

Studying the Effect of Both Gas Oil and Diesel Fuel on Polypropylene-Polycarbonate Reinforcement with Carbon Black

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ABSTRACT

In the present research, the diffusion of prepared sample blends (PP/PC) unfilled-filled with different amounts of carbon black (2 – 7) wt% and at different temperatures (25°C, 40°C and 55°C) were studied. Absorption test was carried out in (Gas-Oil and Diesel-Fuel) at different immersion times as: Two Conditions were used to calculate the diffusion coefficient values. In the first Condition

$\left[\pi \left(\frac{KL}{4M\infty} \right)^2 / 60 \right]$, the diffusion coefficient values ranged from (0.252 to 1.619)

cm²/sec for immersed in Gas-Oil and it ranged from (0.321 to 1.783) cm²/sec for

immersed in Diesel-Fuel. In the second Condition $\left[\pi \left(\frac{\theta}{4} \right)^2 / 60 \right]$ the diffusion

coefficient values ranged (0.37 to 2.649) cm²/sec for immersed in Gas-Oil and it ranged from (0.562 to 2.635) cm²/sec for immersed in Diesel-Fuel. It was found that the results obtained by the two equations were approximately the same. Indeed the blend (PP/PC) filled with (4 wt%) of carbon black has the lowest values of diffusion coefficient (calculated by the above two equations) in Gas-Oil and Diesel-Fuel which indicates this sample has better performance than other samples. The diffusion test also was carried out at different temperatures in order to show the effect of temperature on diffusion coefficient. It was found that the diffusion coefficient values increase with increasing temperature. All these samples are obeyed Fickian behavior and the activation energy (E) increases with increasing amounts of carbon black (2 – 7) wt%.

دراسة تأثير زيت الغاز ووقود الديزل على المخلوط البوليمري المكون من بولي
كاربونات المدعم بالكربون الاسود بروبيلين- بولي

الخلاصة

في هذا البحث تم تحضير مخاليط مختلفة من بولي-بروبيلين وبولي كاربونات الغير المدعمة والمدعمة بنسب وزنيه مختلفة من الكاربون الاسود (السحام) % (٢ - ٧) وعند درجات حراره مختلفه (٢٥.٤٠ و ٥٥) °م , حيث تم غمر النماذج في زيت الغاز ووقود الديزل وملاحظه امتصاصيه تلك المواد واستخدم شرطان لحساب قيم معامل الانتشار , الشرط الاول $\left[\pi \left(\frac{KL}{4M\infty} \right)^2 / 60 \right]$, والشرط الثاني $\left[\pi \left(\frac{\theta}{4} \right)^2 / 60 \right]$. في الشرط الأول تراوح معامل الانتشار بين ٠.٠٢٥٢ - ١.٦١٩ سم^٢ / ثانيه عند غمرها في زيت الغاز وتراوح بين (١.٧٨٣-٠.٣٢١) سم^٢ / ثانيه عند غمرها في وقود الديزل باستخدام الشرط الثاني تراوح معامل الانتشار بين (٢.٦٤٩-٠.٣٧) سم^٢ / ثانيه عند غمرها في زيت الغاز وتراوح بين (٢.٦٣٥-٠.٥٦٢) سم^٢ / ثانيه عند غمرها في وقود الديزل. وقد تم التوصل الى أن النتائج التي تم الحصول عليها باستخدام المعادلتين متقاربه. تم التوصل الى ان المخلوط البوليمري (PP / PC) الحاوي على نسبة وزنيه ٤% من الكاربون الاسود لديه أدنى قيم معامل الانتشار في زيت الغاز ووقود الديزل مشيرا الى ان العينة لها أداء أفضل من عينات أخرى , ووجد ايضا أن قيم معامل انتشار تزداد مع زيادة درجة الحرارة. بالإضافة الى ذلك ان هذه العينات تخضع للسلوك Fickian وطاقه التنشيط تزداد مع زياده كميّه الكاربون الاسود.

INTRODUCTION

Composites are formed when two or more materials are joined to give a combination of properties that cannot be attained in the original materials (1,2,3).

Fick's first law is the fundamental law of diffusion whereas, Eq.1 the flux- direction (Fx) is proportional to concentration gradient ($\delta c / \delta x$).

$$Fx = -D(\partial C / \partial X) \quad \dots(1)$$

Flux is the amount of substance diffused across unit area, in unit time and D is the diffusion coefficient-Fick's second law of diffusion describes the non steady- state. Diffusion is the process by which matter is transported from one part of the system to another as a result of random molecule. It can be described in terms of the random molecular motion (4). In general, diffusion behavior and transport in glassy polymers have been classified according to the relative rate of mobility of the penetrant and of polymer segments. Such classification produces the following three basic categories of behavior.

(i) case I, or Fickian diffusion, in which, the rate of diffusion is much less than that of the polymer segment mobility. Sorption equilibrium is rapidly established, leading to time independent boundary conditions which exhibit no dependence or swelling kinetics.

(ii) case II (or super case II), the other extreme in which diffusion and penetrant mobility are much greater compared with relaxation processes, sorption processes are strongly dependent on swelling kinetics.

(iii) Non-Fickian, or anomalous diffusion which occurs when the penetrant mobility and polymer segment relaxation are comparable.

Case I (Fickian) and case II can be viewed as two limiting types of transport processes with anomalous diffusion being between them.

They can be distinguished by the shape of sorption, time and curve represented by:

$$M_t/M_\infty = Kt^n \quad \dots(2)$$

Where M_t is the relative weight gain at time, M_∞ is the equilibrium relative weight gain, k and t are constants.

For Fickian system $n < \frac{1}{2}$ while for case II $n = 1$ (and for super case II $n > 1$),

for anomalous systems $\frac{1}{2} < n < 1$.

