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Effect of γ Irradiation on the Flexural Strength and the Deflection Behavior of Epoxy and its Composites

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KEYWORDS
Gamma Irradiation, Epoxy, Degradation and Cross-linking reactions.

ABSTRACT:
A series of composites has been prepared by adding lead powder and lead shots with different masses to the epoxy resin. The influence of gamma radiation on the traction behavior of the composite's mechanical characteristics given the damage of the radiation-related reactions was analyzed. The analyzed of the researcher's possible effect (pause-long and tensile strength) of gamma irradiation on certain physical properties utilizing an Instron Tensile test. The results observed that remarks of the changes in the epoxy color of composites, the variation from yellow up to dark brown gradually as a result of different radiation doses effect of radiation exposure to the composites.

1. Introduction

Radiation ionization produces chemical reactions on polymers, leading to both molecular and macroscopic alterations in the structure. The study of the mechanical, thermal and morphological Gamma radiation can easily deliver a consistent dose over a sample volume. In a Cobalt-60 facility, controlling the temperature of the samples is also quite simple. [1].

Polymer are becoming more and more important in industry, such as electronic component manufacture, aircraft structure, an insulation of the magnet coil, and coating. The composites are widely utilized in spacecraft structural components such truss structures, antennas, and solar-cell panels [2].

Electrical devices such as circuit over current protection devices can benefit from polymer conductive compositions.

Sensitive to the epoxy cure process are the short and long durability of advanced composites, coatings or adhesives. Following alpha or beta decay, or after neutron capture (a type of nuclear reaction) in a nuclear reactor, gamma decay occurs when there remains remaining energy in the nucleus. [3].

2. Mterial Used

A. Epoxy Resin

Epoxies are thermosetting hydrocarbon resins, which are formed by mixing two-part epoxies. Part A" is usually a difunctional or higher epoxide (oxirane) molecule, while Part B" is usually a multifunctional amine or an acid anhydride (sometimes termed the catalyst or hardener). The two components are combined and dried to create a hard, inert resin. [4]. The mixing ratio by weight is about 3:1. At room temperature, the first curing takes 24 hours. In general, powerful mineral and oxidizing acids, hypo-chlorites, low molecular weight polar organic matter and chlorinated aromatic materials attack epoxies. Standard epoxies are frequently employed in the production of glass, aramid and carbon fiber-enhanced composites. Glass enhanced materials are commonly employed to produce electric insulators and circuit boards. The chemical structure of Epoxy resin is shown in Figure (1).

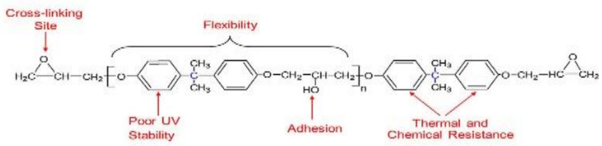

Fig. 1. Chemical structure of Epoxy resin [5].

B. (EPLV) Low viscosity epoxy injection resin system properties

Properties were obtained for Nitofil EPLV and at a temperature of 35°C and at seven days unless otherwise specified. [6].

C. Lead powder

Lead powder is mixed with a plasticizer and applied to polymers to make sheets of lead-loaded plastic. The radiation-protective apparel and aprons for medical, scientific, and nuclear applications are produced by this material. The sound isolating characteristics are also available. Lead powder is also the basis for certain corrosion-resistant layers.

D. Shot/Ball Lead

Lead is used for bullets and shot, chiefly because of its high density. Shot alloys have been given as 99.8 Pb, 0.2 As, or 94 Pb, 6 Sb [7].

E. Lead powder and lead shots

The lead powder and lead shots are used in this study. there were product In BDH (Poole, Chemical Reagent Co. England. UK.

Pb =207.19 Lead shot product about 100 mesh to dust No.29018

Pb =207.19 Lead powder product No. 29017 [8].

3. Sample Preparation

A. Preparation of the epoxy

The mixing ratio by weight is about 3:1. The hardener solution was mixed once the compounds were fully dissolved in the hardener. The epoxy solution was then placed in a 20 mm-long, 6 mm-thick and 15 mm-wide glass container. At room temperature, first curing takes 24 hours. The same sample measurements for all tests are (12.5, 1, 6 cm).

B. Prepare the composites of lead powder and epoxy

The plume/epoxide composites with 5 various weights (10,20,30,40,50) gm. of lead powder were made similarly to the prior Preparation to ensure multiple irradiation. Five identical materials were used for irradiated. With the same process, same weight and period of radiations, the lead shots / epoxy composites were produced.

