Transport Behaviour of Some Selected Solvents Through Epoxy Coated Grey Fabrics

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Abstract- Transport Behaviour of selected solvents through Epoxy Coated Grey Fabrics had been studied. The grey fabrics were formulated by coating the grey cotton (GC), grey nylon (GN), grey linen (GL), and grey polyester (GP) with epoxy resin in the Laboratory of the Department of Polymer and Textiles Engineering, Imo State. 20ml of Hydrogen peroxide was mixed with colbalt and methyl ethyl ketone to form mixture 1, 20ml of borax was mixed with cobalt, and methyl ethyl ketone peroxide to form mixture 2. 40ml of epoxy was measured out in a beaker and poured into a basin and 20ml each of mixture 1 and 2 were injected gradually at different points in the basin. The grey fabrics were then dipped in each of mixtures to form epoxy coated grey fabrics; Grey cotton treated with borax (GCB), Grey cotton treated with hydrogen peroxide (GCH), Grey cotton treated with hydrogen peroxide and borax (GCHB), Grey linen fabric treated with hydrogen peroxide (GLH), Grey linen fabric treated with borax (GLB), Grey linen fabric treated with hydrogen peroxide and borax (GLHB), Grey polyester fabric (GP), Grey polyester fabric treated with borax (GPB), Grey polyester fabric treated hydrogen peroxide polyester (GPH), Grey polyester fabric treated with hydrogen peroxide and borax (GPHB), Grey nylon treated with borax (GNB), Grey nylon treated with hydrogen peroxide (GNH), and Grey nylon treated with both borax and hydrogen peroxide (GNBH). The methyl ethyl ketone peroxide (MEKP) and cobalt were used as catalyst and accelerator respectively. The grey fabrics were then dipped in the mixture of 1 and epoxy and 2 and epoxy to form epoxy coated grey fabrics and allowed to cool at room temperature. The epoxy grey coated fabrics were totally immersed in water bath at temperatures of 18°C and 27°C at intervals of 300 seconds until equilibrium was reached. Sorption properties were calculated using the molar percentage uptake (qt) obtained from molar uptake at equilibrium (qe). The results obtained were validated using the least square technique with Matlab software.

Indexed Terms- Transport behaviour, Fabrics, Isotherms, Kinetics, Modelling.

I. INTRODUCTION

Fabrics filled with epoxy in contact with organic solvents have not been researched extensively. This has given rise to this study. Each day materials come in contact during service with very strong toxic chemicals causing degradation to fabric composites due to swelling. The development of fabric composite with polymer filler that possesses the requisite properties to overcome the challenges enumerated in the problem statement. The use of epoxy resin, a strong and chemical resistant matrix would reduce the chances of failure and render the fabric composite impermeable to organic solvents. The use of boron for the treatment of grey fabric which is not reactive to water, oxygen, alkalis and acids would give synergetic hydrophobic properties in outdoor environments.

In the study by Alvarez, Franscisco Velasco, Asuncion Bautista, and Juana Abenoja (2020) , the wear resistance of an epoxy powder coating was improved by SiO2 nanoparticles and their possible effect on curing kinetics of the coating was also evaluated. The epoxy powder coating was prepared with different percentages of nanoparticles (1-3 by wt.%) using a hot mixer, a method that can be more economic than other ones. The particle size distribution and Fourier-transform infrared spectroscopy (FT-IR) of epoxy powder were evaluated to examine the effect of mixing on the powder. The effect of SiO2 on the curing of epoxy powder was studied by differential scanning calorimetry (DSC). The Kissinger and model free kinetics (MFK) methods were used to calculate the activation energy (Ea) of the curing process of powders. The coating spraying process was carried out in an industrial installation on carbon steel substrates. The glass transition temperature (Tg) of the coatings was also studied using DSC. The morphology of the cured organic coatings was observed by scanning electron microscopy (SEM). Stiffness and hardness Vickers (HV) were evaluated. A test based on ASTM D969 was developed to perform erosion measurements. The results obtained by both the Kissinger and MKF methods showed that nanoparticles do not influence significantly the Ea of curing of the coatings. The addition of 1% SiO2 improves the erosion wear at 45 and 60°, due to the increase in stiffness and hardness provided by the nanoparticles, though, when particles collide at 60° with the samples, the lowest thickness loss was found for the epoxy with 3% nanoreinforcement [1].

