CHAPTER V

RESULTS AND DISCUSSION

5.1 The Solid-Liquid Dissolution Rate Correlation

Dissolution rate coefficient of the solid-liquid system is expressed by the equation

$$Sh_T = r\, Re_a^{\,p}\ Sc^q$$

Where a dimensionless group, Sh_T is a function of other dimensionless groups, Re_a, Sc. In this paper, the solid-liquid dissolution rate correlation for standard six blade disc turbine and paddle impellers are obtained as show in Table 5.1 and 5.2. By analytical calculation technique, constant r for each system is obtained as in Table 5.3

Table 5.1 : Styrene-Butadiene Dissolution Rate Correlation for Standard six blade disc turbine

Experimental Systems	Correlation
System I	$Sh_T = r\, Re_a^{\,1.35}\ Sc^{3.20}$ $8.3864\text{x}10^3 < Re_a < 13.1786\text{x}10^3$ $10.279\text{x}10^9 < Sc < 11.333\text{x}10^9$
System II	$Sh_T = r\, Re_a^{\,1.35}\ Sc^{3.20}$ $3.0710\text{x}10^3 < Re_a < 4.8258\text{x}10^3$ $2.7331\text{x}10^{10} < Sc < 3.0879\text{x}10^{10}$
System III	$Sh_T = r\, Re_a^{\,1.35}\ Sc^{3.20}$ $2.5685\text{x}10^3 < Re_a < 4.0463\text{x}10^3$ $3.2091\text{x}10^{10} < Sc < 3.7200\text{x}10^{10}$

Table 5.2 : Styrene-Butadiene Dissolution Rate Correlation for Paddle

Experimental Systems	Correlation
System IV	$Sh_T = r\,Re_a^{0.57}\,Sc^{2.22}$ $8.3864 \times 10^3 < Re_a < 13.1786 \times 10^3$ $1.0002 \times 10^{10} < Sc < 1.1646 \times 10^{10}$
System V	$Sh_T = r\,Re_a^{0.57}\,Sc^{2.22}$ $8.3864 \times 10^3 < Re_a < 13.1786 \times 10^3$ $2.7331 \times 10^{10} < Sc < 3.0879 \times 10^{10}$
System VI	$Sh_T = r\,Re_a^{0.57}\,Sc^{2.22}$ $2.5685 \times 10^3 < Re_a < 4.0463 \times 10^3$ $3.2091 \times 10^{10} < Sc < 3.7200 \times 10^{10}$

Where:

System I,IV is 2wt% of Styrene-Butadiene In Mineral Oil

System II,V is 3wt% of Styrene-Butadiene In Mineral Oil

System III,VI is 4wt% of Styrene-Butadiene In Mineral Oil

Table 5.3 :Values of r for this experimental systems

Experimental Systems		r	Range of Re_a	Range of Sc
Standard 6-blade turbine	System I	$9.0769\text{x}10^{-22}$	$8.3864\text{x}10^{3}$ - $13.1786\text{x}10^{3}$	$10.279\text{x}10^{9}$ - $11.333\text{x}10^{9}$
	System II	$3.6008\text{x}10^{-23}$	$3.0710\text{x}10^{3}$ - $4.8258\text{x}10^{3}$	$2.7331\text{x}10^{10}$ - $3.0870\text{x}10^{10}$
	System III	$1.1397\text{x}10^{-23}$	$2.5685\text{x}10^{3}$ - $4.0463\text{x}10^{3}$	$3.2091\text{x}10^{10}$ - $3.7200\text{x}10^{10}$
Paddle	System IV	$4.1153\text{x}10^{-12}$	$8.3864\text{x}10^{3}$ - $13.1786\text{x}10^{3}$	$10.279\text{x}10^{9}$ - $11.333\text{x}10^{9}$
	System V	$2.8897\text{x}10^{-13}$	$3.0710\text{x}10^{3}$ - $4.8258\text{x}10^{3}$	$2.7331\text{x}10^{10}$ - $3.0870\text{x}10^{10}$
	System VI	$2.0053\text{x}10^{-13}$	$2.5685\text{x}10^{3}$ - $4.0463\text{x}10^{3}$	$3.2091\text{x}10^{10}$ - $3.7200\text{x}10^{10}$

Where :

System I is 2%wt of Styrene-Butadiene in mineral oil for 6- blade turbine

II is 3%wt of Styrene-Butadiene in mineral oil for 6-blade turbine

III is 4%wt of Styrene-Butadiene in mineral oil for 6-blade turbine

IV is 2%wt of Styrene-Butadiene in mineral oil for Paddle

V is 3%wt of Styrene-Butadiene in mineral oil for Paddle

VI is 4%wt of Styrene-Butadiene in mineral oil for Paddle

5.2 The Physico-chemical Properties

The physico-chemical properties of liquid solution obtained in this study are shown in Appendix A to H, the mixing parameter is varied by altering either the temperature, the impeller rotational speed and the solid concentration in solution.

5.3 Comparison with Correlation with Other Investigation

No experimental study of styrene-butadiene polymer dissolution in mineral oil for agitated system have been investigated. Thereore, experimental study of dissolution rate coefficient of styrene-butadiene in mineral oil at several rotational speeds of agitator, temperatures of mineral oil and solid concentation of styrene-butadiene are carried out in this study.

The exponents of Reynolds number and of Schmidt number of the dissolution rate correlation reported by various investigators are summarized in Table 5.4

In Table 5.4, the exponents obtained for various variables of the other researches are compared to this work.

It is seen that the range of exponent value for standard six blade disc turbine

$$0.55 < Re_a < 1.40$$

$$0.30 < Sc < 0.50$$

and paddle impeller

$$Re_a = 0.80$$

$$0.197 < Sc < 0.50$$

Our exponent value lie outside the range above, this result is different from other investigators may be observed that the experimental mixing conditions are not the same such as temperature and solid-liquid system.

Table 5.4 : Comparision of the exponents obtained variables for various

Author	Ref.	Exponent of *Re*	Exponent of *Sc*	System of agitator utilize
Barker and Trey bal.	3	0.833	0.5	Standard 6-blade turbine
Humphrey and Van Ness	7	0.87	0.5	
Johnson and chen-Jung Huang	8	0.71	0.5	Standard 6-blade turbine
Hixson and Baum	1	1.40	0.5	Standard 6-blade turbine
Askew and Beck mann	4	0.55	0.3	Standard 6- blade turbine
		0.667	0.3	Marine
Keey and Glen	5	0.8	0.5	Paddle
Saetun	12	0.8	0.197	Paddle
This work		1.35	3.20	Standard 6-blade turbine
		0.57	2.22	Paddle

Table :5.5 Re_a vs Sh_T of 2wt% Styrene-Butadiene In Mineral Oil At 120°C ($Sc = 1.0595 \times 10^{10}$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Standard 6-Blade Turbine

No.	Speed (rpm)	Re_a $\times 10^{-3}$	Sh_T $\times 10^{-11}$			
			1	2	3	Average
1	350	8.3864	2.3210	2.2831	2.2908	2.2983
2	400	9.5844	2.6890	2.5801	2.5339	2.6010
3	450	10.7825	2.7013	2.6038	2.6608	3.2020
4	500	11.9805	3.3205	3.4120	3.1945	3.3090
5	550	13.1786	3.9050	3.8010	3.9850	3.8970

Table :5.6 Re_a vs Sh_T of 3wt% Styrene-Butadiene In Mineral Oil At 120°C ($Sc = 2.8933x10^{10}$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Stadard 6-Blade Turbine

No.	Speed (rpm)	Re_a $x10^{-3}$	Sh_T $x10^{-11}$ 1	2	3	Average
1	350	3.0710	1.2234	1.1895	1.2333	1.2154
2	400	3.5097	1.5080	1.4089	1.3434	1.4201
3	450	3.9483	1.5010	1.4958	1.5092	1.5020
4	500	4.3817	1.7085	1.9328	1.7272	1.7895
5	550	4.8258	1.9870	2.3290	2.2894	2.2018

Table 5.7 Re_a *vs* Sh_T of 4wt% Styrene-Butadiene In Mineral Oil At 120°C ($Sc = 3.4592\text{x}10^{10}$)

Vessel Diameter, T= 25 cm.

Agitator Diameter, Di= 8.33 cm.

Impeller Type: Standad 6-Blade Turbine

No.	Speed (rpm)	Re_a $\text{x}10^{-3}$	Sh_T $\text{x}10^{-11}$			
			1	2	3	Average
1	350	2.5685	1.3008	1.2654	1.2078	1.2580
2	400	2.9355	1.4080	1.2899	1.4631	1.3870
3	450	3.3025	1.6809	1.7520	1.6701	1.7010
4	500	3.6693	1.8590	2.0080	1.9308	2.9326
5	550	4.0463	2.2153	2.0390	2.3106	2.1883

