Eng. & Tech. Journal, Vol.28, No.17, 2010

Studying The Effect of Some Inorganic Phosphors Salts on Fire Retardant And Mechanical Properties of Unsaturated Polyester Composite

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Received on:18/1/2010
Accepted on:30/6/2010

Abstract

In this work, the effect of four types of inorganic phosphors salts on flammability and mechanical properties (Flexural and Tensile) strength, of unsaturated polyester reinforced with glass fibers has been studied ; also , the influence of two types form of glass fibers (chopped strand mat and woven roving), on flammability and mechanical properties of the composite, were studied . Sheets of composites with different weight percentage of additives and reinforced with two layers of each type of glass fibers, were prepared. Four standard test methods used to measure the flame retardation and mechanical properties, which are: ASTM: D – 2863, ASTM: D – 635, ASTM: D – 790 and ASTM: D – 638.

Results obtained from these tests indicated that, additive IV has high efficiency as a flame retardant, self – extinguishing (S.E.) was occur at the percentage 1.5 % and non – burning (N.B.) was occur at the percentage 2.5 % for resin reinforced with glass fiber type woven roving and showed high effect to reduce the values of the mechanical behaviors, but additive I have low effect on retard composition and showed low effect on the values of mechanical properties.

دراسة تأثير بعض أملاح الفسفور اللاعضوية على تثبيط اللهوبية و الخواص الميكانيكية لمتراكب البولي استر غير المشبع

الخلاصة

في هذا العمل, تم دراسة تأثير أربعة أنواع من أملاح الفسفور اللاعضوية على تثبيط اللهوبية و الخواص الميكانيكية (قوة الشد و قوة الانحناء) لراتنج البولي استر غير المشبع المتراكب مع الألياف الزجاجية, كذلك تم دراسة تأثير نوعين من الألياف الزجاجية (حصائر الألياف المقطعة و حصائر الألياف المحاكة) على تثبيط اللهوبية و الخواص الميكانيكية للمتراكب . تم تحضير ألواح راتنج البولي استر غير المشبع المتراكب بإضافة نسب مئوية (0.5 , 1.0 , 1.5 , 2.0 و 2.5 %) من المضافات و بإبعاد (5 × 150 × 150) ملم مع طبقتين من كل نوع من الألياف الزجاجية . أربعة طرق اختبار قياسية استخدمت لحساب تثبيط اللهوبية و الخواص الميكانيكية و هي : ASTM:D-2863 , ASTM:D-635 , ASTM:D790 و ASTM-D638 .

ان النتائج المستحصلة من هذه الاختبارات تشير إلى إن المضاف IV يمتلك تأثيرعالي على تثبيط اللهوبية , حدوث إطفاء ذاتي (S.E) عند نسبة 1.5% و كذلك حدوث عدم أشتعال للعينة عند النسبة 2.5% للراتنج المتراكب مع الياف الزجاجية من نوع حصائر الياف المحاكة ، وكذلك فأنه يظهر تأثير

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https://doi.org/10.30684/etj.28.17.12
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عالي في خفض قيم الخواص الميكانيكية , لكن المضاف I يمتلك تأثير قليل على تثبيط اللهوبية و يظهر تأثير واطئ على قيم الخواص الميكانيكية .

1. Introduction

Polymers, also called macromolecules are giant molecules in which atoms are linked together by covalent bonds along molecules [1] . The polymers were prepared by process called polymerization where monomers (structural units) react together chemically to form linear or branched chains or three dimensional polymer network [2] . In the cross linked polymers, the chains are joined chemically at fastening points. The degree of cross-linking has effect on the physical and chemical properties of polymer [3] .

Composite is generally defined as any physical combination of two or more dissimilar materials used to produce a result that cannot be obtained by each component individually [4] Properties of composites are strongly influenced by the properties of their constituent materials, their distribution and the interaction between them. Besides specifying the constituent materials and their properties, a composite material as a system is described by the geometry of reinforcement [5] . The geometry of reinforcement may be described by some important factors [6] : shape, size and size distribution of reinforcing materials ; concentration distribution and orientation of reinforcing material.