For Fickian uptake by a specimens of thickness b exposed on both sides to the same environment, mass uptake is related time by the following equation(3).

$$\frac{M_t}{M_\infty} = \frac{4}{b} \left(\frac{Dt}{\pi} \right)^{\frac{1}{2}} \quad \dots(3)$$

Where D the diffusion coefficient and t time ⁽⁵⁾. Eq. (3) can be rewritten as

$$D = \left[\pi \left(\frac{\theta}{4} \right)^2 / 60 \right] \quad \dots (4)$$

Where the value θ is calculated from the slope of plot M_t/M_∞ and \sqrt{t}/L .

- i) Both sorption and desorption curves as a function of square root of time are linear in the initial stage.
- ii) After the linear portion both desorption and absorption curves are concave to the abscissa.
- iii) The sorption behavior obeys the film thickness scaling law, i.e reduced sorption curves for films of different thickness b are all super imposable.
- iv) When D is constant, the desorption and absorption curves coincide over the entire range of t .
- v) The temperature dependence of D can be expressed by the Arrhenius relation.
- vi)

$$D = D_o \exp \left(-Ea/RT \right) \quad \dots(5)$$

Where D_o is the permeability index, Ea , is the activation energy of the diffusion process, R is universal gas constant and T is the temperature. The diffusion coefficient is then calculated by:

$$D = \pi \left(\frac{KL}{4M_\infty} \right)^2 \quad \dots (6)$$

Where D is the diffusion coefficient, L is thickness of the samples, M_{∞} is the maximum weight gain, K is the slope of the linear portion of the plot of M_t versus $t^{1/2}$. The Composites consist of one or more discontinuous phases embedded in a continuous phase. The Diffusion that the process dealing with matter is transported from one part of the system to another as a result of random molecular motion ⁽⁶⁾. In this field several investigators were carried out their work.

Scott, worked with ebonite; a heavily cross linked natural rubber which is a glass at room temperature and it have been found many organic penetrates gave weight increase – time curves, which were substantially linear ⁽⁷⁾.

Alfrey and co-workers, identified the second limiting type of diffusion ,by reporting linear kinetics in the polystyrene-acetone system and discussed possible stress effects took the very significant step of calling such behavior case II ⁽⁸⁾.

Weitsman has undertaken an analysis of stress introduced into adhesive joints by water swelling caused by Fickian diffusion; but it seems unlikely, that they contribute significantly to long term weakening of joints ⁽⁹⁾.

Brewis and Comyn and their group in Leicester, examined the liquid water uptake by series of peroxide adhesive based on (the diglycidle of bisphenol A) (DGEBA). Films were periodically removed for careful surface, drying and weighting; plots of mass uptake against \sqrt{t} are initially linear and diffusion coefficient can be obtained from the slope ⁽¹⁰⁾.

Apicella has demonstrated Fickian uptake with an equilibrium plateau for water uptake by adhesive based on (DGEBA) and (TETA) at different temperatures (23, 45, and 75)°C. However, on changing the temperature of an equilibrated samples, the weight always increased and did not move necessarily towards the level of equilibrium uptake first associated with the new temperature ⁽¹¹⁾.

AL-Abdly has studied the effect of various liquids on tubular shaped fiber reinforced composites, he was noted that at immersion epoxy and unsaturated polyester reinforced with (glass, carbon and Kevlar – 49) fibers in NaOH have higher values than HCL. These polymeric materials obey Fickian diffusion ⁽¹²⁾.

Majeed examined the effect of different liquids (H_2O , HNO_3 and $NaOH$) on mechanical properties of epoxy resin (EP – 10) reinforced with (rock wool fiber and carbon black particles). He found that the diffusion process obeys the Fickian diffusion ⁽¹³⁾.

Mahmood examined, the effect of various liquids such as (H_2SO_4 , $NaOH$ and Oil) on sample blend (PP/PC) unfilled and filled with carbon black (1 wt%). He was found that the behavior of diffusion process obey to Fickian diffusion ⁽¹⁴⁾.

In the present research the diffusion of prepared sample blends (PP/PC) unfilled-filled with different amounts of carbon black (2 – 7) wt% and at different temperatures (25°C, 40°C and 55°C) were studied. Absorption test was carried out in (Gas-Oil and Diesel-Fuel) at different immersion times by using two equations were used to calculate the diffusion coefficient values. It was found that the results obtained by the two equations were approximately the same. The blend (PP/PC) filled with (4 wt%) of carbon black has the lowest values of diffusion coefficient (calculated by the above two equations) in Gas-Oil and Diesel-Fuel which indicates this sample has better performance than other samples.

EXPERIMENTAL WORK**Raw materials****Matrix phase****Polypropylene (PP)**

Commercial polypropylene was used, it was supplied by Saudi Arabia SABIC Company. The general properties of this type of polypropylene are shown in the table 1.

Table (1) Properties of Polypropylene.

Specifications	Value
Melt index , gm/10 min	11
Density ,gm / cm ³	0.908
Molecular weight ,gm / mol	254

Polycarbonate (PC)

Commercial polycarbonate was used, it was supplied by BASF German Company. The general properties of this type of polycarbonate are shown in the Table 2.

Table (2) Properties of Polycarbonate.

Specifications	Value
Melt index , gm/10 min	2.1
Density ,gm / cm ³	1.20
Molecular weight ,gm / mol	420.7

Filler (Carbon black)

The carbon black used in this work was produced by Iraqi Asala Company. The general properties of this type of carbon black are shown in the table 3.

Table (3) Properties of Carbon black.

Specifications	Value
Particle size, μm	66.21
Blackness index	90
Surface area , m ² /g	33

Solvents(Gas oil and Diesel fuel)

The gas oil and diesel fuel used in this work were produced by AL-Daura Refinery. The general properties of these gas oil and diesel fuel are shown in the Table (4).

