

**Thermal Properties of Polyvinyl acetate (PVA) and Toluene
Diisocyanate (TDI) With Prepared Solfonated Phenol Formaldehyde
Resin (SPF) as Composites.**

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Abstract:

Two similar specimens of polyvinyl acetate (PVA) and toluene diisocyanate (TDI) blend and prepared solfonated phenol formaldehyde resin (SPF) as a mixture composite. SPF was diagnosed by infrared Fourier transformation (FTIR) spectrophotometer. The specimens were subjected to thermal heating by using copper electric heater; this was connected to d.c power supply. Three copper-constantan thermocouples were connected from junctions in two copper plates with dimension 4.2x 3.5x 0.2 cm³. in length, width and thickness respectively, to voltmeters for measuring the temperature across two similar specimens, with respect to the ambient and ice point temperatures. Negative electric potential (voltage) -2.7 mv and -3.1 mv dependence for thermal conductivity of the composite has indicated at 0.3% wtSPF. The calculated thermal conductivity were 0.0043 W.m⁻¹.k⁻¹ and 0.00239 W.m⁻¹.k⁻¹ at temperature 303 k and 203 k. for 0.2% wtSPF and 0.3% SPF respectively to 0.007 W.m⁻¹.k⁻¹ and 0.001 W.m⁻¹.k⁻¹ at 602.985 k and 582.999 k for 0.4% wtSPF and 2% wtSPF respectively. Maximum extrapolation is 0.07 W.m⁻¹.k⁻¹ for 1% wtSPF.

Keywords: PVA, TDI; SPF, mixtures, FTIR spectroscopy, composites, bonds, Thermal conductivity.

Introduction:

A thermoplastic, also known as a thermo-softening plastic, is a polymer that becomes pliable or moldable above specific temperature and returns to solid state upon cooling. Most thermoplastic a high molecular weight, whose chains associate through intermolecular forces, this property allows thermoplastic to be remolded because the intermolecular interactions spontaneously reform upon cooling. Therefore, thermoplastic differ from thermosetting polymer, this form irreversible chemical bonds during curing process, thermoset often do not melt bond break down and do not reform upon cooling. Above glass transition temperature T_g and below its melting point, T_m . The physical properties of thermoplastic change drastically without associate phase change. Within this temperature range, most thermoplastic are rubbery

due to alternating rigid crystalline and elastic amorphous region [Wikipedia, 2013]. Thermosets and thermoset materials are polymer materials that have been irreversibly cured. They are generally stronger than thermoplastics due to polymer cross-linked and have higher resistance to heat. Cured thermoset resins may soften when heated, but do not melt or flow. They tend to be more brittle than thermoplastic and may cannot be recycled due to irreversibility [www.globl spec.com 2013].

Structural transitions are the change from one crystal structure to another, the change from an amorphous state to a crystalline state, the glass transition, melting, solidification, cold crystalline and solid state curing[D. D. L. Chung 2001].

Polymers can also be classified in terms of their chemical composition; this gives a very important indication as to their reactivity, including their mechanism of thermal decomposition and their fire performance [G. L. Beyler *et al.* 2002].

Composites are engineering materials made from two or more constituents with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure. Most composites are made up of just two materials. One material is (the matrix or binder) surrounds and binds together a cluster of fibers or fragments of a much stronger material (the reinforcement). For the matrix, many composites use thermosetting or thermoplastic polymers (also called resins). The resin holds the reinforcement together and helps to determine the

thermo-physical properties of the end product [S. Bhagat 2013].

Polymer matrix composites are regarded as one of the most attractive and relatively new materials. Many scientific investigations concerning these materials have been carried out in recent years. Fibre reinforced polymer composites are increasingly used in many high performance applications due to their widely described advantages. Due to the new applications of these composites, there is an increasing need for reliable thermo-physical properties data. Reliable thermal properties such as thermal conductivity values are essential in a selection of a material in order to get the best performance of these materials in a specific application. In the case of reinforced polymer composite-fibres (with different thermo-physical properties) to polymer

matrix and using different fibre contents [G. Wrobel *et al.* 2011].