Most composite materials developed thus for have been fabricated to improve mechanical properties [7]. The interaction between the matrix and rcfibers are effective in improving the fracture resistance of the matrix. The fibers have small cross sectional dimensions so that they are embedded in matrix materials to form fibrous composites [8] . Most of reinforced plastics are glass fiber reinforced polyesters . They are used in many important applications [9,10] , so that , in this work the influence of increasing the ratio of additives as flame-resistance on mechanical properties of reinforced polyester composite were studied .

2-Experimental Methods:

2.1. Materials

a. Unsaturated polyester resin, hardener type (MEKP), imported from Industrial Chemical & Resin Co. LTD. , Kingdom of Sudia Arabia .

b. Glass fiber type (E-Glass), were used as a reinforcing materials in the two forms; chopped strand mat, randomly oriented, has surface density equal to (0.277 Kg/M^2), and woven roving, has surface density equal to (0.5 Kg/M^2), imported from company (Moulding, LTD. , UK) .

c. Flameretardant; Monoammoniumphos-phate,withpurity99% (additiveI);Diammoniu-mphosphate , with purity 99.5%(additiveII);Triamm-oniumphosphate,with purity 98% (additive III)& Polyammoniumphosphate with purity 97% (additive IV), in powder form ; imported from MERCK Co.

2.2 Standard Tests

a- ASTM: D-2863 : The measurement of limiting oxygen index (LOI), is widely used for measuring flammability of polymers [11].

b- ASTM: D-635 : The measurement of rate of burning (R.B), average extent of burning (A.E.B) , average time of burning (A.T.B) , self - extinguishing (S.E) and non – burning (N.B.) [12] .

c- ASTM : D-790 : The measurement of flexural strength, by three point method[13], with constant rate of displacement (crosshead speed) equal to 1 mm/Min. , by using Instron-1122 instrument.

d- ASTM: D-638 : The measurement of tensile strength[14], with constant rate of displacement (crosshead speed) equal to 1 mm/Min., by using Instron - 1122 instrument .

2.3 Preparing of specimens

The specimens of polymeric material containing additives and reinforced with two layers from two types of glass fibers were prepared in dimensions (150 x 150 x 5) mm, two sheets were prepared for each percentage, weight (0.5, 1.0, 1.5, 2.0 & 2.5) % of flame retardant materials with each type of glass fibers. These sheets cut as a samples according to ASTM standard were used in this work .

3. Results and discussion

A/ Flammability Tests:

The results of the flammability tests for unsaturated polyester resin reinforced with glass fibers in the form of chopped strand mat and in the form of woven roving, were showed in Tables 1 – 4 , for limiting oxygen index and rate of burning respectively . The limiting oxygen index (LOI), were increased with increasing the weight percentage of additives, as shown in Tables 1 & 2 respectively, and illustrated in Figures 1 & 2 for tow types form of glass fibers respectively.

The rate of burning (R.B) of the resin reinforced with glass fibers in two types form with the additives has a continuous reduction with increasing the percentage weight of additives (inversely proportional), as in tables 3 & 4 respectively. Figures 3 & 4 showed the flame speed curves of flame retardation for resin in two types form . This results indicated that, the additive IV has high efficiency on self-extinguishing (S.E) of resin, especially in percentage 2.0 % for the resin reinforced with glass fiber type chopped strand mat and in percentage 1.5 % for resin reinforced with glass fiber type woven roving. Non-burning (N.B) occur in percentage 2.5 % for the resin reinforced with glass fiber type woven roving .