Table (4) Properties of Gas oil and Diesel fuel.

Specifications	Gas oil	Diesel fuel
API	37.5	30
Density, kg/m ³	837.3	875.6
I.B.P, °C	189	335
E.B.P, °C	338	400
Flash Point, °C	86	90
Color	0.5	2.5

EXTRUSION PROCEDURE

(PP), (PC) and (C.B) samples were kept in an air circulation dry oven at 80°C for 4 hr then (10 wt% of PP, 90 wt% of PC and different amounts of carbon black (2– 7) wt% were measured by using digital balance (Sartorius-Germany). Various formulation were prepared for (PP/PC) blend unfilled-filled with different amounts of carbon black as shown in Table 5. A weighed samples were transferred to single- screw machine at temperature ranging (210 – 220)°C with rotation (30) rpm. The compounding time involved was less than (5min). The extrudates produced in the form of about (1.5 – 2)mm diameter sheet were cooled in water at room temperature and cut well in suitable forms for each test.

Table (5) Extrusion parameters.

No.	Formulations PP/PC/C.B ,wt%	Temperature, °C			Screw speed , R.P.M
		Zon (1)	Zone(2)	Zone(3)	
1	10/90/0	210	220	220	30
2	10/90/2	210	220	220	30
3	10/90/3	210	220	220	30
4	10/90/4	210	220	220	30
5	10/90/5	210	220	220	30
6	10/90/6	210	220	220	30
7	10/90/7	210	220	220	30

PROCEDURE OF MOLDING PROCESS

The homogenous mixture was then pressed in the hydraulic press applying temperature and pressure at the same time. The temperature 200°C was applied to the upper and lower sides of mold while the samples were still under the applied pressure. The sample sheet with dimensions 15 * 5cm * 4mm was obtained. From this sheet test specimens were prepared. The parameters shown in Table (6).

Table (6) Compression molding parameters.

Temperature, °C		Pressure, kg/cm ²	Time, min
Upper plate	Lower plate		
200	200	20	5
200	200	150	5

RESULTS & DISCUSSION

Diffusion behavior according to solvent and temperature is as follows:

Determination of diffusion coefficient by using an Equation (6) for PP/PC = 10/90 unfilled-filled with different amounts of carbon black (2 – 7) wt%, were immersed in Gas-Oil & Diesel-Fuel

Figures (1-3) show the relation between percent of weight and-square root of soaking time.

It is clearly seen that the penetration for pure blend PP/PC is higher than the PP/PC filled with amounts of carbon black (2 and 3) wt%; but the penetration for PP/PC filled with amounts of carbon black (4, 5, 6 and 7) wt% is lower than PP/PC unfilled- filled with amount of carbon black (2 – 3) wt%, whereas the PP/PC filled with carbon black (4 wt%) has lowest value of penetration than of all previous samples.

It has been concluded from Figures (1-3) that the behavior of diffusion process obeys the Fickian diffusion and this can be summarized by both sorption and description curve as function of $(t)^{1/2}$. The plots show linear part in the initial stage and then both absorption curves are concave to the abscissa.

It is clearly observed that the diffusion coefficient values increase with increasing the amount of carbon black (2 – 7) wt% due to the small particle size of carbon black , thus the surface area of particles is small consequently the particles agglomerate, then the distance between pore size will be small then the penetration of (Gas-Oil and Diesel-Fuel) decreases. These results are in good agreement with the results obtained by Alfrey ⁽⁸⁾ Brewis ⁽¹⁰⁾, Apicella ⁽¹¹⁾, AL-Abdly ⁽¹²⁾, Majeed ⁽¹³⁾ and Mahmood ⁽¹⁴⁾.

The value of diffusion coefficient is calculated from the slope of plot weight gain percentage versus square-root of soaking time.

The value of diffusion coefficient is increased with prolonged exposure to Gas-Oil at different temperatures . This is due to the fact that the absorbed liquid acts as plasticizer and crazing agent, consequently deteriorates the mechanical integrity of the resin matrix.

This deterioration or degradation of composite materials under the influence of an aggressive solvent and temperature can result in the loss of strength of reinforcing additive by stress corrosion and loss bond strength through degradation of the interfacial carbon black/matrix bond, whereas the de-bonding process starts immediately upon exposing the composite to various of liquids and temperatures. These results are similar to the results obtained by Alfrey ⁽⁸⁾, Brewis ⁽¹⁰⁾ and Mahmood ⁽¹⁴⁾

Figures (4-6) show the relation between the percent of weight and square-root of soaking time for PP/PC unfilled-filled with different amounts of carbon black (2–7) wt%, at three temperatures of (25°C, 40°C and 55°C), whereas the samples were immersed in Diesel-Fuel nearly three days.

It is clearly seen that the behavior of these samples obeys the Fickian diffusion, and the pp/pc filled with carbon black (4wt %), has lowest value of penetration of all samples. These results are agree well with the results obtained by Alfrey ⁽⁸⁾, Brewis ⁽¹⁰⁾ and Mahmood ⁽¹⁴⁾.

Determination of diffusion coefficient by using an Equation (4) for PP/PC unfill-filled with different amounts of carbon black, immersed in Gas-Oil and Diesel-Fuel

Figures (7-9) show the relation between M_t/M_∞ and \sqrt{t}/L for PP/PC filled- unfilled with different amounts of carbon black (2 – 7) wt% at three temperatures (25°C, 40°C and 55°C), the samples were immersed in Gas – Oil nearly three days.

It is clearly observed that the diffusion process obeys the Fickian diffusion and PP/PC filled with carbon black (4 wt %) has lowest value of diffusion than of all samples. These results are similar to the Pervious results Alfrey ⁽⁸⁾, Brewis ⁽¹⁰⁾ and Mahmood ⁽¹⁴⁾ .

