CHAPTER III

RESULTS

3.1 Force Scanning Experiments

The force scanning was carried out to make sure that experiments were done in the linear viscoelastic region. Young's modulus, E, for each sample composition can be obtained from the slope of force scanning curve, stress (σ) against strain (ε). The Young's modulus was obtained with the aging time (t_a) and the effect of compositions and the aging temperatures are shown in figs.3.1a and 3.1b, respectively.

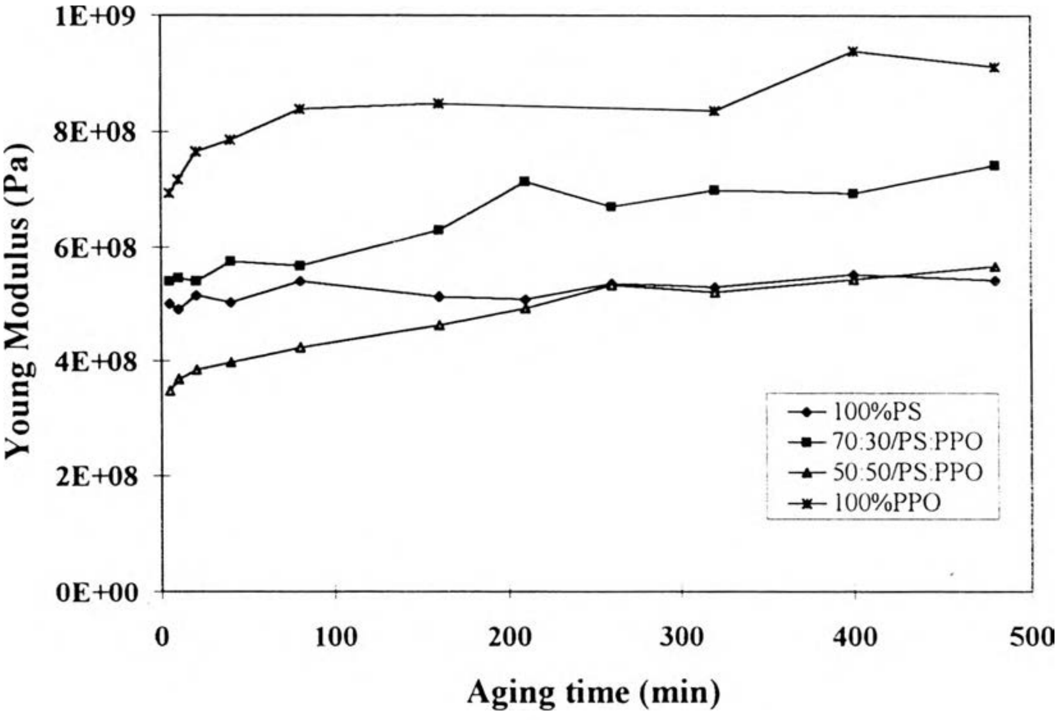

Figure 3.1a Effect of compositions on the aging of Young's modulus.

