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Gasoline Diffusivity of Polypropylene-Polycarbonate Composites

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Abstract- This manuscript explores the effect of polypropylene-polycarbonate composite (PP-PC) on gasoline absorption. Composites were prepared from PP-PC of different ratios with and without carbon black as a stabilizer. Further, the effect of aging gasoline in the presence of carbon black for a period of two months was studied. A single screw extruder was used to produce these composites and form them into 2mm thick sheets. A hydraulic compressor was then used to produce a 4mm sheet. Absorption test was carried out in gasoline at different immersion times and different blends. The results showed that the polycarbonate performance was improved upon addition of polypropylene. The results of absorption show that it obey Fick's second law of diffusion and after the addition of carbon black the absorption decrease. Further, a polymer composite comprised of PP/PC/carbon black at a ratio of 30/70/1 % (V/V/V %) performs best as suitable composite for the manufacture of fuel tanks.

Keywords: diffusion, polymer, absorption, composites

I. INTRODUCTION

Polymer blends have attracted much attention in scientific research for industrial production, and polymeric composite materials have been extensively used in the manufacture of new technical materials [1]. Advanced polymer composite materials are promising because of their economic versatility of application and excellent mechanical properties. However, due to growing demands and diverse applications, a common objective of polymer materials research is improving physical properties. Polymer blends combine materials with different qualities, which ideally conjoin physically without chemical reaction, to give the desired components and qualities [3-4]. Structures and properties of products made from immiscible polymer blend enhanced plastics are more strongly influenced by treatment than those of simple, single phase polymers [5]. In the field of polymer research there has been much focus on blending PP with PC. Polypropylene is an extremely versatile plastic available in many grades and as a copolymer (ethylene/propylene). It has the lowest density of all thermoplastics (on the order of 900 kg/m^3) and this combined with strength, stiffness, and excellent fatigue and chemical resistance make it attractive in many applications [6]. Including crates, small machine parts, car components (fans, fascia panels etc.), chair shells, media cabinets, and tool handles. The excellent fatigue resistance of PP is utilized in the moulding of integral hinges (e.g. accelerator pedals and forceps/tweezers). Polypropylene is also available in fiber form (for ropes, carpet backing) and as a film (for packaging) [7]. Polycarbonate, on the other hand, is an engineering plastic that has many advantages over conventional materials in terms of mechanical and physical properties. Including extreme toughness. These plastics are diaphanous and have good temperature resistance but are attacked by alkaline solutions and hydrocarbon solvents. Typical applications include vandal-proof street lamp covers, baby bottles, machine housings and guards, camera parts, electrical components, safety equipment and compact discs [8]. Due to differences in polarity and solubility PP and PC are immiscible with each other [11]. Carbon black, on the other side, is a generic term for an important family of products that is used principally for the reinforcement of rubber, as a black pigment and because of its electrically conductive properties. It is an extremely fluffy fine powder with a large surface area and is composed essentially of elemental carbon. Carbon black is one of the most stable chemical products. [15]

In this work on the effect of immersion of a polymer melt composed of varying ratios of filled and unfilled PP and PC, with and without carbon black as a stabilizer in gasoline and with or without aging for two months was studied. For each sample flow curves were determined and the diffusion coefficient was calculated.

II.EXPERIMENTAL WORK

2.1Materials used

The filler and polymers used in this study are listed in table (1) [2, 5]:-

Table (1) Materials used in the experiments

polymer	Melt index	density	Molecular weight
PP	11 gm/10 min	0.9 gm / cm^3	12.000
PC	2.1 gm/10 min	1.2 gm / cm^3	45.000
filler	Particle size	Blackness index	Surface area
CB	66µm	90	$33m^2/g$

2.2Polymer synthesis

PP, PC and C.B samples were kept in an air circulation dry oven at 80 C^o for 4 hr then different amounts of PP and PC (wt% of PP/ wt% of PC [50/50,100/00, 00/100, 30/70]) [2] and carbon black (1%) wt% were measured using a digital balance (Sartorious – Germany) and mixed.

