown in Fig. 3. It is clearly shown that, the yield strength of all epoxy composites decreases with increasing filler loading. Significant drop in the value of yield strength was observed at filler loading as in the range of (0-10) wt.%.

In Polymer Matrix Composites (PMC), most of the deformation occurs in the matrix phase. As the percentage of kaolin content increases, the ability of the matrix phase to deform plasticity is also reduced as shown in Figure 3. This can be explained by plastic deformation mechanism. Ability of the material to plasticity deformed is largely determined by the mobility of the molecular chain (molecular motion) to take place under applied load. The presence of rigid particles such as kaolin in this case has restricted the mobility of the molecular chain to pass each other and orientation which consequently resulted in instantaneous failure (brittle failure) as the yield stress is reached. Therefore, Rigidity of kaolin particles has directly responsible for the decreases in the yield strength value. However, at similar filler loading, kaolin filled epoxy composites with smaller particle size have higher yield strength than similar composites with larger particle size. This may be attributed to an increase in the kaolin particle strength with a decrease in particle size, because the probability of a strength-limiting flaw existing in the volume of the material decreases. At relatively large particle sizes of this material, a significant amount of particle cracking takes place during extrusion prior to testing. Cracked particles do not carry any load effectively and can be effectively thought of as voids, so the strength is lower than that of the unreinforced material. The same trend was found by Shao-Yun Fu et al. [12] and Samir Nassaf Mustafa [13].

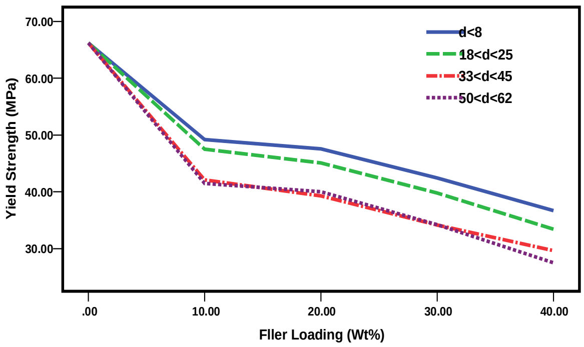

Fig. 3. Variation in yield strength of different particle size kaolin with varying concentration.

3.4. Compressive Strength

The variation of compressive strength for the composites under study with filler content is presented in Fig. 4. In this figure it was observed that the compressive strength increased drastically on addition of filler in both the larger and smaller particle sizes of kaolin but the rate of change of compressive strength with varying percentage of filler was higher in the case of smaller particle size as compared to larger particle size of kaolin. The smaller kaolin particles are expected to improve the stress transfer between the matrix and the filler by the formation of a strong filler/matrix interface.

A similar observation was made by Singla and Chawla [14] and Ibtihal et.al. [15] in the case of fly ash/ Epoxy composites and Silica/ Epoxy composites respectively. The trend of the variation of compressive properties with filler is similar to that of the variation of Young's modulus properties. Further, the enhanced compressive strength properties of the composites over that of the matrix may be due to the stiff nature of the filler.

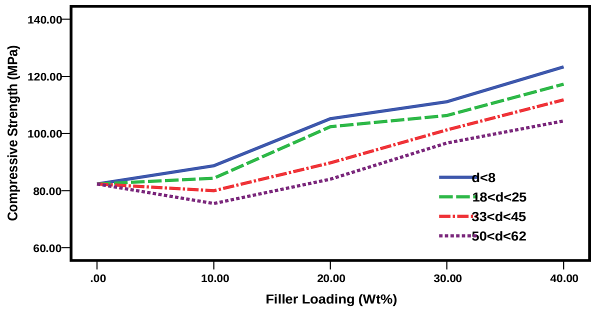

Fig. 4. Variation in compressive strength of different particle size kaolin with varying concentration.

Table 4,
All experimental results for each testing.

No.	Kaolin added (%)	Particle size (µm)	Modulus of elasticity (GPa)	Yield strength (MPa)	Tensile strength (MPa)	Compressive strength (MPa)
1	.00	.00	1.5	40.5	66.22	82.3
2	10.00	d≤8.00	2.93	40.3	49.21	88.67
3	20.00	d≤8.00	3.46	. 34.25	47.56	105.22
4	30.00	d≤8.00	4.28	31.56	42.43	111.15
5	40.00	d≤8.00	5.66	27.42	36.7	123.3
6	10.00	18≤d≤25	2.77	38.5	47.52	84.36
7	20.00	18≤d≤25	3.08	33.59	45.1	102.4
8	30.00	18≤d≤25	4.11	27.22	39.8	106.3
9	40.00	18≤d≤25	5.31	25.52	33.4	117.22
10	10.00	33≤d≤45	2.53	35.22	42.11	82.27
11	20.00	33≤d≤45	2.99	30.59	39.3	91.23
12	30.00	33≤d≤45	3.82	26.4	34.15	98.9
13	40.00	33≤d≤45	4.76	23.9	29.62	108.59
14	10.00	50≤d≤62	1.58	30.15	41.5	78.86
15	20.00	50≤d≤62	2.87	28.15	39.99	84.04
16	30.00	50≤d≤62	3.95	23.44	34.22	93.18
17	40.00	50≤d≤62	4.43	19.22	27.5	99.11

4. Reference

[1] ErfanSuryani Abdul Rashid, Hazizan MdAkil, KamarshahAriffin, Chee Choong Kool, "The Flexural and Morphological Properties of α-Alumina Filled Epoxy Composites", Malaysian Polymer Journal (MPJ), Vol 1, No. 1, 2006.