Thermal properties such as thermal conductivity are important parameters to simulate the temperature variation inside the composite during specific process. Thermal conductivity describes a material's ability to transport heat. Studying the effect of volume fraction of pineapple leaf on thermal properties on the Hemp composite using transient plan source technique it was found that increasing the fiber content in the matrix decreases the thermal conductivity of the pineapple leaf fiber reinforced composite, which means that it could not provide the conductive path to the heat energy in the composite material. Theoretical values of thermal conductivity of composites were also obtained through Rayleigh-Maxwell and Meredith –Tobias models to compare with experimental data. Rayleigh –Maxwell model is

applicable for two phase dispersion of spherical particles in continuous medium for entire range of filler concentration in the composites. However, the Meredith-Tobias model does not consider the size and shape of filler particles. Develop of a new experimental method to determine the in-plane and through thickness thermal conductivities of polymer matrix composites was investigated. The transient temperature gradient in the given direction is recorded using thermocouples and the result processed numerically by inverse approach to determine the directional thermal conductivity [T. Behzard *et al.* 2007].

Composite materials have primarily used for structural applications. Polymer composite materials have found extremely useful for heat dissipation like in electronic packaging, in electronic chips. Polymer composite filled with SPF is of interest. The interest in this

composite material arises from the fact that the thermal characteristics of such composite is close to the properties polymer composite filled with metal[D. Chauhan *et al.* 2012]. The transfer conditions of heat flow determine thermal conductivity level in the heterogeneous polymer-filler system, in which the conductivity phase is formed by dispersed filler. The influence of the type of polymer matrix and filler on the thermal conductivity of the composite which gave significant differences of thermal conductivity behavior filled system[Y. P. Mamunya *et al.* 2002].

Methods:

Preparation of Sulfonated Phenol Formaldehyde resin (SPF):

42.5 moles of phenol was put in clean tri-neck round flask 500 ml. in capacity, which was emplaced in Isomental heater sort

LabHeat BAECO, Germany. The side neck (B19) (mm. inner diameter) of the round flask was close by stop-fit thermometer and the other side neck (B19) (mm. in diameter) by a condenser which is connected to water pump in ice path, while a stirrer sort Heidolph, Germany is inert in the middle neck (B24) (mm. inner diameter). The system was run and the phenol was heated to appropriate temperature to dissolve any solid bodies. The system was stopped and 4 moles of sulfuric acid 97% in concentration Thomas Baker India, was added slowly from one side neck of the round flask by using pipettes. The round flask was closed again as above and the system was run, while the stirrer adjusted to appropriate speed and the temperature of the isomental heater is raised, which is maintained between 100-120 °C for two hours. The system was stopped and the temperature was

cooled slowly, then the round flask was emplace in ice path and 12 moles of Formaldehyde Thomas Baker, India. was added by using pipettes, a fizzing and bubbling is occurred, the temperature is raised and stirring by hand using glass rod was done, the temperature was cooled to 35 °C then below 22 °C. stirring was continued until a viscose solid mass is obtained, the product was left over night. The pH was examined by using indicator paper which is colored red low PH. NaOH solution was prepared in a spread flask and drops were added until over saturation is reached high PH, a few drops of H₂SO₄, were added for equilibrium until pH=7 was reached. Remove the solution and put the precipitate resin in a glass plate to be dried at room temperature and the product was collected in plastic container.

FTIR Test:

Sample of sulfonated phenol-formaldehyde resin (SPF), was examined with KBR disc by Fourier transform Infrared Instrument (FTIR) as in Fig.(1). The peaks at 1128.39 cm⁻¹ and 1175cm⁻¹ corresponding to C-C-O asymmetric stretch and C-H in plane formulations respectively while the 1000 cm⁻¹ and 748.8 cm⁻¹ peaks belonged to the C-H out of plane vibration. The peak at 1034.14 is carbonyl group C=O. The peak at 1506.37 cm⁻¹ corresponded to the C=C aromatic ring vibration. The above mentioned peaks diminished with increasing reaction time while the absorbance band of hydroxyl groups increased. Table (1) show the functional groups and their wave numbers obtained in this investigation and comparison with other functional group from previous study. [I. Poljansek *et al.* 2005].