The investigation of reinforcement integration into matrix in order to determine specific functions has been studied [2]. They are usually heterogeneous in nature; created in assembly of two or more components; where the additive is not natural, a compactibiliser is employed to bring about adhesion.
The study of sorption of fabric composites is of high importance since most swollen fabric composites had decreased properties. In commercial applications and in the area of chemical production processes, it is important that these polymers and composites remain chemically stable while retaining their mechanical properties on contact with solvents. It is as result of this that the basic transport phenomenon plays vital role in engineering and industrial uses of textile and polymers [3].

Epoxy polymers are famous for their superior barrier properties in various environmental conditions. This is evident in the modification of epoxy to balance the hydrophilic-hydrophobic properties and as such control the absorption, cross-linking and degradation [4].

The specific objectives of the work are to investigate fully the properties of epoxy coated grey fabrics made from natural and synthetic fabrics, to investigate the effect of chemical treatment on the sorption properties of epoxy coated grey fabrics, and to determine the isotherm and kinetic rates of sorption of the epoxy coated grey fabrics.

II. EXPERIMENTAL

2.1.1 Materials and Method

The materials used in this research were fabrics (grey and treated). The chemicals included, epoxy, benzene, toluene, xylene, chlorobenzene, acetone, hydrogen peroxide, cobalt as accelerator and borax. The equipment used were: water bath, precision electronic weighing machine, stop watch, beakers and medical gloves.

The fabrics were formulated according ISO standard, 1172:1996 by coating the grey and treated states of cotton, linen, nylon and polyester. The grey state fabrics were treated with hydrogen peroxide and borax for comparison with the finished ones, all in 1x1 weave no. Methyl ethyl ketone peroxide (MEKP) and cobalt were used as catalyst and accelerator used in respectively. 40ml of epoxy was measured out in a beaker and poured into a basin. A syringe was used to measure out 20ml each of cobalt and methyl ethyl ketone peroxide and injected gradually at different points in the basin. This was done to avoid evolution of fumes, flames or possible fire when the accelerator (cobalt) and catalyst (MEKP) come into contact. Homogeneity was achieved by continuous vigorous stirring. The samples were subjected to oven drying at 70°C for 30 minutes to eliminate stickiness of the resultant composites.

The transport of the aromatic solvents, chlorobenzene, and acetone through epoxy coated grey fabrics were studied at 18 and 27°C by conventional weight loss experiment. The epoxy coated fabrics in rectangular sheets measuring 0.015 x 0.015cm with thickness of 0.36cm uniform samples were cut off from the sample and soaked in 40cm^3 of the solvents. The dry weight of the samples was measured and recorded with an electric weighing balance of 0.001g accuracy. The samples of known mass (M_i) were each placed in an equilibrated thermostatic water bath at different temperatures stated above. The samples were withdrawn at different time intervals, the solvents adhering to their surfaces was removed with the aid of the filter paper, weighed and returned to the reagent bottles. The increases in mass with time (M_t) of the swollen samples were recorded. This process was repeated for the different samples until a state of equilibrium adsorption was reached at which time, the weights of the samples remained steady. The results obtained were carefully taken and recorded accordingly. The readings were tabulated and the difference between the dry sample and the wet sample were obtained.

III. THEORY/CALCULATIONS

The experimental data obtained was analyzed using parameters such as molar percentage uptake (Q), Diffusion Coefficient (D), Sorption Coefficient (S), and Permeability Coefficient. The results obtained by experiment was used to key into computer applications to obtain mathematical as well as theoretical values using established theories of sorption such as the equations Arrhenius, enthalpies and entropies of sorption, diffusion and permeation. To select a suitable model for describing the transport behavior of epoxy coated fabrics, the results from experiment were fitted to two widely used sorption isotherm models, Langmuir and Frieunlich. The coefficient of determination (R^2) was one of the main criteria for selecting the best equation. In addition to R^2, the goodness of fit was determined by root mean square error (RMSE). For the best fit, the R^2 value should be high close to "1" and RMSE value should be low, close to "0".