Figures (10-12) show the relation between M_t/M_∞ and \sqrt{t}/L for PP/PC unfilled-filled with different amounts of carbon black (2-7) wt%, at three temperatures (25°C, 40°C and 55°C), the samples were immersed in Diesel nearly three days.

It is clearly seen that the behavior of these samples obey Fickian diffusion, and pp/pc filled with carbon black (4 wt %) has lowest value of diffusion of all samples. These results are in good agreement with the results obtained by Pervious results Alfrey ⁽⁸⁾, Brewis⁽¹⁰⁾ and Mahmood ⁽¹⁴⁾ .

ESTIMATION THE TYPE OF DIFFUSION MECHANISM

The type of diffusion can be determined by calculating the value of (n), the value of (n) can be calculated from the slope of plot $\log M_t/M_\infty$ versus $\log t$.

Figures (13-18) show the relation between $\log (M_t/M_\infty)$ and $\log t$ for PP/PC unfilled- filled with different amounts of carbon black (2 – 7) wt%, at three temperatures (25°C, 40°C and 55°C), the samples were immersed in (Gas-Oil and Diesel-Fuel), nearly three days. It is clearly observed that the data sorption have been further analyzed from the empirical relation.

$$[\text{Log}(M_t/M_\infty) = \log K + n \log t] \quad \dots (7)$$

Where the value of (n) decides the type of diffusion mechanism, the values of (n) estimated from the least square analysis of the slope of plots of $\log (M_t/M_\infty)$ versus $\log t$. Representative plots are given in Figures (13-18) the magnitude of $n = (-0.0166 \text{ to } -1.7627) < 1/2$ then the diffusion process obeys Fickian diffusion. These results are in good agreement with the results obtained by Lucht⁽¹⁵⁾ and Chiou⁽¹⁶⁾.

DETERMINATION THE ACTIVATION ENERGY

The activation energy from equation(4) is calculated from the slope of $\ln D$ versus $(10^3/T)$.

Figures (19-20) show, the relation between $\ln D$ versus reciprocal absolute temperature ($1/T$) for PP/PC unfilled-filled with different amounts of carbon black (2 – 7) wt%, at three temperatures (25°C, 40°C and 55°C), the samples were immersed in (Gas-Oil and Diesel-Fuel), nearly three days.

From Equation (5), known as Arrhenius relation. It is clearly observed that from Figures (19-20) the slope of Arrhenius plots can be calculated the activation energy. These results are in good reasonable agreement with results obtained by Giba⁽¹⁷⁾ and Dannenberg⁽¹⁸⁾.

Figures (21-22) show the relation between activation energy for PP/PC blends were immersed in (Gas-Oil and Diesel-Fuel) versus different amounts of carbon black (0, 2, 3,4,5,6 and 7) wt%.

It is clearly observed that the activation energy increases with the increasing amounts of carbon black as filler (2-7)wt% which means more energy is needed to break the samples. These results good reasonable with the results obtained by Moisan⁽¹⁹⁾.

CONCLUSIONS

1-The ability of diffusion of (Gas-Oil and Diesel-Fuel) as solvent of polymer blend (PP/PC) unfilled-filled with different amounts of carbon black decreases with increasing amounts of carbon black from (2 – 7) wt% and the behavior of these samples proves to obey Fickian law.

2-The polymer blend (PP/PC) filled with (4 wt %) of carbon black has lowest diffusion coefficients of all other samples.

3-Two methods have been used in this work to calculate the diffusion coefficient, the calculated values by both methods prove to be a approximately the same.

4-The activation energy of diffusion increases linearly with increasing amount of carbon black from (2 – 7) wt% used as a filler.

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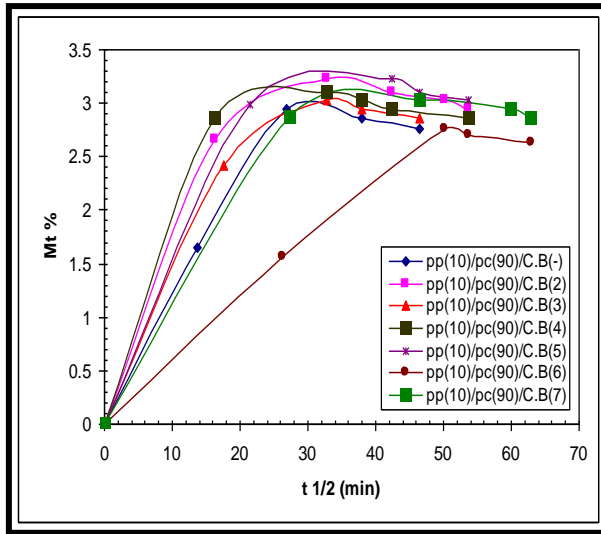


Figure (1) $M_t\%$ versus $(t)^{1/2}$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. immersed in Gas- Oil at 25°C by

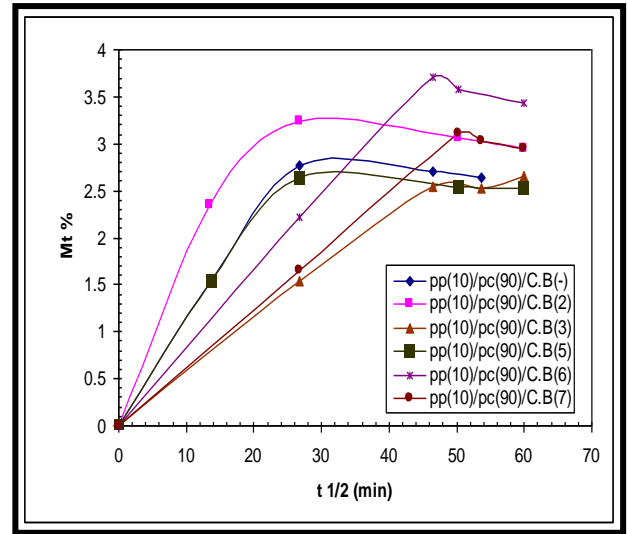


Figure (2) $M_t\%$ versus $(t)^{1/2}$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas- Oil at 40°C by using first equation.