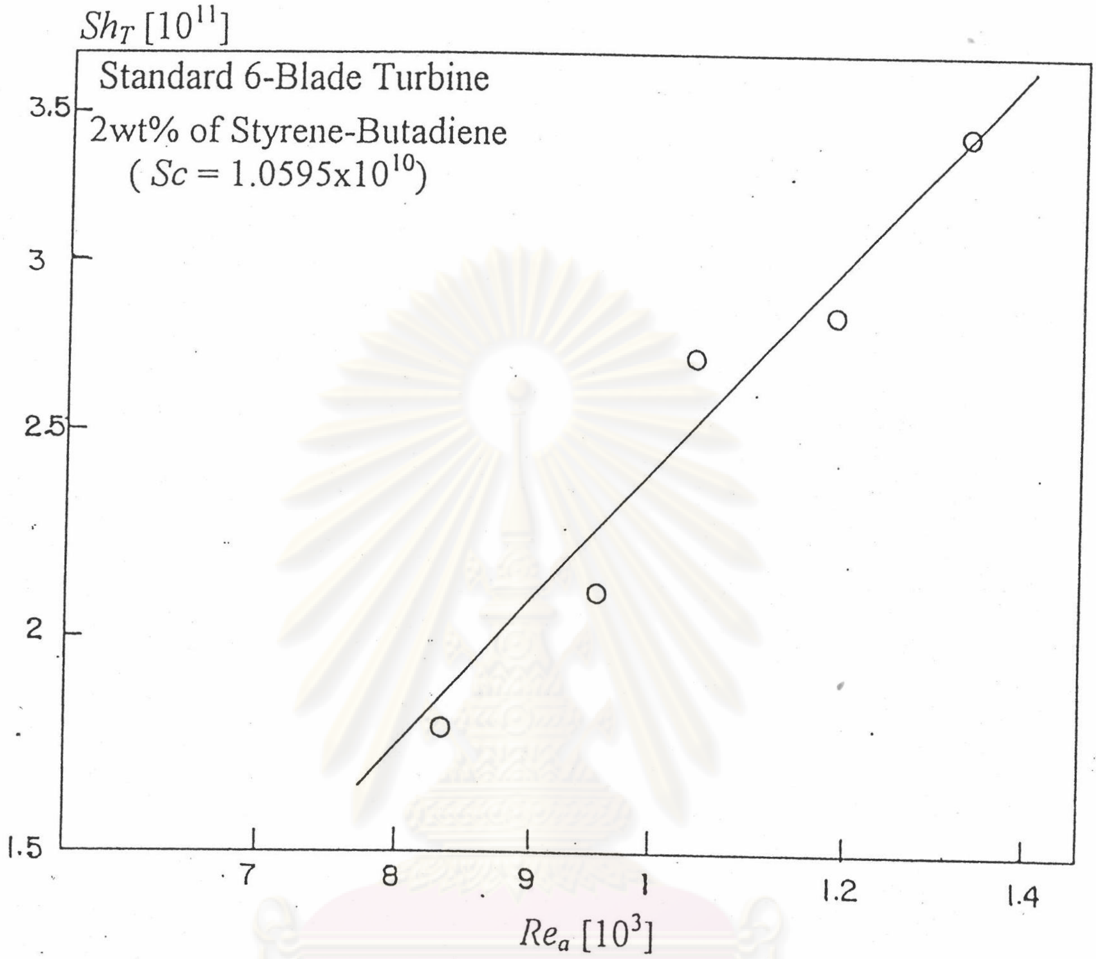

Figure 5.1 : Plot of Sh_T as a function of Re_a

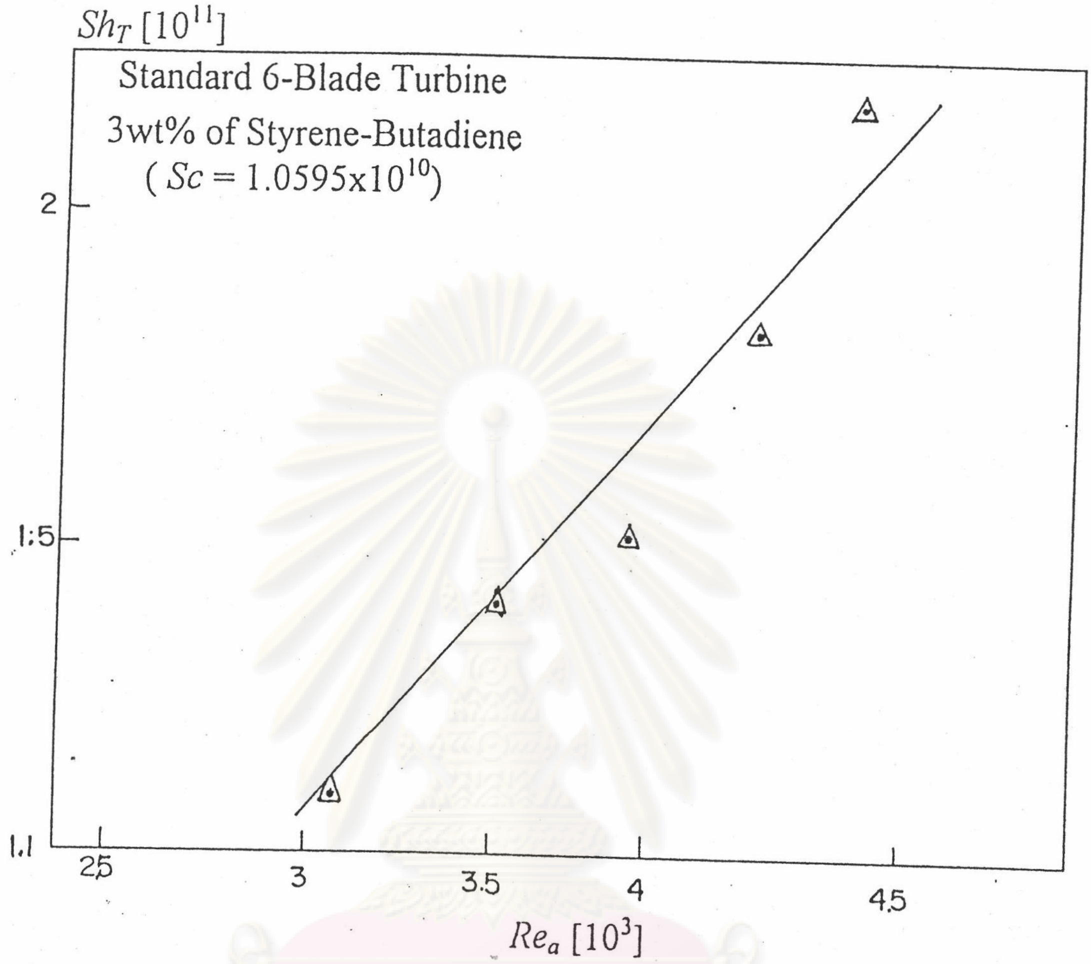

Figure 5.2 : Plot of Sh_T as a function of Re_a

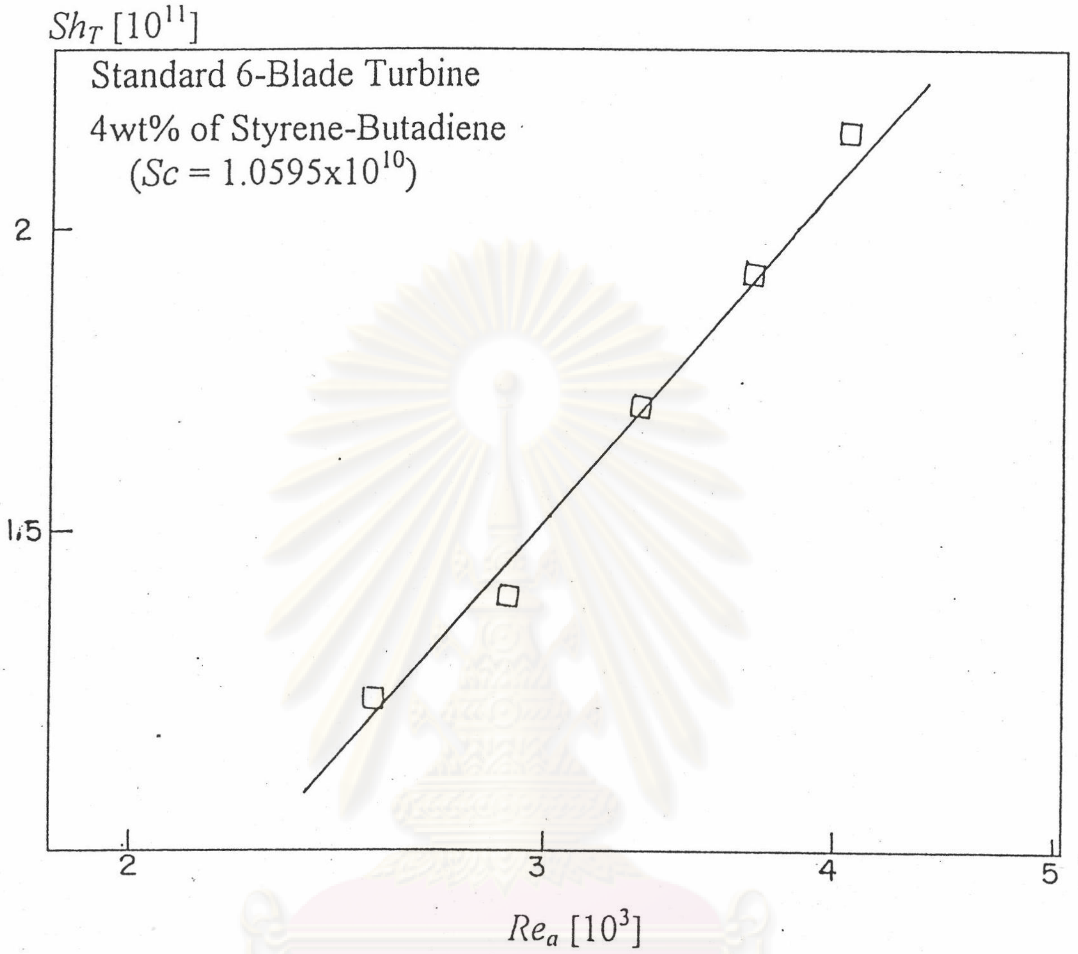

Figure 5.3 : Plot of Sh_T as a function of Re_a

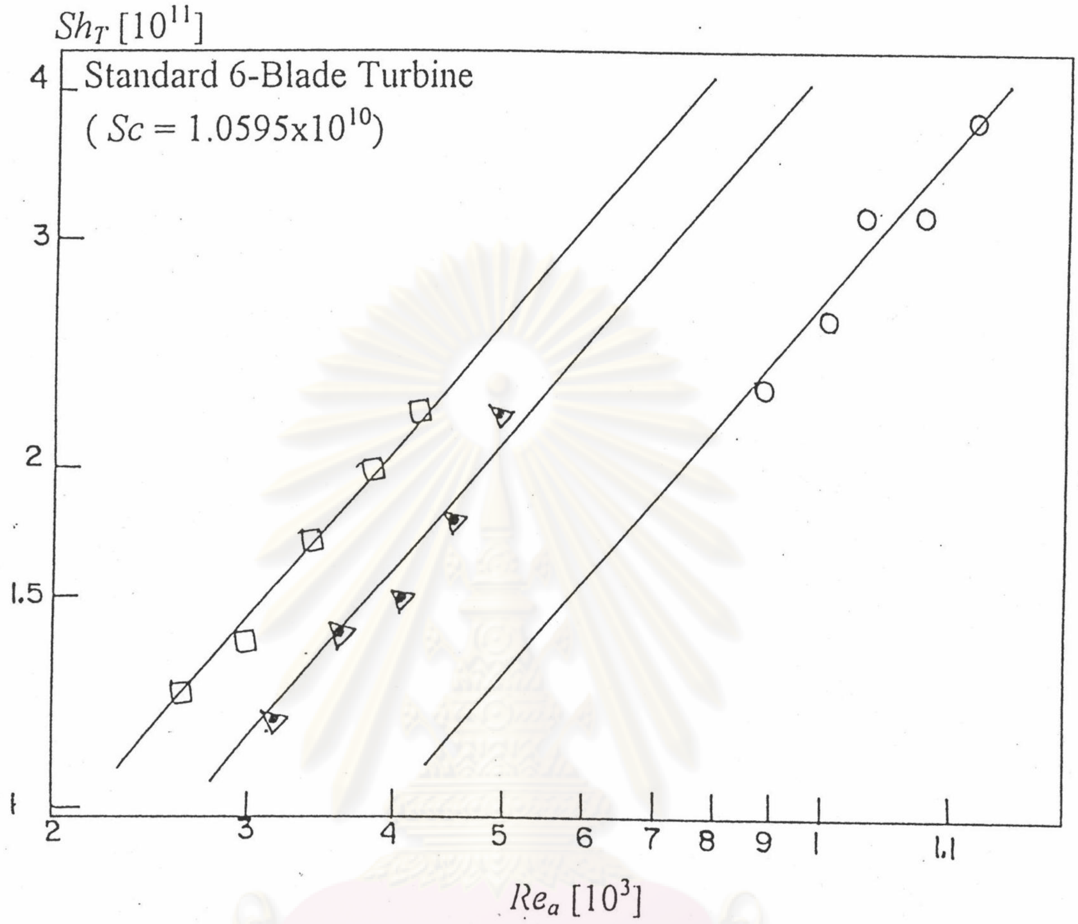

Figure 5.4 : Plot of Sh_T as a function of Re_a

○ :2wt% of Styrene-Butadiene
△ :3wt% of Styrene-Butadiene
□ :4wt% of Styrene-Butadiene