Table (1) The obtained functional groups compared with literature and previous functional groups from Reference.[I. Poljansek *et al.* 2005].

| Literature data cm ⁻¹ Ref. | Functional group obtained | Wave number cm ⁻¹ | Functional group. Ref. | Observe d cm ⁻¹ |
|--|-------------------------------|---------------------------------|--|-------------------------------|
| 1240 | C-C-O | 1128.39 | C-C-O phenol | 1224 |
| 1180 | C-H in plane | 1175 | C-H aromatic phenol | 1170 |
| 835 | C-H out of plane phenol | 1000 and 748.8 | C-H out of plane, para | 826 |
| 760 | | | C-H out of plane, ortho | 756.6 |
| 1153 | C-O | 1034.14 | C-O stretch | 1154 |
| | C-H unsaturated | 3024.43 | C-H unsaturated stretchd phenol | 3026 |
| 1610 and 1517 | C=C | 1506.37 | C=C | 1610 and 1552 |
| 3400 | OH | 3530.3 | OH | 3389 |

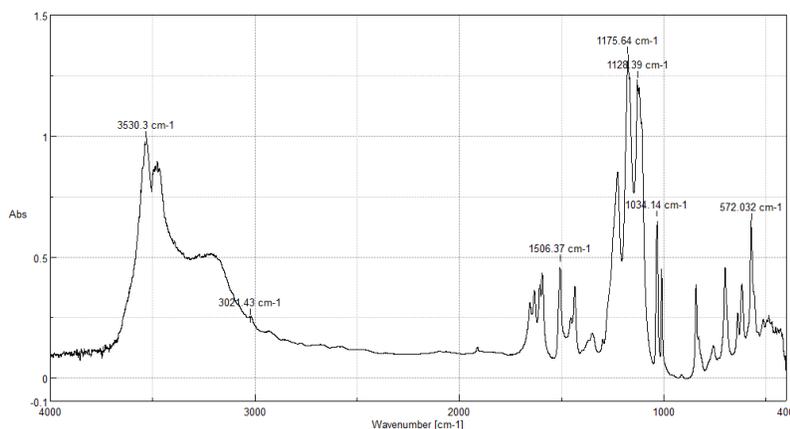


Figure (1). FTIR spectroscopy of SPF.

Samples Preparation:

PVA and TDI were blended by hand using spatula in a percent of 3:1 by weight, in clean flask, different percentages of SPF by weight of the total blend were grinded in Pyrex mortar and were dissolved in 1 cm³ boiling distilled water, which was poured on the blend and was mixed by hand using spatula as in Table 2. The mixture was poured into two similar casts which were made into polyethylene sheet, 4.2x 3.5x 0.2 cm³ in length, width and thickness respectively. The two similar specimens for each percentage of added SPF were performed and the

specimens were left over night to be dried.

Thermal properties Measurements:

The two similar specimens were subjected to thermal heating, using electrical copper heater, Figure (2) shows the apparatus used for the thermal conductivity measurement of the composite. the heater was connected to Stabilized power supply sort FARNELL INSTRUMENTS LTD. Made in England, as the heat source sandwiched between two similar specimen halves. Three copper-constantan thermocouples TC1, TC2 and TC3 were used for measuring the temperatures ΔT the temperature

difference between hot and cold surfaces of the specimen, T_c is the temperature of the cold surface of the specimen and T_A is the ambient temperature. These thermocouples are from the same length and spot welded by soldering at atmosphere to overcome the problem of temperature discontinuities and were fixed at junctions in copper plates (grooves of 0.7 mm deep and 0.5 mm nearer to the working surface of the plates) with same dimension of the specimen were placed on either side of each specimen with wires of the thermocouples used as electrodes to create a uniform heating profile and prevent any convective thermal loss directly from the samples to the environment, were shielded and connected to two digital voltmeters (trade mark) for

measuring the temperature across a hot point in the cover plates of the electric heater, ambient temperature and ice point temperature across the two similar specimens at junctions of hot, the ambient and ice points temperatures. Set up of apparatus used in measurements as shown in Figure (3). The measurements data as in Table 2. Table of temperature dependence of thermoelectric voltage in copper-constantan (type T) thermocouples. Temperature of reference junction: 0°C . The heater calibration with polymethyl methacrylate (PMMA)[W. A. Hussian 2006]. From this Table temperatures were measured as in Table 3.

Thermal conductivity of the composite was calculated using the formula[T. Bahzard *et al.* 2007]:

$$k = \frac{Qd}{2A(\Delta T)} \quad (1)$$

Where: k is the thermal conductivity of the specimen.

$Q = I \times V$ is the power used in the circuit, I is the current from the power supply and v is the voltage supplied to the circuit.

$Q/2A$: is the heat flux through the sample in $W.m^{-2}$.

d is the thickness of the sample in the direction of the heat flow (m).

ΔT is the temperature gradient across the sample in °C. ($^{\circ}C+273$) k.

A is the cross sectional area of the sample (m^2).

Extrapolation method was applied to determine theoretically values of thermal conductivity[Y. Mao *et al.* 2002].