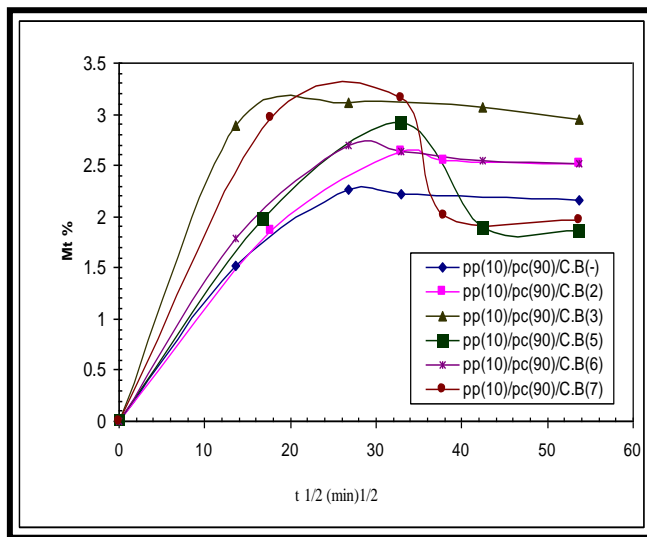


Figure (3) $M_t\%$ versus $(t)^{1/2}$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. immersed in Gas- Oil at 55°C by using first equation.

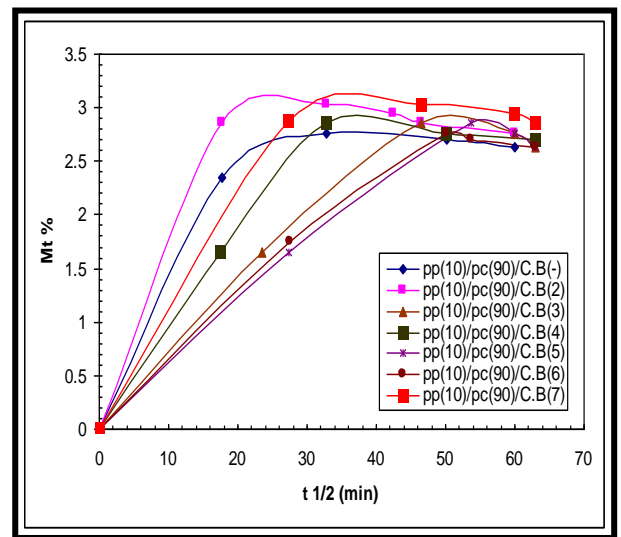
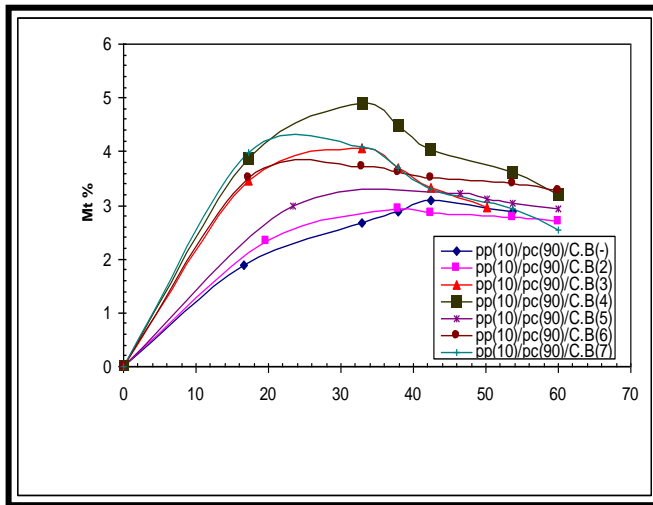


Figure (4) $M_t\%$ versus $(t)^{1/2}$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. immersed in Diesel- Fuel at 25°C by using first equation.



Figure(5) $M_t\%$ versus $(t)^{1/2}$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. immersed in Diesel- Fuel at 40°C by using first equation.

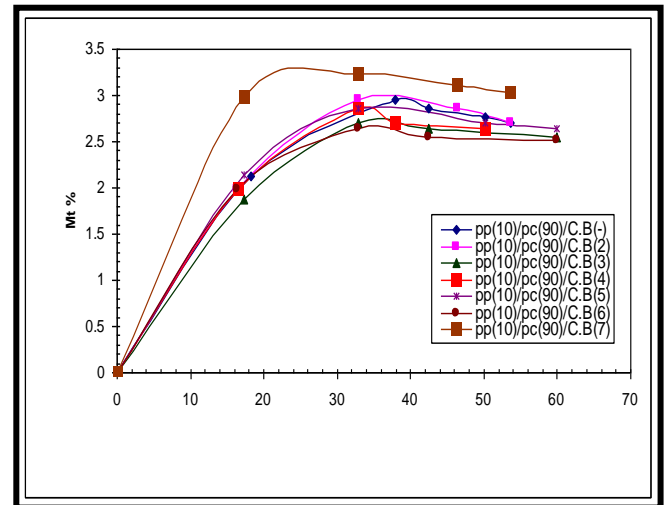
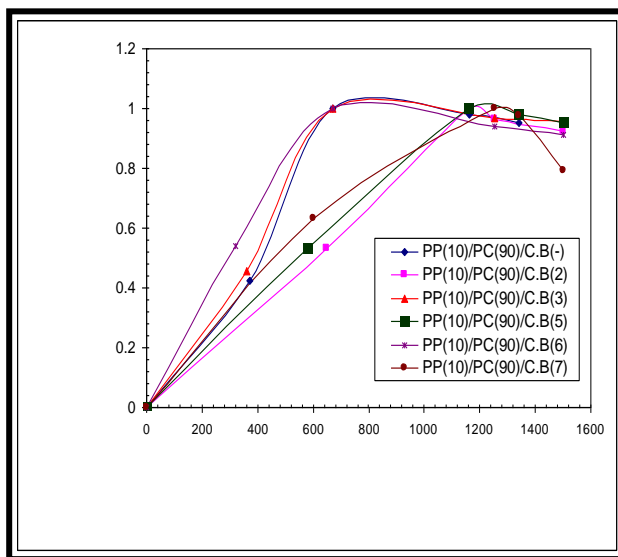