Table 5.8 *Sc vs Sh_T* of 2wt% Styrene-Butadiene In Mineral Oil At 550 rpm ($Re_a = 1.3178x10^4$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Standad 6-Blade Turbine

No.	Temp. (°C)	*Sc* $x10^{-9}$	Sh_T $x10^{-11}$			
			1	2	3	Average
1	135	1.0279	1.3420	1.2874	1.2496	1.2930
2	130	1.1485	1.5601	1.4653	1.4113	1.47989
3	125	1.1600	1.5012	1.6021	1.5776	1.5603
4	120	1.2595	1.9035	1.8684	1.7877	1.8532
5	115	1.6333	2.2981	2.7187	1.8982	2.3050

Table 5.9 Sc vs Sh_T of 3wt% Styrene-Butadiene In Mineral Oil At 550 rpm ($Re_a = 4.8258 x10^3$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Standad 6-Blade Turbine

No.	Temp.	Sc	Sh_T x10^{-11}			
	(°C)	x10^{-10}	1	2	3	Average
1	135	2.7331	1.3980	1.4123	1.4047	1.4050
2	130	2.8250	1.5589	1.3250	1.7616	1.5485
3	125	2.8708	1.7012	1.9268	1.7735	1.8005
4	120	2.8933	1.9501	1.7392	1.8814	1.8569
5	115	3.0879	2.2320	2.0125	2.3840	2.2095

Table 5.10 *Sc vs* Sh_T of 4wt% Styrene-Butadiene In Mineral Oil At 550 rpm ($Re_a = 4.0363 \times 10^3$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Standad 6-Blade Turbine

No.	Temp. (°C)	*Sc* $\times 10^{-10}$	Sh_T $\times 10^{-11}$			
			1	2	3	Average
1	135	3.2091	1.4895	1.4560	1.4840	1.4765
2	130	3.3086	1.8050	1.6589	1.9031	1.7890
3	125	3.3850	1.8901	2.0890	1.9633	1.9808
4	120	3.4592	2.1500	2.2310	1.7990	2.0600
5	115	3.7200	2.5965	2.4180	2.1885	2.4010