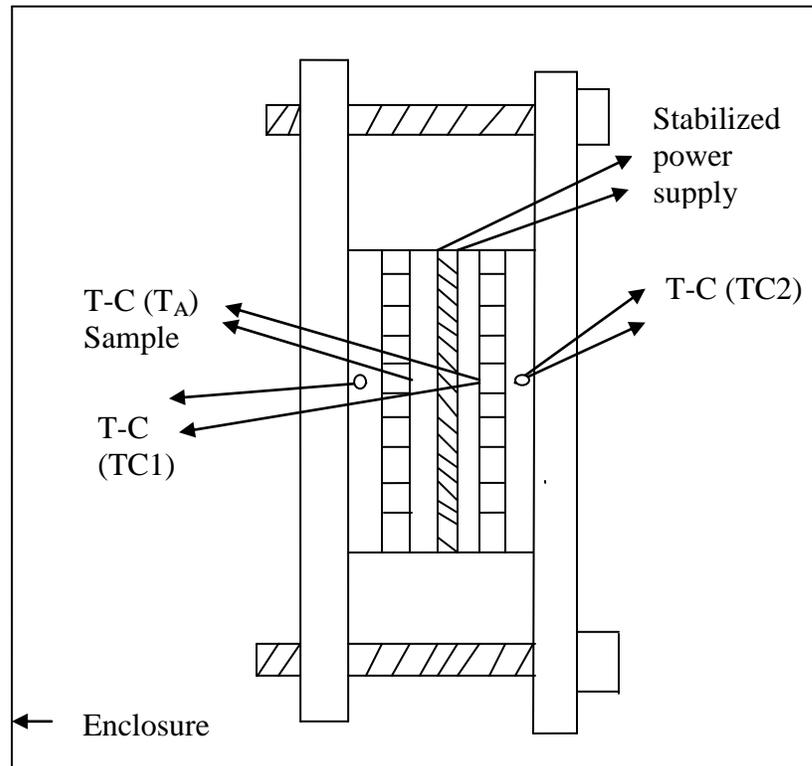


Figure (2) the apparatus used for the thermal conductivity measurement of the composite.  a copper heater,  copper plates,  composite, T-C thermocouple.



Figure (3) Set up used for measurements.

Table (2). Sample preparation Content.

| PVA gm. | TDI gm. | percent SPF | Thickness cm. |
|------------|------------|----------------|------------------|
| 12 | 4 | 0.1% wt | 0.2 |
| 12 | 4 | 0.2% wt | 0.2 |
| 12 | 4 | 0.3% wt | 0.2 |
| 12 | 4 | 0.4% wt | 0.2 |
| 12 | 4 | 1% wt | 0.2 |
| 12 | 4 | 2% wt | 0.2 |

Table (3) Thermal properties measurements and calculations.

| 0.1% wt SPF | | | | 0.2% wt SPF | | | |
|-----------------|------------------|------------------------------|-------------------------------------|-----------------|------------------|-------------------------|-------------------------------------|
| V _{mv} | ΔT °C | Q= I _x V W. | K W.m ⁻¹ k ⁻¹ | V _{mv} | ΔT °C | Q=I _x VW. | K W.m ⁻¹ k ⁻¹ |
| 5.4 | 120. 004 | 0.232 | 0.000401 | 1.6 | 40 | 2.021 | 0.00439 |
| 5.9 | 130. 005 | 0.638 | 0.00107 | 2.1 | 50.0 022 | 2.021 | 0.00425 |
| 7.7 | 160. 013 | 0.95 | 0.0015 | 6.7 | 150 | 2.021 | 0.00325 |
| 7.9 | 170. 005 | 1.216 | 0.00186 | 11.2 | 239. 994 | 3.688 | 0.00489 |
| 8.0 | 160. 999 | 1.216 | 0.0019 | 7.0 | 159. 994 | 4.098 | 0.00643 |
| 8.8 | 190. 001 | 1.992 | 0.00297 | 6.7 | 150 | 5.794 | 0.00931 |
| 9.9 | 210. 002 | 2.091 | 0.00294 | 6.8 | 150. 002 | 5.794 | 0.00931 |
| 10.0 | 219. 991 | 2.141 | 0.00295 | 7.2 | 160 | 5.794 | 0.0091 |
| 10.1 | 219. 999. | 2.191 | 0.00302 | | | | |
| 12.0 | 249. | 2.998 | 0.00389 | | | | |