3.1.1 Molar percentage uptake (q_t)

The molar percentage uptake (q_t) was obtained using the equation [3.1]:

$$q = \frac{(M_{t}\_\ M_0)/M_n}{M_0} \text{ x } 100 \qquad (3.1)$$

From equation 3.1, sorption rate at equilibrium is obtained as:

$$qe = \frac{(M_{e}\_\ M_0)/M_n}{M_0} \text{ x } 100 \qquad (3.2)$$

where M_t = Mass of Sample at a particular time, M_o = initial mass of sample, M_n = molar mass of solvent and M_e = Mass of sample at equilibrium.

But $M_t = (M_0 M_n x100) + M_o$, (3.3)

Matlab code for equation 3.2:

$q_e = [(M_t\text{-}M_o)/M_n]/M_o*100$ (3.4)

The rate of sorption, molar uptake of the solvent can be calculated mathematically (Emperical Modelling) by using coefficient of regression, R^2 after generating an equation using Engineering softwares such as Matlab.

3.1.2 Diffusion Coefficient

The diffusion coefficient (D) for the samples of different filler content was obtained using Fickian's second law of diffusion:

$$D = \left[\frac{h\text{Ø}}{4Q_{\infty}}\right]^2 \qquad (3.5)$$

where h is the initial sample thickness (m), Ø is the slope of the linear portion of the sorption curve of the plots of % q_t versus $\sqrt{t}$, and Q_∞ is the mass at equilibrium of sorption. Note, the slope was obtained by first order differential equation.

3.1.3 Sorption Coefficient

The sorption coefficient was calculated using the equation:

$$S = \frac{M_\infty}{M_0} \qquad (3.6)$$

where $M\infty$ is the mass (g) of solvents sorbed at equilibrium and M_0 is the initial mass of the composite.

3.1.4 Permeability coefficient

The permeability coefficient, P was obtained using the equation:

$$P = D \times S \qquad (3.7)$$

where D = Diffusion coefficient and S = Sorption Coefficient.

IV. RESULTS AND DISCUSSION

The results of the sorption properties of epoxy coated fabrics and the corresponding contact time is recorded and plotted in Figure 4.1

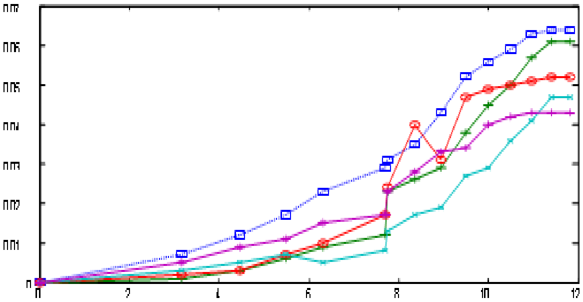


Figure 4.1 Plot of rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for treate cotton in boron and hydrogen peroxide solvent at 18°C.

Similarly, the results of the epoxy coated grey cotton and treated cotton at 27°C is given in Figure 2. The result showed an increase in sorption for the grey cotton treated with boron.

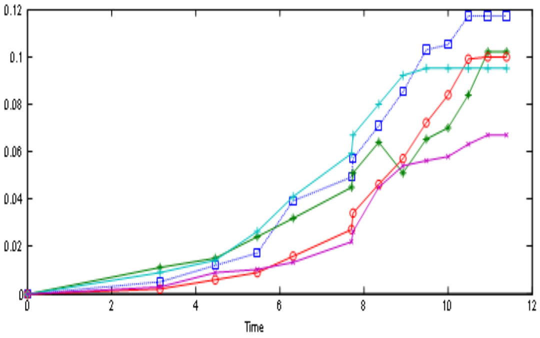


Figure 4.2 Plot of rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for epoxy coated Cotton fabrics at 27°C.

4.1.1 Results of Chemical Treatment on Sorption Properties of treated Polyester in Chlorobenzene at18°C

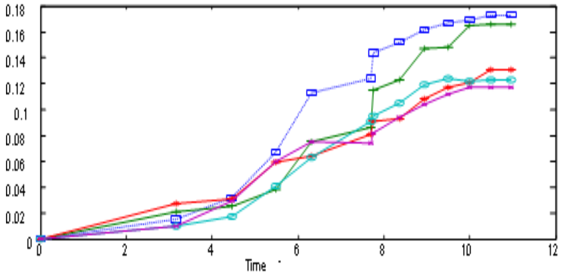


Figure 4.3 Plot of rate of sorption (%q_e) verses squareroot of Time ($T^{1/2}$) for epoxy coated Polyester Fabrics in chlorobenzene at 18°C.