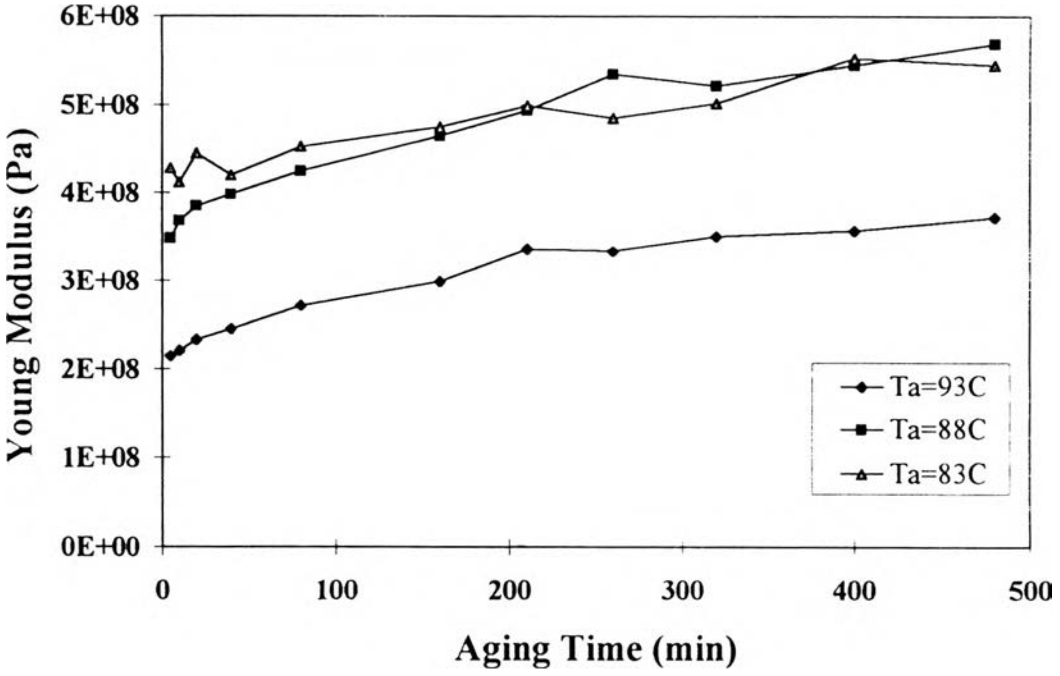

Figure 3.1b Effect of temperatures on the aging of Young's modulus of 50:50 / PS:PPO blends.

It can be observed that Young's modulus, E, increases with the aging time, t_a, for every composition and temperature systems. It can be seen that E values of the blends are in between E values of the pure components, PS and PPO.

3.2 Aging of Components

Table 3.1 Survey of all creep tests.

Composition	T_g (°C)	T_a (°C)	$\Delta T, (T_g - T_a)$ (°C)	t_a (min)
100%PS	72	60	12	5-480
70:30/PS:PPO	92	80	12	5-480
50:50/PS:PPO	100	93	7	5-480
50:50/PS:PPO	100	88	12	5-480
50:50/PS:PPO	100	83	17	5-480
100%PPO	194	182	12	5-400

3.2.1 Aging of Pure PS

The PS sample was tested for the creep measurement by applying a constant force of 180 mN. The strain was measured as a function of time. The creep curves for different aging times, t_a, were plotted against time on a logarithmic scale as shown in fig.3.2a.

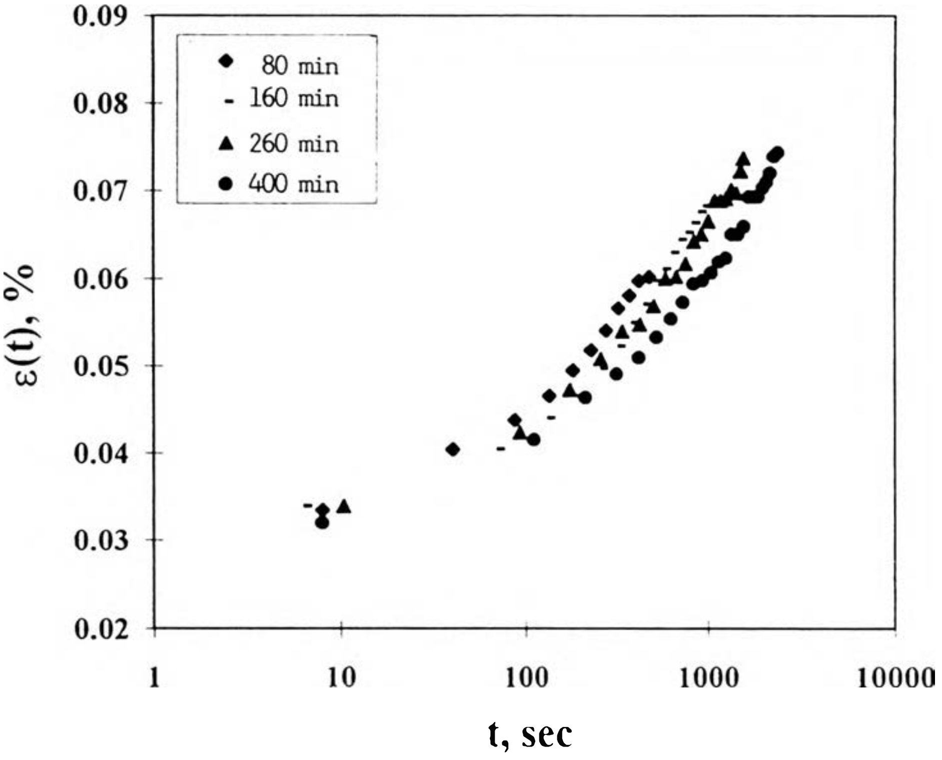

Figure 3.2a Isothermal tensile creep curves of pure PS. Curves are shown for t_a = 80 - 400 min at 60°C.

The influence of aging on the creep behavior can be seen as the shifts in the creep curves. All creep curves were separately computer fitted to Eq.(1.7) to get individual values of β. The average value for β was estimated and found to be β = 0.57. Next all creep curves were fitted to Eq.(1.7) using the average β value of 0.57 in order to obtain t_0 values. The individual values of β and t_0 in the order of aging time, t_a, are shown in Table 3.2.