| | | | | | | | |
|---------------|------------------|----------------------------|--|-------------|------------------|----------------------------|--|
| | 999 | | | | | | |
| 12.4 | 259. 831 | 2.998 | 0.00382 | | | | |
| 13.2 | 270. 002 | 1.584 | 0.00198 | | | | |
| 14.4 | 299. 989 | 1.584 | 0.00188 | | | | |
| 10.7 | 299. 999 | 1.584 | 0.00188 | | | | |
| 12.6 | 250. 002 8 | 1.584 | 0.00206 | | | | |
| 13.2 | 270. 002 9 | 1.584 | 0.001984 | | | | |
| average | | | 0.002257 | | | | 0.006366 |
| Extrapolation | | | 0.0065 | | | | 0.02 |
| 0.3% wt SPF | | | | 0.4% wt SPF | | | |
| Vmv | ΔT °C | $Q = I \times V \times w.$ | $K \text{ W.m}^{-1} \cdot \text{k}^{-1}$ | Vmv | ΔT °C | $Q = I \times V \times w.$ | $\text{KW.m}^{-1} \cdot \text{k}^{-1}$ |
| -2.7 | -70. 006 | 0.715 | 0.00239 | 4.00 | 99.9 53 | 1.478 | 0.00269 |

| | | | | | | | |
|---------------|------------------|-------|---------|------|------------------|-------|----------|
| -3.1 | -90. 000 7 | 1.072 | 0.00398 | 5.9 | 130. 016 | 1.790 | 0.00302 |
| 6.3 | 140. 002 | 1.072 | 0.00176 | 6.9 | 150. 017 | 2.958 | 0.00475 |
| 5.1 | 120. 005 | 0.995 | 0.00172 | 7.5 | 160. 005 | 4.164 | 0.00654 |
| 0.4 | 10.0 01 | 2.94 | 0.00706 | 7.9 | 170. 017 | 4.428 | 0.00680 |
| 0.5 | 10.0 03 | 2.94 | 0.00706 | 8.5 | 180. 001 | 4.701 | 0.00705 |
| 0.6 | 10.0 09 | 4.098 | 0.00985 | 9.7 | 200. 007 | 5.033 | 0.00723 |
| 0.7 | 10.0 08 | 4.166 | 0.01 | 10.5 | 220. 008 6 | 5.324 | 0.00737 |
| 0.8 | 20.0 | 4.776 | 0.011 | 12.1 | 250. | 5.624 | 0.00733 |
| 1.0 | 29.9 58 | 5.089 | 0.0114 | 12.7 | 259. 998 | 5.624 | 0.0072 |
| 1.2 | 30.0 04 | 6.710 | 0.015 | 13.3 | 270. 001 | 5.612 | 0.00646 |
| | | | | 16.4 | 329. 985 | 6.249 | 0.00705 |
| average | | | 0.01316 | | | | 0.006124 |
| Extrapolation | | | 0.04 | | | | 0.015 |

| 1% wt SPF | | | | 2% wt SPF | | | |
|-----------------|------------------|------------------------------|---|-----------------|------------------|--------------------------|-------------------------------------|
| V _{mv} | ΔT °C | Q= I _x V W. | KW.m ⁻¹ . k ⁻¹ | V _{mv} | ΔT °C | Q=I _x V W. | K W.m ⁻¹ k ⁻¹ |
| 4.7 | 100. 006 8 | 1.26 | 0.00229 | 7.4 | 160. 005 | 0.853 | 0.00134 |
| 7.8 | 169. 995 | 1.472 | 0.00226 | 9 | 199. 993 | 0.95 | 0.00136 |
| 9.7 | 209. 999 | 1.551 | 0.00218 | 10.5 | 220. 003 | 0.95 | 0.001296 |
| 10.5 | 219. 999 | 1.632 | 0.00225 | 11.8 | 240. 011 | 0.95 | 0.001267 |
| 11.7 | 239. 915 | 1.995 | 0.00266 | 12.7 | 260. 013 | 0.95 | 0.00121 |
| 12.4 | 249. 999 | 2.177 | 0.00283 | 14.8 | 290. 006 | 1.05 | 0.00127 |
| 12.9 | 260. 014 | 2.297 | 0.00293 | 16.9 | 330. 015 | 1.177 | 0.00132 |
| 13.5 | 270. 002 | 2.553 | 0.00319 | 17.8 | 350 | 1.455 | 0.00136 |
| 13.9 | 280. 017 | 2.979 | 0.00366 | 19.4 | 379. 985 | 1.455 | 0.00131 |
| 14.3 | 290. 006 | 3.157 | 0.00381 | 17.6 | 349. 979 | 1.045 | 0.00098 |

