Investigation of The Thermal Conductivity of Binary Polymer Blends

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Abstract In this research, binary polymer blends are formed from epoxy, unsaturated polyester and polyurethane. The concentration were chosen with varying percentages of components, resulting in three groups; polyurethane / epoxy (PU/EP), epoxy/unsaturated polyester (EP/UPE) and polyurethane /unsaturated polyester (PU/UPE) blends. Hand lay-up technique was used to prepare the samples with 6 mm thickness prepared from simultaneous mixing of the two constituents in the required percentages.

Thermal conductivity K for these blends was carried out by using Lee's disk method at room temperature. The experimental results showed that an increment and /or decrement of thermal conductivity depend on type and blend concentration. Also the experimental results indicated that the thermal conductivity has the highest values of (K) (0.78 J/m².k) at ratios (PU 10% / EP 90 %), (0.70 J/m².k) at ratios (EP 50% / UPE 50%) and (0.50 J/m².k) at ratios (PU 40% / UPE 60%) respectively. This increment of (K) implies that the penetration of molecules of both polymer components in the same direct then a good transfer of energy by the vibration and rotation of the chain molecules.

Also the experimental results indicated that the thermal conductivity has the lowest value of (K) (0.52 J/m².k) at ratios (PU 40% / EP 60%), (0, 0.53 J/m².k) has obtained at ratios (EP 30% / UPE 70%) and (0, 0.31 J/m².k) has obtained at ratios (PU 60% / UPE 40%) respectively.

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1. Introduction

In recent years there has been rapid growth in the development of polymer blends and their end user applications. These applications associated with lower cost with improved properties have spurred more research activities on polyblends. Polyblends of the type thermoset – thermoset offer property advantages such as enhanced processability, thermal properties, strength and adhesion properties, chemical resistancy, optical properties, flame retardancy, etc. [1 - 3].

Polyurethane (PU) has been used in several technical applications due to high tensile strength, chemical resistance, process ability, and mechanical properties [4, 5]. In polyurethane, hydrogen bonding is sufficient to produce a physical link between polymer chains to enhance overall improved properties. Phase separation in PU has been found to influence by hard and soft segment structures, molecular weight, polydispersity, and crosslinking ability. Epoxy polymers are tough and flexible with good corrosion and chemical resistance. The epoxy reactions are highly temperature dependent, epoxy oligomer/monomer dependent, and energetic [6, 7]. Polyester resins have a number of advantages, including versatility in structure and properties, overall low cost, and ease of application. However, they suffer from some decisive drawbacks, such as low mechanical properties, alkali resistance, and low hardness. So, to improve these drawbacks of polyester resins, blending with other suitable resins, such as epoxy resin, amino resin, silicone resin, and ketonic resin, can be performed, as polyester resins have good compatibility with a wide variety of other resins. The better compatibility comes from the relatively low viscosity of the resin and from the structure of the resin, which contains a relatively polar and aromatic backbone and aliphatic side chains with low polarity. The blending technique may be used effectively to improve the inferior properties of both the components. Miscible polymer blends produce a new improved material from less superior individual components, where as well established miscible polymer blends are very rare to obtain. However, semi-miscible blends with a uniform distribution of components also improve properties to an acceptable range [8-11].

There are numerous numbers of previous studies related to polymer blends and their industrial applications, for examples: Awham et al. [12] prepared binary and ternary polymer blends by hand lay-up method with different weight ratios. The binary blends are epoxy/unsaturated polyester (EP/UPE) and epoxy/polysulfide rubber (EP/PSR) while the ternary blend is epoxy/unsaturated polyester/polysulfide rubber (EP/UPE/PSR). Impact, tensile and flexural characteristics for these blends were investigated at room temperature. The morphology of impact fracture surfaces for the prepared blends was examined by using the optical microscopy. The results revealed that the blending process of epoxy resin with UPE, PSR or both together within certain weight percentages forms compatible blends with improved toughness. The brittleness phenomenon of epoxy resin disappears with increasing the content of added polymer

Kalid [13] prepared binary polymer blends by hand lay-up method with different weight ratios from epoxy, unsaturated polyester, polyurethane, polymethyle methacrylate and polystyrene in 10 groups; thermoset-thermoset, termoset-thermoplastic, and thermoplastic- thermoplastic blends. Impact test, hardness test, differential scanning calorimetry test, thermogravometry test, and morphology by optical microscopy and scanning electron microscopy were carried out to investigate whether these blend are classified as compatible blends. The main aim of the present study was to characterization and comparison among three groups of binary polymer blends; polyurethane / epoxy (PU/EP), epoxy/unsaturated polyester (EP/UPE) and polyurethane /unsaturated polyester (PU/UPE) blends. In this study the mixing ratios effect on the thermal conductivity have been studied.
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 component 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 (Methyle Ethyle Keton Peroxide, MEKP) as a hardener, while cobalt octoate acts as a catalyst to accelerate the solidification process. Platine clear polyurethane gloss-057ME is a highly durable two-component polyurethane varnish with high gloss, excellent weathering and UV resistant properties. Theoretical spreading rate: 16.7 m²/litre.