Table 3.2 Values for individual β and t_0 obtained by computer fitting of tensile creep data of pure PS to Eq.(1.7) at 60°C.

t_a (min)	β (β_{avg} = 0.57)	t_0 (10^3 sec)
10	3.80	-
20	2.49	-
40	1.41	-
80	*0.68	1.48
160	0.82	2.25
260	*0.55	2.61
400	*0.49	3.17

* used to calculate β_{avg}

\- cannot be obtained by computer fitting

β_{avg} can be obtained from the average of β values of t_a = 80, 260 and 400 min which were determined to be the same group of data. It can be observed that t_0 increases with the aging time.

The superposition of creep curves of pure PS is shown in fig.3.2b.

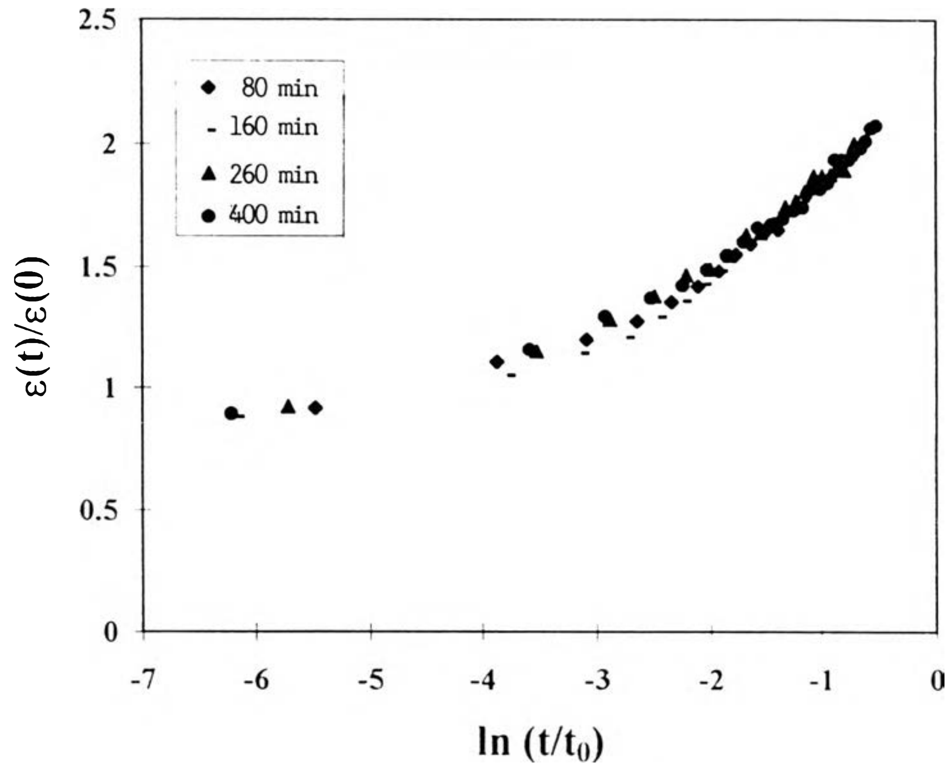

Figure 3.2b Superposition of creep curves for pure PS at 60°C.

By using a reference aging time of $t_{a,ref} = 260$ min, shift factors, a, were calculated and shown in Table 3.3. Log a plotted against log t_a for pure PS component is shown in fig.3.2c.

Table 3.3 Shift factors vs aging times of pure PS.