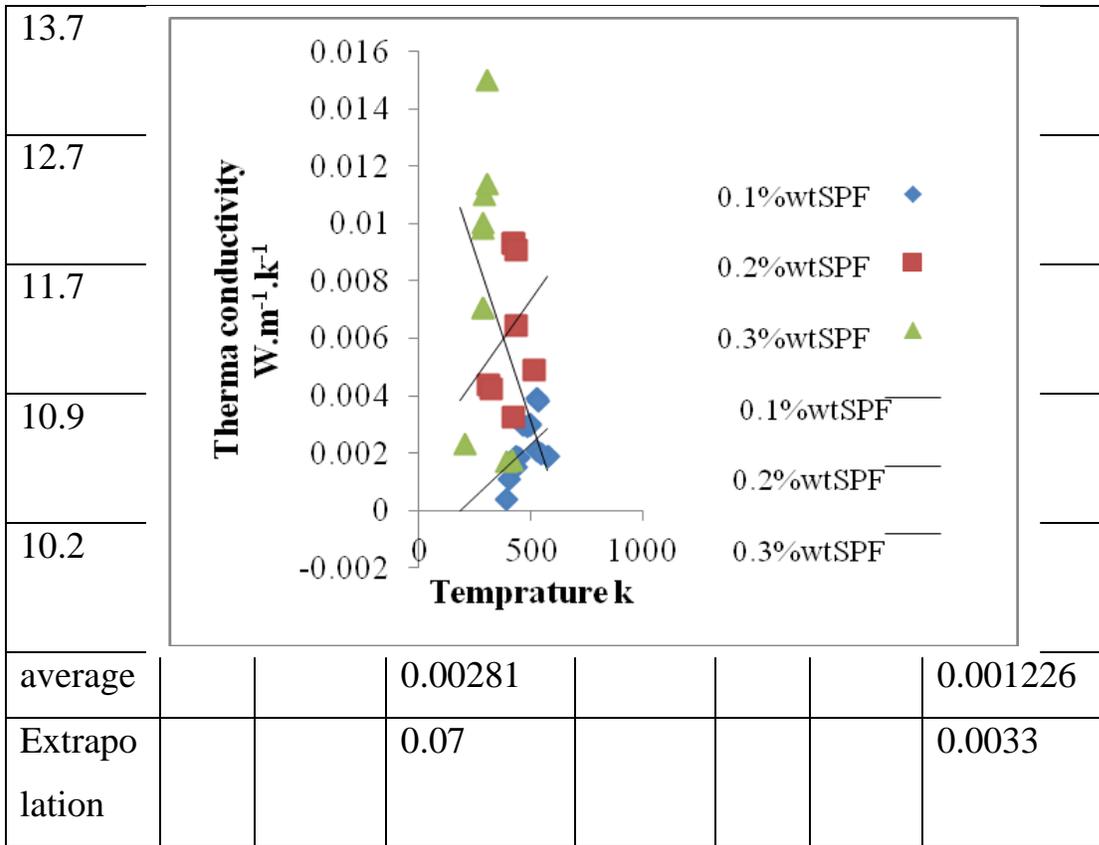


Fig.(4). Thermal conductivity variation with temperature.

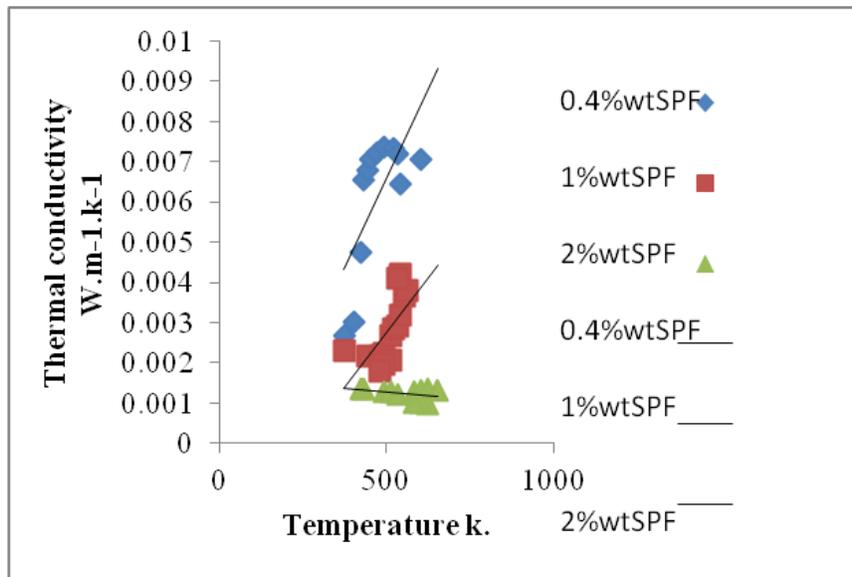


Figure (5) Thermal conductivity variation with temperature.