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Various formulations of unfilled and- filled PP/PC blends (different amounts of (pp/pc) with carbon black as shown in Table (2)) were prepared. Weighed samples were transferred to single – screw extruder (Leistritz) at temperatures ranging from 210 – 220 C° with rotation (30 rpm). The compounding time involved was less than 5 min. The extradites produced in the form of an approximately 1.5 – 2 mm diameter sheet were cooled in water at room temperature and cut into suitable forms for each test [5]. Finally, the homogenous mixture was then pressed in a hydraulic press with simultaneous application of temperature and pressure. Sample sheets with dimensions 15 cm * 5 cm * 4 mm were obtained and specimens were prepared from this sheet [6, 8].

Table (2) Extrusion parameters of Polymer blend with Carbon black

No.	Formulations PP/PC/C.B, (wt %)	Temperature C° Zone (1)	Zone (2)	Zone(3)	Screw speed,(r.p.m)
1	00/100/1	210	220	220	30
2	30/70/1	210	220	220	30
3	50/50/1	210	220	220	30
4	100/00/1	210	220	220	30

2.3Gasoline

Gasoline is a refined product of petroleum composed of a blend of hydrocarbons, mixing agents, and additives. The composition of gasoline varies considerably based on the crude oils used, the refinery processes available, the overall balance of product required, and the product specifications. The typical composition of gasoline hydrocarbons (% volume) is as follows: 4-8% alkanes; 2-5% alkenes; 25-40% isoalkanes; 3-7% cycloalkanes; l-4% cycloalkenes; and 20-50% total aromatics (0.5-2.5% benzene). Mixing agents and additives were added to the hydrocarbon blend to improve the performance and stability of gasoline. The physical and chemical properties of the gasoline mixtures are listed in Table (3) [13-14].

Table (3) shows physical and chemical properties of gasoline

property	Information
Molecular weight	108
density	0.7-0.8g/cm^3
Flashpoint	-46°C
Solubility Water at 20°C	Insoluble
Auto ignition temperature	280-486°C
Boiling point	Initially 39°C

2.4 Diffusion experiments

We followed this procedure of immersion of samples in gasoline solution:-

1- Small pieces were prepared from the sheet generated by the single extruder and hydrolyic compressor.
2- The thickness and dimensions of each piece was determined.
3- The mass of all pieces before immersion in solution was determined using an electronic balance.
4- The pieces were transfer to glass bottles containing gas oil at laboratory temperature (25 C°±2).
5- The pieces were weighed weekly for 8 weeks after drying.
6- The difference in weight over time was determined using the equation (1) [9]:-

Weight Gain % = $[(w_2-w_1)/w_1]*100$ (1)

Whereas that:-

w_1= weight of pieces before

w_2= weight of pieces after

The diffusion factor was determined using equation (2):-

$D= B(kb / 4M)$ ^$^{0.5}$ (2)

K= slope of the linear part for the relation between mass with square root to time (t)$^{0.5}$

D= thickness of the piece

M= solution content at reaching into refection state (rate maximum for profit with mass)

If assuming that had been reacting to saturation state (M) can applicate this equation (3) [10-11]:-

M_t / M∞ = 4 / b (D_t / ∏) ^ 0.5 (3)

III. RESULTS & DISCUSSION

3.1 PP/PC blend

The results of aging of PP/PC samples in gasoline at 25 C° are shown in Figure 1, which shows the relationship between weight gain percentage of each PP/PC blend with the square root of time. From this figure it is clear that the diffusion obeys Fick's second law.

The continuous phase PP/PC samples with compositions of 100/00 or 00/100 have the lowest gain in weight and hence, lowest diffusion of gas oil through the matrix (either PP or PC). This is may be due to the stiff matrix where debonding is limited resulting in decreased diffusion and minimal weight gain in weight.