t_a (min)	Shift factor, a
80	0.57
160	0.86
260	1.00
400	1.22

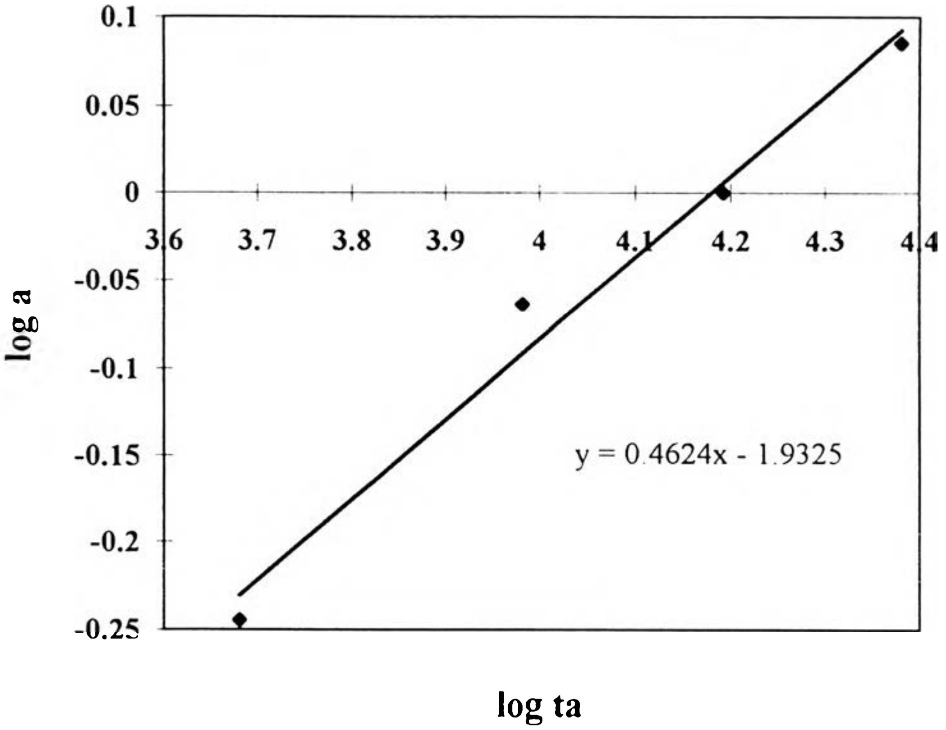

Figure 3.2c Logarithm of the shift factors, a, for creep experiments plotted against the logarithm of aging time for pure PS.

The points lie approximately on a straight line with slope μ, which was found to be 0.46.

3.2.2 Aging of Pure PPO

For the creep test of pure PPO, it shows similar behavior as pure PS. The results for pure PPO were obtained in the same way as those for pure PS.

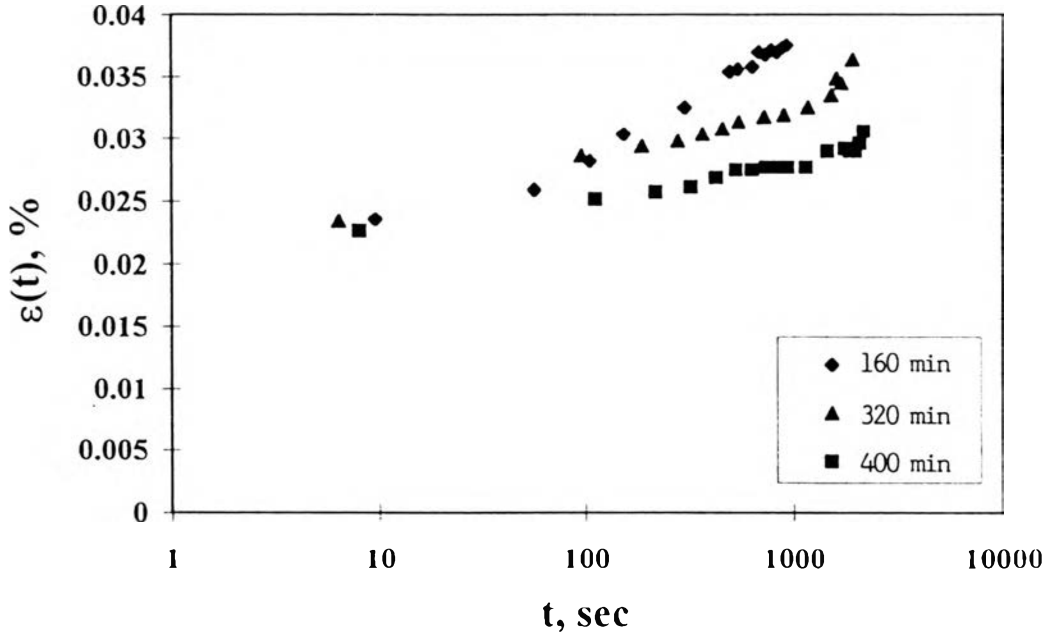

Figure 3.2d Isothermal tensile creep curves of pure PPO for aging time = 160 - 400 min at 182°C.

The creep curves were shifted as a function of the aging time. From computer fitting, values of β and t_0 were shown in Table 3.4.

Table 3.4 Values for individual β and t_0 obtained by computer fitting of tensile creep data of pure PPO at 182°C.

t_a (min)	β (β_{avg} = 0.50)	t_0 (10^3 sec)
80	2.09	-
160	*0.65	8.28
320	*0.45	20.33
400	*0.40	26.32

* used to calculate β_{avg}

- cannot be obtained by computer fitting

The set of β values used for obtaining β_{avg} are in the range of t_a = 160 - 400 min. It can be observed that t_0 increases with the aging time.