In general , additive IV has the best efficiency on retard combustion. This high efficiency depends in basically on the structure of this material (Polyammoniumphosphate), its contain in their structure on phosphour element and nitrogen which have high effect on retard combustion. The free radicals were form from decomposition of this materials ($P^{\cdot}$ and $N^{\cdot}$) will reacted rapidly with the free radicals of flame chain, such as ($H^{\cdot}$,$O^{\cdot}$,$O^{\cdot}OH$,…,etc.) to form inert compounds like (HPO, NH_4OH ,…., etc.) and work on inhabitation of thermal decomposition will occur in flame front, because decreases of amount of generation heat and to formed a group from the non-flammable gases, such as (CO,CO_2 , H_2O,…,etc) thus will decreases from volatile materials flammable. The char will form as results from the thermal decomposition of the specimen; it covered the polymer specimen's roof . The difference in the results of the flammability tests between the polyester reinforced with chopped strand mat and that reinforced with woven roving, results from the difference in the form and size distribution of glass fibers. The layers of glass fibers in the resin reinforced with the woven roving of glass fiber would move away from one another during the burning of the composite due to the presence of the resin– rich layers between the plies, this movement led to facility in the flame spread, while that did not occur in the case of the resin reinforced with the chopped strand mat of glass fiber.

B/ Mechanical Properties Tests

The mechanical properties of polymers depend on many factors like: molecular structure, types of branching, space distribution between main chains which contains molecular groups and the percentage of cross linking density between these back-bones chains [15-17].

In this work, the mechanical properties of composites depend on two factors; the types form of glass fibers and the structure of additives. The woven roving form of glass fibers caused increase in the mechanical behavior comparing with the chopped strand mat form, because regularly distribution of fibers in woven roving form, caused high density cross linking of this composite . The results of the mechanical tests for the resin reinforced with two types form of glass fibers and containing different percentage of additives, shown that the mentioned additives would led to lower values, as illustrated in Figures 5 & 6 . This reduction in the mechanical behaviors is attributed to influence of these additives on matrix, because the hard particles placed in brittle material lead to stress concentration in adjacent matrix and the presence of these additives between polymer chains obstructs local mobility of chains and thus, the polymer will show little strain, and their effect on the interface where they reduce the adhesion (interfacial bonding) between the fibers and matrix . Also, results of tests appeared that the additives caused decrease in mechanical strength and modulus for composites with increasing of the percentage of additives, as shown in Tables 5 & 6 for both tests (flexural and tensile) respectively.

4. Conclusions

The main conclusions of this work can be summarized as follows:

1- The efficiency of the flame retardation for additives were in the following order:

IV > III > II > I

2- Limiting oxygen index (LOI) was increased with increasing of weight percentage of additives, but the rate of burning (R.B) was decreased with increasing of weight percentage of additives.

3- Additive IV has high effect on retard combustion for two type of composite, but it reduces the mechanical properties.

4- Additive I showed low effect on retard combustion for two types of composite, and it showed little effect on the values of mechanical properties comparing with additive IV.

5- The glass fiber type woven roving showed high effect in both tests (flammability and mechanical properties) comparing with chopped strand mat form.

6- The ideal percentage of additive is 1.5% from additive IV with woven roving form of glass fiber, to using for the general propose, as shown in the following tables and figures .

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Table (1) Limiting Oxygen Index (LOI) of unsaturated polyester resin reinforced with glass fiber type chopped strand mat, with additives

% / Additives	(LOI)					
	Non	0.5	1.0	1.5	2.0	2.5
I	19.6	20.31	20.84	21.32	21.85	22.33
II	19.6	20.52	21.17	21.68	22.21	22.69
III	19.6	20.78	21.48	22.19	22.88	23.56
IV	19.6	21.01	21.89	22.70	23.69	24.35

Table (2) Limiting Oxygen Index (LOI) of unsaturated polyester resin reinforced with glass fiber type woven roving, with additives

% / Additives	(LOI)					
	Non	0.5	1.0	1.5	2.0	2.5
I	19.8	20.74	21.28	21.73	22.25	22.80
II	19.8	20.93	21.65	22.34	23.06	23.73
III	19.8	21.25	21.85	22.63	23.45	24.61
IV	19.8	21.83	22.24	23.20	24.36	25.34

Table (3) Rate of burning (R.B) of unsaturated polyester resin reinforced with glass fiber type (chopped strand mat) with additives