Results and Discussion:

The variation of thermal conductivity with temperature is an intrinsic behavior of polymer composites as in Table (3). Figure (4) Shows increase in thermal conductivity with increasing temperature to the value $0.00389 \text{ W.m}^{-1}.\text{k}^{-1}$ at temperature 522.999 k , in series 1. at 0.1%wtSPF. This behavior is normal for amorphous polymers as low thermal conductivity is obtained, the explanation of this result could be based on the solid state theory, which suggests that the increase of temperature cause increase in the intermolecular vibration, which dominant mechanism of heat transfer[S. A. Shokralla *et al.* 2010]. In series 2 for 0.2%wt SPF the behavior is still the same but the increase in the thermal conductivity is reached $0.0093 \text{ W.m}^{-1}.\text{k}^{-1}$ at temperature 423 k . This is less as in 0.1%wtSPF. Thermal conductivity less than 0.1

$\text{W.m}^{-1}.\text{K}^{-1}$ and therefore is basically thermal insulator. It is clear that the experimental data are lower than extrapolation values, suggesting a higher fibre thermal conductivity was used in these calculations. Extrapolation of the experimental data of series1 gives thermal conductivity of $0.0065 \text{ W.m}^{-1}.\text{k}^{-1}$ of series1 for heat-treated of the composite and for series 2 gives a value of thermal conductivity $0.02 \text{ W.m}^{-1}.\text{k}^{-1}$ [Y. Mao, *et al.*, 2002]. In series 3 at 0.3%wt SPF, the maximum thermal conductivity was $0.015 \text{ W.m}^{-1}.\text{k}^{-1}$. At temperature 303.004 k . Low temperature dependant according to negative electric potential (voltage) -2.2 mv and -3.1 mv has indicated dependence for the thermal conductivity of the composite, this is heat flux transfer from region of low temperature to a region of higher temperature depend on the SPF concentration [C. Z. Fan *et al.*, 2008]. The first

data is in agreement with data obtained for 0.3%wtSPF as shown in Figure (4) series 3. Extrapolation of experimental data gives value of thermal conductivity $0.04 \text{ W.m}^{-1} \cdot \text{k}^{-1}$. The absence of percolation behavior of the thermal conductivity with increasing SPF, it should pointed out to explain the more steep rise there are no additional thermal conductivity related to shape and size of particles. The reason for the percolation threshold absence is due to the fact that the thermal conductivity of dispersed SPF and that of the polymer matrix are comparable to each other[Y. Mao, et al, 2002]. [Y. P. Mamunya *et al.* 2002].

In Figure (5). Series 1 at 0.4%wt SPF the maximum thermal conductivity is $0.0073 \text{ W.m}^{-1} \cdot \text{k}^{-1}$ at temperature 493.008 k, the behaviors yield thermal insulator. Extrapolation method gives value of thermal conductivity 0.015

$\text{W.m}^{-1} \cdot \text{k}^{-1}$. Series 2 at 1%wt SPF the maximum value of thermal conductivity is reached $0.0042 \text{ W.m}^{-1} \cdot \text{k}$, at temperature 543.014 k. By extrapolation calculation for series 2 is $0.07 \text{ W.m}^{-1} \cdot \text{k}^{-1}$, this result reflect that the composite is thermal insulator rather than conductive[S. A. Shokralla *et al.* 2010].

Scientists work out new technologies to manufacture materials that have continuous distribution of composition and properties. These kinds of materials, named Functionally Gradient Materials (FGMs), offer a solution for many advanced applications by suitable connection of two or more materials that have dissimilar properties without definite boundaries between them in macroscopic level[S. Bhagat 2013].