Diffusion results indicate that weight gain for 50/50 (PP/PC) blend samples is higher than that of 30/70 blends, which suggests that 50/50 blends have a higher diffusion than 30/70 blends. Thus, debonding occurs at higher rate as the percentage of polypropylene increases.

From the slope of the straight lines in Figure 1 the diffusion coefficients were calculated as follows:

PP/PC ≈ PP/PC < PP/PC < PP/PC
100/00 ≈ 00/100 30/70 50/50
45.2 ≈ 47.1 < 71 < 75.4

From Equation 3, Diffusion coefficients (D_t) after time (t) were calculated and plotted against the square root of time (t^$^{0.5}$) as shown in Figure 2. It is clearly seen that the diffusion coefficients at saturation for different samples were as follows:

D_t PP/PC ≈ D_t PP/PC < D_t PP/PC < D_t PP/PC
100/00 00/100 30/70 50/50

Thus, the trend among diffusion coefficients at saturation reflects the result seen with the diffusion coefficient.

3.2 PP/PC/ Carbon black

Figure 3 shows the results of aging of composite material made of PP/PC in the presence or absence of carbon black.

The relationship between the percentage weight gain of PP/PC composite and the square root of time shown in this figure further supports the finding that the diffusion obeys Fick's second law. Furthermore, it is clearly demonstrated that the order of diffusion of gas oil into different polymer sample composites is as follows:

PP/PC/CB	>	PP/PC/CB	≈	PP/PC/CB	>	PP/PC/CB
50/50		100/00		00/100		30/70

Thus, a polymer composite made of PP/PC/carbon black at a ratio of 30/70/1% has higher resistance to diffusion and would therefore be a more suitable composite for fuel tank applications.

From the slopes in Figure 3 diffusion coefficients of all samples were calculated, and the order of diffusion coefficients is as follows:

PP/PC/CB	≈	PP/PC/CB	<	PP/PC/CB	<	PP/PC/CB
00/100/1%		100/00/1%		30/70/1%		50/50/1%
54.4		56.3		57.5		76

After calculation of the diffusion coefficient of saturation, The diffusion coefficient at saturation was calculated according to equation 3 and plotted against the square root of time (Figure 4).

This data in this figure follow the same trend as mentioned before:

PP/PC/CB	>	PP/PC/CB	>	PP/PC/CB	>	PP/PC/CB
50/50/1%		30/70/1%		100/00/1%		00/100/1%

IV. CONCLUSION

In conclusion, we have concluded the following:

- The process ability of polycarbonate is improved upon addition of polypropylene.
- Polymer samples of blends and composites obey Fick's second law of diffusion.
- On blending polypropylene with polycarbonate it's resistance to gasoline was in the following order:

PP/PC		PP/PC		PP/PC		PP/PC
100/00	≈	00/100	<	30/70	<	50/50

- On addition of carbon black to polymer blend it resistance to gasoline increased to a level even greater than 100/00 or 00/100 PP/PC.
- PP/PC at 50/50 has the highest diffusion coefficient in gasoline, which indicates a higher debonding of blend and composite.
- The 30/70/1% PP/PC/carbon black polymer composite used in this work is strongly recommanded for use in the manufacture of fuel tanks for used gasoline.

V. RECOMMENDATION

Further study of the immersion properties of the 30/70/1% composite used in this work in gasoline at different temperatures in order to calculate the activation energy of the diffusion reaction should be undertaken.

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Conflict of Interest Statement

The authors declare that there is no conflict of interests regarding the publication of this article.