Test \ Additives%	Non	0.5	1.0	1.5	2.0	2.5	Additives
AEB (cm)	10	10	10	9.7	9.0	8.3	I
	10	10	10	9.1	8.2	7.1	II
	10	10	9.8	8.5	7.4	6.6	III
	10	10	9.3	7.8	6.5	4.9	IV
ATB (Min.)	5.03	5.81	6.09	6.34	6.21	6.34	I
	5.03	5.95	6.41	6.15	6.03	5.92	II
	5.03	6.13	6.53	6.40	6.22	6.17	III
	5.03	7.09	7.75	7.03	7.65	7.78	IV
R.B (Cm/Min.)	1.988	1.72	1.64	1,53	1.45	1.31	I
	1.988	1.68	1.56	1.48	1.36	1.20	II
	1.988	1.63	1.50	1.33	1.19	1.07	III
	1.988	1.41	1.20	1.11	0.85	0.63	IV
S.E	-	-	-	-	-	-	I
	-	-	-	-	-	-	II
	-	-	-	-	-	yes	III
	-	-	-	-	yes	yes	IV
N.B	-	-	-	-	-	-	I
	-	-	-	-	-	-	II
	-	-	-	-	-	-	III
	-	-	-	-	-	-	IV

Table (4) Rate of burning (R.B) of unsaturated polyester resin reinforced with glass fiber type (woven roving) with additives

Test \ Additives%	Non	0.5	1.0	1.5	2.0	2.5	Additives
AEB (cm)	10	10	10	9.2	8.4	7.2	I
	10	10	9.6	8.5	7.9	6.8	II
	10	10	9.0	8.0	7.1	5.7	III
	10	10	8.8	7.2	6.0	-	IV
ATB (Min.)	5.08	6.02	6.36	6.43	6.22	6.05	I
	5.08	6.25	6.32	6.03	6.12	6.07	II
	5.08	6.49	6.16	6.20	6.17	5.64	III
	5.08	7.52	7.65	6.92	7.69	-	IV
R.B (cm/Min.)	1.968	1.66	1.57	1.43	1.35	1.19	I
	1.968	1.60	1.52	1.41	1.29	1.12	II
	1.968	1.54	1.46	1.29	1.15	1.01	III
	1.968	1.33	1.15	1.04	0.78	-	IV
S.E	-	-	-	-	-	-	I
	-	-	-	-	-	-	II
	-	-	-	-	-	yes	III
	-	-	-	yes	yes	yes	IV
N.B	-	-	-	-	-	-	I
	-	-	-	-	-	-	II
	-	-	-	-	-	-	III
	-	-	-	-	-	yes	IV

Table (5) Flexural Strength (S_F) and Flexural Modulus (E_F) of unsaturated polyester resin reinforced with glass fiber (in two forms) with additives

Form of glass fiber	Test of mechanical properties	Additives %						Additives
		Non	0.5	1.0	1.5	2.0	2.5	
Chopped strand mat	Flexural strength (S_F) MPa	3.58	3.55	3.52	3.49	3.46	3.43	I
		3.58	3.54	3.51	3.48	3.45	3.42	II
		3.58	3.53	3.50	3.47	3.44	3.41	III
		3.58	3.51	3.48	3.45	3.42	3.38	IV
	Flexural Modulus (E_F) MPa	143.4	141.0	139.6	137.3	135.4	133.0	I
		143.4	140.2	138.0	136.1	134.3	132.9	II
		143.4	139.4	137.1	135.3	133.2	130.7	III
		143.4	138.0	135.8	134.0	132.0	128.9	IV
Woven roving	Flexural strength (S_F) MPa	4.32	3.29	3.26	3.23	3.20	3.17	I
		4.32	3.28	3.25	3.22	3.19	3.16	II
		4.32	3.27	3.23	3.21	3.18	3.15	III
		4.32	3.25	3.21	3.18	3.15	3.12	IV
	Flexural Modulus (E_F) MPa	231	229.8	227.6	225.0	223.8	221.1	I
		231	228.0	226.2	224.5	221.6	219.8	II
		231	227.3	225.1	223.0	220.7	218.4	III
		231	226.5	224.0	222.4	219.6	217.1	IV

Table (6) Tensile Strength (σ_T) and Young Modulus (E) of unsaturated polyester resin reinforced with glass fiber (in two forms) with additives