Figure (6) $M_t\%$ versus $(t)^{1/2}$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. immersed in Diesel- Fuel at 55°C by using first equation



Figure(7) M_t/M_∞ versus $((t)^{1/2}/L)$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas - Oil at 25°C by using second equation

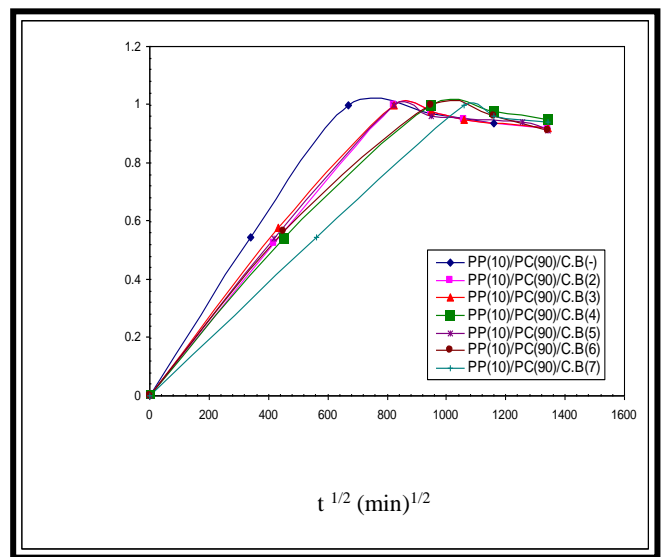


Figure (8) M_t/M_∞ versus $((t)^{1/2}/L)$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas - Oil at 40°C by using second equation

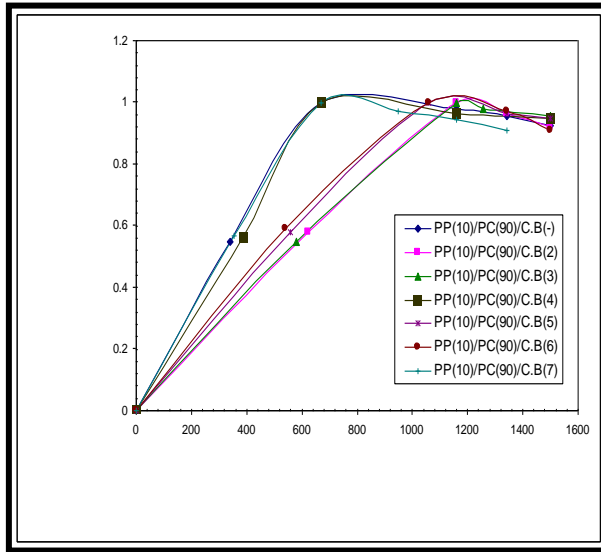


Figure (9) M_t/M_∞ versus $((t)^{1/2}/L)$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas -Oil at 55°C by using second equation.

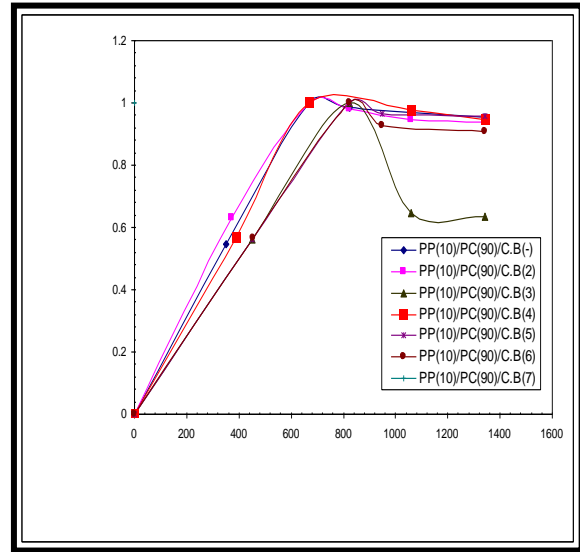


Figure (10) M_t/M_∞ versus $((t)^{1/2}/L)$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Diesel-Fuel at 25°C by using second equation.

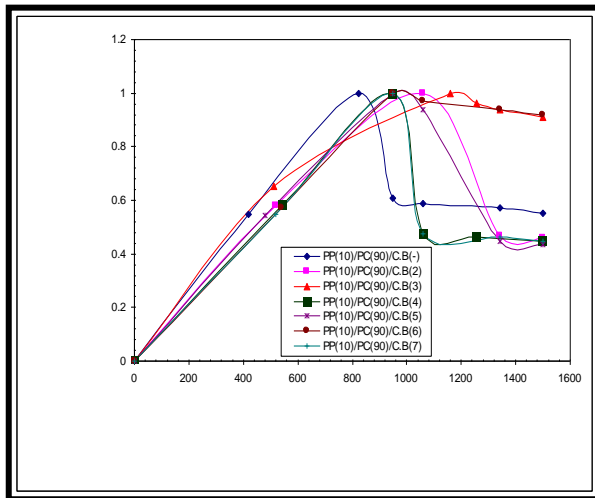


Figure (11) M_t/M_∞ versus $((t)^{1/2}/L)$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Diesel- Fuel at 40°C by using second equation