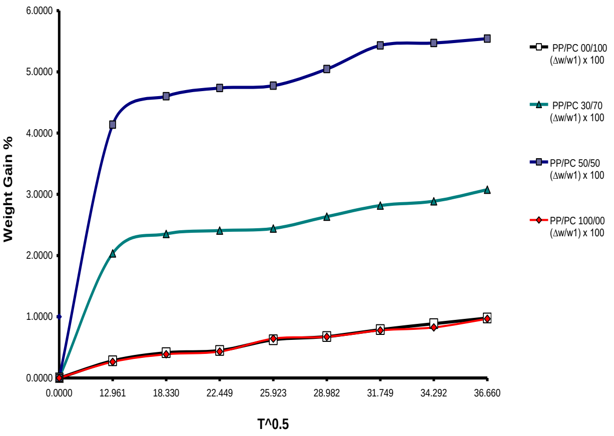

Fig.1. The relationship between the square root of time and the percentage weight gain of polymer blends (PP/PC).

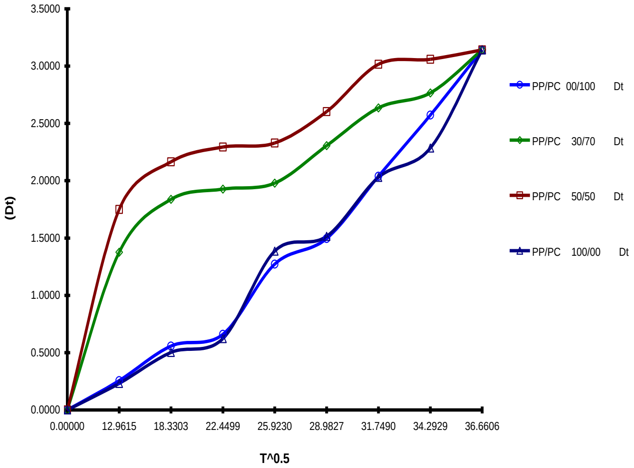

Fig.2. The relationship between the diffusion coefficient for samples of polymer blend and the square root of time at saturation.

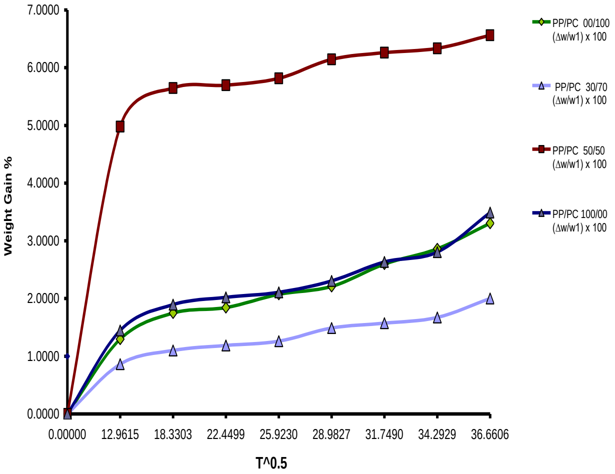

Fig.3. The relationship between the percentage weight gain of polymer composites and the square root of time.

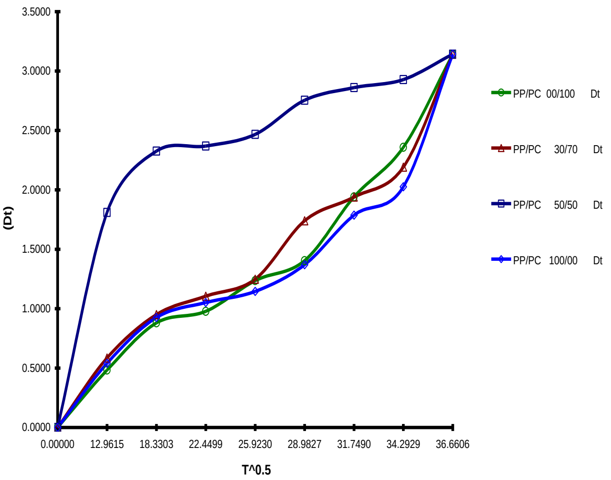

Fig.4. The relationship between the diffusion coefficient of samples of polymer composite and the square root of time at saturation.

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Table (1) Represents percentage for gain in weight of polymer blend (pp/pc) with square root of time.