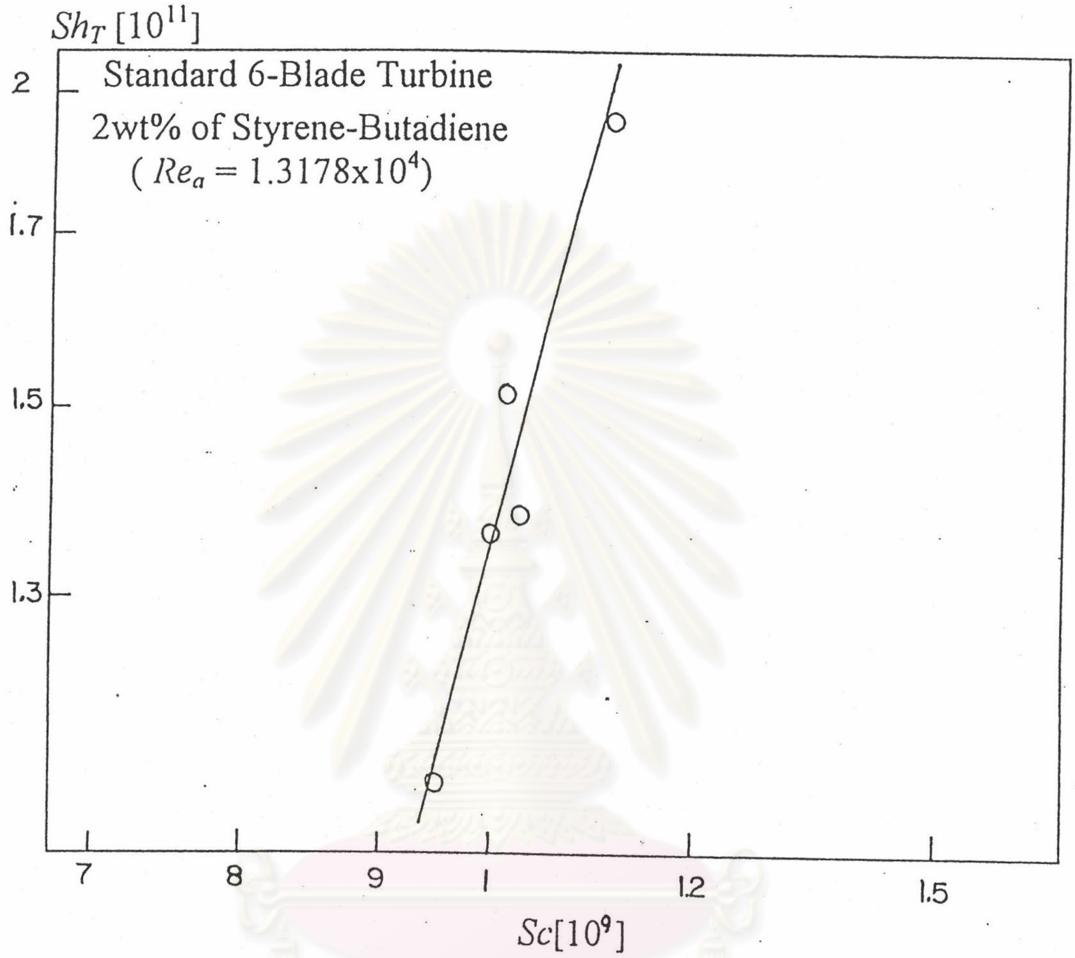

Figure 5.5 : Plot of Sh_T as a function of Sc

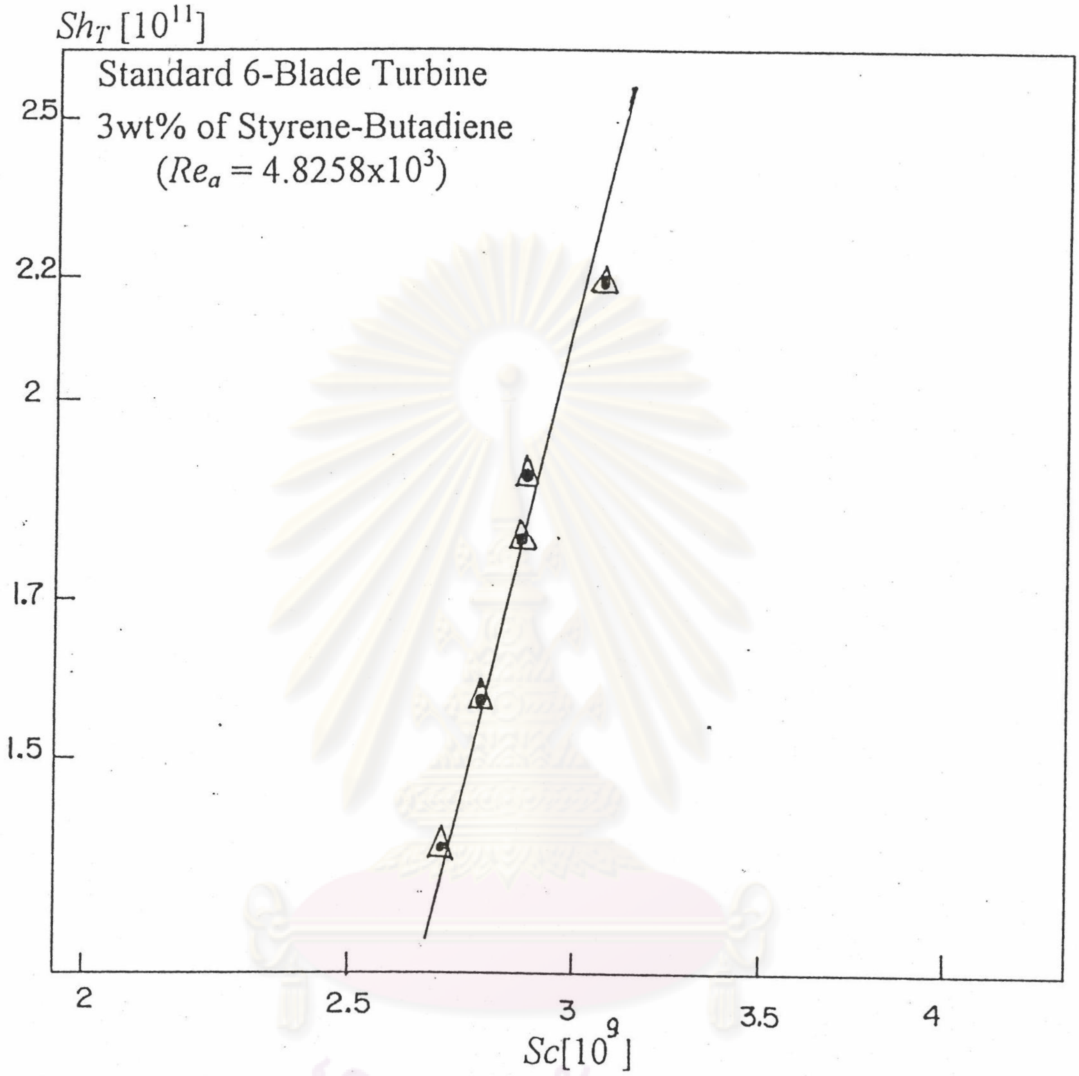

Figure 5.6 : Plot of Sh_T as a function of Sc

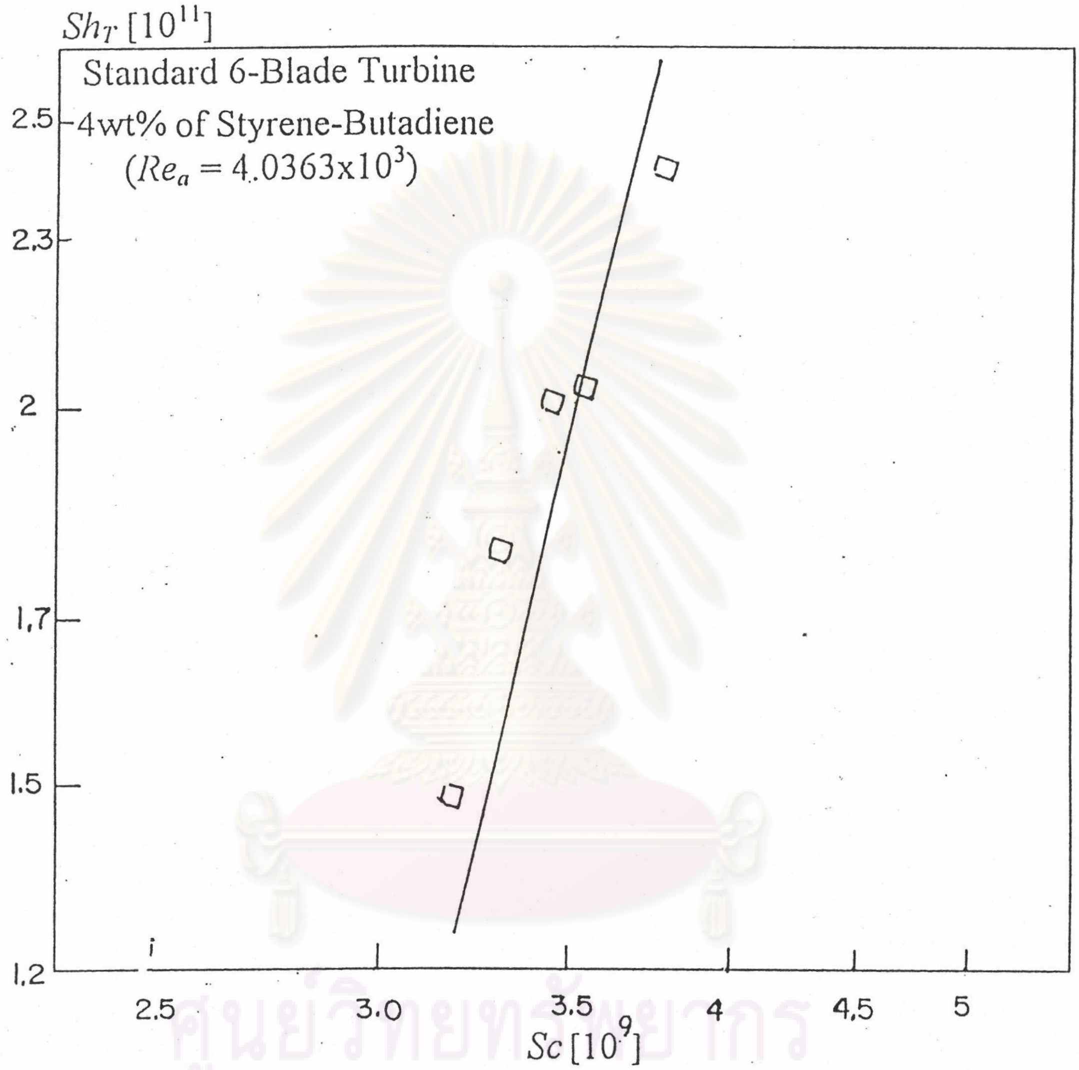

Figure 5. 7 : Plot of Sh_T as a function of Sc

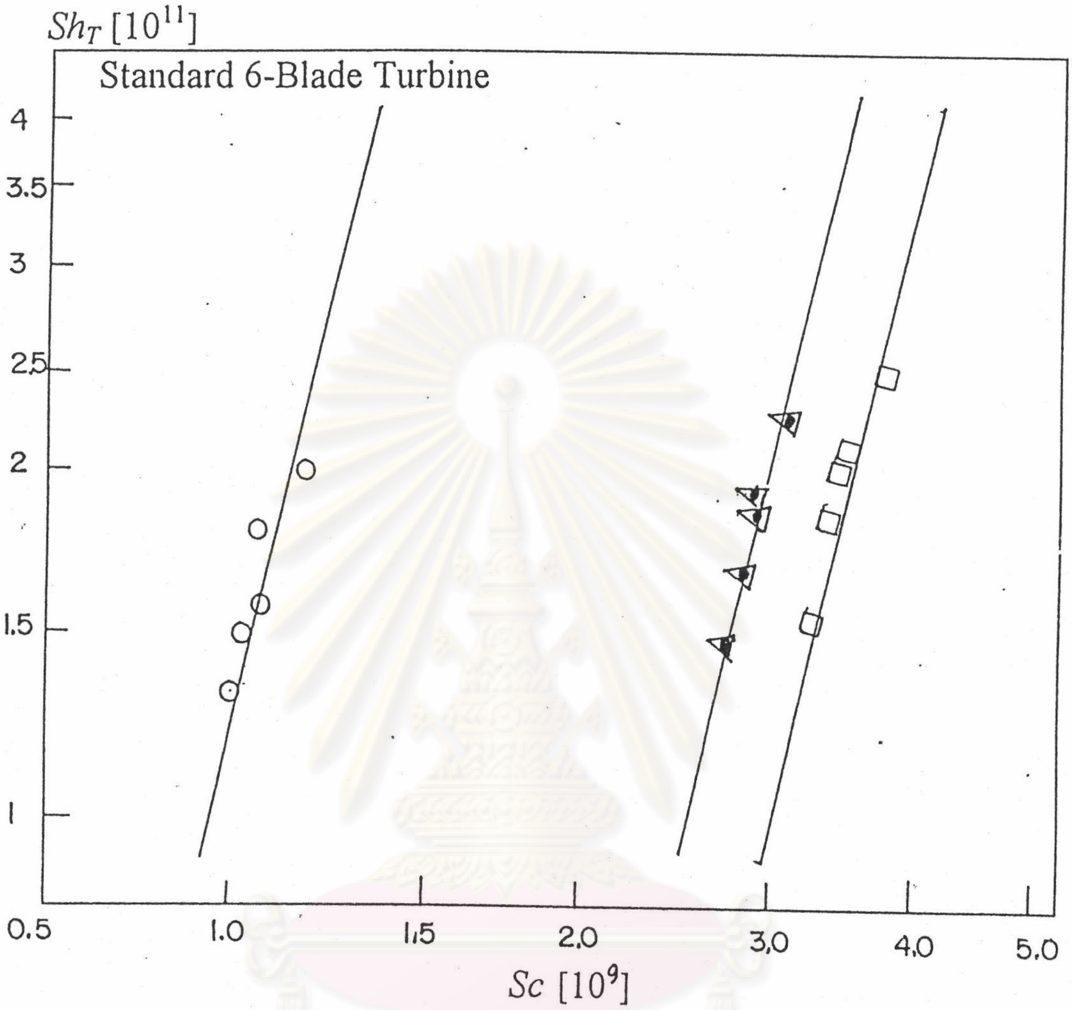

Figure 5.8 : Plot of Sh_T as a function of Sc

○:2wt% of Styrene-Butadiene
▲:3wt% of Styrene-Butadiene
□:4wt% of Styrene-Butadiene

Table 5.11 Re_a *vs* Sh_T of 2wt% Styrene-Butadiene In Mineral Oil At 120°C (Sc = 1.0485x10^{10})

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Paddle

No.	Speed (rpm)	Re_a x10^{-3}	Sh_T x10^{-11}			
			1	2	3	Average
1	350	8.3864	1.7235	1.6980	1.7052	1.7089
2	400	9.5844	1.7432	1.8900	1.6228	1.7520
3	450	10.7825	2.0130	1.7850	2.1636	1.9872
4	500	11.9805	2.0590	1.8890	2.0190	1.9890
5	550	13.1786	2.3100	2.2451	2.3119	2.2890

Table 5.12 Re_a *vs* Sh_T of 3wt% Styrene-Butadiene In Mineral Oil At 120°C ($Sc = 2.8933 \times 10^{10}$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Paddle

No.	Speed	Re_a	Sh_T $\times 10^{-11}$			
	(rpm)	$\times 10^{-3}$	1	2	3	Average
1	350	3.0710	1.2015	1.0085	1.3102	1.1734
2	400	3.5096	1.2111	1.1987	1.2172	1.2090
3	450	3.9483	1.4018	1.3545	1.3342	1.3635
4	500	4.3817	1.4089	1.4258	1.4277	1.4208
5	550	4.8258	1.5040	1.6584	1.3316	1.4980

Table 5.13 Re_a *vs* Sh_T of 4wt% Styrene-Butadiene In Mineral Oil At 120°C ($Sc = 3.4592\text{x}10^{10}$)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Paddle

No.	Speed (rpm)	Re_a $\text{x}10^{-3}$	Sh_T $\text{x}10^{-11}$			
			1	2	3	Average
1	350	2.5685	1.2058	1.1970	1.1912	1.1980
2	400	2.9355	1.2950	1.4320	1.1895	1.3055
3	450	3.3025	1.3895	1.2590	1.4039	1.3508
4	500	3.6693	1.4158	1.2865	1.4647	1.3890
5	550	4.0363	1.7890	1.6500	1.1594	1.5328