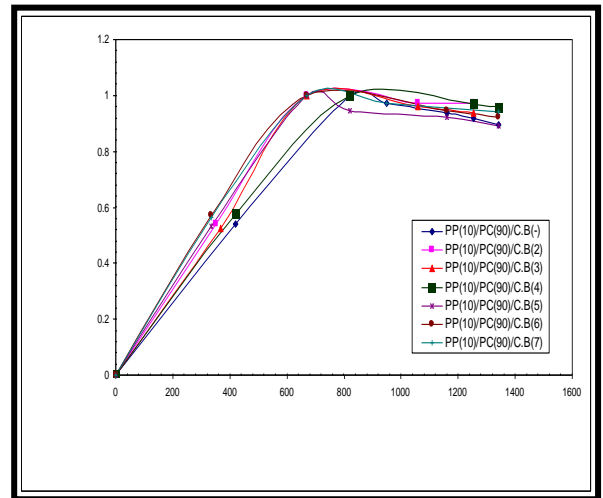


Figure (12) M_t/M_∞ versus $((t)^{1/2}/L)$ for PP/PC unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Diesel- Fuel at 55°C by using second equation

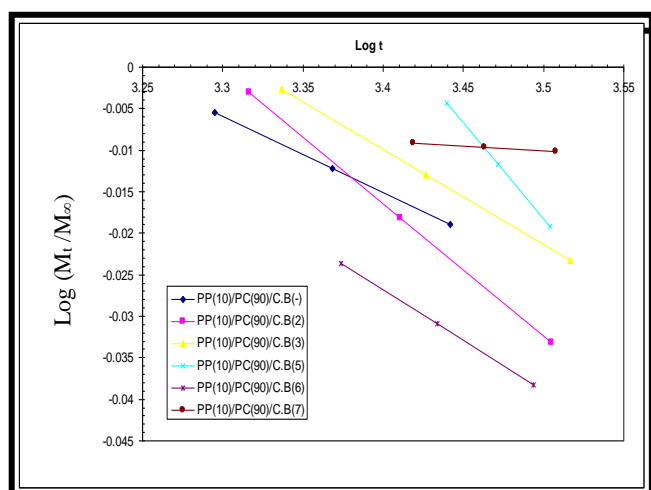


Figure (13) Log (M_t/M_∞) versus log (t) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas – Oil at 25°C

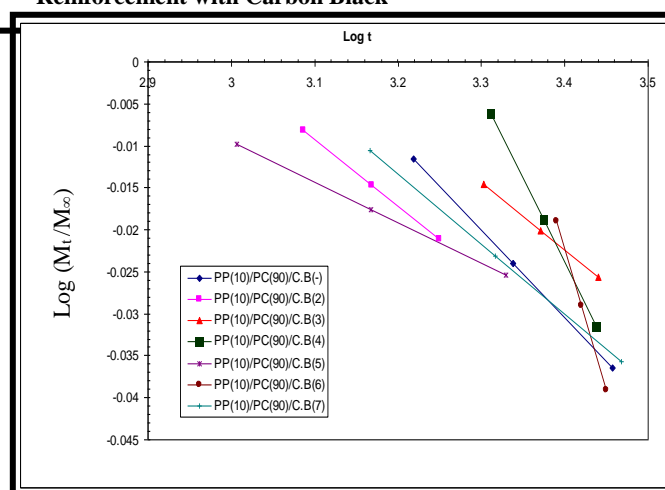


Figure (14) Log (M_t/M_∞) versus log (t) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas – Oil at 40°C

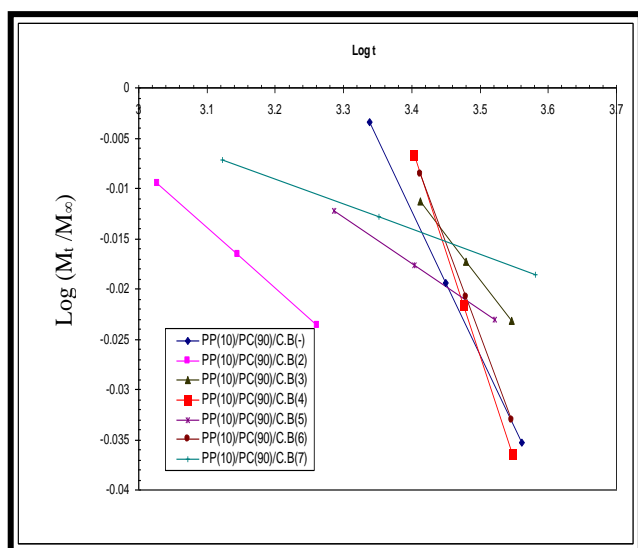


Figure (15) Log (M_t/M_∞) versus log (t) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas – Oil at 55°C

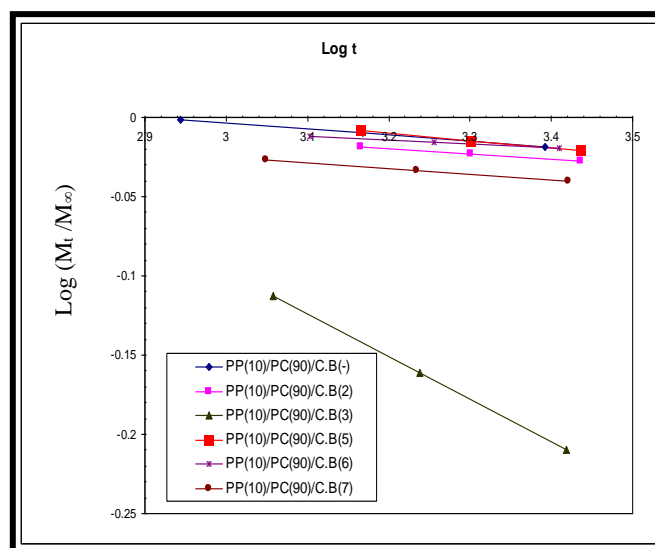


Figure (16) Log (M_t/M_∞) versus log (t) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Diesel- Fuel at 25°C