[2] Haiying Wang a, Yilong Bai, Sheng Liu, Jiali Wu, C.P. Wong, "Combined Effects of Silica Filler and Its Interface in Epoxy Resin", ActaMaterialia, Vol.50, 2002.

[3] Sun, Y., Zhang, Z., Wong, C.P., "Influence of Interphase and Moisture on the Dielectric Spectroscopy of Epoxy/silica Composites, Polymer Journal, Vol.46, 2005.

[4] Ramakrishna H. V. and Rai S. K, "Utilization of Granite Powder as a Filler for Polybutylene Terepthalate Toughened Epoxy Resin", Journal of Minerals & Materials Characterization & Engineering, Vol. 5, No.1, 2006

[5] Alvarez, V.A., Valdez, M.E., Vasquez, A., "Dynamic Mechanical Properties and Interphase Fiber/Matrix Evaluation of Unidirectional Glass Fiber/Epoxy Composites", Polymer Testing, Vol.22, 2003.

[6] Annual Book of ASTM, Section 8, Vol.08.01 Plastic, "Am.Soc. Test Mat." Philadelphia, (2004).

[7] H. Salmah, C.M. Ruzaidi and A.G. Supri, "Compatibilisation of Polypropylene/ Ethylene Propylene DieneTerpolymer/ Kaolin Composites: The Effect of Maleic Anhydride-Grafted-Polypropylene", Journal of Physical Science, Vol. 20, No.1, 2009.

[8] Suryasarathi Bose, and P.A. Mahanwar, " Effect of Particle Size of Filler on Properties of Nylon-6", Journal of Minerals & Materials Characterization & Engineering, Vol. 3, No.1, 2004.

[9] Jawad Kadhim Oleiwi, Farhad M. Othman, Israa Faisal qhaze, " A Study of Mechanical Properties of Poly Methacrylate Polymer Reinforced by Silica Particles (Sio2)", Eng. & Tech. Journal, Vol. 31, No. 15, 2013.

[10] Suryasarathi Bose and P.A.Mahanwar, " Effect of Fly ash on The Mechanical, Thermal, Dielectric, Rheological and Morphological Properties of Filled Nylon6", Journal of Minerals & Materials Characterization & Engineering, Vol. 3, No.2, 2004.

[11] Najat J. Saleh & Samir Nassaf Mustafa, " A Study of Some Mechanical, Thermal and Physical Properties of Polymer Blend with Iraqi Kaolin Filler", Eng. & Tech. Journal, Vol. 29, No. 11, 2011.

[12] Shao-Yun Fu, Xi-Qiao Feng, Bernd Lauke, and Yiu-Wing Mai, " Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites", Science Direct, Composite Journal, Part B, No. 39, 2008

[13] Samir Nassaf Mustafa, " Effect of kaolin on the mechanical properties of polypropylene/ polyethylene composite material", Diyala Journal of Engineering Science, Vol. 5, No. 2, 2012.

[14] Manoj Singla, and Vikas Chawla, " Mechanical Properties of Epoxy Resin – Fly Ash Composite ", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.3, 2010.

[15] Ibtihal-Al-Namie, Ahmed Aladdin Ibrahim, Manal Fleyah Hassan, " Study the Mechanical Properties of Epoxy Resin Reinforced With silica (quartz) and Alumina Particles", The Iraqi Journal For Mechanical And Material Engineering, Vol.11, No.3, 2011.

خواص الشد والانضغاط للأيبوكسي المدعم بالكاؤولين

جبار حسين محمد
قسم هندسة المواد/ الجامعة التكنولوجية
البريد الاكتروني: jabbaraljanaby@yahoo.com

الخلاصة

تقوية راتنجات الايبوكسي بإضافة مركبات عضوية أو لا عضوية هي ذات أهمية كبيرة في الوقت الحاضر نظرا للمدى الواسع من التطبيقات في العمل الحالي، تم عمل متراكبات من الايبوكسي مع حبيبات الكاؤولين بأحجام حبيبية مختلفة بوصفها مادة تقوية. تم تحضير متراكبات الايبوكسي بتراكيز مختلفة (٠-٤٠% من الوزن) من الكاؤولين باستخدام طريقة القولبة اليدوية. تم دراسة التغير في الخواص الميكانيكية مثل معامل المرونة، مقاومة الخضوع، الشد، والانضغاط مع محتوى التقوية. اظهرت المتراكبات تحسن في معامل المرونة وخواص الانضغاط مع إضافة مادة التقوية. من جانب آخر، انخفضت مقاومة الشد والخضوع للمتراكبات مع زيادة محتوى الكاؤولين. كذلك، لوحظ تحسن الخواص الميكانيكية مع تقليل حجم الحبيبات في جميع الحالات.