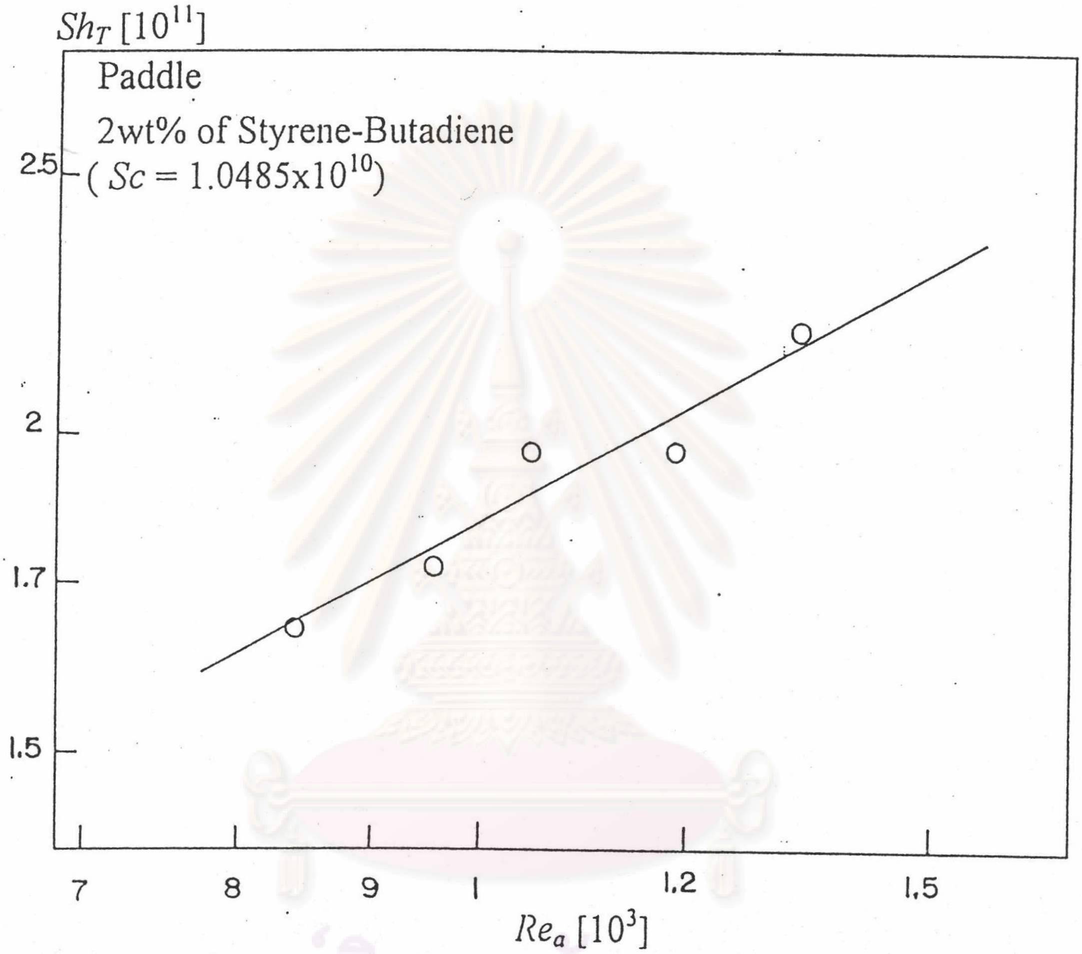

Figure 5.9 : Plot of Sh_T as a function of Re_a

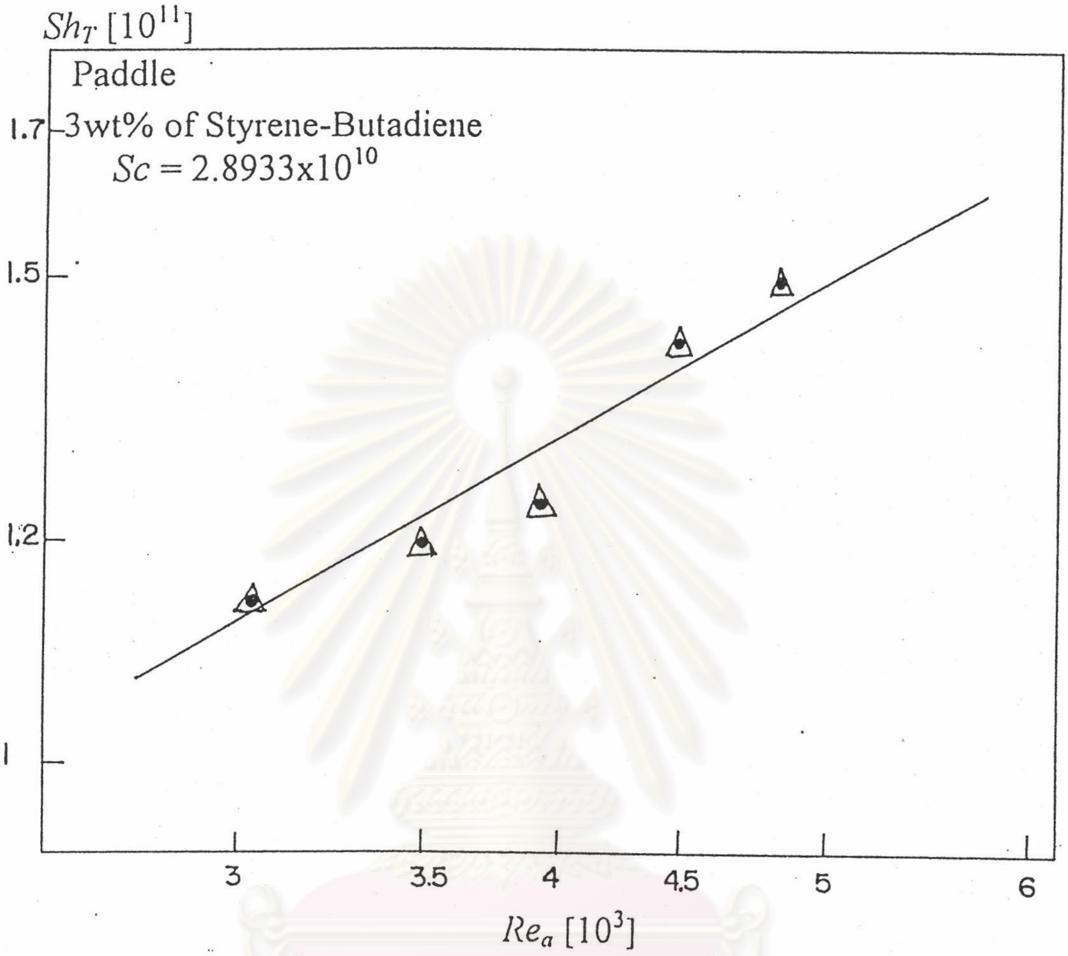

Figure 5. 10 : Plot of Sh_T as a function of Re_a

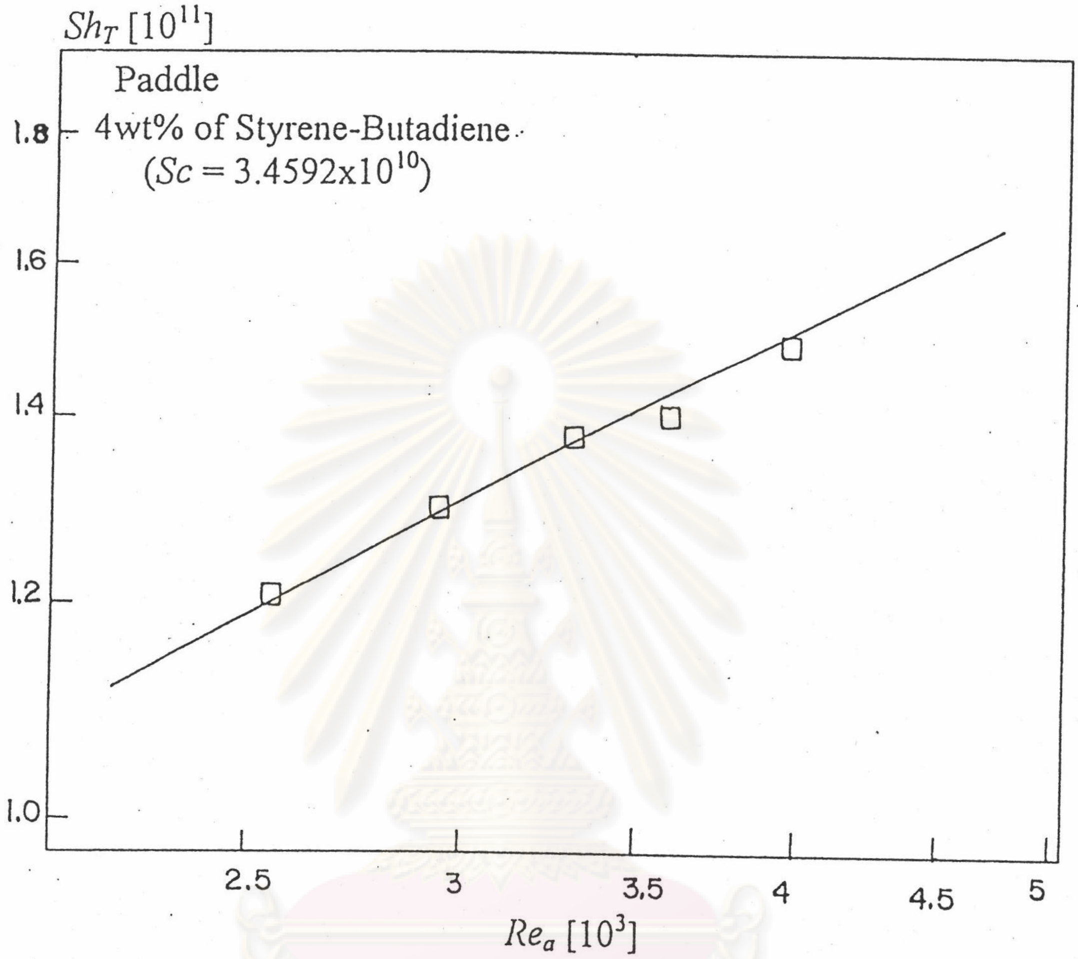

Figure 5.11 : Plot of Sh_T as a function of Re_a

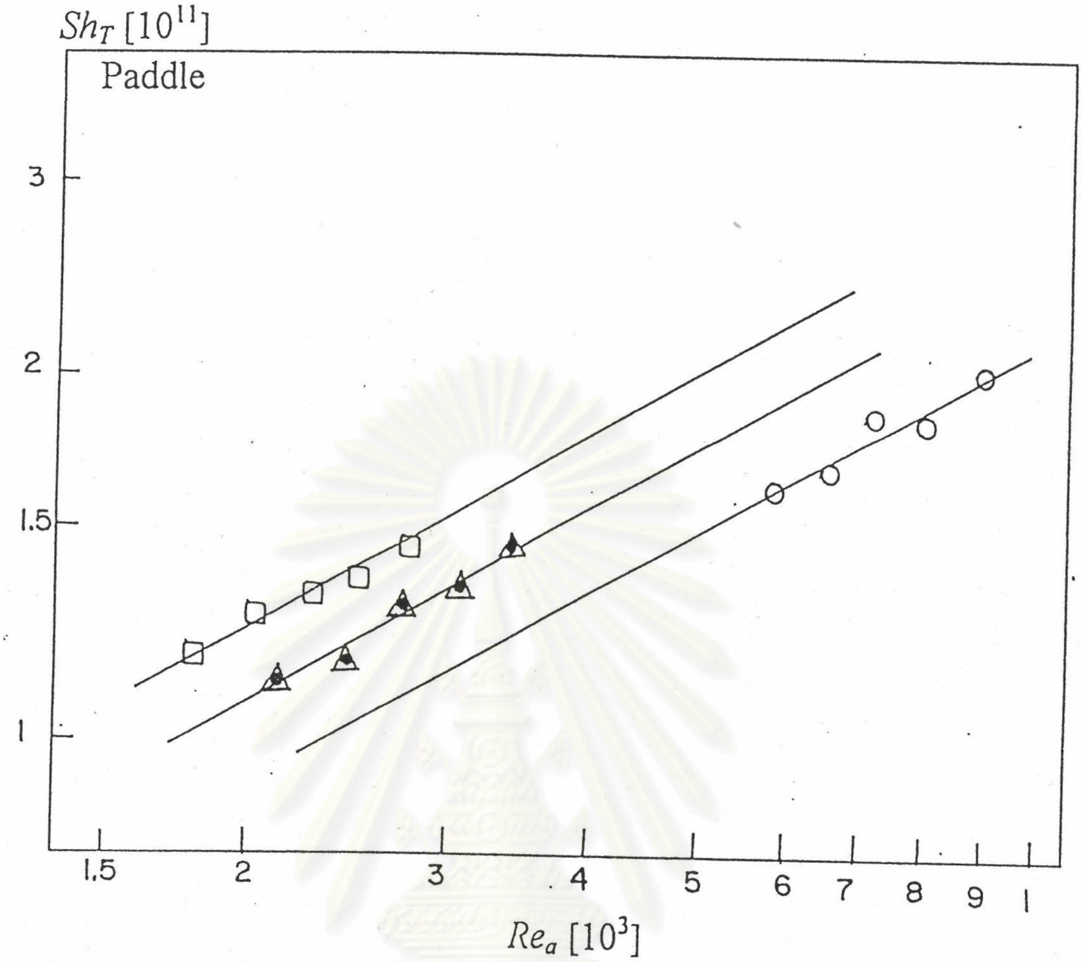

Figure 5.12 : Plot of Sh_T as a function of Re_a

○ :2wt% of Styrene-Butadiene
△ :3wt% of Styrene-Butadiene
□ :4wt% of Styrene-Butadiene

