Effect of RTV Silicon Rubber on Some Mechanical Properties of Epoxy /Polyester Polymer Blends

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Abstract: In this research the epoxy/ RTV silicon rubber and unsaturated polyester / RTV silicon rubber blends were prepared by adding varying weight (3, 5, 7, 10 and 20)% of (SR) to either of EP and UPE resins. The aim of research to analyze effect of RTV silicone rubber composition (3, 5, 7, 10 and 20) wt% of the mechanical properties of the epoxy and unsaturated polyester. Mechanical properties such as impact strength, shore D hardness, young modulus and flexural strength were tested. The experimental results showed that the specimens of EP/SR and UPE/SR blends have a maximum values of impact strength (8.13 KJ/m² and 11.91 KJ/m²) at the addition of 10% SR and 5% SR respectively. Hardness No. decreased slightly when the content of SR increased at a range of 3% to 20% in both of EP/SR and UPE/SR. Also flexural strength decreased rapidly when the content of SR increased at a range of 3% to 20% in both of EP/SR and UPE/SR.

Keywords: Polymer blends; Unsaturated polyester; Epoxy; RTV silicon rubber, Mechanical properties.

1. Introduction

Polymer-polymer blends have gained significant commercial growth, as it saves nearly 36% weight of the total polymer consumption without compromising weight. Epoxy is a versatile and widely accepted matrix material for fabrication of advanced composites, hardware components, electrical circuit board materials and missile equipments; because of its excellent bonding, physicochemical, thermal, mechanical, dielectric and aging characteristics. Epoxy resins belong to the most important thermosetting polymers with a high crosslinking degree and that contain many hydroxyl groups. Epoxy resins available in a wide variety of properties that are unattainable with other thermoset resins, they are easily cured without evolution of volatiles or by -products by a broad range of chemical species. These polymers have brilliant characteristics such as good chemical and moisture resistance and high dielectric properties, epoxy resins are widely working in modern industries, as adhesives, coatings and paints, and packaging materials for microelectronic devices[1,2].

Polyester resins (UPE) are comparatively hard and brittle materials and one of the important thermosetting materials used for the manufacture of glass-reinforced plastics and polymeric
composites. These resins have wide spread use is due to their relatively low cost, comfortable of processing, high wetting properties with reinforcements, and good balance of properties. UPE are solutions of unsaturated polyester with unsaturated co reactent diluents like styrene [3]. Silicone sealant RTV (Room Temperature Vulcanizing) is a liquid form of adhesive. Typically, it looks, feels, and acts like a gel. It has a different chemical make-up from other organic polymer-based adhesives. Unlike other adhesives, silicone keeps its elasticity and stability in both high and low temperatures. Furthermore, silicone sealant is resistant to other chemicals, moisture, and weathering[4].

RTV silicone rubber is also one type of elastomer which have glass transition temperature, Tg, which is very low, have high elastic properties, hydrophobic properties, as well as good resistance to thermal and oxides [5]. There are numerous numbers of previous studies related to polymer blends and their industrial applications, for examples:

Fahriadi Pakaya, Hosta Ardhyananta, and Sigit Tri Wicaksono [6]. Analyzed effect of RTV silicone rubber composition (0, 5, 10, 15, 20) wt% of the mechanical properties and thermal stability of thermoses epoxy. Testing and characterization conducted on thermoses epoxy by the addition of RTV silicone rubber. Results show that tensile strength, elongation at break and hardness has decreased, energy and impact strength increased maximum on the addition of 15% RTV silicone rubber respectively 0.294 J/ m2 and 6175 J/ m2. The maximum degradation of temperature increase in the addition of 15% RTV silicone rubber is 328 and 349°C respectively at 5 and 10% degradation. Shatha H. Mahdi, Widad H. Jassim, Intisar A. Hamad and Kareem. A. Jasima[7]. Prepared epoxy/silicon rubber blends by adding the silicone rubber with varying weight (0.0, 0.25, 0.5, 0.75 and 1gm) to epoxy resin. Some thermal properties are determined for different samples of blends. The bulk resistivity and dielectric constant were evaluated and related to the neat epoxy. The results suggest that the inclusion of silicone epoxy effectively improved in the glass transition temperature (Tg) and the thermal insulation also improved the electrical properties like resistance and dielectric constant for using it as capacitor at high frequencies and in the high voltage strength applications.

2. Experimental Procedure

2.1. Materials

Epoxy resin (Sikadur-52) was used in this research; it is a low viscosity, free flowing and fast curing injection resin and primer/coating based on a two components solvent free epoxy resin; ideally suited to a wide range of building and civil engineering applications where highly penetrative material is required. Unsaturated polyester resin (UPE) is a liquid with moderate viscosity which can be cured to the solid state by adding (MethyleEthyleKeton Peroxide, MEKP) as a hardener, while cobalt octoate acts as a catalyst to accelerate the solidification process. SUPERMAX universal RTV silicon sealant made in U.A.E. was used in this research.