Form of glass fiber	Test of mechanical properties	Additives %						Additives
		Non	0.5	1.0	1.5	2.0	2.5	
Chopped strand mat	Tensile strength (σ_T) MPa	14.65	14.62	14.59	14.56	14.53	14.49	I
		14.65	14.61	15.58	14.55	14.52	14.48	II
		14.65	14.60	14.57	14.54	14.51	14.47	III
		14.65	14.56	14.53	14.49	14.45	14.44	IV
	Young Modulus (E) MPa	205.3	203.6	201.4	198.2	196.0	194.3	I
		205.3	202.3	200.1	197.8	195.3	193.1	II
		205.3	201.4	199.6	196.4	194.2	192.0	III
		205.3	195.1	193.2	191.0	189.4	187.5	IV
Woven roving	Tensile strength (σ_T) MPa	15.90	15.80	15.51	15.20	14.96	14.93	I
		15.90	15.71	15.40	15.11	14.84	14.80	II
		15.90	15.60	15.29	15.09	14.75	14.72	III
		15.90	15.53	15.5	15.47	15.43	15.38	IV
	Young Modulus (E) MPa	390.2	387.8	384.3	381.5	378.0	374	I
		390.2	386.4	383.1	380.7	377.3	373.4	II
		390.2	385.0	382.4	379.6	376.1	372.0	III
		390.2	379.4	377.1	375.6	372.4	369.7	IV

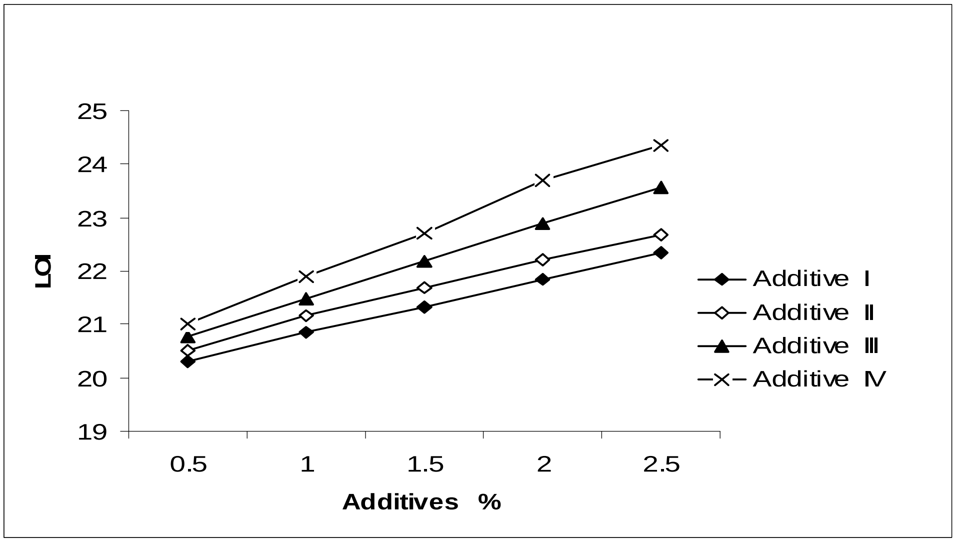

Figure (1) Limiting oxygen index (LOI) for resin reinforced with glass fiber from type chopped strand mat with different percentage of additives .