Table :5.14 Sc *vs* Sh_T of 2wt% Styrene-Butadiene In Mineral Oil At 550 rpm (Re_a =1.3178x10^4)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Paddle

No.	Temp. (°C)	Sc x10^{-10}	Sh_T x10^{-11} 1	2	3	Average
1	135	1.0002	1.8830	1.9150	1.9020	1.2701
2	130	1.0473	1.7328	1.5427	1.5395	1.4535
3	125	1.0590	1.6090	1.4980	1.6870	1.5980
4	120	1.0607	1.5521	1.3965	1.4119	1.6050
5	115	1.1646	1.3005	1.2598	1.2500	1.9000

Table 5.15 *Sc vs* Sh_T of 3wt% Styrene-Butadiene In Mineral Oil At 550 rpm (Re_a =4.8258x10^3)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Paddle

No.	Temp. (°C)	*Sc* x10^{-10}	Sh_T x10^{-11}			
			1	2	3	Average
1	135	2.7331	2.1085	2.1100	2.0665	1.4159
2	130	2.8250	1.8957	1.6595	1.8133	1.6238
3	125	2.8708	1.8096	1.6970	1.6522	1.7196
4	120	2.8933	1.8254	1.6896	1.8535	1.7895
5	115	3.0879	1.5096	1.4080	1.3301	2.0950

Table: 5.16 Re_a *vs* Sh_T of 4wt% Styrene-Butadiene In Mineral Oil At 550 rpm (Re_a =4.0363x10^3)

Vessel Diameter, T = 25 cm.

Agitator Diameter, Di = 8.33 cm.

Impeller Type: Paddle

No.	Temp. (°C)	Sc x10^{-10}	Sh_T x10^{-11}			
			1	2	3	Average
1	135	3.2091	1.7010	1.5895	1.5170	1.6025
2	130	3.3086	1.7023	1.6545	1.8275	1.7281
3	125	3.3850	1.9890	1.8895	1.8605	1.9130
4	120	3.4592	1.8534	2.0138	1.8748	1.9140
5	115	3.7200	2.4503	2.2989	2.3248	2.3580