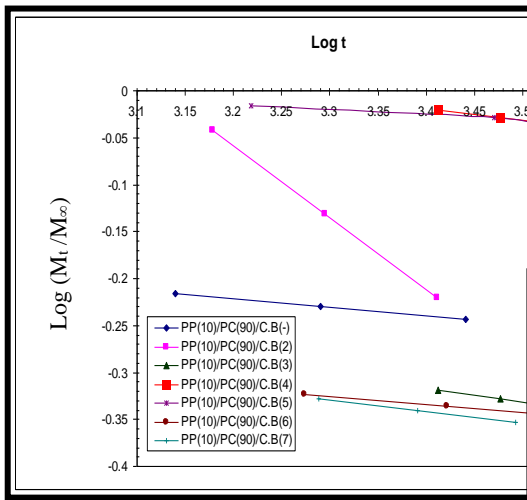


Figure (17) Log (M_t/M_∞) versus log (t) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas - Oil at 40°C.

Figure (18) Log (M_t/M_∞) versus log (t) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Diesel- Fuel at 55°C.

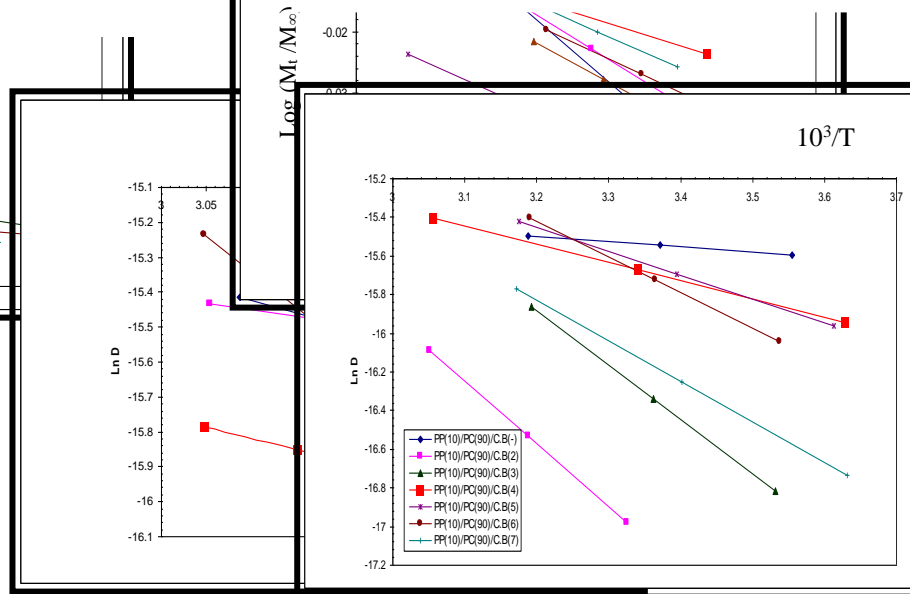


Figure (19) Ln (D) versus ($10^3/T$) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Gas - Oil

Figure (20) Ln (D) versus ($10^3/T$) for PP/PC = 10/90 unfilled – filled with different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt%. Immersed in Diesel- Fuel.

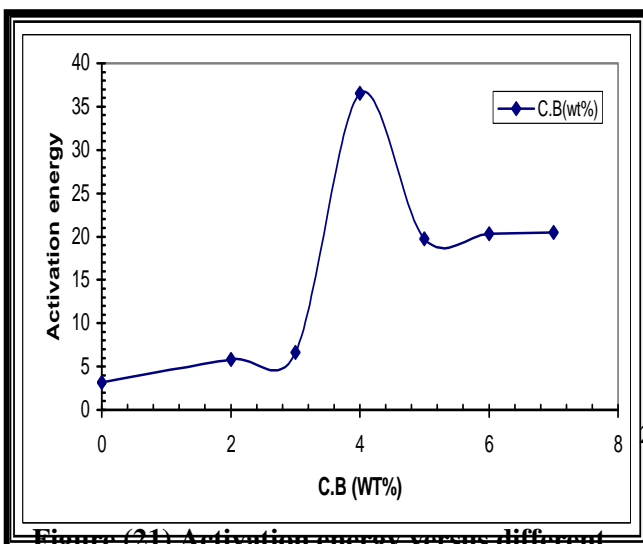


Figure (21) Activation energy versus different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt% Immersed in Gas-Oil.

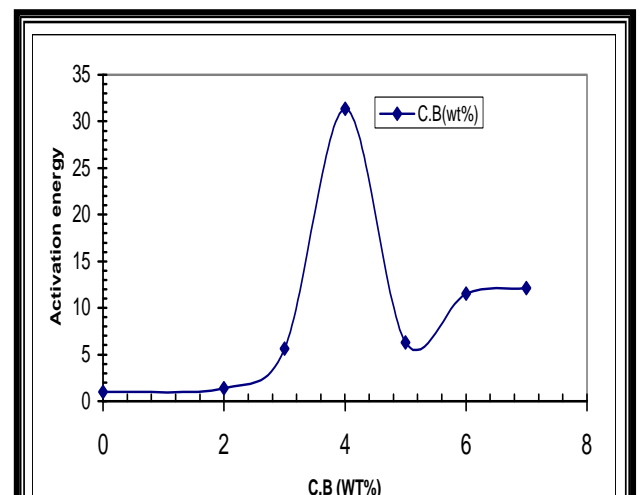


Figure (22) Activation energy versus different amounts of carbon black are (0, 2, 3, 4, 5, 6 and 7) wt% Immersed in Diesel-Fuel