4.1.2 The Sorption of Polyester fabrics in chlorobenzene at 27°C

The sorption of polyester fabrics in benzene solvent at the temperature of 27°C was plotted against the square root of time (√ t or $T^{1/2}$) as shown in Figure 4.4. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 7800s.

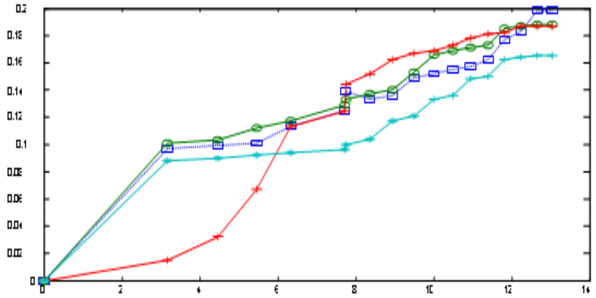


Figure 4.4 Plot of rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for Polyester fabrics in chlorobenzene at 27°C.

4.1.3The Sorption of Polyester fabrics in acetone at 18°C

The sorption of polyester fabrics in acetone solvent at the temperature of 18°C was plotted against the square root of time (√ t or $T^{1/2}$) as shown in Figure 4.5.

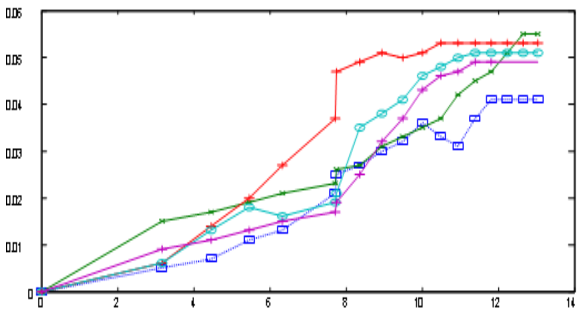


Figure 4.5Plot of rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) of treated anduntreatedpolyester in acetone solvent at 18°C.

4.1.4 Sorption of Polyester Fabrics in acetone at 27°C

The results of the effect of treatment on the Sorption of properties of Polyester fabrics soaked in acetone at 27°C was recorded and tabulated in Table 4.2.

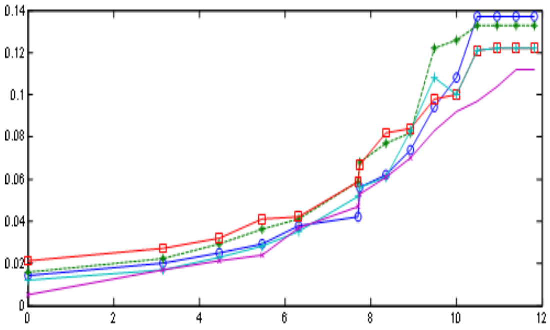


Figure 4.6 Plot of rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) of polyester fabrics in acetone solvent at 27°C.

4.1.5 Sorption of polyester Fabrics in chlorobenzene at 18°C

The sorption of polyester in chlorobenzene solvent at the temperature of 18°C was plotted against the square root of time (√ t or $T^{1/2}$) as shown in Figure 4.7. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 7200s. The calculated values of diffusion D, and permeation coefficient P, increase gradually, while the sorption coefficient S, decreased.

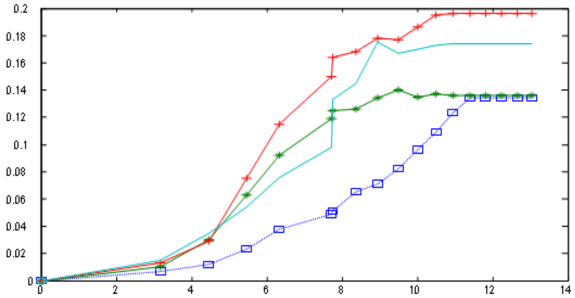


Fig. 4.7 Plot of the rate of sorption (%q_e) vs square root of Time ($T^{1/2}$) of Cotton in acetone solvent at -18°C

The sorption of linen in chlorobenzene uptake (%q_e) solvent at the temperature of 18°C was plotted against the square root of time (√ t or $T^{1/2}$) as illustrated in Figure 4.8. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 7200s. Furthermore, sorption rate was moderate in the highest filled sample GCBH