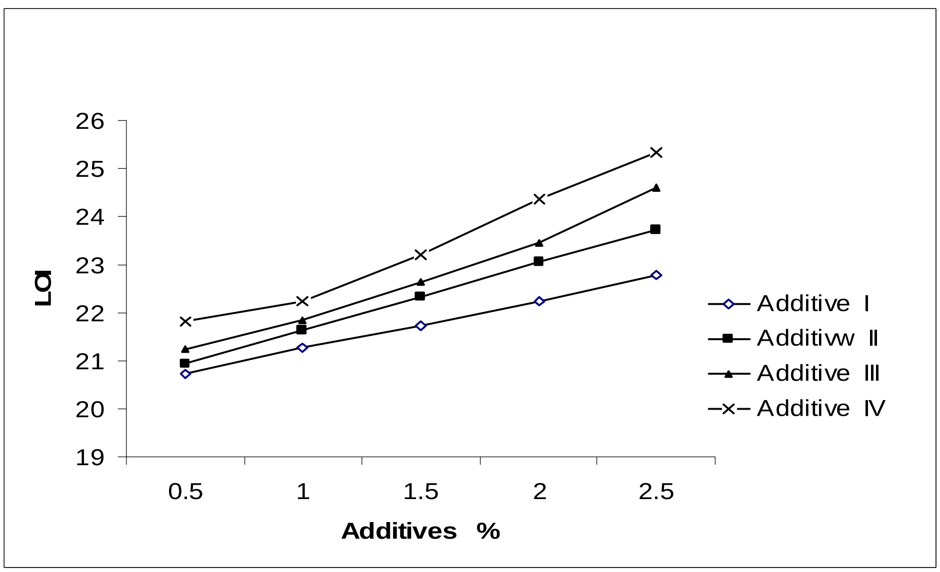

Figure (2) Limiting oxygen index (LOI) for resin reinforced with glass fiber from type woven roving with different percentage of additives .

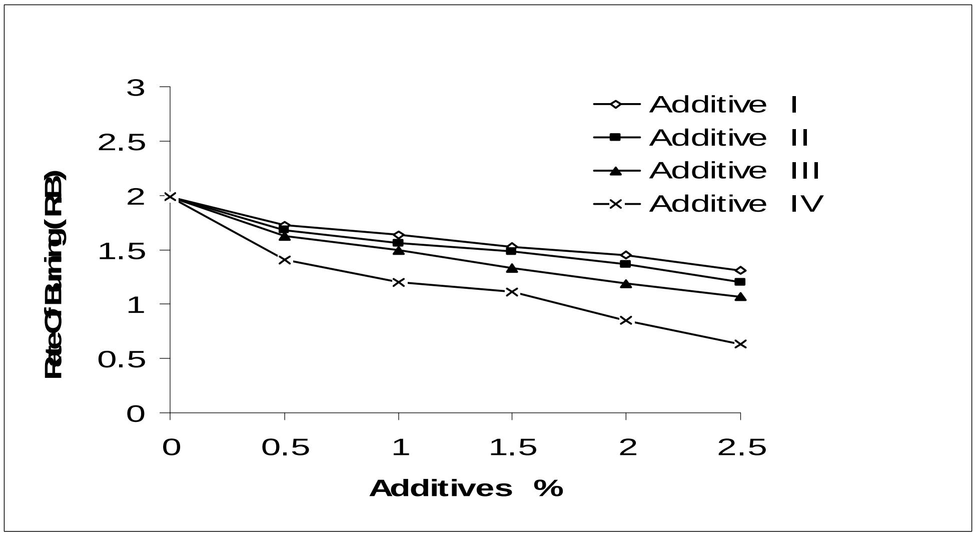

Figure (3) Rate of burning (R.B.) for resin reinforced with glass fiber from type copped strand mat with different percentage of additives .

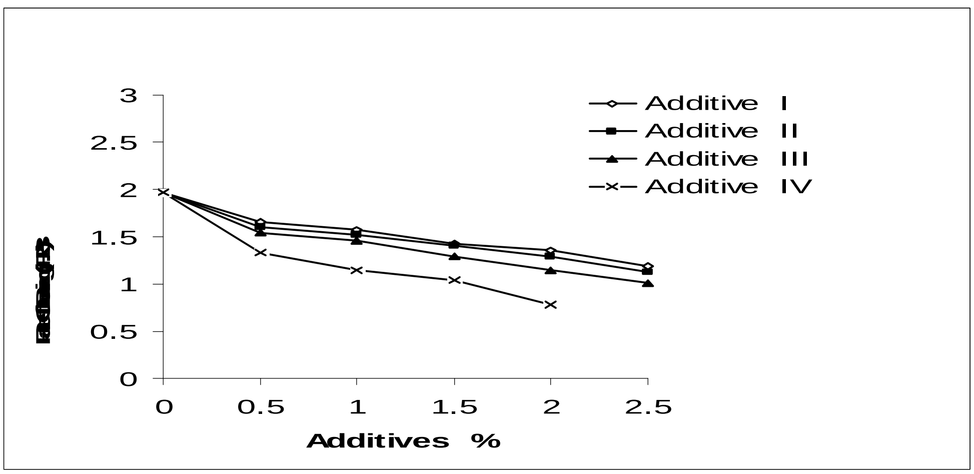

Figure (4) Rate of burning (R.B.) for resin reinforced with glass fiber from type woven roving with different percentage of additives .