The superposition of creep curves of pure PPO is shown in fig.3.2e.

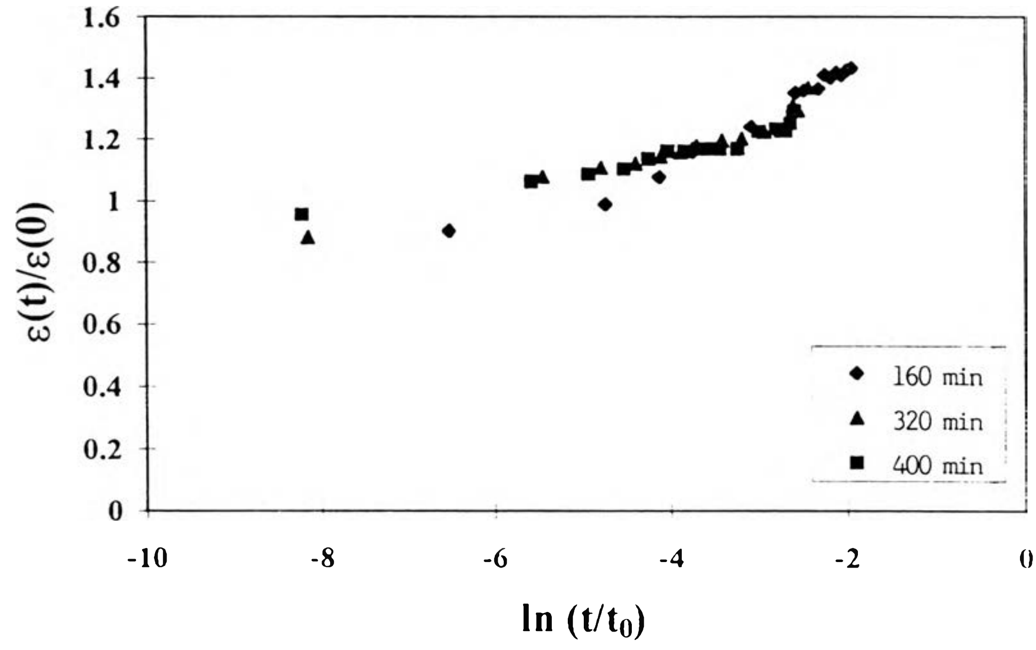

Figure 3.2e Superposition of creep curves for pure PPO at 182°C.

It can be seen that the curves are not quite superimposed. All curves could not be fitted on the single line.

The shift factors calculated by using $t_{a,ref}$ = 320 min are shown in Table 3.5.

Table 3.5 Shift factors varied with aging time of pure PPO.

t_a (min)	Shift factor, a
160	0.41
320	1.00
400	1.29

Log a were plotted against log t_a to determine μ of pure PPO. μ was found to be 1.26.