4. Gamam Iradiation Test

Co-60 Gamma cell 900 was used as the irradiation source was used in this study to irradiation all the samples for (1, 2, 3, 4, 5. weeks). Irradiated Samples with various doses were achieve. The dose rate of the cell is 0□1669 KGy/h. Samples were irradiated with the following doses: 28, 56, 84, 112, and 140 Kgy.

5. Three-Point Flexury Testing

With three-point bending testing the elastic bending module of every sample was measured. At room temperature the mechanical tests were performed. Figure (2) and the Instron traction test show the geometry of a three-point flexural strength experiment (model 1121).

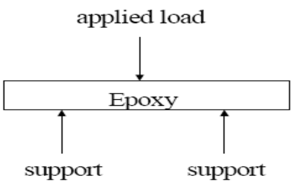

Fig. 2. Three-point flexure geometry.

A force-deflection curve was obtained for each specimen and used for analysis. A typical force-deflection curve is illustrated in Figure (3) [9].

The span length was 19. 8mm.The cross-head speed was set at 2mm/min.

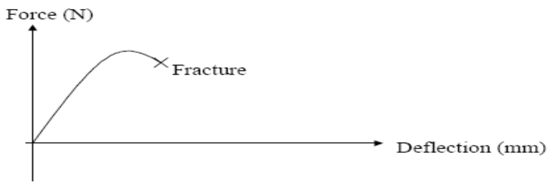

Fig. 3: Force-deflection curve from a three-point flexure testing

6. Experimental details and data analysis

Three-point flexure testing was used to evaluate the flexural strength and the deflection of the non-irradiated pure epoxy. Table (1) includes the values of flexural strength and the deflection for non-irradiated Pure Epoxy.

Table (2) includes the values of flexural strength and the deflection for Pure Epoxy irradiated for (1, 2,3,4,5 Weeks). The samples were irradiated with γ- rays at integral doses 28,56,84,112 and 140 kGy, respectively with a dose rate of 0.167 KGy/h in the presence of air, at room temperature, with a Co-60 source.

A. Results of flexural strength for Ep

The many different rectangular specimens of polymeric composites have been used in this research, two types of lead powder, lead shots and epoxy.

Table (1) represents the results of flexural strength and the deflection for non-irradiated epoxy and Table (2) represents the results of flexural strength and the deflection for irradiated epoxy for five periods irradiation.

Table 1: Three-point flexure testing for non-irradiated Pure Epoxy.

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Table I. Three-point flexure testing for non-irradiated Pure Epoxy

D.(mm)	F.(N)
0	0
1.4	20
3	40
4.4	60
6	80
7.6	100
9.6	120
12.6	140
15.4	150
17.4	146
19.4	140
23.4	124

Table II. Pure Epoxy Irradiated For (1, 2,3,4,5 Weeks) of Three-point flexure

1W		2W		3W		4W		5W	
D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)
0	0	0	0	0	0	0	0	0	0
1.2	20	1.2	20	1.4	20	1.2	20	1.2	20
2.4	40	2	40	2.4	40	2.4	40	2.4	40
3.6	60	3.2	60	4	60	4	60	3.6	60
4.8	80	4.4	80	5.2	80	5.2	80	4.8	80
6.4	100	5.6	100	7.2	100	6.4	100	5.4	100
7.2	120	7	120	8.4	120	7.6	120	6.4	120
8.8	140	8.4	140	10.4	140	9.4	140	9	150
10.8	160	10.4	160	13	160	11.6	160	10.8	170

The flexural strength and the deflection properties increase in the last period and the maximum strength at break also increases as shown in Fig.4. The deflection at break decreases as the irradiation doses increase as shown in Fig.4. To explain these behaviors, these variation due to the increasing of cross-linking bonds between the back bonds chains [10,11] .

Fig.4 represents the variation of flexural strength and the deflection with and without irradiation epoxy. This variation of flexural strength confirms the results observed by [12].