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. For 100 gm of EP resin a sufficient amount of hardener (Sikadur-52-B) was added. The ratio of hardener of 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.

2.2.3. Polyurethane preparation

With the same above procedures the required polyurethane resin was weighed. For 100 gm of PU resin (polyol) a sufficient amount of the hardener (isocyanate) was added. The ratio of hardener to resin was approximately 1:4 by weight. Again both were thoroughly mixed to be ready for blend specimens casting.

2.3. Polymer Blends Preparation

Epoxy/ Polyurethane, Epoxy/Unsaturated Polyester and Unsaturated Polyester / Polyurethane were added together and thoroughly prepared mixed to obtain the polymer blend required table(1), shows the percentages from which we have obtained the controlled and suitable blends, however the unsuccessful blends that were ignored due to their complete immiscibility between the two polymers. The mixture was stirred for 30 sec, then cast in a mold and finally left overnight at room temperature for complete curing.
Table 1. The blend percentages of three group.

| Group No. | Blend No. | Material Concentration | Description |
|-----------|-----------|------------------------|-------------|
|           |           | PU% | EP%   | success |
| 1 PU/EP   | 1         | 0   | 100   | success |
|           | 2         | 10  | 90    | success |
|           | 3         | 20  | 80    | success |
|           | 4         | 30  | 70    | success |
|           | 5         | 40  | 60    | success |
|           | 6         | 50  | 50    | success |
|           | 7         | 60  | 40    | success |
|           | 8         | 70  | 30    | success |
|           | 9         | 80  | 20    | success |
|           | 10        | 90  | 10    | success |
|           | 11        | 100 | 0     | success |
|           | 12        | 0   | 100   | success |
|           | 13        | 10  | 90    | Failure |
|           | 14        | 20  | 80    | Failure |
|           | 15        | 30  | 70    | success |
|           | 16        | 40  | 60    | success |
|           | 17        | 50  | 50    | success |
|           | 18        | 60  | 40    | success |
|           | 19        | 70  | 30    | success |
|           | 20        | 80  | 20    | success |
|           | 21        | 90  | 10    | success |
|           | 22        | 100 | 0     | success |
| 2 EP/UPE  | 23        | 0   | 100   | success |
|           | 24        | 10  | 90    | success |
|           | 25        | 20  | 80    | success |
|           | 26        | 30  | 70    | success |
|           | 27        | 40  | 60    | success |
|           | 28        | 50  | 50    | success |
|           | 29        | 60  | 40    | success |
|           | 30        | 70  | 30    | success |
|           | 31        | 80  | 20    | success |
|           | 32        | 90  | 10    | success |
|           | 33        | 100 | 0     | success |

3 Measurements

3.1. Thermal Conductivity Test Instrument

Lee's disc instrument showed in figure 1, manufactured by the Griffen and George Company, was used to calculate the thermal conductivity of the samples under test. The figure below shows this instrument which consists of three discs of brass (40 mm diameter by 12.25 mm thickness) and a heater. The sample (S) is placed between the discs A and B, while the heater is placed between B and C. Heater was supplied with voltage (6 volt) and the current value through the apparatus was about (0.25A). The heat transfers from the heater to the near two discs then to the third disc across the
sample. The temperature of the three discs (T_A, T_B, and T_C) is measured by using a thermometers placed inside them. After reaching thermal equilibrium, the temperatures were recorded[14].

**Figure 1.** Thermal Conductivity Test Instrument.

### 4. Results and Discussion

Thermal conductivity (K) is the ability of a material to conduct heat. This quantity represents the rate of heat flow per unit time in a homogenous material under steady conditions, per unit area, per unit temperature gradient in a direction perpendicular to area [15]. Polymers are often utilized as thermal insulators because of their low thermal conductivities. For these materials, energy transfer is accomplished by the vibration and rotation of the chain molecules [16,17].

Figure 2 shows the relation between the thermal conductivity (K) for blending ratio of (PU/EP) blends. It can be seen that the highest value of (K) (0.78 J/m².k) has obtained at ratios (PU 10% / EP 90%) respectively. This increment of (K) implies that the penetration of molecules of both (PU) and (EP) in the same direct then a good transfer of energy by the vibration and rotation of the chain molecules. Also it was noticed the thermal conductivity (K) reach to minimum value (0.52 J/m².k) at ratios (PU 40% / EP 60%), but the results of thermal conductivity still higher than that of neat polyurethane.