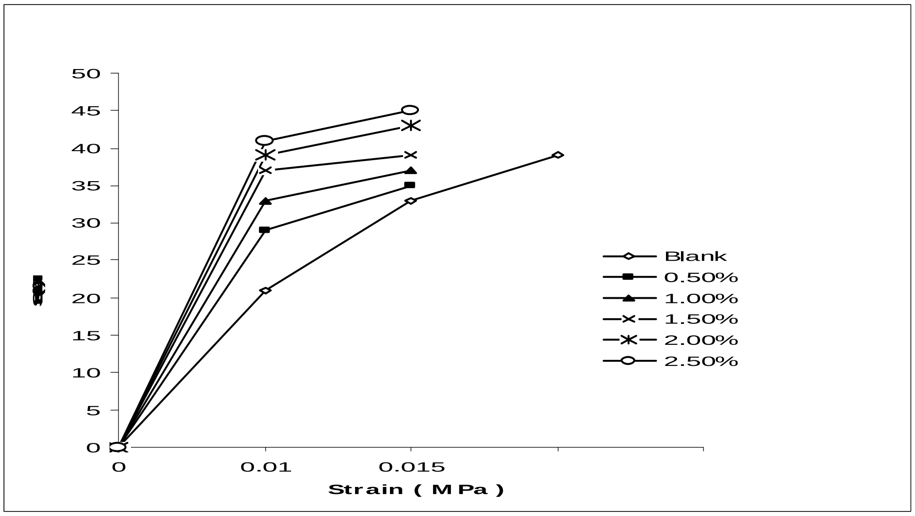

Figure (5) Stress – strain curve for resin reinforced with glass fiber type chopped strand mat with different percentage of polyammoniumphosphate

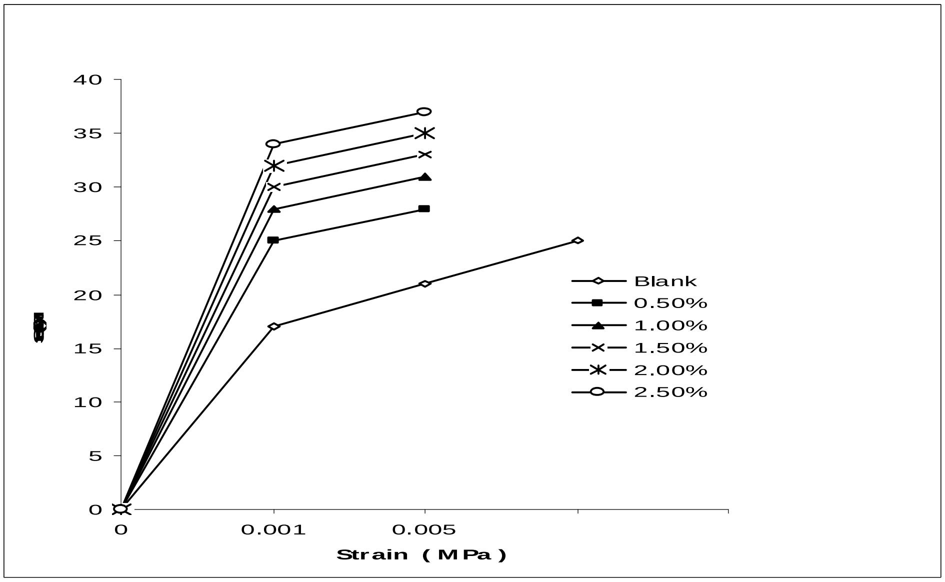

Figure (6) Stress – strain curve for resin reinforced with glass fiber type woven roving with different percentage of polyammoniumphosphate .