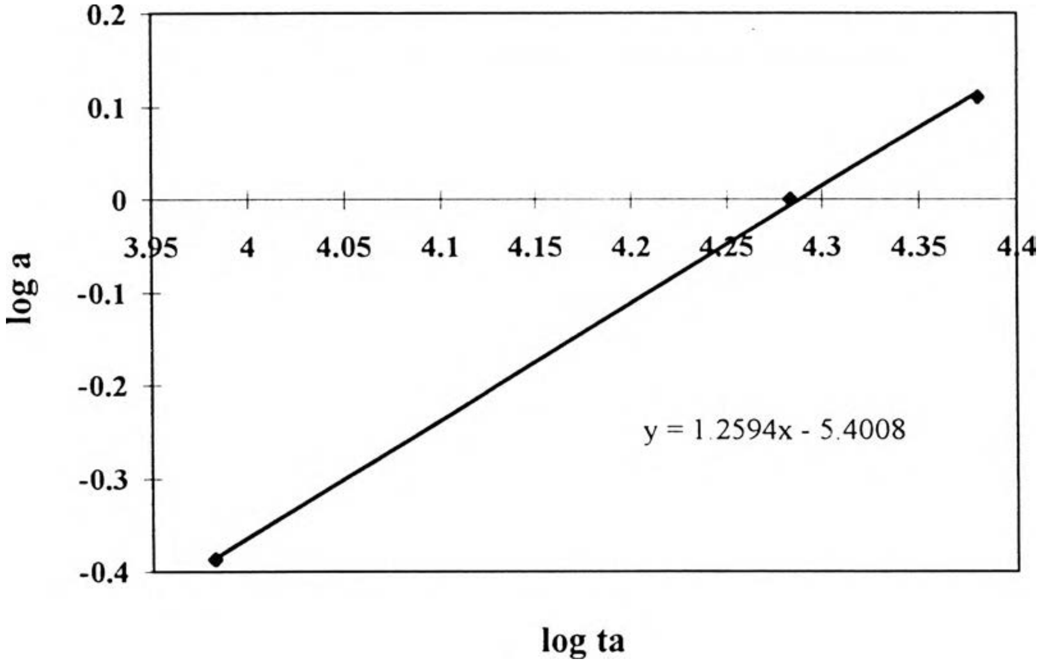

Figure 3.2f Logarithm of the shift factors, a, for creep experiments of pure PPO plotted against the logarithm of the aging times.

3.2.3 Aging of Blends

For the 50:50 / PS:PPO and 70:30 / PS:PPO blends, same procedure was used to obtain β and t_0 and these values are tabulated in table 3.6.

Table 3.6 Values for β, t_0 and a obtained by computer fitting of tensile creep data of blends, $\Delta T = 12$ °C.

t_a (min)	70:30 / PS:PPO			50:50 / PS:PPO		
	β	t_0 (10^3 sec)	a	β	t_0 (10^3 sec)	a
40	1.71	-	-	28.13	-	-
80	1.54	-	-	2.10	-	-
160	0.85	2.55	0.63	0.85	-	-
210	-	-	-	*0.72	8.65	0.66
260	*0.65	3.82	0.77	*0.56	10.92	0.83
320	*0.57	5.04	1.00	*0.52	13.10	1.00
400	*0.58	5.15	1.17	-	-	-
480	-	-	-	*0.49	13.61	1.04

* used to calculate β_{avg}.

\- cannot be obtained by computer fitting.

The average values of β for the 70:30 / PS:PPO and 50:50 / PS:PPO blends were estimated to be β = 0.60 and 0.57, respectively, and μ was found to be 0.68 and 0.99, respectively.

3.3 Effect of Compositions

3.3.1 Retardation Time, t_0

For all components in this study, we can see the trend of the effect of composition on t_0 by plotting t_0 against t_a, as shown in fig.3.3a.

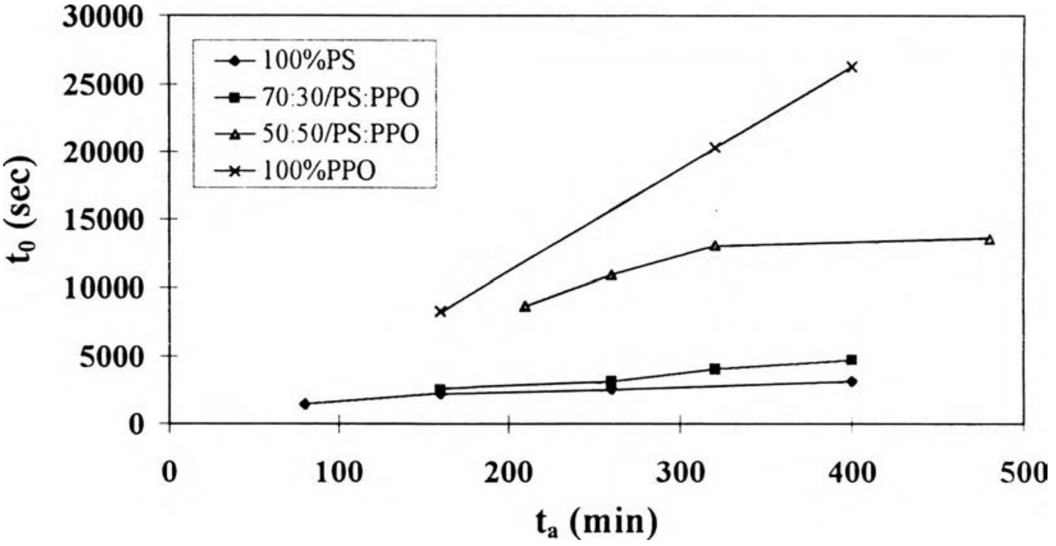

Figure 3.3a The effect of compositions on t_0, $\Delta T = 12^{\circ}C$.

It can be observed that t_0 increases with the % PPO and t_0 of the blends are in between t_0 of pure components; t_0 of PPO has the highest values and t_0 of PS has the lowest values.

3.3.2 Aging Rate, μ

As mentioned above μ can be obtained from the slope of log a plotted against log t_a curves When ΔT was held fixed at 12 °C, the effect of composition on μ is shown in fig.3.3b.