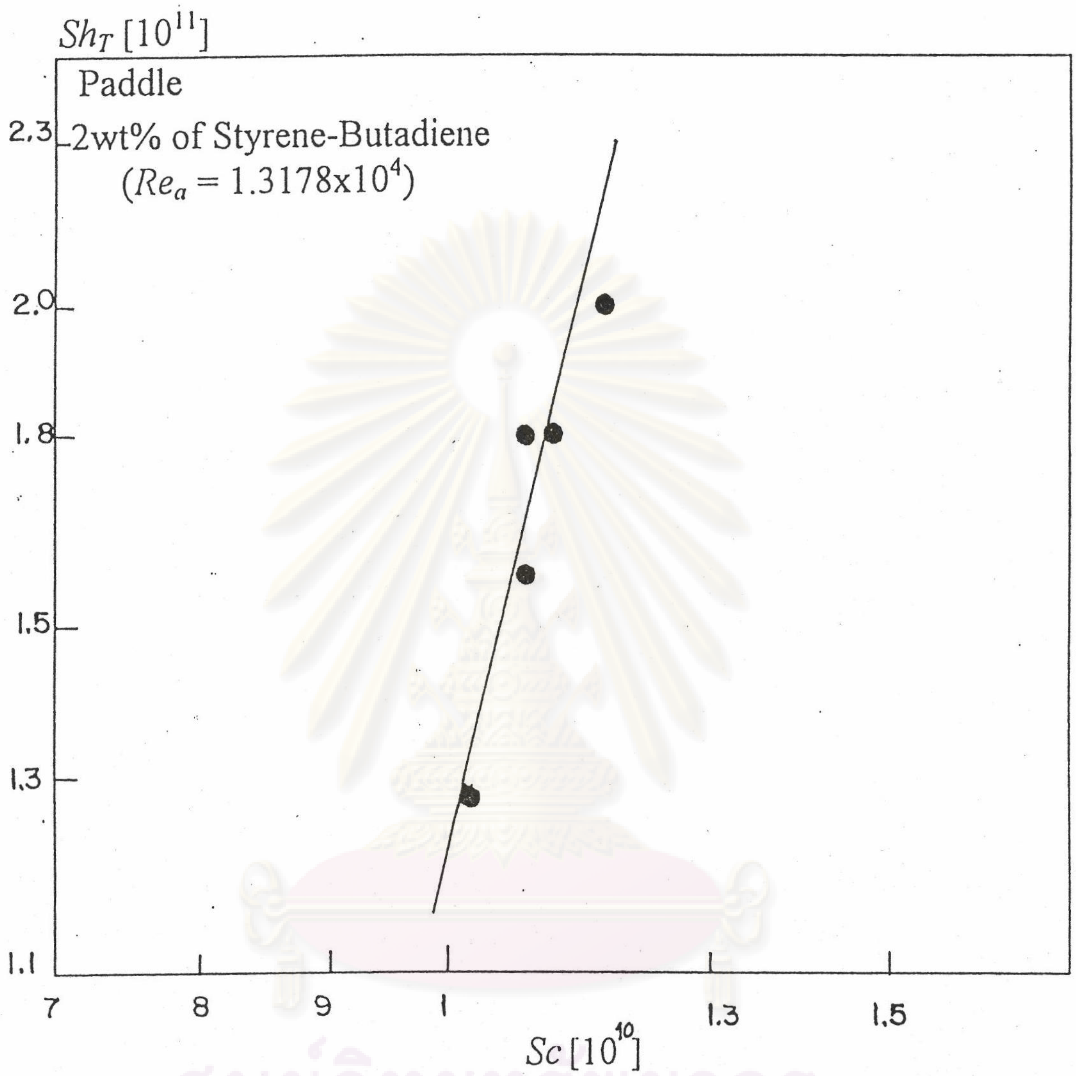

Figure 5. 13 : Plot of Sh_T as a function of Sc

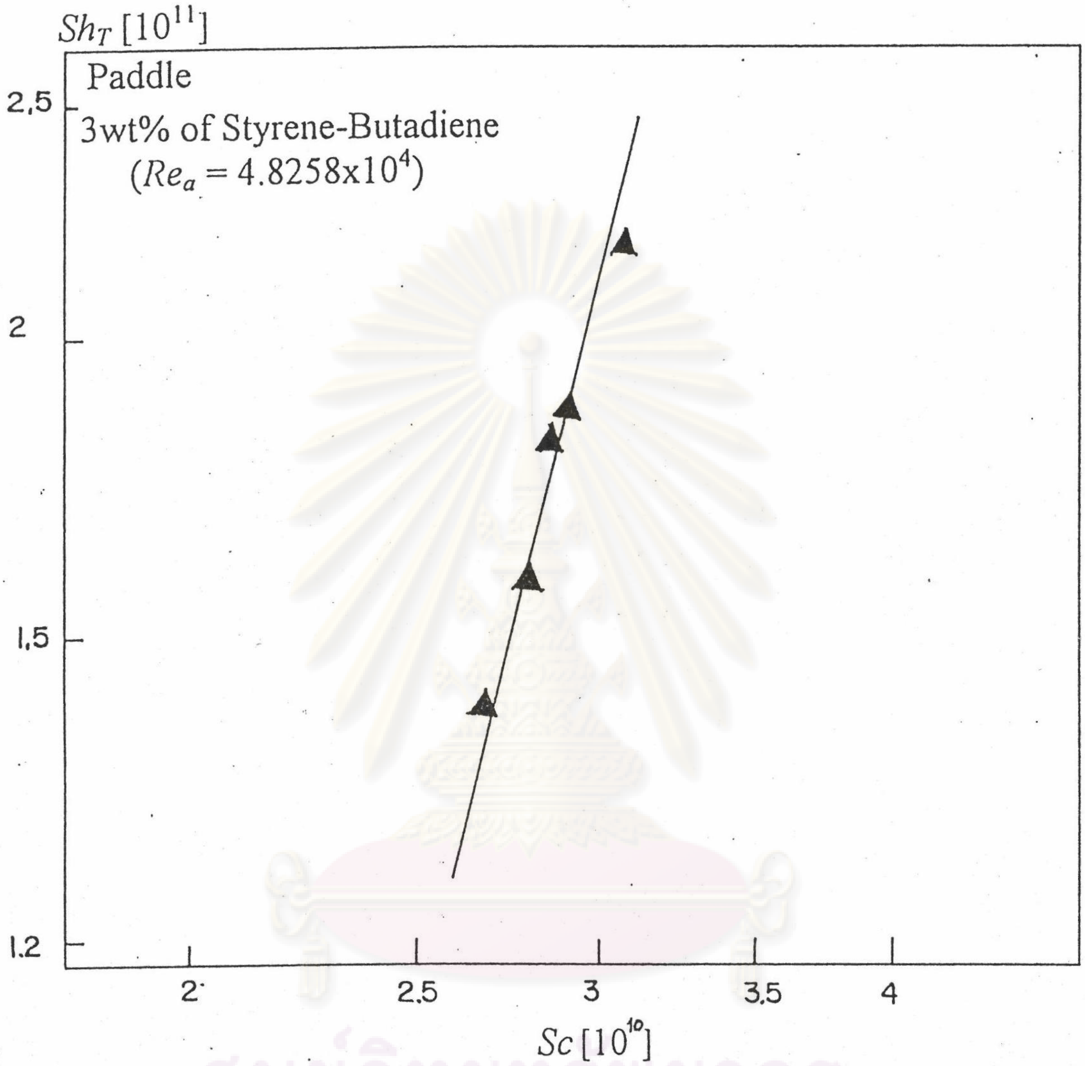

Figure 5. 14 : Plot of Sh_T as a function of Sc

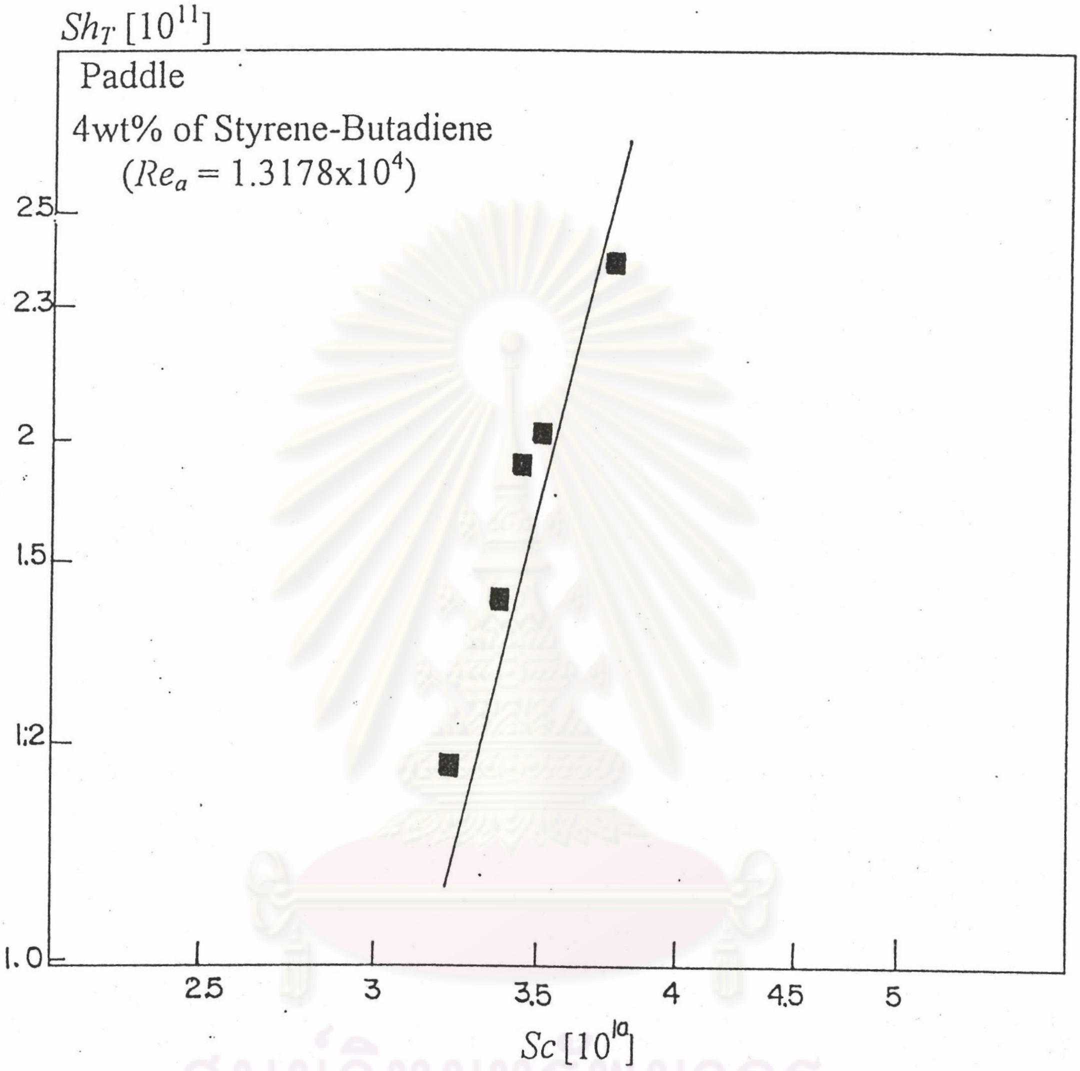

Figure 5. 15 : Plot of Sh_T as a function of Sc

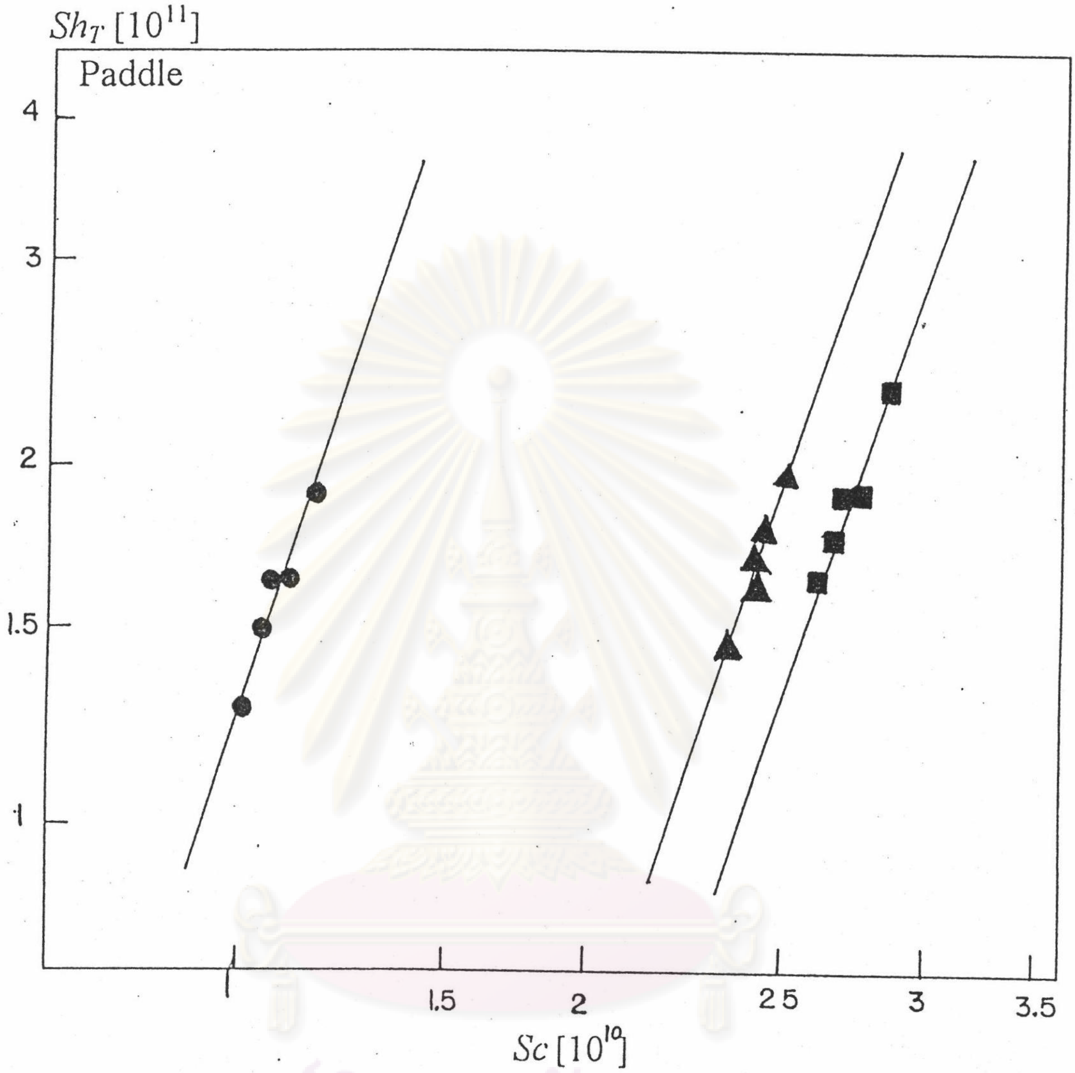

Figure 5. 16 : Plot of Sh_T as a function of Sc

● :2wt% of Styrene-Butadiene
▲ :3wt% of Styrene-Butadiene
■ :4wt% of Styrene-Butadiene

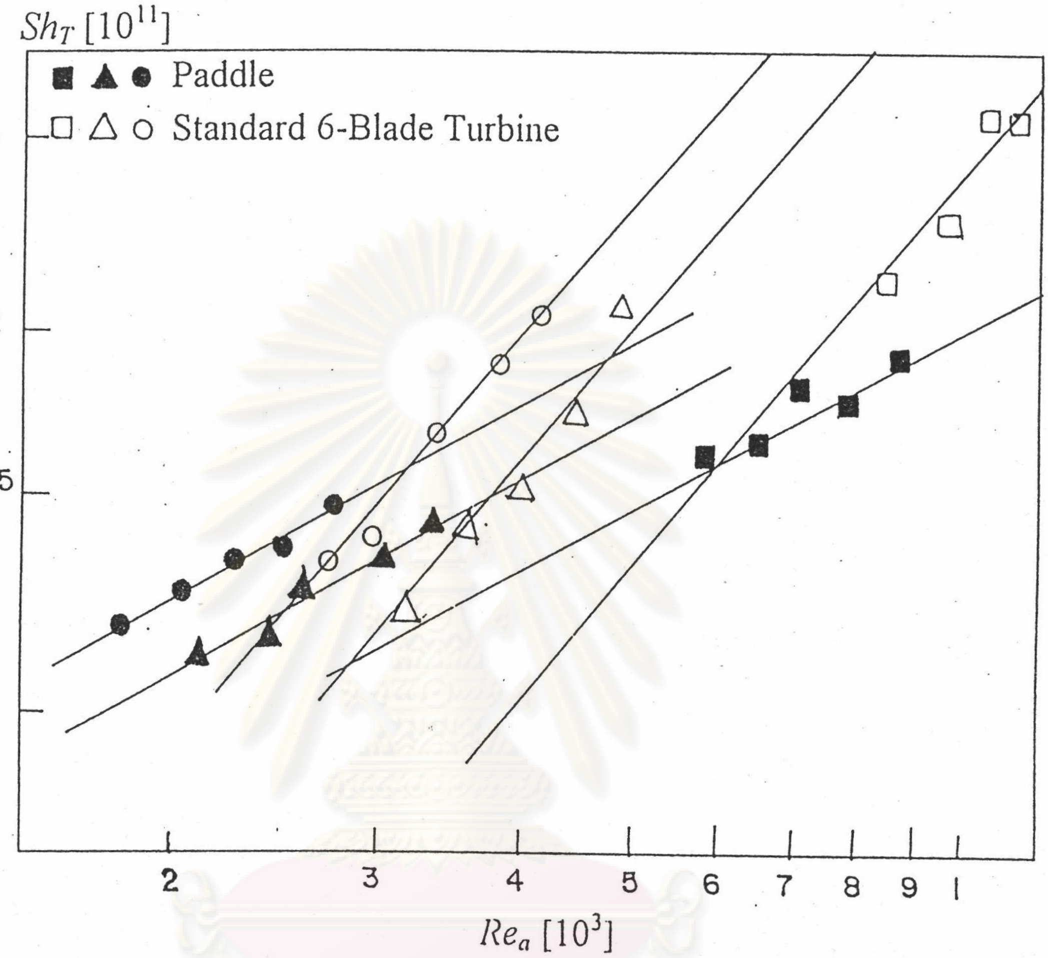

Figure 5.17 : Influence of Impeller Types

□ ■ :2wt% of Styrene-Butadiene
△ ▲ :3wt% of Styrene-Butadiene
○ ● :4wt% of Styrene-Butadiene

5.3.1 Influence of Impeller Types

Solid dissolution rate coefficient for different concentration of styrene-butadiene in mineral oil at various rotation of styrene-butadiene in mineral oil at various rotational speed of agitator and temperatures are shown in Appendix H. From Figures 5.17 is found that the solid dissolution rate coefficient,K for standard six blade disc turbine is greater than paddle. The different in the value K between the two types of agitators are due to the different in the flow pattern. Since the turbine impeller has lead to generate strong currents which persist throughout the vessel, seeking out and destroying stagnant pockets. Thus, near the impeller is a zone of rapid currents, high turbulence, and intense share.