Time (week)	T0.5 (hr)0.5	PP/PC 00/100 (Δw/w1) x 100	PP/PC 30/70 (Δw/w1) x 100	PP/PC 50/50 (Δw/w1) x 100	PP/PC 100/00 (Δw/w1) x 100
1	12.9615	0.2795	2.0360	4.1372	0.2630
2	18.3303	0.4132	2.3522	4.6016	0.3872
3	22.4499	0.4496	2.4088	4.7367	0.4310
4	25.923	0.6238	2.4411	4.7730	0.6429
5	28.9827	0.6765	2.6351	5.0463	0.6721
6	31.749	0.7899	2.8170	5.432	0.7780
7	34.2929	0.8871	2.8857	5.4712	0.8255
8	36.6606	0.9803	3.0756	5.5437	0.9679

Table (2) Represent diffusion coefficient of polymer blend (pp/pc).

polymer blend	DX10^8 (M^2.sec)
PP/PC 00/100	47.1
PP/PC 30/70	71
PP/PC 50/50	75.4

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PP/PC 100/00	45.2

Table (3) Represent diffusion coefficient at saturation of polymer blend (pp/pc).

Time (week)	T0.5 (hr)0.5	PP/PC 00/100 D_t	PP/PC 30/70 D_t	PP/PC 50/50 D_t	PP/PC 100/00 D_t
1	12.9615	0.2554	1.3767	1.7497	0.2319
2	18.3303	0.5582	1.8375	2.1646	0.5028
3	22.4499	0.6608	1.927	2.2935	0.6229
4	25.923	1.2721	1.9791	2.3288	1.3860
5	28.9827	1.4961	2.3061	2.6031	1.5148
6	31.749	2.0397	2.6355	3.0163	2.0298
7	34.2929	2.5726	2.7656	3.0599	2.2852
8	36.6606	3.1416	3.1416	3.1416	3.1416

Table (4) Represents percentage for gain in weight to polymer composite material (pp/pc/carbon black) with square root of time.

Time (week)	T0.5 (hr)0.5	PP/PC 00/100 (Δw/w1) x 100	PP/PC 30/70 (Δw/w1) x 100	PP/PC 50/50 (Δw/w1) x 100	PP/PC 100/00 (Δw/w1) x 100
1	12.9615	1.2959	0.8635	4.9795	1.4481
2	18.3303	1.7495	1.1009	5.6459	1.8954
3	22.4499	1.8438	1.1873	5.6971	2.0199
4	25.923	2.0735	1.2613	5.8143	2.1075
5	28.9827	2.209	1.4895	6.1438	2.3058
6	31.749	2.5978	1.5728	6.2610	2.6333
7	34.2929	2.8629	1.6715	6.3342	2.8039
8	36.6606	3.3047	2.0014	6.5612	3.4911

Table (5) Represent diffusion coefficient of polymer composites (pp/pc).

polymer composites	$DX10^8$ (M^2.sec)
PP/PC 00/100	54.4

PP/PC 30/70	57.5
PP/PC 50/50	76
PP/PC 100/00	56.3

Table (6) represent diffusion coefficient at saturation of polymer composites (pp/pc).

Time (week)	T0.5 (hr)0.5	PP/PC 00/100 D_t	PP/PC 30/70 D_t	PP/PC 50/50 D_t	PP/PC 100/00 D_t
1	12.9615	0.4831	0.5848	1.8095	0.5405
2	18.3303	0.8805	0.9506	2.3262	0.926
3	22.4499	0.9779	1.1056	2.3686	1.0517
4	25.923	1.2368	1.2477	2.4671	1.1449
5	28.9827	1.4037	1.7401	2.7546	1.3705
6	31.749	1.9413	1.9401	2.8607	1.7874
7	34.2929	2.3578	2.1913	2.928	2.0265
8	36.6606	3.1416	3.1416	3.1416	3.1416

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