Figure 3 shows the relation between the thermal conductivity (K) with blending ratio of (EP/UPE) blends. It can be noticed that the highest value of (K) (0.70 J/m².k) has obtained at ratios (EP 50% / UPE 50%), but results of thermal conductivity still lower than that of neat unsaturated polyester. Also it can be noticed that the lowest value of (K) (0.53 J/m².k) has obtained at ratios (EP 30% / UPE 70 %), but results of thermal conductivity still lower than that of both neat epoxy and unsaturated polyester. In general due to nature of cross link properties some blends are unsuccessfully prepared at ratios (EP 10% / UPE 90%) and (EP 20% / UPE 80%) respectively.

Figure 4 shows the relation between the thermal conductivity (K) with blending ratio of (PU/UPE) blends. It can be noticed that the highest value of (K) (0.49 J/m².k) has obtained at ratios (PU 40% / UPE 60%), but results of thermal conductivity still only lower than that of neat unsaturated polyester. This figure also shows that the lowest value of (K) (0.31 J/m².k) has obtained at ratios (PU 60% /
UPE 40%), but results of thermal conductivity still lower than that of both neat polyurethane and unsaturated polyester.

Finally the experimental results indicated that the thermal conductivity (K) has the highest value at ratios (PU 10% / EP 90%). Also it has the lowest value at ratios (PU 70% / UPE 30%) as shown in Figure 5.

Table 2. thermal conductivity test results

| Group No. | Blend No. | Material Concentration | Thermal conductivity (K) |
|-----------|-----------|------------------------|--------------------------|
| 1 PU/EP   | 0 PU%     | 100 EP%                | 0.588891108              |
|           | 10 PU%    | 90 EP%                 | 0.780901142              |
|           | 20 PU%    | 80 EP%                 | 0.748959999              |
|           | 30 PU%    | 70 EP%                 | 0.662203083              |
|           | 40 PU%    | 60 EP%                 | 0.522667544              |
|           | 50 PU%    | 50 EP%                 | 0.591965052              |
|           | 60 PU%    | 40 EP%                 | 0.614968254              |
|           | 70 PU%    | 30 EP%                 | 0.60131201               |
|           | 80 PU%    | 20 EP%                 | 0.641581322              |
|           | 90 PU%    | 10 EP%                 | 0.576047154              |
|           | 100 PU%   | 0 EP%                  | 0.458610635              |
| 2 EP/UPE  | 0 EP%     | 100 UPE%               | 0.674592014              |
|           | 10 EP%    | 90 UPE%                | 0.605051827              |
|           | 20 EP%    | 80 UPE%                | 0.60081057               |
|           | 30 EP%    | 70 UPE%                | 0.69017215               |
|           | 40 EP%    | 60 UPE%                | 0.644594821              |
|           | 50 EP%    | 50 UPE%                | 0.589127944              |
|           | 60 EP%    | 40 UPE%                | 0.579927478              |
|           | 70 EP%    | 30 UPE%                | 0.723933312              |
| 3 PU/UPE  | 0 PU%     | 100 UPE%               | 0.674592014              |
|           | 10 PU%    | 90 UPE%                | 0.397359579              |
|           | 20 PU%    | 80 UPE%                | 0.447877533              |
|           | 30 PU%    | 70 UPE%                | 0.43544589               |
|           | 40 PU%    | 60 UPE%                | 0.49548859               |
|           | 50 PU%    | 50 UPE%                | 0.446673486              |
|           | 60 PU%    | 40 UPE%                | 0.315848843              |
|           | 70 PU%    | 30 UPE%                | 0.360776919              |
|           | 80 PU%    | 20 UPE%                | 0.447030908              |
|           | 90 PU%    | 10 UPE%                | 0.408571945              |
|           | 100 PU%   | 0 UPE%                 | 0.458610635              |
Figure 2. Thermal conductivity (K) values as a fraction with blending ratio of (PU/EP) concentrations.

Figure 3. Thermal conductivity (K) values as a fraction with blending ratio of (EP/UPE) concentrations.
Figure 4. Thermal conductivity (K) values as a function with blending ratio of (PU/UPE) concentrations.

Figure 5. Thermal conductivity (K) values as a function with blending ratios of (PU/EP), (EP/UPE) and (PU/UPE) concentrations respectively.
5. Conclusions

Thermal conductivity decreases when increasing the ratios of PU to EP concentrations. From the experimental results noted that thermal conductivity (K) has the highest value at ratios (PU 10% / EP 90%). Also it has the lowest value at ratios (PU 70% / UPE 30%), that still lower than that of all neat epoxy, unsaturated polyester and polyurethane.

6. References

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