2.2. Material Preparation

2.2.1. Epoxy Resin preparation

A clean disposable aluminum container was put on sensitive electronic balance, and the required epoxy resin was then poured in. For100 gm of EP resin a sufficient amount of hardener (Sikadur-52-B) was added. The ratio of hardener to epoxy was approximately 1:2 by weight. The content was thoroughly mixed to be ready for further applications; blend specimens casting.
2.2.2. Unsaturated polyester Resin preparation

With the same above procedure the required unsaturated polyester resin was weighed. 100 gm of UPE resin were mixed with 0.5 gm of cobalt naphthenate as accelerator and 2 gm methyl ethyl keton Peroxide (MEKP) as hardener. The resin was mixed thoroughly with accelerator and hardener until a homogeneous state of the mixture evolved, and ready for blend specimens casting.

2.3. Polymer Blends Preparation

Epoxy/silicon rubber (SR) and unsaturated polyester/silicon rubber (SR) blends are selected for investigation. Epoxy resin was prepared as in section (2.2.1), with weight fractions 3, 5, 7, 10 and 20% percentages of silicon rubber (SR). The epoxy and silicon rubber were added together and thoroughly prepared mixed to obtain the polymer blend required. Unsaturated polyester/silicon rubber (SR) polymer blend were prepared by the same manner.

3. Measurements

3.1. Impact test

Charpy impact test involve the use of hammer blow that will be delivered to the sample until reaches to breaking point. The sample is positioned in such a way that both of its ends are fixed in position and the blow is delivered to the middle part. Samples of impact device has a dimensions of (10*55*10mm) according to ASTM (D4812). Figure1 shows the impact test specimens to carry the test. The apparatus used in this test is manufactured by (Testing Machines, Inc, Amityville New York). The following equation can be used to calculate the impact strength (I.S.):[8]

\[ \text{I.S.} = \frac{U_c}{A} \]

Uc: the fracture energy (Joule) from Charpy impact device.
A: the area of the samples (m²) (cross-sectional)

![Figure 1](image_url)

Figure 1. (a) Impact test, (b) Hardness test, and (c) Three – Point Bending test Specimens.
3.2. Hardness test

Shore D was utilized for calculating the hardness of the specimens, thickness of samples at least more than (3mm) which must have smooth surface and not be exposed to mechanical vibrations therefore the prepared sample has (5mm) thickness and (30mm) diameter with reference to ASTM (D 2240). Figure 1. shows the hardness test specimens to carry the test. The shore D device involve a needle that is positioned vertically to the specimen for period about half a minute. To register an accurate reading, the average of three values measured from various sites of each specimen is estimated[9].

3.3. Three – Point Bending Test

Bending tests were carried out by using a Tinus Olsen machine model H50KT of (5kN) full scale load capacity, according to ASTM standard (D-790), this test method covers the determination of flexural properties of unreinforced and reinforced plastics in the form of rectangular bars molded directly or cut from sheets, plates or molded shapes. In this method the bar tests on two supports and is loaded by means of a loading nose midway between the supports. This method includes:

a) Preparation of test specimens. Number of specimens were cut from the prepared sheets, each specimen was in (125 mm) long, (96 mm) support span and (10 mm) width. Figure 1. shows the bending test specimens to carry the test.

b) Procedure: The specimen is placed on two supports and a load is applied in center at constant rate of displacement (crosshead speed) equal to 0.5 mm / min. The loading at failure (psi) is the flexure strength [10].

4. Results and Discussion

4.1. Impact Behavior

The conventional charpy impact test is used to evaluate the impact strength of the blends that have (3,5,7,10 and 20)% of (SR) in either of EP and UPE. The results of this test are shown in Table 1. and Figure 2. which show the effect of rubber content on the impact strength values of the prepared blends.

Table 1. clearly demonstrates the effect of blending (SR) with EP and UPE respectively on the impact strength of the resulting blends. In general, it is well known that the cured rubber-modified epoxy exhibits a two – phase microstructure which consisting of relatively small rubbery particles [11]. These particles are dispersed into the matrix of epoxy and the resulting phase separation nature will be related to the percentages of the rubber and the methodology of the preparation. Any increase in the rubber amount in the matrix would lead to an increase in the average size of the dispersed phase particles and eventually failing to produce a compatible and applicable blend [12].

The above-mentioned phenomenon is clearly noted in the present work, it can be seen that when the percentages of (SR) rubber in both of the EP and UPE blends increases to more than 20% wt., (Figure 2.), the rubber phase has notably separated from the epoxy or unsaturated polyester leading to decrease in the impact strength of the blends.