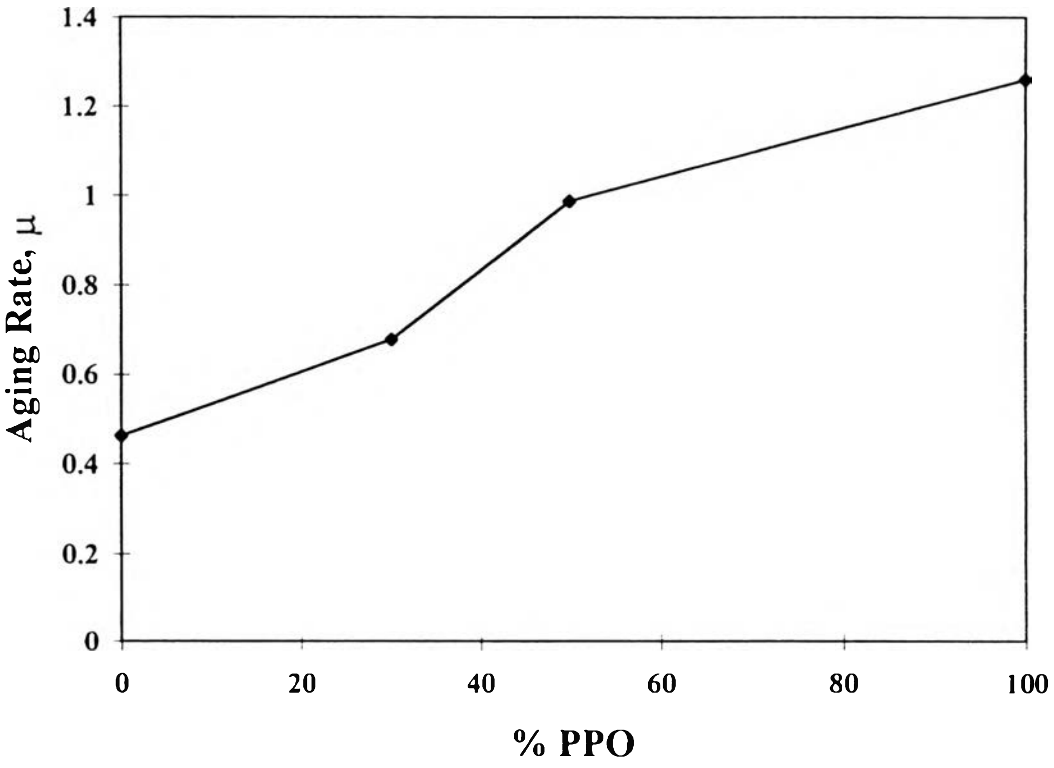

Figure 3.3b The effect of compositions on aging rate.

It can be observed that μ increases with % PPO and μ of blends are in between μ of the pure components, PS and PPO. μ of PS has the lowest value and μ of PPO has the highest value because of different chemical structures allowed different chain mobilities.

3.4 Effect of Temperature or ΔT

For the effect of temperature, 50:50 / PS:PPO blend was chosen to be the blend to be studied.

3.4.1 Retardation Time, t_0

The effect of temperature or ΔT, T_g-T_a, on t_0 is shown in fig.3.4a.