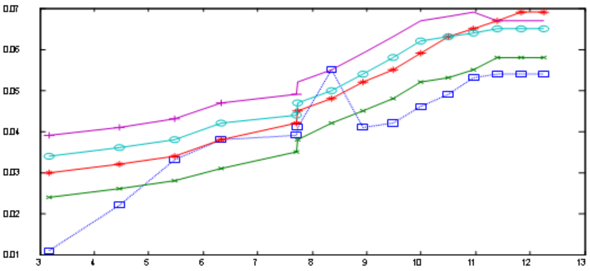


Figure 4.8 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for sample Linen in chlorobenzene solvent at 18°C.

4.1.6 The Sorption (%q_e) of Linen in Chlorobenzene at 27 °C

The sorption of linen fabrics in chlorobenzene solvent at the temperature of 27°C was plotted against the square root of time (√ t or $T^{1/2}$) as illustrated in Figure 4.9. From the graph it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at points 7200s. The result shows that enthalpies and Gibb's energy was positive, while the entropies was negative and the mode of transport was inconsistent (anomalous).

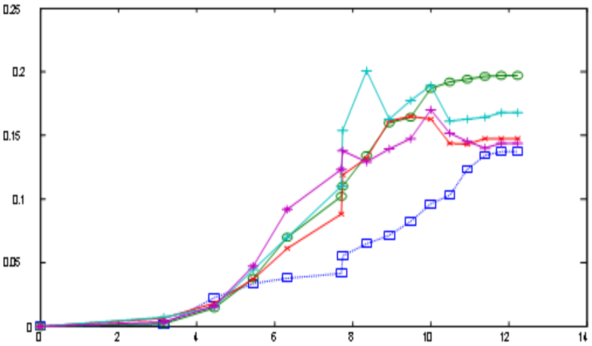


Figure 4.9 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for samples Linen in Chlorobenzene solvent at 27°C.

4.1.7 The Sorption (%q_e) of epoxy coated linen fabrics in acetone at 18 °C

The sorption of epoxy filled linen fabrics in acetone solvent at the temperature of 18°Cwas plotted against the square root of time (√ t or $T^{1/2}$). The sorption curve is shown in Figure 4.7. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 6600-7220s. However, adsorption rate was highest in the highest filled sample LNBH.

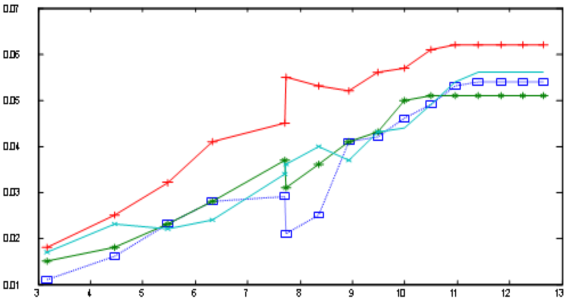


Figure 4.10 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for linen fabrics in acetone solvent at 18°C.

4.1.8 Sorption of acetone in epoxy coated nylon fabrics at 18°C

The sorption of acetone in nylon filled epoxy fabrics solvent at the temperature of 18°Cwas plotted against the square root of time (√ t or $T^{1/2}$). The sorption curve is shown in Figure 4.11. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 6600-7200s. However, adsorption rate was highest in the highest filled sample LNBH. The calculated values of diffusion D, and permeation coefficient P, increase gradually, while the sorption coefficient S, decreases with increasing filler loadings. The result shows that enthalpies and Gibb's energy was positive, while the entropies was negative and the mode of transport was inconsistent. In-addition the activation energy of diffusion was negative and permeations positive.

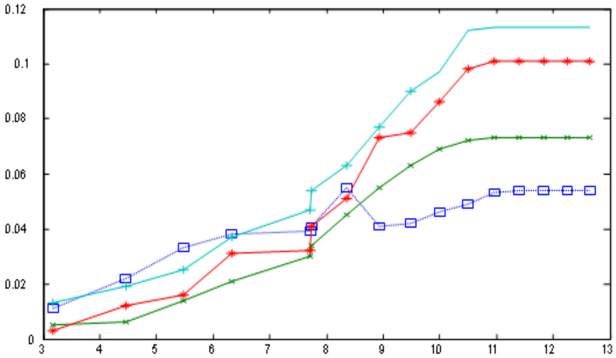


Figure 4.11 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for grey epoxy coated fabrics in acetone solvent at 18°C.