Figure 2. demonstrates that the Charpy impact strength of (thermoset /elastomer) blend is higher than that of brittle matrix itself, which implies the positive role of elastomer on the impact fracture toughness of brittle materials. Impact strength of (EP) can be maximized to almost (8.4) KJ/m2 on addition of (5) wt% of silicon rubber. The impact strength of (UPE) could be maximized to almost
(11.91) KJ/m² on addition of about (5%) of silicon rubber. If the percentage of elastomer in the brittle matrix increased to more than the above-mentioned percentages, the impact strength would decrease to lower values. This indicates that the impact strength of binary blend is not simply an additive, and its dependence on blend composition reveals the influence of blend morphology, state of dispersion and any other structural parameter on impact toughening of this blend. Occurrence of a maximum in the impact strength at a particular blend composition may be attributed to the critical size and geometry of dispersed phase domains. Chiang and Song [13] have suggested that the rubber particles are often spherical with spherical inclusions of the brittle phase. At concentrations larger than the related maximum value of the rubbery phase, the dispersed particles tend to agglomerate or to form elongated rather than spherical particles, which reduce the impact strength.

| Composition | Silicon rubber (SR) content (wt %) |
|-------------|----------------------------------|
|             | 0%  | 3%  | 5%  | 7%  | 10% | 20% |
| EP/SR       | 7.3  | 6.16 | 8.4  | 6.07 | 8.13 | 6.4 |
| UPE/SR      | 7.12 | 5.13 | 11.91 | 5.71 | 8.65 | 6.2 |

**Figure 2.** Charpy impact strength variation with SR rubber content in EP, UPE resins.
4.2. Hardness Test

The hardness is a measure of resistance to indentation and, hence, will not be greatly influenced by the matrix [14]. The shore D hardness is used to evaluate the hardness of the blends that have (3, 5, 7, 10 and 20)% of (SR) in either of EP and UPE. The results of this test are shown in Table 2 and Figure 3, which show the effect of silicon rubber (SR) content on the Hardness No. values of the prepared blends. It can be noticed that the presence of silicon rubber would reduce the hardness of the blends and when increased the silicon rubber (SR) ratio, the values of hardness No. are decreased for both epoxy and polyester blends. The reason for that is obvious, which is the elasticity of the silicon rubber.

Table 2. The effect of silicon rubber content (wt %) on the Hardness No. of (EP/SR) and (UPE/SR) blends.

| Composition | Hardness No. |
|-------------|--------------|
|             | Silicone rubber content (wt) |
|             | 0% | 3% | 5% | 7% | 10% | 20% |
| EP/SR       | 79  | 63.9 | 60.2 | 67.2 | 60.4 | 66.6 |
| UPE/SR      | 88.4 | 80.9 | 79.7 | 78.3 | 79.9 | 74.6 |
Figure 3. Hardness No. variation with SR rubber content in EP, UPE resins.

4.3. Bending Properties and Young's Modulus

The Young's modulus (E) is a measure of stiffness (rigidity) of the material. The greater the Young's modulus, the smaller the elastic strain resulting from the application of a given stress \[19\]. This reflects the importance of measuring the (E) of the blends that have (3, 5, 7, 10 and 20)% of (SR ) in either of EP and UPE, which were measured and are shown in Table 3. This measurement was performed by using 3-point bending test method.

Table 3 states that the Young's modulus of (EP) and (UPE) has been reduced after blending them with the used silicon rubbers (SR). The reason for this reducing is the increasing in the flexibility of the polymer chains for the blends compared with that of pure (EP) or (UPE). This implies an increase in the strain rate and reduction in the stiffness (rigidity), which means, these blends will have new prospect of application. \[15\].

Table 3. The effect of silicon rubber content (wt %) on the Young's modulus (E) of (EP/SR) and(UPE/SR) blends.

| Composition | Young's modulus (E), MPa. |
|-------------|---------------------------|
|             | 0% | 3% | 5% | 7% | 10% | 20% |
| EP/SR       | 1187 | 781 | 976 | 856 | 700 | 714 |
| UPE/SR      | 3134 | 2573 | 1991 | 1605 | 1800 | 1294 |
4.4.  **Flexural Strength Behavior**

Flexural strength is a measure of the resistance of material to be bent, when it goes under bending moment. During bending, the material undergoes gross flexural deformation before fracture, because the material is exposed to three types of stresses. The convex side of the material is extended (tensioned), while the concave side is compressed and, at the same time, the internal layers of the material shear each other [16].

The simple three-point bend method was used to calculate the flexural strength (F.S) for epoxy blends and unsaturated blends under study. According to the results shown in table 4. and displayed in Figure 4, the flexural strength of (EP) and (UPE) are decreased when they are mixed with silicone rubber due to the dispersion phase between silicone rubber and polymer matrix. Any increase in the rubber amount in the matrix would lead to an increase in the average size of the dispersed phase particles and eventually failing to produce a compatible and applicable blend.

| Composition | Flexural Strength, F.S (MPa) |
|-------------|------------------------------|
|             | Silicon rubber content (wt %) |
|             | 0%  | 3%  | 5%  | 7%  | 10% | 20%  |
| EP/SR       | 38.59 | 23.88 | 27.02 | 20.01 | 19.42 | 15.75 |
| UPE/SR      | 105.4 | 48   | 48.31 | 40.22 | 46.39 | 28.14 |

Table 4. The effect of silicon rubber content (wt %) on the Flexural Strength of (EP/SR) and (UPE/SR) blends.
5. Conclusions

The results showed that the specimens of UPE/SR blend have the highest values of impact strength at the addition of 5% SR. Hardness No. decreased slightly when the content of SR increased both of EP/SR and UPE/SR blends. Also flexural strength decreased rapidly when the content of SR increased in both of EP/SR and UPE/SR blends.

6. References

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