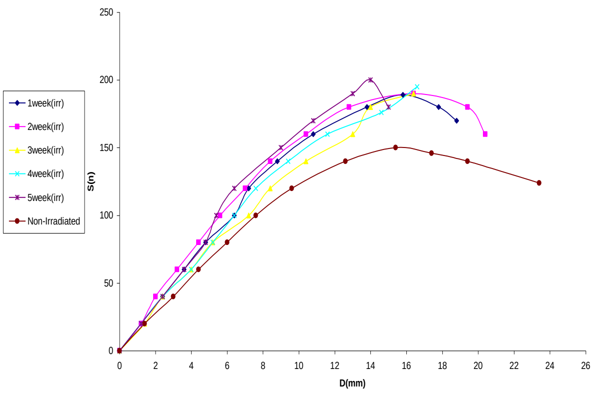

Fig. 4. The relation between the flexural strength and the deflection with and without irradiation.

B. Results of flexural strength for EP/Pb powder and shots composites

The homogenous epoxy/lead powder composites with (10 gm.) lead powder which irradiated for one week is better flexural strength than the other samples of the epoxy/lead powder irradiated for longer times and the epoxy/lead shots with respect to the physical properties. The results of flexural strength and the deflection for epoxy/lead powder composites with (10 gm.) lead powder and epoxy/lead shots which irradiated one week, respectively.

Table III. Epoxy/Lead shots blend irradiated for (1Weeks) with different masses of Pb (10,20,30,40,50 gm) of Three-point flexure testing.

1W/10gm Pb		1W/20gm Pb		1W/30 gm Pb		1W/40gm Pb		1W/50gm Pb	
D.(m)	F.(N)	D.(mm)	F.(N)	D.(m)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)
0	0	0	0	0	0	0	0	0	0
2	20	0.8	20	1.8	20	2	20	0.8	20
3.6	40	2	40	3.6	40	3.6	40	2	40
5.6	60	3.2	60	5.2	60	5.6	60	3.2	60
7.6	80	4	80	6.8	80	7.6	80	4	80
10	100	5.2	100	9.2	100	9.6	100	5.2	100
12.4	120	6.4	120	12	120	14.8	120	6.4	120
14.8	122	7.6	140	14	126	16.8	120	8.4	140
17.6	116	8.8	160	16	126	19.2	112	10.4	160
21.6	112	10	180	18	120	24	104	12.4	168
23.8	108	11.6	200	20	112			15.4	160

Table IV. Epoxy/Lead powder blend irradiated for (1Week) with different masses of Pb (10,20,30,40,50 gm) of Three-point flexure testing.

1W/10gm Pb		1W/20gm Pb		1W/30 gm Pb		1W/40gm Pb		1W/50gm Pb	
D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)
0	0	0	0	0	0	0	0	0	0
1.2	20	1.6	20	1.2	20	1.2	20	1.2	20
2.4	40	3.2	40	2	40	2	40	1.8	40
3.6	60	4.8	60	3.2	60	3.2	60	3.14	60
4.8	80	5	80	4	80	4.4	80	4.24	80
6	100	7.8	100	5.6	100	6	100	5.51	100
7.6	120	10	120	6.8	120	7.6	120	6.45	120
9.2	140	10.4	130	8.4	140	10.4	140	7.6	136
12.4	156	12	140	10.8	156	11.2	144	10.8	160
14.4	156	14	155	12.8	158	12.6	144	15.2	160
16.4	148	15	150	14.4	140	13.4	140	19.27	140
18.4	140	16	140			14.6	120	21.67	120
20.4	124							24.4	100
								27.8	92

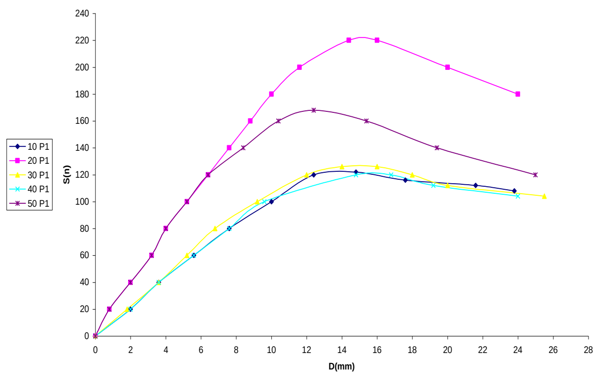

Fig. 5. The relation between the flexural strength and the deflection of epoxy/lead powder composites irradiated for 28.05 kGy (1Week).

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The epoxy/lead shots are lightly variation. The distribution of the lead shots of the composites and the heterogeneous affected in the physical properties of the shot's composites. These variations due at least to the inhomogeneous of the composites as shown in figure 5, 6.