4.1.9 Sorption of acetone through Epoxy coated grey Fabrics at 27°C

The sorption of acetone through nylon epoxy filled fabrics at the temperature of 27°Cwas plotted against the square root of time (√ t or $T^{1/2}$). The sorption curve is shown in Figure 4.10. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 6600-7200s. However, adsorption rate was highest in the highest filled sample GNBH.

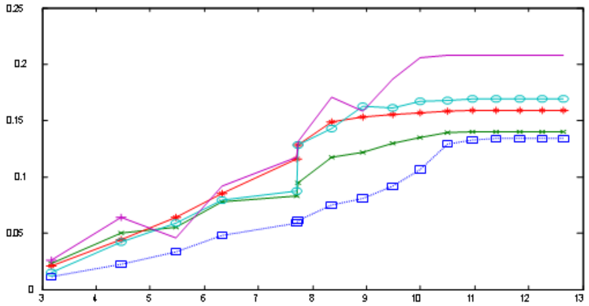


Figure 4.12 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for grey epoxy coated fabrics in acetone solvent at 27°C.

4.1.10 Sorption of chlorobenzene through epoxy grey Nylon Fabrics at 18°C

The molar percentage uptake (%q_t) of nylon in chlorobenzene solvent at the temperature of 40°Cwas plotted against the square root of time (√ t or $T^{1/2}$). The sorption curve is shown in Figure 4.6. From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 6600-7200s.

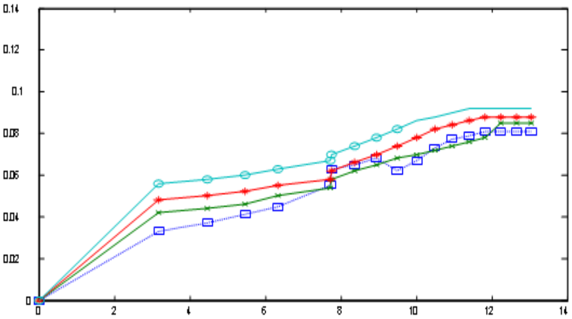
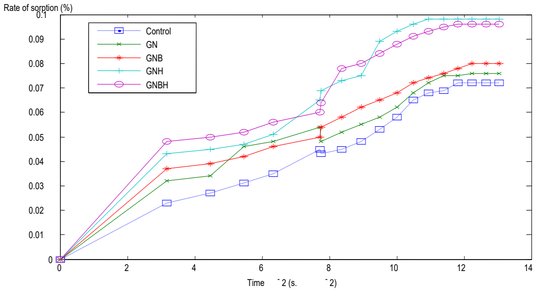


Figure 4.13 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for epoxy coated grey nylon fabrics in chlorobenzne solvent at 18°C.

4.1.11 Sorption of chlorobenzene through epoxy coated Nylon Fabrics at 27°C

The sorption of nylon for the chlorobenzene solvent at the temperature of 27°C was plotted against the square root of time (√ t or $T^{1/2}$). The sorption curve was shown in Figure 4.14 From the graph, it was observed that there was a gradual increase in solvent uptake with increase in time of experiment, until equilibrium point of sorption occurs at 6600-7200s.

Figure 4.14 Plot of the rate of sorption (%q_e) verses square root of Time ($T^{1/2}$) for Epoxy Coated Grey Nylon Fabrics in chlorobenzene solvent at 27°C.



CONCLUSION

From the results, it was observed that diffusion D, and permeation coefficient P, values increased gradually, while the sorption coefficient decreased with increasing time, and temperatures. It was also observed that the activation energy for diffusion was all negative and permeation positives. The thermodynamics such as the Enthalpies and Gibbs's energy of sorption was all positive, while the entropies of sorption were all negatives and increased with increasing fabric treatments. It was evident that the transport mechanism of most of the samples followed non-Fickian mode of transport (inconsistency in the process was observed). Finally, from the results above, it is evident that the epoxy coated fabrics had good resistance to solvents in the temperatures studied and therefore very good in the storage of chemicals in the laboratory and chemical industries because of low solvent sorption.

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