5.3.2 The Influence of Reynolds Number , $Re_a = Di^2N\rho/\mu$

Under isothemal condition for any particular solid-liquid system , μ , ρ and D_v are constant. The value of Reynolds number depends on the rotation speeds of the agitator, N

The number and the parameter of the dimensionless group proposed by various, researchers are different therefore, it is difficult to carry out a complete comparisons. However, there are three important variables; the Reynolds number, Schmidt number, and type of impeller which are in common.

To determine the influence of the disc turbine agitator type , the data from table 5.5 to 5.7 were plotted as shown in Figures 5.1-5.4 Each line represents constant temperature.

As seen in Figures 5.9-5.12 the lines are parallel having a slope of 1.35, which is the exponent of the Reynolds Number in the correlation.

For paddle impeller, the data are shown in table 5.8 to 5.10 and are plotted as shown in Figures 5.5-5.9. Each line represents constant temperature. As curve between the lines are parallel have a slope of 0.57 which is the exponent of the Reynolds number in the correlation

5.3.3 Influence of Schmidt Number , $Sc = \mu/\rho Dv$

To determine the influence of the Schmidt number on solid dissolution the temperatures were varied while the Reynolds number was kept constant. Data from the table 5.8-5.10 are plotted as shown in Figures 5.5-5.7. From Figure 5.8, it is found that the lines are parallel , having a slope of 3.20 which is the exponent of Schmidt number in the correlation for standard 6-blade disc turbine agitator. For paddle impeller, data shown in Table 5.14-5.16 are plotted as shown in Figures 5.13-5.15, From Figure 5.16, it is found that the lines are parallel having a slope of 2.22 which is the exponent of Schmidt number in the correlation.

The results obtained in this work are compared with other correlation for geometrically similar in term of experimental Sherwood number versus calculated Sherwood number by subtituting the experimental data from Table 5.5 and 5.11 in the correlations of other investigators.

Figure 5.18 shows the comparison of this work with three correlation (1,3,7) for standard six blade disc turbine

Figure 5.19 shows the comparison of this work with Keey and Glen'correlation (5) for paddle.

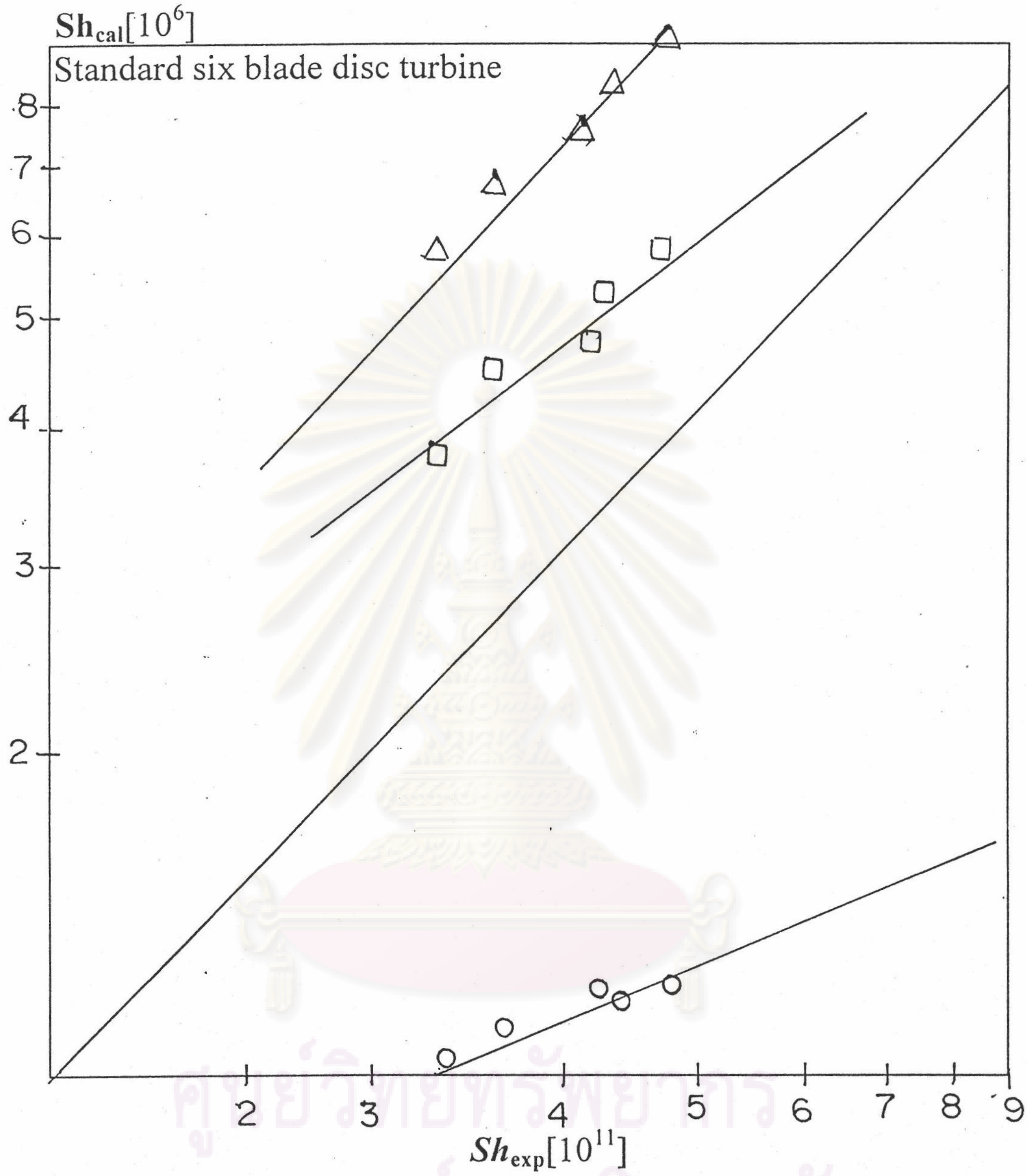

Figure 5.18 Comparison with other investigations

O Hixson & Baum (1)
□ Barker & Trey bal (4)
Δ Humphrey & Van Ness (12)

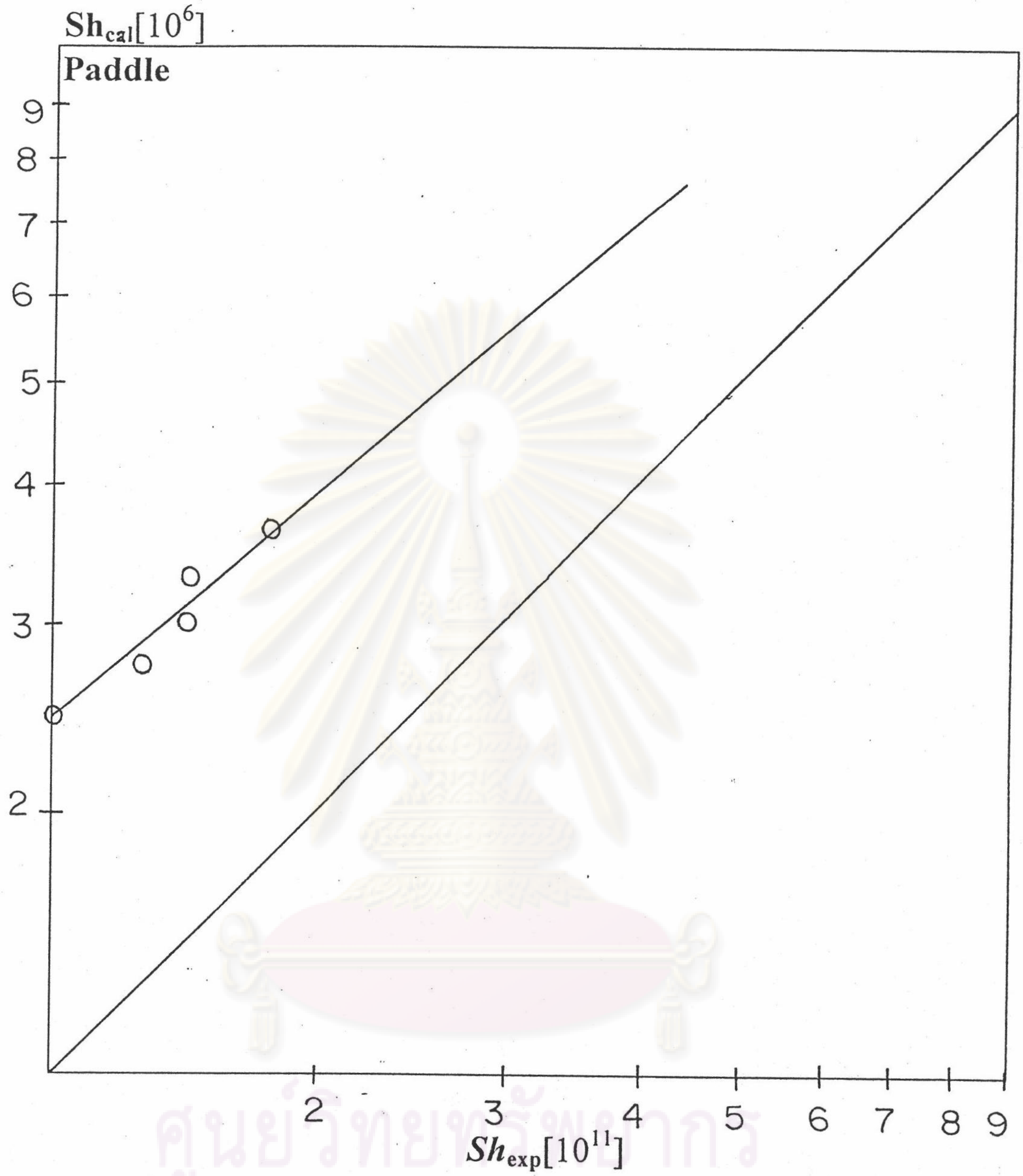

Figure 5.19 Comparison with Keey and Glen.