The same behaviors in series 3 at 2%wt SPF the maximum thermal conductivity was reached $0.0013 \text{ W.m}^{-1} \cdot \text{k}^{-1}$. In temperature 652.985

k. Extrapolation of experimental data gives value of thermal conductivity $0.0033 \text{ W.m}^{-1} \cdot \text{k}^{-1}$. The increase of SPF did not give more high thermal conductivities, the effect can be explained due to the absence of percolation path or the decrease of disorder of alignment through the constituent of the composite [E. S. Choi *et al.* 2003]. Thermal resistance of a compound is related to the breakdown of the weakest bond at a certain temperature as the temperature was raised. And also the thermal resistance of the composites related to the temperature of thermal dissociation of the bonds present in the rigid structure of the fibre [I. Vitkauskiene *et al.* 2011]. From Table 3. at 0.1%wt SPF the increases in thermal conductivity occur in temperatures range (463.001-572.999) k. At 0.2%wt SPF the increase in thermal conductivity occur at 433 k and the system maintain the thermal

conductivity when the temperature has decreased to 423 k. at 0.3%wt SPF although the temperatures were low but the thermal conductivity increased at 303.004 k. at 0.4%wt SPF the thermal conductivity was increased at 473.007 k. after this the system has maintained its thermal conductivity. At 1%wt SPF thermal conductivity was increased at 553.017 k. and the system has maintained the thermal conductivity when the temperature has decreased to 533.013 k. further decrease has reduced the thermal conductivity. When SPF was increased to 2%wt SPF, the thermal conductivity was increased at 623 k. as the temperature was increased; there is no extra increase in thermal conductivity.

Conclusions:

The investigation was used the method was described, to measure the thermal conductivity

of PVA/TDI with SPF composites. This indicates that the thermal conductivity was increased to a certain temperature. Experimental results show that the percentages by weight of SPF have a significant effect on the thermal conductivity of the composite. Polymer is reinforced with unidirectional arranged fibres. In those systems, the thermal conductivity of the composite is the highest. This is due to the anisotropic nature of the fibres; while the conductivity is good along the fibres, the heat flow across the fibres is poor. On the other hand, if the alignment of the fibres is perpendicular to the direction of thermal flux, the thermal conductivity will be the lowest. The transfer conditions of heat flow determine the thermal conductivity level in the heterogeneous PVA/TDI-SPF system, in which the conductive phase is formed by dispersed SPF.

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الخلاصة:

تم عمل نموذجين متشابهين من مزج البولي فينايل اسيتيت و تلوين داي ايسوسيانيت مع نسب وزن مختلفة من راتنج الفينول-فورمالديهايد المسلفن المحضر لعمل خليط المكون. تم سكب الخلائط في قالبين متشابهين تم عملهما في صفيحتين من البولي اثلين، لتحضير نموذجين متشابهين لكل خليط. تم تشخيص البولي فينايل أسيتيت/تلوين داي ايسوسيانيت مع راتنج الفينول-فورمالديهايد المسلفن باستخدام جهاز مطياف تحويلات فورير للاشعة تحت الحمراء. تم تعريض النماذج للتسخين الحراري باستخدام مسخن من النحاس والذي تم أوصاله الى مجهز قدرة. ثلاث مزدوجات حرارية تم أوصالها عبر نقاط في صفيحتين متشابهتين من النحاس بابعاد 0.2x 3.5x 4.2 سم³ في الطول، العرض والسك على التوالي، الى فولتمترين لقياس درجة الحرارة النموذجين المتشابهين والمتماثلين لابعاد المسخن بالنسبة الى درجة حرارة المسخن والمحيط داخل المستودع ونقطة أنجماد الجليد. تم تعيين جهد سالب 2.7- ملي فولت

3.7- ملي فولت عند النسبة 0.3% wtSPF. تم حساب التوصيلية الحرارية، 0.0043 واط.م-1. كلفن-1، ، 0.00239 واط.م-كلفن-1، عند درجة حرارة 313 كلفن و203 كلفن، للنسبة للنسبة 0.2% wtSPF و 0.3% wtSPF. على التوالي و 0.007 واط.م-كلفن-1 و 0.001 واط.م-كلفن-1. عند درجة حرارة 602.985 كلفن و 582.999 كلفن للنسبة 0.4% wtSPF و 2% wtSPF على التوالي. أعلى قيمة استقرائية للمكون 0.07 واط.م-1 كلفن-1 للنسبة 1% wtSPF.

الكلمات المفتاحية: البولي فينايل اسيتيت، تلوين داي ايسوسيانيت، راتنج الفينول-فورمالديهايد المسلفن، خلائط، طيف الاشعة تحت الحمراء، مكونات، مادة رابطة، التوصيل الحراري.