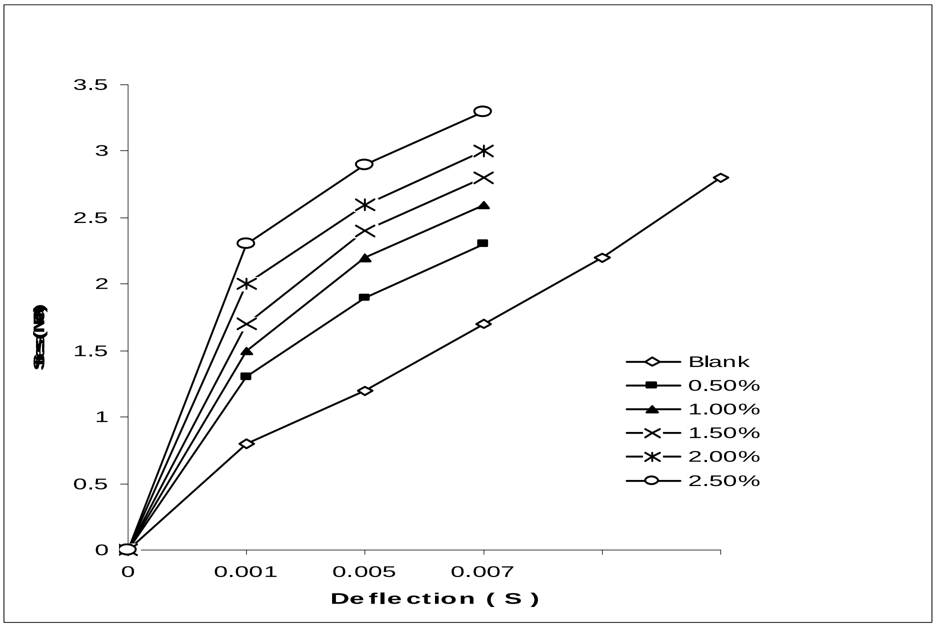

Figure (7) Stress – deflection curve for resin reinforced with glass fiber type chopped strand mat with different percentage of polyammoniumphosphate

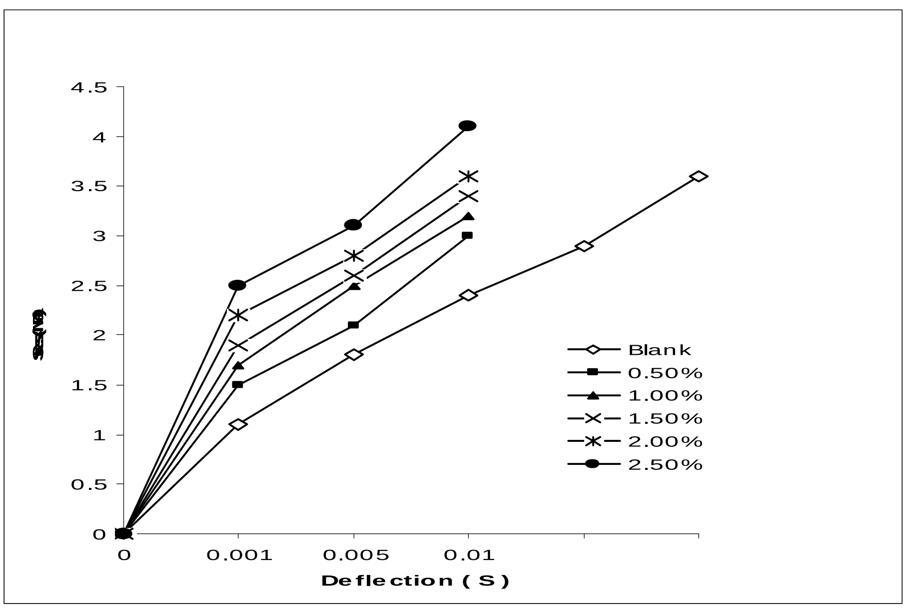

Figure (8) Stress – deflection curve for resin reinforced with glass fiber type woven roving with different percentage of polyammoniumphosphate