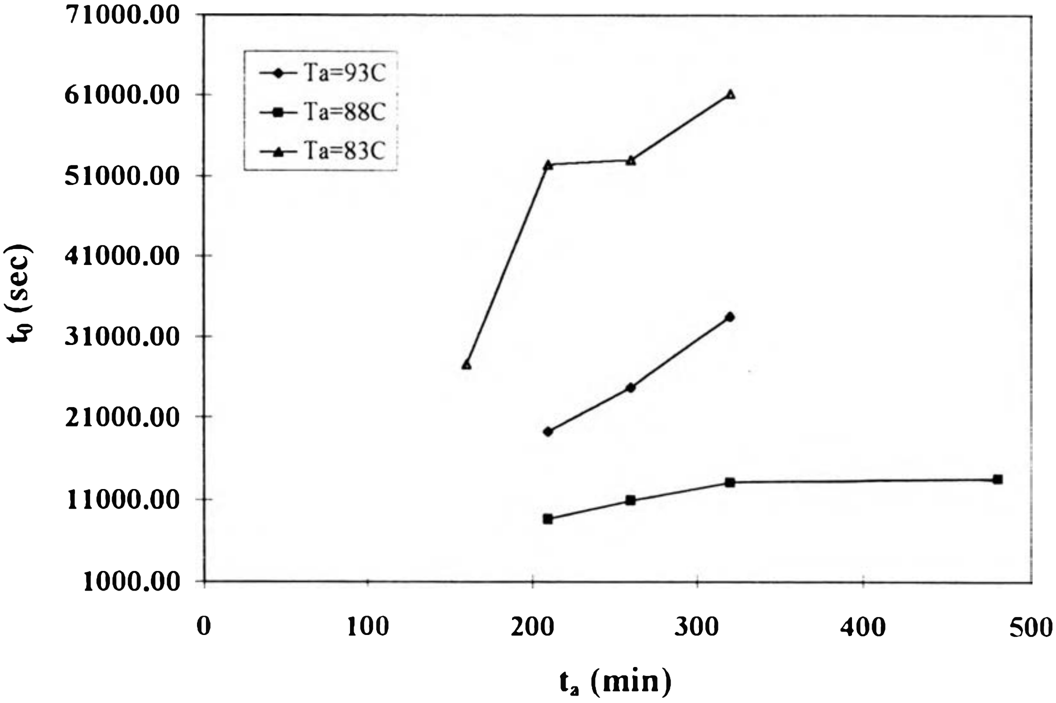

Figure 3.4a Effect of temperatures on t_0 of 50:50 / PS:PPO blend.

3.4.2 Aging Rate, μ

The effect of temperature on μ is shown in fig.3.4b, $\Delta T = T_g - T_a$.

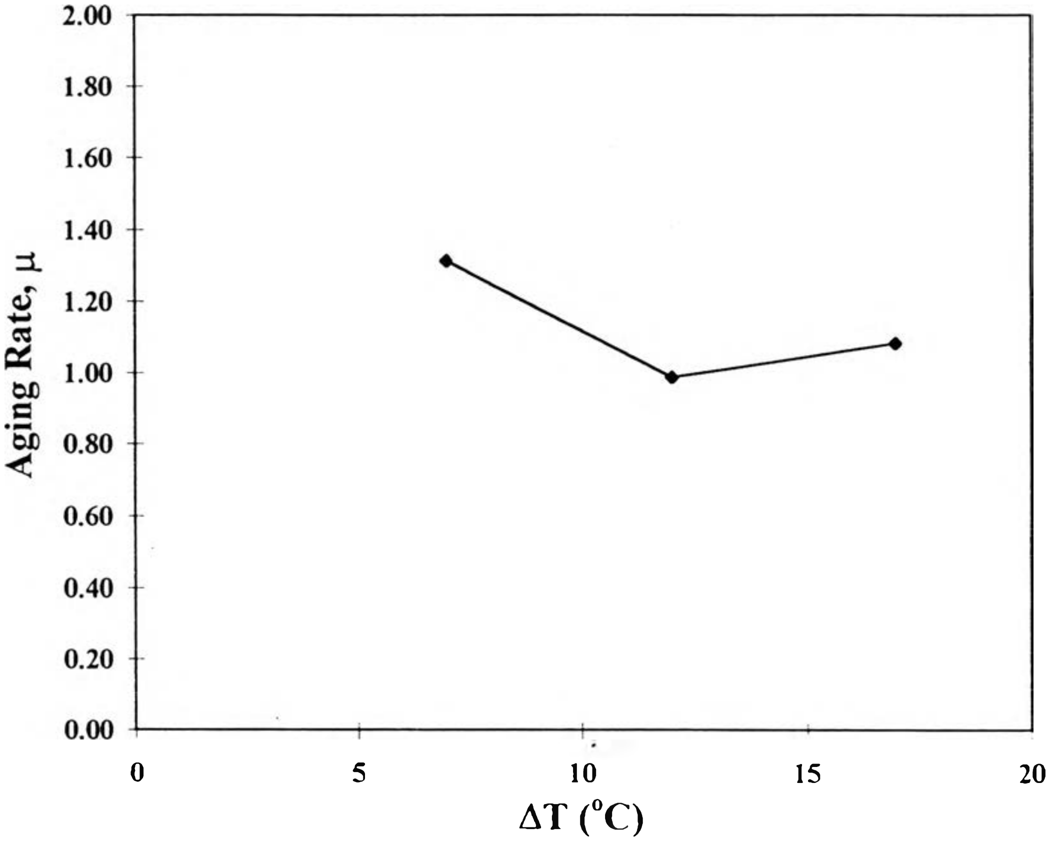

Figure 3.4b Effect of temperatures on aging rate.

It can be observed that μ in the range of ΔT = 7 - 17°C are nearly the same. The values of μ are about unity, or close to 1.