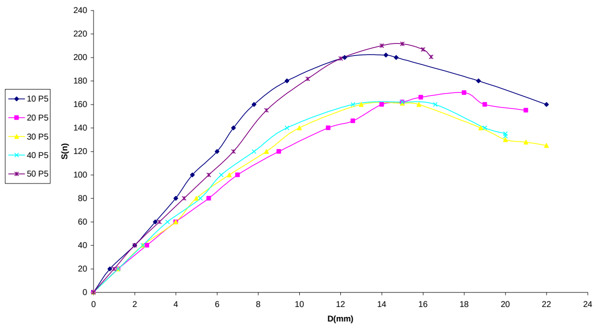

Fig. 6. The relation between the flexural strength and the deflection of epoxy/lead shots composites irradiated for 28.05 kGy (1Week)

The composites of epoxy /lead powder with (40 gm.Pb. powder) and (50 gm. Pb shots) appears to be better flexural strength and deflection than the other samples for fifth period irradiation which represents the last period of irradiated samples as shown in table (5) and figures (7).

Table V. Epoxy/Lead powder blend irradiated for (5Weeks) with different masses of Pb (10,20,30,40,50 gm) of Three-point flexure testing.

5W/10gm Pb		5W/20gm Pb		5W/30 gm Pb		5W/40gm Pb		5W/50gm Pb	
D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)	D.(mm)	F.(N)
0	0	0	0	0	0	0	0	0	0
1	20	1.6	20	1.2	20	1.2	20	1.2	20
2	40	2.8	40	2.8	40	2.4	40	2	40
3	60	3.4	60	4	60	3.6	60	3.2	60
4	80	5.6	80	5.6	80	4.4	80	4.2	80
5.2	96	7	100	7.2	100	6	100	5.6	100
6.7	110	8.6	120	9.2	120	7.6	120	6.8	120
8	120	10.2	140	11.2	140	9.6	140	8.4	140
				13.2	150	12.8	160	10	160
				15.2	156	13.8	162	12.8	180
				17.2	156	14.8	160	14.8	184
				19.2	140	18.4	140	17.8	180
				20.2	130	19.6	124	20.8	160

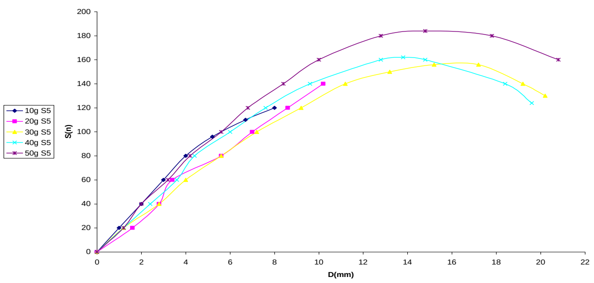

Fig. 7. The relation between the flexural strength and the deflection of epoxy/lead shots composites irradiated for 140.274 kGy (5Weeks)

Table (6) represents the deflection as a function of irradiation dose for epoxy. These results show that the deflection decreases as the irradiation dose increases, because a slightly higher dose degradated the bonds to unacceptable values, hence, resulting in changing the physical properties of the composites. These results confirm the other previous research [12,13].

Table VII. Maximum Deflection as a function of dose for pure Epoxy

Dose KGY	Max. Deflection(mm)
0	23.4
28.055	18.8
56.11	20.4
84.16	19.4
112.22	16.6
140.27	15

7. Conclusion

The research shows that the effect of γ irradiation on the flexural strength and the deflection behavior of epoxy and its composites that the composites present a high degradation resistance at low doses.

The deflection at break decreases as the irradiation doses increase. To explain these behaviors, these variations due to the increasing cross-linking bonds between the back bonds chains.

The flexural strength and the deflection properties of the composites with (50 gm.Pb powder) and (30 gm. Pb shots) shows better properties than the other composites samples, but the difference in the maximum strength is less than the other composites .This period appears that the behavior of lead shots blends is approximately better than the other composites with respect to the same type.

The deflection as a function of irradiation dose for epoxy. These results show that the deflection decreases as the doses Increases due to the slightly greater dose which can decrease the characteristics to inappropriate values. This tends to embrittle the material. These results confirm the other previous research. The behavior of the flexural of epoxy variation is due to the cross linking reactions produced in the components of the composites as a result of irradiation. Crosslinking is equivalent to degradation, that is, crosslinking is a process by which two radicals or molecules of the same type are combined [14]. A significant difference exists between the various weights of the lead powder for the previous samples, which due to the oxidative degradation of material at or near the surface of these samples.

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